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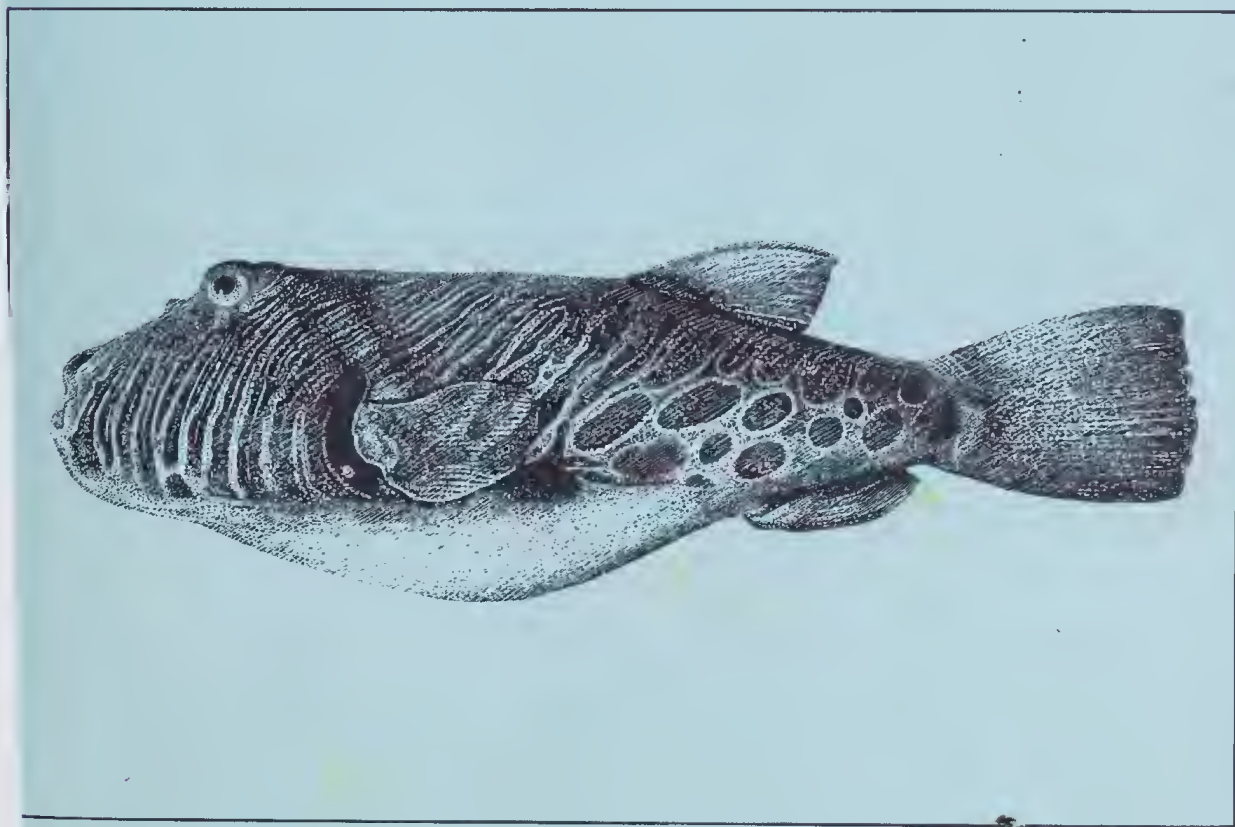# Western Australian Museum

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RECORDS of the Western Australian Museum

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Cover
Feroxodon multistriatus illustrated by Jill Ruse.

A catalogue of type specimens of
Crustacea in the Western Australian Museum, Perth

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Abstract

Data are given for the type specimens of 223 species of Crustacea held in the Western Australian Museum collection. Taxa are arranged in a systematic order, and a list of references contains all papers in which the taxa are first described. The types of eight species could not be located at the time of writing.

Introduction

The Western Australian Museum (WAM) crustacean collection comprises approximately 13 000 registered specimen lots which include type specimens of 223 species of Recent Crustacea. Two partially completed type lists exist for the years 1965-66 and 1973 but a complete list of crustacean types has not previously been published. The following account includes all the types that can be found to date in the WAM crustacean collection. Associated pertinent information is also given for each type specimen. Unless otherwise stated, specimens are stored in glass jars in 70 per cent (v/v) ethanol with 10 per cent (v/v) glycerine.

Crustacean classes and orders are based on the sequence given by Bowman and Abele (1982), and the families, genera and species are arranged alphabetically within each order. Species are listed by the scientific name under which they were originally described. Any changes in nomenclature which have been made by later authors are noted in Remarks, together with a reference to the source of the change. Under Remarks are also noted any inconsistencies between the original description and the specimen, its register entry or label, or any additional comments which may be of use to future workers when identifying particular material cited by the describer. Paratype material that has been donated to or deposited in other institutions is also indicated under Remarks.

Some early crustacean taxonomists did not designate type specimens in their descriptions of new species. Where no holotype was designated and where there is no clear indication that the description has been based on a single specimen, specimens of the type series held in the WAM are considered syntypic (Article 73 (b) ICZN) even if only one specimen is held. Where the description is based on a single specimen and the specimen is in the WAM collection, this specimen is

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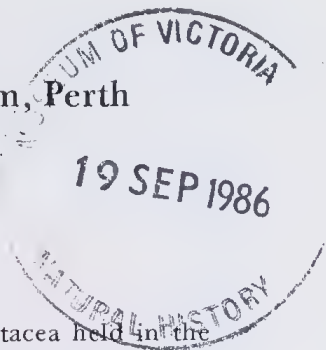
considered to be the holotype (Article 73 (a) ICZN). Where an author has designated a holotype, the other specimens of the type series are considered to be paratypes (Recommendation 73D ICZN). The WAM collection also contains some specimens which have been labelled 'probable types' by previous workers and this material, which may be of use to future workers, has been included in the Appendix.

Eight types had not been located by the date of submission of the present paper, and their absence is noted in the relevant Remarks. The collections of Professor G.E. Nicholls were originally housed in the Zoology Department, Univeristy of Western Australia, where some specimens were used for teaching purposes and where unfortunately most appear to have been lost. The remains of the Nicholls' collections, both amphipod and isopod material, were moved to the WAM and registered into the crustacean collection in the late 1950s. Most of the remaining gammaridean amphipods collected by the Australian Antarctic Expedition 1911-14 (see Nicholls 1938) were transferred to the Australian Museum, Sydney in 1966. Lowry (1982: 320) lists the missing gammaridean amphipod material from the Nicholls' collection. The types of two species in this collection are apparently lost — *Colomastix simplicicauda* is absent from the WAM collection and was never registered into the AM collection, and *Atylopsis megalops* was registered into the AM collection but cannot be found (J.K. Lowry, pers. comm.).

Western Australian Museum registration numbers are prefaced by the letters WAM. In 1901, when collections were begun, all invertebrate material was collectively registered in the WAM Register of Zoological Invertebrates, in chronological order, and numbered sequentially. After December 1913 (WAM 8731) insects, scorpions and spiders were registered separately, but Crustacea were still included in the invertebrate register. After 1930 (WAM 16647) the invertebrates (excluding insects, scorpions and spiders) were still collectively registered, but numbered on a yearly basis, with the specimen registration number followed by the year and separated by a dash. For example, the first specimen registered for the year 1932 is 1-32, followed by 2-32, etc., and similarly for 1933, 1-33, 2-33 etc. Series of registration numbers prior to 1930 sometimes cause confusion to workers from other institutions, but should present no problem if the practice of separating the first and last numbers of a series by a slash, as used in the old WAM invertebrate registers, is noted. For example, WAM 10016/39 refers to the specimens WAM 10016 through to 10039, and not to lot 10016 registered in 1939 (which would be WAM 10016-39). Since 1958 the Crustacean Department has maintained its own catalogue and hence the numbers quoted in this paper for material accessed after 1.1.1958 are Crustacean Department registration numbers.

The type collection comprises largely Western Australian species (168) although 27 types are from other Australian states (Tasmania 17, Northern Territory 1, New South Wales 5, Queensland 2, Victoria 2), 1 is from Christmas

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Island, Indian Ocean, 20 are from the Antarctic and Macquarie Island, 1 is from New Zealand, 1 from Hong Kong, 3 from the Sulu Archipelago and 2 from the South-East Pacific.

The following abbreviations are used in the text: c.l. carapace length; c.w. carapace width; AM, The Australian Museum, Sydney; BM, The British Museum (Natural History), London; ICZN, International Commission on Zoological Nomenclature; S. Aust. Mus., South Australian Museum, Adelaide; USNM, United States National Museum, Smithsonian Institution, Washington, DC; WAM, Western Australian Museum, Perth; ZIZM Hamburg, Zoologisches Institut und Zoologisches Museum, University of Hamburg; ZM Uppsala, The Zoological Museum of the University, Uppsala.

Historical development of the Western Australian Museum crustacean collection*

In 1892 the Public Museum was established in Perth. The institution changed its title to 'The Western Australian Museum and Art Gallery' in 1897, but it was not until 1960 that the Western Australian Museum became a separate independent institution. In the early years there were many collecting expeditions which laid down the foundations of many of the present day collections. The first fully professional scientific expedition to Western Australia occurred during this period — the Hamburg South-Western Australian Research Expedition of 1905, under Drs W. Michaelsen and R. Hartmeyer. The expedition collected mainly invertebrates including Crustacea. Results appeared in *Die fauna Südwest-Australiens* in five volumes, published between 1907 and 1930, and contain the first systematic studies of Crustacea from Western Australia (Wolf 1911, Budde-Lund 1912, Krüger 1912, Mayer 1912). The Swedish Scientific Expedition of 1910-13, under Dr E. Mjöberg, visited the area between Perth and Albany, and the Kimberley area in the north, and the results were published between 1913 and 1922 in 32 parts of the *Arkiv för Zoologi, Svenska Vetenskapsakademien*, with crustaceans being well represented (Broch 1916, Schwartz 1917, Skogsberg 1917, Balss 1921, Zimmer 1921, Wahrberg 1922, Rathbun 1924). Over a decade later, Balss published on the Brachyura collected by the Mjöberg expedition in southwestern areas of Western Australia (1934-35) and on *Pilumnus* and allied genera (1933), and described one further new Australian species together with a brief zoogeographical review of the Mjöberg collections in 1935. The third expedition of this period was that of Montague to the Montebello Islands in 1912 (Montague 1913). The general collections were published in *Proceedings of the Zoological Society of London* 1914 where Rathbun (1914) reported on the Crustacea.

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* From Serventy 1957, 1967, 1979, and WAM documents.

W.B. Alexander, the Keeper of Biology at the Museum (1914-19) vigorously expanded the invertebrate collections. In 1914 he collected extensively all over Australia with William Bateson and made large collections of insects and marine specimens. In the Crustacea he published on branchiopods (Alexander 1914a, 1914b) and stomatopods (Alexander 1916a, 1916b). Alexander worked in close association with Professor W.J. Dakin, Professor of Biology in the newly established University of Western Australia. Dakin was a marine and freshwater biologist, with a special interest in the lower Crustacea, and he investigated the Branchiopoda (Phyllopoda) occurring in the inland lakes and claypans of Western Australia (Dakin 1914). In 1913 and 1915 Dakin organised and led two scientific expeditions to the Abrolhos Islands, financed by the Percy Sladen Trust, and Tattersall (1922) published on the amphipods and isopods, and Montgomery (1931) on the Brachyura collected by the expedition.

Between the two World Wars there were stringent financial restrictions on the institution and there was none of the widespread collecting that had been a feature prior to World War I. However, Ludwig Glauert, the Curator of the Museum, collected locally and extensively in the Darling Range, and in the swamps of the Swan Coastal Plain, and conducted a thorough zoological survey of Rottnest Island, making repeated visits there. In the Crustacea he described a new species of freshwater isopod, *Phreatoicus palustris*, from the local swamps of the Perth area (Glauert 1924), and also discovered the shore isopod *Deto marina* at Freshwater Bay on the Swan River, the only mainland colony of this species known on the west coast of Australia (Nicholls 1932). At the University of Western Australia Professor G.E. Nicholls, stimulated by Glauert's discovery of *P. palustris*, specialised in the group and ultimately produced his notable monograph on Australian Phreatoicoidea (1942, 1943). Nicholls also worked on the gammaridean amphipods collected by the Australasian Antarctic Expedition of 1911-14 (Nicholls 1938) and on various freshwater amphipod and marine isopod groups in Western Australia (Nicholls 1924b, 1926b, 1926c, 1929, 1939). His review of the fauna of Western Australia in 1932 indicated the existence of a rich fauna of damp earth and aquatic invertebrates in the state. The earlier work of Sayce (1903), Wolf (1911) and Dakin (1914) had emphasised the rich and varied branchiopod fauna of the inland lakes and claypans of Western Australia. Nicholls made many collections of these animals which were studied by his students — e.g. Milner (1929) on Anostraca, Richardson on Conchostraea (this work remains in manuscript in the Zoology Department, University of Western Australia). In 1936-37 Linder, a visiting Swedish expert on Anostraca, was based at the Zoology Department, conducting fieldwork which was part of his world revision of the order (Linder 1941).

The 1950s heralded a new era of research activity in the state. In the WAM the large increase in available funding enabled the scientific staff to be enlarged. There was an increase in emphasis on zoological research and an active resumption of the exploratory work which had been so characteristic of the institution in

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its early days. From 1958 onwards crustacean specimens were recorded in their own catalogue, and in 1965 the first Curator of Crustacea, Dr R.W. George, was appointed. His research interests lay with the higher Crustacea, namely the Palinuridae (George and Holthuis 1965, George and Main 1967, George 1968) and he described the commercial rock lobster of Western Australia (George 1962). He also published on the Scyllaridae (George and Griffin 1972), the Ocypodidae (George and Knott 1964, George and Jones 1984) and the Oxystomata and Gymnopleura (Tyndale-Biscoe and George 1962). Dr George retired in 1984 and was succeeded by Dr G. Morgan.

Since 1958 the emphasis of the crustacean collection has been on the higher marine groups. The collection has greatly expanded due to increased collecting activity by the Crustacean Department, other museum natural history departments, and other agencies. Crustacean material has been accessed from a number of collecting expeditions both within Australian waters (e.g. Cockburn Sound Survey 1958; WAM/USNM Barrow Island Expedition 1966; Ningaloo Expedition 1968; Crown of Thorns Survey, Dampier Archipelago 1972-74; WAM Abrolhos Island Expedition 1974; WAM Rowley Shoals Expedition 1982; WAM Scott Reef Expedition 1984) and without (Norton-Wilson Philippines Expedition 1965; National Geographic Marquesas Expedition 1967; Mariel King Memorial Expedition to the Moluccas 1970). The collecting activities of colleagues from other institutions have yielded large quantities of crustacean material — notably alpheids (A.H. and D.M. Banner), gammaridean amphipods (J.L. Barnard), *Uca* (V. Semeniuk) and oniscoidean isopods (A.J.A. Green). Large collections of majids, portunids, alpheids, marine carids, albunids, galatheids and xanthids have been amassed through the activities of fisheries research vessels and CSIRO research vessels such as the *Lancelin, Dorothea, Peron, Davena, Endeavour, Rama, Sprightly* and *Diamantina*. More recently explorations on the continental slope of the North-West Shelf by the CSIRO research vessel *Soela* have yielded an interesting deep-water fauna, especially deep-water lobsters and deep-water barnacles, which are now housed in the collection of the WAM.

List of type specimens

Class Branchiopoda Latreille, 1817
Subclass Calmanostraca Tasch, 1969
Order Notostraca Sars, 1867
Family Triopidae Kielhack, 1910

Lepidurus viridis Baird var. **elongatus** *nov.* Wolf, 1911: 267, Figs 11-12. Syntype, 1 WAM 7182. Locality: Broome Hill, WA, Stn 159.

Subclass Diplostraca Gerstaecker, 1866
Order Conchostraca Sars, 1867
Family Cyzicidae Stebbing, 1910

Cyzicus (Estheria) rufa Dakin, 1914: 301, Pl. II Figs 19-21. Syntypes, 2♀♀ WAM 7730. Locality: Lakeside, Boulder City, WA.

Family Limnadiidae Baird, 1849

Eulimnadia badia Wolf, 1911: 270, Figs 14-24. Syntypes, 2 WAM 7185. Locality: Boorabbin, WA.

Eulimnadia cygnorum Dakin, 1914: 299, Pl. I Figs 9-13. Syntypes, WAM 5180. Locality: Cannington, near Swan R., WA, in fresh water.

Subclass Sarsostraca Tasch, 1969
Order Anostraca Sars, 1867
Family Artemiidae Grochowski, 1896

Parartemia cylindrifera Linder, 1941: 221, Fig. 27, Pl. I Figs 3-6. Holotype, ♂ WAM 739-32. Locality: Buniche, Lake Biddy, WA.
Paratype, ♀ WAM 740-32. Locality: As in holotype.
Remarks: Only two specimens are known of this species.

Parartemia extracta Linder, 1941: 220, Fig. 26. Holotype, ♂ WAM 13700. Locality: Minnivale, WA.
Paratypes, 4♂♂ + 1♀ WAM 13700/09. Locality: As in holotype.
Remarks: Only four paratypes present, all badly preserved. Paratype (1♂) also in ZM Uppsala.

Parartemia informis Linder, 1941: 225, Fig. 29. Holotype, ♂ WAM 138-62. Locality: Lake Monger, WA.

Paratypes, ♂ WAM 10337, ♀ WAM 10338, many WAM 139-62. Locality: As in holotype.

Remarks: Paratype material not well preserved. Paratypes (2♂♂, 1♀) also in ZM Uppsala.

Parartemia serventyi Linder, 1941: 223, Fig. 28. Holotype, ♂ WAM 136-62. Locality: Lake Gilmore, WA.

Paratypes, many WAM 137-62.

Remarks: Paratypes also in USNM (2♂♂, 2♀♀) and in ZM Uppsala (many).

Family Thamnocephalidae Simon, 1886

Branchinella affinis Linder var. ***wonganensis*** *nov.* Linder, 1941: 261, Fig. 39d. Holotype, ♂ WAM 143-62. Locality: Wongan Hills (Agriculture Research Station), WA.

Paratypes, many WAM 144-62. Locality: As in holotype.

Remarks: Geddes (1981: 271) considers this material synonymous with *Branchinella affinis* Linder, 1941: 257-61, Fig. 36. Paratype material also in the ZM Uppsala (10♂♂, 16♀♀).

Branchinella australiensis (Richters) var. ***occidentalis*** *nov.* Dakin, 1914: 296, Pl. I Figs 1-5. Syntypes, 2♂♂ WAM 4488/9. Locality: Lake Violet, 5 km from Wiluna, WA.

Remarks: 1♂ dissected. Geddes (1981: 260) synonymised this species with *Branchinella occidentalis* Linder, 1941: 251-2.

Branchinella basispina Geddes, 1981: 281, Fig. 15a-e.

Paratypes, many (unregistered). Locality: Homestead Dam, Balladonia Station, WA, 32°28'S, 123°52'E.

Remarks: Holotype ♂, Allotype ♀, Paratypes ♂♂ + ♀♀ deposited in the AM, registration numbers P28419, P28420 and P28421 respectively. The WAM paratype material is unregistered and had not been located at the time of writing.

Branchinella denticulata Linder, 1941: 262, Figs 38, 39a-c. Holotype, ♂ WAM 145-62. Locality: Lake Gidgee, near Kalgoorlie, WA.

Paratypes, many ♂♂ + ♀♀ WAM 146-62. Locality: As in holotype.

Remarks: WAM 146-62, ♂♂ and ♀♀ paratypes in two tubes. No locality data but locality is probably the same as the holotype as the date and the collector for both agree. Paratypes also in the ZM Uppsala.

Branchinella longirostris Wolf, 1911: 257, Figs 1-4. Holotype, WAM 7131. Locality: Boorabbin, WA.

Remarks: Specimens have not been located. Geddes (1981: 268) remarks that the type material of Wolf (1911) has disintegrated.

Branchinella nichollsi Linder, 1941: 249, Fig. 33.
Paratypes, 11♂♂ + 11♀♀ WAM 142-62. Locality: Lake Gidgee, near Kalgoorlie, WA.
Remarks: Linder (1941: 249) states that the ♂ holotype was also deposited in the WAM. However, there is no record of this in the registers and the holotype has not been located in the collection. Paratype material is present. Paratypes also in ZM Uppsala (4♂♂, 3♀♀). Geddes (1981: 264) designated this material as the subspecies *Branchinella nichollsi nichollsi*.

Branchinella simplex Linder, 1941: 247, Fig. 32. Holotype, ♂ WAM 140-62.
Locality: Lake Kopai, near Kurrajong, WA, 30°46′S, 121°15′E.
Paratypes, 25♀♀ WAM 141-62. Locality: As in holotype.
Remarks: Lake Kopai mis-spelt as Lake Kofar in Linder (1941: 247). Paratypes also in ZM Uppsala (1♂, 2♀♀).

Class Maxillopoda Dahl, 1956
Subclass Cirripedia Burmeister, 1834
Order Thoracica Darwin, 1854
Suborder Lepadomorpha Pilsbry, 1916
Family Heteralepadidae Nilsson-Cantell, 1921

Paralepas georgei Daniel, 1970: 33, Figs 1-10. Holotype, WAM 190-62. Locality: Off Rottnest I., WA, from *Panulirus cygnus* George.
Paratypes, 5 WAM 191-62 Tasmania, from *Jasus novaehollandiae* Holthuis; 2 WAM 193-62 Doubtful I. Bay, WA, from *Pseudocarcinus gigas* (Lamarck); 21 WAM 196-62 off Rottnest I., WA, from *Hypothalassia armata* (de Haan); 3 WAM 226-68 off Rottnest I., WA, from *P. cygnus* George.

Subclass Copepoda Milne-Edwards, 1840
Order Calanoida Sars, 1903
Family Arietellidae Sars, 1902

Paramisophria variabilis McKinnon and Kimmerer, 1985: 85, Figs 1-2.
Paratypes, 2♂♂ + 2♀♀ WAM 44-84. Locality: Fauré Sill, Shark Bay, WA.

Family Centropagidae Giesbrecht, 1892

Boeckella shielii Bayly, 1985: 79, Fig. 1A-1F. Holotype, ♂ WAM 89-84. Locality: Pool, 60 km NNE of Esperance, WA.
Allotype, ♀ WAM 90-84. Locality: As in holotype.
Paratypes, ♂ WAM 91-84, ♀ WAM 92-84, 18♂♂ WAM 93-84, 35♀♀ WAM 94-84. Locality: As in holotype.
Remarks: WAM 89 to 92-84 slides; WAM 93 and 94-84 formalin.

Hemiboeckella andersonae Bayly, 1974: 88, Figs 1a-e, 2a-d.
Paratypes, 3♀♀ WAM 182-73, 3♂♂ WAM 183-73, 10♂♂ + 10♀♀ WAM 184-73. Locality: Culeenup I., Yunderup Delta, WA.
Remarks: WAM 182-73, 3 slides; WAM 183-73, 3 slides; WAM 184-74, formalin.

Class Malacostraca Latreille, 1806
Subclass Eumalacostraca Grobben, 1892
Superorder Peracarida Calman, 1904
Order Amphipoda Latreille, 1816
Suborder Gammaridea Latreille, 1803
Family Acanthonotozomatidae Stebbing, 1906

Iphimediella intermedia Nicholls, 1938: 71, Fig. 37a-h. Syntypes, several WAM 309-64. Locality: Commonwealth Bay, Australian Antarctic Territory, Stn 2, 527-549 m.
Remarks: Specimens now located in AM (P31682).

Iphimediella margueritei Chevreux var. *acuta nov.* Nicholls, 1938: 69, Fig. 36a-c. Syntypes, 3 WAM 308-64. Locality: Commonwealth Bay, Australian Antarctic Territory, 640-732 m.
Remarks: Specimens now located in AM (P18716).

Panoploea joubini Chevreux var. *bidentata nov.* Nicholls, 1938: 64, Fig. 33a-g.
? Syntypes, 2 WAM 264-64, 5 WAM 265-64, 1 WAM 266-64. Locality: Commonwealth Bay, Australian Antarctic Territory, Stn 7, 46 m; Stn 7, 110 m; Stn 2, 527-549 m, respectively.
Remarks: Specimens now located in AM (P18721, P18731-32).

Pariphimediella octodentata Nicholls, 1938: 75, Fig. 39a-h. Holotype, WAM 307-64. Locality: Commonwealth Bay, Australian Antarctic Territory, 527-549 m.
Remarks: Specimen now located in AM (P18720).

Family Amphilochidae Boeck, 1871

Austropheonoides mundoe Barnard, 1972: 18, Figs 2-3. Holotype, ♀ 3.6 mm WAM 219-68. Locality: Middleton Beach, Albany, WA, intertidal; algae and rocks.

Narapheonoides mullaya Barnard, 1972: 21, Figs 6-7. Holotype, ♀ 2.9 mm WAM 220-68. Locality: Sugarloaf Rock, Cape Naturaliste, WA, intertidal; wash of rocks and algae, mainly green *Caulerpa* species.

Unyapheonoides dabber Barnard, 1972: 26, Figs 8-9. Holotype, 1.95 mm WAM 174-70. Locality: Cheyne Beach, E of Albany, WA, intertidal; weedy rocks.
Remarks: Animal cut to pieces.

Family Calliopiidae Sars, 1893

Atylopsis megalops Nicholls, 1938: 93, Figs 49a-e, 52a. Syntypes, 2 WAM 302-64. Locality: Commonwealth Bay, Australian Antarctic Territory, 82-91 m.
Remarks: Specimen transferred to and registered in AM, now missing (see Lowry, 1982: 320).

Calliope fluviatilis Thomson, 1879: 240, Fig. C4. ? Holotype, WAM 280-64. Locality: ? Dunedin, New Zealand.
Remarks: Specimen is from Prof. Nicholls' collection and is probably Thomson's (1879) type. Barnard and Karaman (1982: 181) transferred this species to the genus *Paracalliope* in the family Paracalliopiidae.

Family Ceinidae Barnard, 1972

Ceina wannape Barnard, 1972: 29, Figs 10-11. Holotype, ♂ 7.5 mm WAM 218-68. Locality: Inside Forsythe Bluff, 19 km W of Albany, WA, intertidal; wash of dense algae on heavily wave-splashed smooth rocks.

Family Colomastigidae Stebbing, 1906

Colomastix simplicicauda Nicholls, 1938: 62, Fig. 32. Holotype, ♀ WAM 253-64. Locality: Macquarie I.
Remarks: Specimen has not been located in either the WAM or the AM.

Family Dexaminidae Leach, 1813

Guernea endota Barnard, 1972: 165, Figs 98-100. Holotype, ♀ 3.0 mm WAM 167-70. Locality: Cheyne Beach, E of Albany, WA, intertidal; weedy rocks.

Guernea melape Barnard, 1972: 173, Figs 104-106. Holotype, ♀ 1.85 mm WAM 164-70. Locality: W of Bunker Bay, Cape Naturaliste, WA, intertidal; wash of algae and rocks.

Guernea unchalka Barnard, 1972: 177, Figs 107-108. Holotype, ♀ 1.8 mm WAM 168-70. Locality: Middleton Beach, WA, intertidal; wash of sandy coralline algae.

Paradexamine churinga Barnard, 1972: 57, Figs 21-27. Holotype, ♀ 3.4 mm WAM 211-68. Locality: Jervois Bay, Cockburn Sound, WA, on groin 3 km SE of Woodman Point, 1 m; algae on rocks.

Paradexamine goomai Barnard, 1972: 92, Figs 47-49. Holotype, ♀ 5.3 mm WAM 214-68. Locality: Sugarloaf Rock, W of Bunker Bay, Cape Naturaliste, WA, intertidal; wash of algae, mainly green *Caulerpa* species.

Paradexamine linga Barnard, 1972: 101, Figs 53-55. Holotype, ♀♀ 3.4 mm WAM 159-70. Locality: 5 km NE of Dunsborough, near Cape Naturaliste, WA, on jetty pilings; wash of sponges and tunicates on pilings of old jetty.

Paradexamine marlie Barnard, 1972: 105, Figs 56-58. Holotype, ♀ 3.3 mm WAM 221-68. Locality: Jervois Bay, Cockburn Sound, WA, on groin 3 km SE of Woodman Point, 1 m; algae on rocks.

Paradexamine narluke Barnard, 1972: 115, Figs 62-63. Holotype, ♂ 3.3 mm WAM 39-70. Locality: Sugarloaf Rock, Cape Naturaliste, WA, intertidal; wash of common seaweeds.

Paradexamine otichi Barnard, 1972: 118, Figs 64-66. Holotype, ♀ 2.85 mm WAM 160-70. Locality: Middleton Beach near Albany, WA, intertidal; wash of sandy rocks, coralline algae.

Paradexamine quarallia Barnard, 1972: 126, Figs 70-72. Holotype, ♀ 2.9 mm WAM 156-70. Locality: Cheyne Beach, E of Albany, WA, intertidal; on weedy rocks.

Paradexamine rongii Barnard, 1972: 130, Figs 73-74. Holotype, ♀ 3.25 mm WAM 158-70. Locality: 5 km NE of Dunsborough, near Cape Naturaliste, WA, on pilings of old jetty; wash of sponges and tunicates.

Paradexamine thadalee Barnard, 1972: 133, Figs 75-77. Holotype, ♀ WAM 162-70. Locality: Cheyne Beach, WA, intertidal.

Paradexamine windarra Barnard, 1972: 138, Figs 78-80. Holotype, ♀ 3.95 mm WAM 161-70. Locality: Cheyne Beach, E of Albany, WA, intertidal; on weedy rocks.
Remarks: Specimen dissected.

Prophlias anomalus Nicholls, 1939: 314, Figs 1-2. ? Syntypes, '8 examples', WAM 575-85. Locality: W side of Bathurst Pt, Rottnest I., WA, in fine sand and weed between large boulders where waves break continually.
Remarks: 3 slides — note in slide box reads 'This is a Nicholls' species. pbl. - 1939. May be "type" material, W. Zeidler. March 1977.' Syntypes in S. Aust. Mus. Barnard (1972: 162) transferred this species from the family Phliantidae

Nicholls, 1939 to the family Dexaminidae Leach, 1813 subfamily Prophliantinae Barnard, 1970.

Syndexamine wunda Barnard, 1972: 143, Figs 81-83. Holotype, ♂ 3.7 mm WAM 222-68. Locality: Middleton Beach, Albany, WA, intertidal; wash of sandy rocks, coralline algae.

Family Eusiridae Stebbing, 1888

Pontogeneiella maneroo Barnard, 1972: 187, Figs 112-114. Holotype, ♀ 3.4 mm WAM 192-70. Locality: Sugarloaf Rock, Cape Naturaliste, WA, intertidal; wash of common seaweeds.

Tethygeneia elanora Barnard, 1972: 200, Figs 119-121. Holotype, ♀ 6.8 mm WAM 172-70. Locality: Middleton Beach, Albany, WA, intertidal; wash of sandy rocks, coralline algae.

Tethygeneia nalgo Barnard, 1972: 205, Fig. 122. Holotype, ♂ 6.1 mm WAM 171-70. Locality: Middleton Beach, Albany, WA, intertidal; wash of sandy rocks, coralline algae.

Tethygeneia tulkara Barnard, 1972: 208, Fig. 123. Holotype, ♀ 4.5 mm WAM 169-70. Locality: Sugarloaf Rock, Cape Naturaliste, WA, intertidal; wash of common seaweeds.

Tethygeneia waminda Barnard, 1972: 210, Figs 124-126. Holotype, ♀ 6.6 mm WAM 170-70. Locality: Sugarloaf Rock, Cape Naturaliste, WA, intertidal; wash of algae — mainly green *Caulerpa* species.

Family Gammaridae Leach, 1813

Ceradocoides chiltoni Nicholls, 1938: 123, Fig. 63a-c. Holotype, WAM 256-64. Locality: Commonwealth Bay, Australian Antarctic Territory, Stn 4, 549 m. Remarks: Specimens now located in AM (P18710).

Cottesloe berringar Barnard, 1974: 29, Figs 19-21. Holotype, ♂ 13.3 mm WAM 136-71. Locality: Cottesloe, WA.
Remarks: Lowry and Fenwick (1983: 228) transferred this species to the genus *Gammarella* Bate, 1862 in the family Melitidae Bousfield, 1973, 1977 (emend.).

Elasmopus menurte Barnard, 1974: 21, Figs 14-15. Holotype, ♂ 10.2 mm WAM 129-71. Locality: W of Bunker Bay, Cape Naturaliste, WA, intertidal; wash of algae and rocks.

Elasmopus yunde Barnard, 1974: 23, Figs 16-18. Holotype, ♂ 4.8 mm WAM 130-71. Locality: Point Peron, WA; weed washing.

Hurleya kalamundae Straskraba, 1966: 291, Pls 56(1)-57(2). Holotype, ♀ WAM 404/6-54. Locality: Kalamunda, WA.
Remarks: ♀ with oostegites.

Mallacoota carteta Barnard, 1972: 252, Fig. 147 (part). Holotype, ♂ 8.8 mm WAM 196-70. Locality: Cheyne Beach, E of Albany, WA, intertidal; weedy rocks.
Remarks: Lowry and Fenwick (1983: 228) transferred this species to the genus *Hoho* in the family Melitidae Bousfield, 1973, 1977 (emend.).

Melita matilda Barnard, 1972: 231, Figs 136, 137 (part). Holotype, ♂ 8.9 mm WAM 225-68. Locality: Matilda Bay, Swan R., WA; in dead clam.

Melita oba Barnard, 1972: 231, Fig. 137 (part). Holotype, ♂ 7.2 mm WAM 213-68. Locality: W of Bunker Bay, Cape Naturaliste, WA, intertidal; on seaweed.

Melita zeylanica Stebbing *kauerti subsp. nov.* Barnard, 1972: 235, Figs 139-141. Holotype, ♂ 8.0 mm WAM 189-70. Locality: Middle Swan Bridge, Swan R., WA.

Neoniphargus branchialis Nicholls, 1924b: 105, Pls X-XI. Syntypes, 4 WAM 249-64, 1 WAM 11781. Locality: King River district, Albany, WA.
Remarks: WAM 249-64, 3 whole specimens, 1 specimen in two halves. Straskraba (1964: 133, Fig. 7) transferred this species to the genus *Perthia*.

Neoniphargus nichollsi Straskraba, 1964: 128, Fig. 3. Holotype, ♂ 5 mm WAM 11781. Locality: Cannington, WA.
Remarks: Lot consists of 6 specimens of *N. nichollsi* together with 2 specimens of *Perthia acutitelson*. Holotype of *N. nichollsi* is specimen No. 1.

Parelasmopus echo Barnard, 1972: 255, Figs 148-149. Holotype, ♂ 14.0 mm WAM 41-69. Locality: SW of Bunbury, WA, 20 m.

Parelasmopus ya Barnard, 1972: 258, Figs 150-152 (part). Holotype, ♂ 12.3 mm WAM 10-69. Locality: Cockburn Sound, WA.

Perthia acutitelson Straskraba, 1964: 134, Figs 8-9. Holotype, ♂ WAM 11781. Locality: Cannington, WA.
Remarks: Lot consists of 2 specimens (1♂ holotype and 1♀) together with 6 specimens of *Neoniphargus nichollsi*.

Family Hyalidae Bulycheva, 1957

Hyale loorea Barnard, 1974: 59, Figs 38-40. Holotype, ♂ 3.5 mm WAM 141-71. Locality: W of Bunker Bay, Cape Naturaliste, WA, intertidal; wash of algae and rocks.

Hyale yake Barnard, 1974: 76, Figs 49-50. Holotype, ♂ 7.2 mm, WAM 140-71. Locality: Cheyne Beach, WA.

Family Leucothoidae Dana, 1852

Leucothoe gooweera Barnard, 1974: 94, Fig. 58. Holotype, ♀ WAM 9-69. Locality: NW of Bluff Pt, Geraldton, WA.
Remarks: ♀ ovigerous.

Family Lysianassidae Dana, 1849

Ambasiopsis tumicornis Nicholls, 1938: 21, Fig. 7a-j. Syntypes, several WAM 315-64, 2 WAM 316-64, several WAM 317-64 (?1, WAM 318-64). Locality: Commonwealth Bay, Australian Antarctic Territory, all at 640-732 m except WAM 318-64, 110 m.
Remarks: A note written in register for WAM 318-64 is as follows 'not designated as *tumicornis* but agrees with locality etc.'. Specimens now in AM (P18705-07).

Lepidepecreella emarginata Nicholls, 1938: 31, Fig. 13a-p. Holotype, ♀ WAM 312-64. Locality: Commonwealth Bay, Australian Antarctic Territory, 527-549 m.
Remarks: Specimens now located in AM (P18717).

Parawaldeckia dilkera Barnard, 1972: 269, Fig. 159. Holotype, '♀-like' 3.9 mm WAM 216-68. Locality: W of Bunker Bay, Cape Naturaliste, WA, intertidal; wash of algae and rocks.

Tryphosella orana Barnard, 1972: 276, Figs 164-165. Holotype, ♂ 4.2 mm WAM 223-68. Locality: Middleton Beach, Albany, WA, intertidal; wash of sandy rocks, coralline algae.

Family Metopidae Stebbing, 1906

Pseudothaumatelson cyproides Nicholls, 1938: 53, Fig. 28a-k. Syntypes, 1♂ + 1♀ WAM 250-64. Locality: Commonwealth Bay, Australian Antarctic Territory, 46 m.
Remarks: Specimens now located in AM (P18730).

Family Nihotungidae Barnard, 1972

Nihotunga iluka Barnard, 1972: 279, Figs 166-167. Holotype, ? sex 1.0 mm WAM 217-68. Locality: W of Bunker Bay, Cape Naturaliste, WA, intertidal; wash of algae and rocks.

Family Oedicerotidae Lilljeborg, 1865

Oediceroides emarginatus Nicholls, 1938: 88, Fig. 47a-d. Holotype, WAM 314-64. Locality: Commonwealth Bay, Australian Antarctic Territory.
Remarks: Specimen now located in AM (P18718).

Oediceroides similis Nicholls, 1938: 89, Fig. 48a-g. Holotype, ♀ WAM 313-64. Locality: Commonwealth Bay, Australian Antarctic Territory.
Remarks: Specimen now located in AM (P18719).

Family Phliantidae Stebbing, 1899

Cylindryllioides mawsoni Nicholls, 1938: 59, Figs 30a-o, 31p-w. Syntypes, 2 WAM 303-64, 1 WAM 304-64, 1 WAM 305-64, 3 WAM 306-64. Locality: Macquarie I., shore collection.
Remarks: Specimens now located in AM (P18711-14).

Family Phoxocephalidae Sars, 1891

Birubius eake Barnard and Drummond, 1978: 357, Figs 179-181. Holotype, ♀ 'a' 3.11 mm WAM 68-81. Locality: Sugarloaf Rock, Cape Naturaliste, WA, intertidal; wash of common seaweeds.

Birubius gambodeni Barnard and Drummond, 1978: 292, Figs 139-143. Holotype, ♀ 'c' 10.6 mm WAM 67-81. Locality: Middleton Beach, Albany, WA, intertidal; wash of sandy rock, coralline algae.

Birubius nammuldus Barnard and Drummond, 1978: 212, Figs 91-92. Holotype, ♂ 'a' 4.98 mm WAM 71-81. Locality: Barrow I., WA.

Ganba pellati Barnard and Drummond, 1978: 125, Figs 48-49. Holotype, ♀ 'a' 5.25 mm WAM 62-81. Locality: Cheyne Beach, Albany, WA, intertidal; on weedy rocks.

Kuritus nacoomus Barnard and Drummond, 1978: 130, Figs 50-51. Holotype, ♂ 'a' 4.16 mm WAM 414-73. Locality: Barrow I., WA.

Limnoporeia wakkine Barnard and Drummond, 1978: 511, Figs 261-263. Holotype, ♂ 'h' 4.72 mm WAM 59-81. Locality: Off Jibbon Pt, NSW; trawl stn 6; dredged, 40 m.

Tipimegus dinjerrus Barnard and Drummond, 1978: 55, Fig. 15. Holotype, ♀ 'w' 8.13 mm WAM 39-81. Locality: Off Jibbon Pt, NSW; trawl stn 6; dredged, 40 m.

Wildus thambaroo Barnard and Drummond, 1978: 134, Figs 52-54. Holotype, ♀ 'a' 2.43 mm WAM 61-81. Locality: Off Jibbon Pt, NSW; trawl stn 6.

Yan tiendi Barnard and Drummond, 1978: 390, Figs 199-200. Holotype, ♀ 'a' 2.47 mm WAM 64-81. Locality: Middleton Beach, Albany, WA, intertidal; wash of algae and rocks.

Family Platyischnopidae Barnard and Drummond, 1979

Platyischnopus mam Barnard and Drummond, 1979: 11, Figs 6-8. Holotype, ♂ 6.10 mm WAM 58-81. Locality: Off Jibbon Pt, NSW; trawl stn 6.

Family Podoceridae Stebbing, 1906

Podocerus capillimanus Nicholls, 1938: 129, Fig. 67a-d. Syntypes, 2 WAM 310-64, 4 WAM 311-64. Locality: Macquarie I.
Remarks: Specimens now located in AM (P31683-89, P18729).

Family Pontogeneiidae Stebbing, 1906

Paramoera hamiltoni Nicholls, 1938: 117, Figs 52h, n; 60a-h. Syntypes, 2 WAM 259-60, several WAM 260-64, 2 WAM 261-64, 2 WAM 262-64, 1 WAM 263-64. Locality: WAM 259 to 262-64, Macquarie I.; WAM 260-64 SE of Harbour, from roots of kelp; WAM 262-64 N end of Macquarie I.; WAM 263-16 Antarctica or Macquarie I., from stomach of *Notothenia macrocephala,* only part of specimen present.
Remarks: Specimens now located in AM (P18724-28).

Paramoera macquariae Nicholls, 1938: 119, Figs 52j, 61a-g. Holotype, ?♂ WAM 258-64. Locality: Macquarie I.
Remarks: Specimen now located in AM (P18722).

Paramoera schellenbergi Nicholls, 1938: 120, Figs 52k, 62a-k. ? Syntypes, several WAM 251-64. Locality: Macquarie I.
Remarks: Specimens now located in AM (P18723) labelled holotypes, may be syntypes (J.K. Lowry, pers. comm.).

Pontogeneia chosroides Nicholls, 1938: 101, Figs 52b, 53a-o. Syntypes, several WAM 297-64, several WAM 298-64, several WAM 299-64, several WAM 300-64, several WAM 301-64. Locality: Macquarie I. — WAM 300-64 N end; WAM 301-64 SE of Harbour, roots of kelp.
Remarks: Specimens now located in AM (P18734-39).

Pontogeneia chosroides var. *denticulata nov.* Nicholls, 1938: 104, Fig. 54a-d. Syntypes, several WAM 255-64. Locality: Macquarie I.
Remarks: Specimens now located in AM (P18740).

Pontogenoides abyssi Nicholls, 1938: 106, Fig. 55a-o. Holotype, ♀ WAM 252-64. Locality: Adelie I., Antarctic, trawl, 1463 m.
Remarks: Specimen now located in AM (P18733).

Family Stenothoidae Boeck, 1871

Ausatelson ule Barnard, 1972: 312, Figs 189-190. Holotype, ♀ 2.2 mm WAM 212-68. Locality: W of Bunker Bay, Cape Naturaliste, WA, intertidal; wash of algae and rocks.

Chucullba alla Barnard, 1974: 108, Figs 65-66. Holotype, ♀ WAM 134-71. Locality: Middleton Beach, Albany, WA, intertidal; wash of sand, rocks and coralline algae.

Chucullba warea Barnard, 1974: 110, Figs 67-68. Holotype, ♀ WAM 135-71. Locality: W of Bunker Bay, Cape Naturaliste, WA, intertidal; wash of algae and rocks.

Goratelson waroo Barnard, 1972: 315, Figs 191-192. Holotype, ♀ 2.6 mm WAM 215-68. Locality: W of Bunker Bay, Cape Naturaliste, WA, intertidal; wash of algae and rocks.

Raumahara dertoo Barnard, 1972: 318, Figs 193-194. Holotype, ♀ 1.55 mm WAM 224-68. Locality: Sugarloaf Rock, Cape Naturaliste, WA, intertidal; wash of common seaweeds.

Stenothoe allinga Barnard, 1974: 118, Figs 73-74. Holotype, ♀ 3.8 mm WAM 128-71. Locality: Middleton Beach, Albany, WA, intertidal; wash of algae and rocks.
Remarks: ♀ ovigerous.

Stenothoe nonedia Barnard, 1974: 124, Figs 77-78. Holotype, ♀ 2.7 mm WAM 132-71. Locality: Sugarloaf Rock, Cape Naturaliste, WA, intertidal; wash of algae, mainly green *Caulerpa* sp.

Stenothoe quabara Barnard, 1974: 126, Fig. 79. Holotype, ♀ WAM 131-71. Locality: Middleton Beach, Albany, WA, intertidal; wash of algae and rocks.

Stenothoe woka Barnard, 1974: 129, Figs 80-81. Holotype, ♀ 2.7 mm WAM 133-71. Locality: Middleton Beach, Albany, WA, intertidal; wash of algae and rocks.
Remarks: ♀ ovigerous.

Family Talitridae Rafinesque, 1815

Austrotroides occidentalis Friend, 1982: 468, Figs 4-6.
Paratypes, WAM 107-80. Locality: No. 4. Gleneagle B068 WA, Mr Havel's plot 171, black swamp soil, Bullich *(Eucalyptus megacarpa)*.

Austrotroides pectinalis Friend, 1982: 463, Figs 1-3.
Paratypes, WAM 92-81. Locality: Pemberton, WA, site 21 HU61, Karri mixed forest, scattered *Casuarina*, grasses, bracken, brown-red gravel, 34°30′S, 116°00′E.

Talorchestia terrae-reginae Haswell, 1880/81: 98, Pl. V, Fig. 4. ? Syntypes, WAM 254-64. Locality: Sandy Beach, Port Dennison, Qld.
Remarks: From Prof. Nicholls' collection. Depository of type species not mentioned by Haswell.

Order Isopoda Latreille, 1817
Suborder Anthuridea Leach, 1814
Family Paranthuridae Menzies and Glynn, 1968

Aenigmathura lactanea Thomson, 1948: 5, Fig. 4a-k. Syntypes, ♂ + ♀ WAM 147-62. Locality: Bathurst Pt, Rottnest I., WA.

Suborder Flabellifera Sars, 1882
Family Cirolanidae Dana, 1853

Cirolana concinna Hale, 1925: 152, Fig. 12a-i. Holotype, ♀ WAM 10789. Locality: Cottesloe, WA.
Paratypes, 1 WAM 7706, 8 WAM 10988, 16 WAM 10790, 1 WAM 10161, 1 WAM 10581. Locality: As in holotype; WAM 10161 from seaweed, floating; WAM 10581 from a rock pool.
Remarks: WAM 10789 spirit and 3 slides, WAM 10790 spirit and 4 slides.

Family Corallanidae Hansen, 1890

Corallana kulai Bruce, 1982: 243, Figs 2-3. Holotype, ♂ WAM 18-81. Locality: Between Rottnest I. and Fremantle, WA, triangle dredge.
Paratypes, ♂ + ♀ WAM 58-80 between Rottnest I. and Fremantle, WA, triangle dredge; WAM 59-80 NW of Bluff Pt, WA, Stn 204, 99 m, triangle dredge, 27°18′S, 112°16′E; 2 WAM 60-80 SW of Dongara, WA, Stn 214, 128-132 m, 29°49′S, 114°24′E.
Remarks: WAM 58-80 specimens damaged, WAM 59-80 spirit and 1 slide (broken), WAM 60-80 donated to the AM.

Family Cymothoidae Dana, 1852

Livoneca turgidula Hale, 1926: 217, Fig. 11a-i. Holotype, ♀ WAM 10034. Locality: Fremantle, WA.
Allotype, ♂ WAM 11126. Locality: Cottesloe, WA.
Remarks: Parasitic, WAM 10034 spirit and 5 slides, WAM 11126 1 slide. Correct spelling of this genus is *Lironeca* Leach, 1818 although it is often misspelt as *Livoneca*.

Family Sphaeromatidae Milne Edwards, 1840

Cilicaeopsis sculpta Baker, 1928: 54, Pl. iii Figs 5-7. Holotype, WAM 10850. Locality: Cottesloe, WA, in rock pools.
Paratypes, WAM 10672, WAM 10496 to 10501. Locality: As in holotype; WAM 10672 from a sponge; WAM 10496 to 10501 from a sponge, slide.

Cymodoce multidens Richardson var. ***australis*** *nov.* Baker, 1928: 52, Pl. i Figs 4-6. Syntypes, ♂ WAM 10385, ♀ WAM 10484. Locality: Cottesloe, WA.
Remarks: ♀ ovigerous; both syntypes from a sponge; 2 slides.

Exosphaeroma serventii Baker, 1928: 49, Pl. i Figs 1-2. Syntypes, 1♂ + 1♀ WAM 11625a, 4 WAM 11625b, 20 WAM 11625c. Locality: Pallinup Estuary, WA.
Remarks: WAM 11625a slide.

Haswellia glauerti Baker, 1928: 59, Pl. v Figs 1-5. Syntypes, 4 WAM 11754 to 11759. Locality: Cottesloe, WA, in sponge.
Remarks: 1 slide and 4 specimens in spirit. In Baker's (1928) paper the WAM numbers are misprinted as 11795-11759.

Haswellia intermedia Baker, 1926: 274, Pl. liii Figs 1-5. Syntypes, 6 WAM 10383. Locality: Cottesloe, WA, from a sponge.
Remarks: Specimens dissected; 2 slides and spirit.

Isocladus excavatus Baker, 1928: 50, Pl. i Fig. 3. Syntype, WAM 10607. Locality: ? Cottesloe, WA.
Remarks: Specimen has not been located.

Moruloidea tumida Harrison, 1984: 271, Fig. 5. Holotype, ♂ WAM 69-80. Locality: Bathurst Pt, Rottnest I., WA.
Paratypes, ♀ WAM 258-82 (ex WAM 69-80), ♀ WAM 259-82 (ex WAM 70-80). Locality: As in holotype.
Remarks: WAM 69-80 3 slides, WAM 259-82 ♀ ovigerous.

Paracilicaea flexilis Baker, 1928: 55, Pl. iv Figs 1-4. Syntypes, 10 WAM 10608 to 10617. Locality: Cottesloe, WA.
Remarks: 3 glass slides, 1 wooden slide.

Paracilicaea gigas Baker, 1928: 54, Pl. iii Figs 1-4. Syntypes, WAM 11043, ♂ WAM 11044, ♂ WAM 132-62. Locality: Cottesloe, WA.
Remarks: WAM 11043 absent; note in register reads 'in S. Aust. Mus.'. WAM 132-62, locality WA but exact locality unknown; 3 slides, young ♂.

Syncassidina aestuaria Baker, 1928: 60, Pl. v Figs 6-10. Holotype, ♀ WAM 11180a. Locality: Rocky Bay, Swan R., WA, under stones.
Paratypes, ♀♀ WAM 11180b. Locality: As in holotype.
Remarks: WAM 11180a, 4 slides.

Waiteolana gibbera Harrison, 1984: 265, Figs 2a-o, 3a-i. Holotype, ♂ WAM 257-82 (ex WAM 60-80). Locality: S end Garden I., WA.
Paratypes, 7♂♂ + 1♀ + 4 immature individuals WAM 68-80. Locality: As in holotype.
Remarks: WAM 68-80, on gorgonians, ♀ ovigerous, 3 slides.

Suborder Asellota Latreille, 1803
Superfamily Stenetrioidea Hansen, 1905
Family Stenetriidae Hansen, 1905

Stenetrium glauerti Nicholls, 1929: 373, Figs 15-22. Syntypes, ♂ WAM 13927, 2♂♂ WAM 106-61 (ex WAM 13927/8), ♀ WAM 13928, 2 WAM 272-64 (ex WAM 13929/40), ♂ + ♀ WAM 273-64 (ex WAM 13929/40). Locality: Bathurst Pt, Rottnest I., WA.
Remarks: WAM 106-61 slide, WAM 13927 slide, WAM 13928 slide.

Stenetrium macrochirium Nicholls, 1929: 363, Figs 1-10. Syntypes, 2 WAM 270-64, 2 WAM 16024/25, 2 WAM 269-64, 2 WAM 267-64, 5 WAM 268-64. Locality: Dongara Pier, WA, crawling on seaweed growing on piles. WAM 16024/25 has no collection data, but locality is probably Dongara Pier. Note

on labels of WAM 267-64 and 268-64 reads 'not designated as types but in bottle with others'.

Stenetrium spinirostrum Nicholls, 1929: 369, Figs 23-25. Syntypes, 8 WAM 12795 to 12806, ♂ WAM 105-61 (ex WAM 12795), 3 WAM 271-64. Locality: Bathurst Pt, Rottnest I., WA, reef, under stones and broken fragments.
Remarks: WAM 12796 ♀ 1 slide; WAM 105-61 ♂ 2 slides. Also one unregistered slide labelled by Nicholls 'S. *? macrochaerus, ? spinirostrum*'.

Stenetrium truncatum Nicholls, 1929: 371, Figs 11-14. Syntypes, WAM 107-61 (ex WAM 12807). Locality: Bathurst Pt, Rottnest I., WA, reef.
Remarks: 2 slides.

Suborder Phreatoicidea Stebbing, 1893
Family Amphisopodidae Nicholls, 1943

Amphisopus annectans Nicholls, 1942: 82, Figs 20-21. Syntypes, WAM 244-74. Locality: Warron, WA.

Amphisopus lintoni (Nicholls) Nicholls, 1942: 75, Figs 18-19. Syntypes, WAM 218-74. Locality: ?Albany area, WA.
Remarks: 10 slides, material originally labelled by G.E. Nicholls as *P. lintoni* (see Nicholls, 1926a: 182, 1924: 93, Pls 8-9, as *Phreatoicus lintoni*).

Eophreatoicus kershawi Nicholls, 1926a: 190, Figs 17-39. Syntypes, WAM 223-74, WAM 224-74, WAM 225-74, WAM 245-74. Locality: Sandstone Bluff, NT, taken in a small pool.
Remarks: From notes made by the collector locality was on or near the Wellington Hills, 122°30'E, 12°00'S, a 'fine rock hole of clear, cool water'. WAM 223-74, 6 slides of ♂; WAM 224-74, 7 slides of ♂; WAM 225-74, 6 slides of ♂.

Hyperoedesipus plumosus Nicholls and Milner, 1923: 24, Figs 1-2, Pls II-V. Syntypes, 2 WAM 10665/6, WAM 229-74. Locality: Lesmurdie Falls, Kalamunda, WA.
Remarks: WAM 229-74, 3 slides. See Nicholls 1942: 49, Figs 12, 13 for a more correct description of this species.

Paramphisopus palustris (Glauert, 1924) Nicholls, 1942: 58, Figs 14-15. Syntypes, WAM 10249, WAM 10250, WAM 10251 to 19273, WAM 217-74, WAM 221-74. Locality: Chinamens' Garden, N end of Smith's Lake, North Perth, WA (WAM 10249 to 10273, 221-74) and Welshpool, WA (WAM 221-74).
Remarks: WAM 10250, 6 slides; WAM 217-74, 13 slides; WAM 221-74, 2 slides. All WAM material was originally identified by G.E. Nicholls and is labelled *Phreatoicus palustris. Paramphisopus palustris* was previously described as

Phreatoicus palustris by Glauert, 1924: 51, Figs 1-6, and by Nicholls, 1924: 92, Pl. 8, Figs 2 and 2a, and as *Amphisopus palustris* by Nicholls, 1926: 182.

Phreatoicoides longicollis Nicholls, 1942: 136, Figs 32-33. Syntypes, WAM 227-74. Locality: No data in register, ?Tasmania.
Remarks: 4 slides.

Family Phreatoicidae Chilton, 1891

Crenoicus harrisoni Nicholls, 1943: 28, Fig. 40. Syntypes, WAM 10277 to 10280. Locality: Barrington Tops, NSW.
Remarks: Specimens have not been located.

Phreatoicus joyneri Nicholls, 1926a: 183, Pls XXV, XXVI, XXIX, Figs 40-44. ?Possibly syntype, WAM 104-61. Locality: ? Probably Mt Buffalo Plateau, Victoria.
Remarks: Labelled by G.E. Nicholls but no type designated [= *Uramphisopus australis* (Chilton, 1891)]. 8 slides.

Suborder Oniscidea Latreille, 1803
Infraorder Ligiamorpha Vandel, 1943
Section Synocheta Legrand, 1946
Superfamily Styloniscoidea Vandel, 1952
Family Styloniscidae Vandel, 1952

Notoniscus chiltoni Green, 1971: 72, Fig. 37.
Paratypes, ♂ WAM 207-70, ♀ WAM 210-70. Locality: Near Collinsvale, Tasmania, in debris in a Myrtle (Southern Beech) forest. Altitude 730 m.
Remarks: See Green, 1971: 73 for designation of plesiotype.

Notoniscus tasmanicus (Chilton) Green, 1961: 289, Figs 57-72. Plesiotypes, ♂ WAM 209-70, ♀ WAM 210-70. Locality: Near Collinsvale, Tasmania, in debris in a Myrtle (Southern Beech) forest. Altitude 730 m.
Remarks: See Green, 1971: 73 for designation of plesiotype.

Styloniscus hirsutus Green, 1971: 64, Figs 14-20.
Paratypes, ♂ WAM 203-70, ♀ WAM 204-70. Locality: Shoobridge Track, Mt Wellington, Tasmania; in debris beside track. Altitude 580 m.

Styloniscus maculosus Green, 1961: 276, Figs 23-31.
Paratypes, ♂ WAM 548-85, ♀ WAM 549-85. Locality: Tarraleah, Tasmania; in debris on ground, in forest of eucalypts and tree ferns.

Styloniscus planus Green, 1971: 67, Figs 21-28.
Paratypes, ♂ WAM 205-70, ♀ WAM 206-70. Locality: Wombat Moore, Mt Field National Park, Tasmania; under stones on damp ground. Altitude 1070 m.

Styloniscus squarrosus Green, 1961: 281, Figs 42-51.
　　Paratypes, ♂ WAM 550-85, ♀ WAM 551-85. Locality: Mt Wellington, Tasmania; in debris or under wood on ground. Altitude 457-914 m.

Styloniscus sylvestris Green, 1971: 61, Figs 5-9.
　　Paratypes, ♂ WAM 201-70, ♀ WAM 202-70. Locality: Shoobridge Track, Mt Wellington, Tasmania; in debris beside track. Altitude 580 m.

Section Crinocheta Legrand, 1946
Superfamily Oniscoidea Dana, 1852 (pro Atracheata)
Family Oniscidae Brandt, 1851

Phalloniscus (Hanoniscus) monodi Bowley, 1934: 63, Pl. VIII, Figs 13-18. Syntypes, several WAM 281-64, 4 WAM 282-64, 3 WAM 283-64, several WAM 284-64, several WAM 287a-64, several WAM 287b-64, WAM 285-64, WAM 286-64, WAM 296-64. Locality: WAM 281-64 — Near creek near Northam Rd, in . . . paddock, Wooroloo, WA. WAM 282 to 287a-64, 296-64, Wooroloo, WA. WAM 287b-64 under bark of a tree.
　　Remarks: Type series was originally in the Zoology Dept, University of Western Australia. At present the WAM holds specimens of the type series from Wooroloo, WA, but a single specimen from Moora, from the type series has not been located. The remaining specimens in the type series are housed in the Stockholm Museum and are from Moora, WA.

Phalloniscus (Hanoniscus) nichollsi Bowley, 1934: 60, Pl. VII, Figs 1-27. Syntypes, WAM 292-64 Deep R., Nornalup Estuary, WA; WAM 293-64 Frankland R., Nornalup, WA; 4 WAM 291-64 Swarbrick's Beach, Nornalup, WA; WAM 288-64, WAM 289-64, WAM 290-64 probably Warpole (?Walpole) Inlet, Nornalup, WA.
　　Remarks: Type series was originally in the Zoology Dept, University of Western Australia. Now the WAM holds specimens of the type series from Nornalup, WA. The remaining specimens in the type series are housed in the ZIZM Hamburg and are from Bunbury, WA.

Phalloniscus (Hanoniscus) tuberculatus (Budde-Lund) Bowley, 1934: 57, Pl. VIII, Figs 1-12. Syntype, WAM 7166. Locality: York, WA.
　　Remarks: = *Hanoniscus tuberculatus* Budde-Lund, 1912: 42, Pl. I, Figs 14-20, Text Fig. 26. The specimen has not been located.

Plymophiloscia notleyensis Green, 1961: 316, Figs 125-131.
　　Paratypes, ♂ WAM 552-85, ♀ WAM 553-85. Locality: Notley Gorge, Tasmania; under stones or among fallen leaves of eucalyptus and dogwood, on damp hillside.

Plymnophiloscia tasmaniensis Green, 1961: 314, Figs 119-124.
Paratypes, ♂ WAM 554-85, ♀ WAM 555-85. Locality: Tinder Box, Tasmania; in debris on ledge of a cliff above the shore.

Plymnophiloscia thomsoni Green, 1961: 308, Figs 101-109.
Paratypes, ♂ WAM 556-85, ♀ WAM 557-85. Locality: Mt Wellington, Tasmania; in debris or under wood or stones on ground. Altitude 723-1250 m.

Plymnophiloscia ulverstonensis Green, 1961: 319, Figs 132-139.
Paratypes, ♂ WAM 558-85, ♀ WAM 559-85. Locality: West Ulverstone, Tasmania; under stones or in debris on ground immediately inland from beach.

Superfamily Armadilloidea (pro Pseudotracheata Verhoeff)
Family Actaeciidae Vandel, 1952

Actaecia thomsoni Green, 1966: 67.
Paratypes, ♂ WAM 570-85, ♀ WAM 571-85. Locality: Pirates' Bay, Eagle-Hawk Neck, Tasmania; in burrows in sand under seaweed, or walking on beach. Remarks: Also see Green, 1961: 295-301, Figs 75-90.

Family Armadillidae Verhoeff, 1917

Armadillo flavus Budde-Lund, 1912: 37, Pl. I Figs 59-60, Text Figs XXIII and XXIV. Syntype, WAM 7144. Locality: Mundaring Weir, WA, Stn 101.
Remarks: Syntypes also in ZIZM Hamburg.

Armadillo integer Budde-Lund, 1912: 35, Pl. I Figs 39-41, Text Fig. XX. Syntype, WAM 7189. Locality: Torbay, WA, Stn 162.
Remarks: Syntypes also in ZIZM Hamburg.

Armadillo (Buddelundia) albomaculatus Budde-Lund, 1912: 33, Pl. I Figs 61-63, Text Fig. XVIII. Syntype, WAM 7190. Locality: Broomehill, WA, Stn 158.
Remarks: Syntypes also in ZIZM Hamburg.

Armadillo (Buddelundia) binotatus Budde-Lund, 1912: 24, Pl. I Fig. 46, Text Fig. VII. Syntype, WAM 7175. Locality: Boorabbin, WA, Stn 95.
Remarks: Syntypes also in ZIZM Hamburg.

Armadillo (Buddelundia) bipartitus Budde-Lund, 1912: 24, Pl. I Figs 25-29, Text Fig. VIII. Syntypes, 2 WAM 7187. Locality: Baba Head, Edel-Land, Stn 69, 26°36'S, 113°41'E.
Remarks: Syntypes also in ZIZM Hamburg.

Armadillo (Buddelundia) callosus Budde-Lund, 1912: 27, Pl. I Figs 23-24, Text Fig. XI. Syntype, WAM 7191. Locality: Northampton, WA, Stn 71.
Remarks: Syntypes also in ZIZM Hamburg.

Armadillo (Buddelundia) cinerascens Budde-Lund, 1912: 26, Text Fig. IX. Syntype, WAM 7154. Locality: Rottnest I., WA, Stn 121.
Remarks: Syntypes also in ZIZM Hamburg.

Armadillo (Buddelundia) inaequalis Budde-Lund, 1912: 27, Pl. I Figs 21-22, Text Fig. X. Syntype, WAM 7159. Locality: Fremantle, WA.
Remarks: Syntypes also in ZIZM Hamburg.

Armadillo (Buddelundia) laevigatus Budde-Lund, 1912: 23, Pl. I Figs 6-9, Text Fig. VI. Syntype, WAM 7174. Locality: Day Dawn, WA, Stn 76, 27°28'S, 117°52'E.
Remarks: Syntypes also in ZIZM Hamburg.

Armadillo (Buddelundia) nigripes Budde-Lund, 1912: 33, Pl. I Figs 54-55, Text Fig. XVII. Syntype, WAM 7192. Locality: Bunbury, WA, Stn 142.
Remarks: Syntypes also in ZIZM Hamburg.

Armadillo (Buddelundia) opacus Budde-Lund, 1912: 29, Pl. I Figs 47-48, Text Fig. XIII. Syntype, WAM 7165. Locality: Gooseberry Hill, WA, Stn 152.
Remarks: Syntypes also in ZIZM Hamburg.

Armadillo (Buddelundia) subinermis Budde-Lund, 1912: 31, Pl. I Figs 33-34, Text Fig. XV. Syntype, WAM 7168. Locality: Eradu, WA, Stn 80, 28°42'S, 115°02'E.
Remarks: Specimen present but note in register says 'presumed lost RWG 11.11.58'. Syntypes also in ZIZM Hamburg.

Armadillo (Buddelundia) sulcatus Budde-Lund, 1912: 22, Pl. I Figs 11-13, Text Figs III-V. Syntype, WAM 7194. Locality: Eradu, WA, Stn 80, 28°42'S, 115°02'E.
Remarks: Syntypes also in ZIZM Hamburg.

Cubaris hickmani Green, 1961: 336, Figs 147-161.
Paratypes, ♂ WAM 560-85, ♀ WAM 561-85. Locality: Tarraleah, Tasmania; in debris or under logs in forest of eucalypts and tree ferns.

Cubaris sulcifrons Green, 1961: 344, Figs 172-180.
Paratypes, ♂ WAM 562-85, ♀ WAM 563-85. Locality: Roaring Beach, South Arm, Tasmania; enrolled and buried in moist sandy soil at base of cliff, above the shore.

Cubaris tamarensis Green, 1961: 348, Figs 181-192.
Paratypes, ♂ WAM 564-85, ♀ WAM 565-85. Locality: Swan Point, West Tamar, Tasmania; in debris under grass tussocks growing immediately inland from shore of R. Tamar.

Cubaris tasmaniensis Green, 1961: 341, Figs 162-171.
Paratypes, ♂ WAM 566-85, ♀ WAM 567-85. Locality: Tinder Box, Tasmania; in debris on ledge of a cliff above the shore.

Echinodillo cavaticus Green, 1963: 77, Figs 1-12.
Paratypes, ♂ WAM 565-85, ♀ WAM 569-85. Locality: Near Whitemark, Flinders I. (Furneaux Gp), Bass Strait; in limestone cave.

Superorder Eucarida Calman, 1904
Order Decapoda Latreille, 1803
Family Atyidae De Haan, 1849

Stygiocaris lancifera Holthuis, 1960: 48, Figs 1-2.
Paratypes, 3 WAM 16-59, 27 WAM 12-59, 54 WAM 13-59. Locality: WAM 16-59, Milyering Well, North West Cape Peninsula, WA. Milyering Well lies under a windmill, bored into coral and limestone. Fresh water, 27°C. WAM 12 and 13-59, Kuddumurra Well, Yardie Creek Station, North West Cape Peninsula, WA. Cemented well with *Melyeringa*. Temp. 29-30° C. Water tidally influenced.

Stygiocaris stylifera Holthuis, 1960: 54, Fig. 3.
Paratypes, 2 WAM 14-59, 7 WAM 15-59. Locality: Kuddumurra Well, Yardie Creek Station, North West Cape Peninsula, WA.

Family Palaemonidae Rafinesque, 1815

Palaemonetes atrinubes Bray, 1976: 76, Figs 23-42. Holotype, ♀ 34 mm WAM 106-75. Locality: Lower Swan River, WA.
Paratypes, 57♂♂ + 60♀♀ + 6 juvs — WAM 456-73 Gladstone, Shark Bay, WA; WAM 515-73 Wapet Ck, Exmouth Gulf, WA; WAM 519-73 Cockatoo I., WA, common in rock pools; WAM 94-75♂ 35 mm Lower Swan R., WA; WAM 95-75♀ 35 mm Lower Swan R., WA; WAM 98-75♂♂ 12-20 mm Bay of Rest, Exmouth Gulf, WA; WAM 104-75 Alfred Cove, Lower Swan R., WA; WAM 105-75 Canning Bridge, Lower Swan R., WA.
Remarks: WAM 94-75 slides, figured.

Palaemonetes australis Dakin. Bray, 1976: 67, Figs 2-22. Neotype, ♀ WAM 108-75. Locality: Upper Swan R., WA.

Remarks: ♀ ovigerous. Depository of type species not given in Dakin's (1915) description and his specimens could not be located in the WAM or the AM. Bray (1976) designated and described the neotype.

Paratypes, numerous — WAM 36-74 Junction Hill R. and Coomalloo Ck, WA; ♂ 26 mm WAM 92-75 Upper Swan R., WA; ♀ 25 mm WAM 93-75 Upper Swan R., WA; ♂♂ 12-45 mm + ♀♀ 19-39 mm WAM 96-75 Moore R. (bridge), WA; ♂♂ 10-26 mm + ♀♀ 12-23 mm WAM 97-75 27 km W of Esperance, WA, small stream; ♂♂ 20-30 mm + ♀♀ 20-36 mm WAM 100-75 Avon (Swan) R., York, WA; ♂♂ 25-32 mm + ♀♀ 31-37 mm WAM 101-75 Swan R., Middle Swan Bridge, WA; ♂♂ 18-33 mm + ♀♀ 17-37 mm WAM 102-75 Nedlands Baths, Swan R., WA; ♂♂ 15-27 mm + ♀♀ 16-33 mm WAM 103-75 Deadwater, Hardy Inlet, WA; ♂♂ 21-29 mm + ♀♀ 27-34 mm WAM 107-75 Upper Swan R., WA; ♂♂ 14-22 mm + ♀♀ 20-26 mm WAM 109-75 Murray R., WA off deep bank, reeds; ♂♂ 18-22 mm + ♀♀ 20-30 mm WAM 110-75 Taylor Inlet, Nanarup, WA.

Remarks: WAM 36-76 type of pool, probably permanent, thick growth, aquatic vegetation, fresh water, 24°C; WAM 92-75, 93-75 and 96-75 slides; WAM 92-75, 93-75 figured.

Family Alpheidae Rafinesque, 1815

Alpheus astrinx Banner and Banner, 1982: 35, Fig. 5. Holotype, ♀ WAM 365-65. Locality: Garden I., WA; in old coral rock 91 m off shore.
Paratypes, 2♂♂ + 2♀♀ (ex WAM 265-65). Locality: As in holotype.

Alpheus balaenodigitus Banner and Banner, 1982: 223, Fig. 70. Holotype, ♀ WAM 172-65. Locality: Port Walcott, WA, 15 m, sand and occasional sponges and coral.
Remarks: ♀ ovigerous.

Alpheus bunburius Banner and Banner, 1982: 213, Fig. 66. Holotype, ♀ WAM 271-65. Locality: Bunbury, WA.

Alpheus georgei Banner and Banner, 1982: 200, Fig. 61. Holotype, ♂ WAM 226-65. Locality: 64 km W of Cape Jaubert, WA, 40 m.

Alpheus papillosus Banner and Banner, 1982: 260, Fig. 80.
Paratypes, WAM 34-65 Exmouth Gulf or Shark Bay, WA, trawled; WAM 49-65 Decres Bay, SA; WAM 205-65 Cockburn Sound, WA, inshore, 2 m; WAM 239-65 Cockburn Sound, WA; WAM 334-79, 335-79, ? locality.
Remarks: WAM 334-79, 335-79, note in register reads 'returned Nov. 79 by Banner and Banner as an unregistered specimen lot from WAM'.

Alpheus parasocialis Banner and Banner, 1982: 72, Fig. 17. Holotype, ♀ WAM 288-65. Locality: Palm Beach, Rockingham, WA, jetty piles; in sponges.

Allotype, ♂ ex WAM 288-65. Locality: As in holotype.

Paratypes, numerous — WAM 23-65 Carnarvon area, WA, trawled; WAM 29-65 Pelsart Gp, Abrolhos Is, WA; WAM 38-65 11 km SW of Bunbury, WA, 20 m; WAM 42-65 Lancelin, WA; WAM 58-65 NE of Garden I., WA, in old boom piles; WAM 87-65 Kwinana, Cockburn Sound, WA, 181-271 m NW of No. 2 Light Buoy; WAM 95-65 near bar of South Passage, Shark Bay, WA, Honolulu dredge, 11 m, sand and weed; WAM 97-65 Emu Pt channel, Albany, WA, 6-12 m, from gorgonians, sponges, stones etc.; WAM 103-65 Busselton, WA; WAM 108-65 near bar of South Passage, Shark Bay, WA, Honolulu dredge, 11 m, sand and mud; WAM 109-65 Trigg I., WA; WAM 111-65 1-3 km W of Seal I., King George Sound, WA; WAM 112-65 Esperance Bay, WA, jetty piles; WAM 113-65 Rockingham, WA, from rocks, near old piles; WAM 117-65 Fremantle, WA, jetty piles; WAM 120-65 Pidgeon I., Wallabi Gp, Abrolhos Is, WA, jet black, in green crinoid; WAM 121-65 Busselton, WA; WAM 130-65 Port Gregory, WA, reef, under stones at low tide on reef flat; WAM 135-65 Eagle Bay, Cape Naturaliste, WA, under intertidal granite boulders; WAM 143-65 Lancelin I., WA; WAM 159-65 Owen Anchorage, off South Fremantle Power House, WA, trawled; WAM 182-65 8 km E of North I., Abrolhos Is, WA, Honolulu dredge, some weed, coral, sponge; WAM 198-65 3 km E of E end of Rottnest I., WA, 17 m; WAM 200-65 W side, Good Friday Bay, Abrolhos Is, WA, dredged, 18-27 m; WAM 201-65 approx. 5 km NW of Ledge Pt, WA, 14-16 m, craypots; WAM 202-65 Beagle I., WA, 10 m, from craypot or cray ropes; WAM 203-65 near bar of South Passage, Shark Bay, WA, Honolulu dredge, 11 m, sand and weed; WAM 228-65 near bar of South Passage, Shark Bay, WA, Honolulu dredge, 11 m, sand and weed; WAM 240-65 Point Peron, WA, among worm rock; WAM 248-65 16-32 km W of Lagrange Bay, WA, 22-46 m; WAM 257-65 Jervoise Groyne, Cockburn Sound, WA, in crevices of old dead coral, 4 m; WAM 266-65 Careening Bay, Garden I., WA, from sponge, under naval jetty; WAM 267-65 Careening Bay, Garden I., WA, beam trawl, 4 m; WAM 269-65 W of West End, Rottnest I., WA, dredged, 135-144 m; WAM 288-65 Palm Beach, Rockingham, WA, jetty piles; WAM 336-79 N of Rat I., Easter Gp, Abrolhos Is, WA, Scallop trawl, 37 m, sand bottom; WAM 337-79 1.6 km N of Jubilee I., Abrolhos Is, WA, Scallop trawl, 32 m, found in small cavities in corals and sponges; WAM 338-79, 339-79, 340-79 Cockburn Sound, near Perth, WA, 18-20 m, trawled, from sponges; WAM 153-31 to 173-31 reef at Bathurst Pt, Rottnest I., WA; WAM 4985 ?FIS *Endeavour*, between Fremantle and Geraldton, WA; WAM 10011 Cottesloe, WA, from *Posidonia*; WAM 11100, 11101 Cottesloe, WA; WAM 10381 Cottesloe, WA, from a sponge; WAM 10467 Craigie Lake, Wanneroo, WA; WAM 10571, 10572 Cottesloe, WA, from a sponge; WAM 251-32 to 278-32 Cottesloe, WA, from a sponge.

Remarks: WAM 10467 locality erroneous, correct locality is possibly Cottesloe, WA, from a sponge.

Alpheus strenuus cremnus Banner and Banner, 1982: 229, Fig. 72.
Paratypes, 3 WAM 89-65, 3 WAM 131-65, 9 WAM 185-65, 5 WAM 221-65, 11 WAM 278-65, 2 WAM 299-65. Locality: Yampi Sound, WA, low tide, reef.

Athanas locincertus Banner and Banner, 1973: 311, Fig. 5. Holotype, ♂ WAM 61-65. Locality: Banner and Banner, 1973 state locality as 'Panchoran Buoy [Western Australia?] '. Correct locality is Panchoran Bay, Christmas I., Indian Ocean.
Allotype, ♀ ex WAM 61-65. Locality: As in holotype.

Synalpheus echinus Banner and Banner, 1975: 374, Fig. 27. Holotype, ♀ WAM 92-65. Locality: Trigg I., Perth, WA.
Paratypes, ♀ ex WAM 92-65 Trigg I., Perth, WA; ♀ WAM 51-65 Carnac I., WA; WAM 409-73 Trigg I., Perth, WA; ♂ + ♀ WAM 12822, 12823 reef at Bathurst Pt, Rottnest I., WA.
Remarks: WAM 51-65 ♀ ovigerous; WAM 12822, 12823, specimens damaged.

Synalpheus harpagastrus Banner and Banner, 1975: 311, Fig. 9. Holotype, ♀ WAM 86-65. Locality: 8 km W of North Beach, Perth, W.A. Allotype, ♂ WAM 11129/30. Locality: Cottesloe, WA.
Paratypes, ♀ ex WAM 11129 Cottesloe, WA; ♂ + ♀ ex WAM 10380 Cottesloe, WA, from sponge; ♀ ex WAM 4985 between Fremantle and Geraldton, WA, FIS *Endeavour;* WAM 583-31 Thomson's Bay, Rottnest I., WA.

Synalpheus neptunus germanicus Banner and Banner, 1975: 321, Fig. 12. Holotype, ♂ WAM 9991. Locality: Cottcsloe, WA, from sponge.
Paratypes, 16♂♂ WAM 410-73 (?ex WAM 9991) Cottcsloe, WA, from sponge; 18♂♂ WAM 32-65 Rottnest I., WA, from sponge.
Remarks: All specimens immature.

Synalpheus sciro Banner and Banner, 1975: 304, Fig. 7. Holotype, ♀ WAM 64-65. Locality: NW of Bluff Pt, WA, 131 m, beam trawl, sponge and bryozoa; 27°40'S, 113°20'E.

Synalpheus tropidodactylus Banner and Banner, 1975: 286, Fig. 2. Holotype, ♂ WAM 90-65. Locality: W of Geraldton, WA, 110 m, beam trawl, bryozoa; 28°14'S, 113°28'E.
Paratype, ♀ ex WAM 90-65. Locality: As in holotype.

Family Nephropidae Dana, 1852

Nephrops australiensis Bruce, 1966: 245, Pls XXV-XXVII. Holotype, ♂ WAM 11-64. Locality: NE of Port Hedland, WA, 402 m, 17°05'S, 119°48'E.
Allotype, ♀ WAM 12-64. Locality: As in holotype.
Paratypes, ♀ WAM 16-64, ♀ WAM 17-64. Locality: As in holotype.
Remarks: WAM 12-64 ♀ ovigerous; WAM 16-64 ♀ ovigerous, specimen donated to the BM, Reg. No. 1964.9.28.14; WAM 17-64, specimen donated to the Rijksmuseum van Natuurlijke Histoire, Reg. No. Crust. D21151.

Family Parastacidae Huxley, 1879

Cherax crassimanus Riek, 1967: 119, Fig. 5d, Pl. 3B. Holotype, ♂ WAM 38-66.
Allotype, ♀ WAM 39-66. Locality: Beedelup Falls (Pemberton area), WA.
Paratypes, 13 WAM 62-66 to 76-66. Locality: As in holotype.
Remarks: Paratypes also deposited in the AM.

Cherax glaber Riek, 1967: 120, Fig. 5f, Pl. 4B. Holotype, ♂ WAM 40-66. Allotype, ♀ WAM 41-66. Locality: 19 km N of Augusta, WA.
Paratypes, 5 WAM 75-66 to 79-66. Locality: As in holotype.
Remarks: Paratypes also deposited in the AM.

Cherax glabrimanus Riek, 1967: 117, Fig. 5c, Pl. 3A. Holotype, ♂ WAM 34-66.
Allotype, ♀ WAM 35-66. Locality: 16 km S of Yallingup, WA.
Paratypes, 8 WAM 42-66 to 49-66. Locality: As in holotype.
Remarks: Paratypes also deposited in the AM.

Cherax neocarinatus Riek, 1967: 118. Holotype, ♂ WAM 36-66. Allotype, ♀ WAM 37-66. Locality: 16 km E of Blackwood R., WA.
Paratypes, 11 WAM 50-66 to 60-66. Locality: As in holotype.
Remarks: Paratypes also deposited in the AM.

Engaewa reducta Riek, 1967: 108, Fig. 3. Holotype, ♂ WAM 643-65. Locality: Dunsborough, WA.
Allotype, ♀ WAM 644-65. Locality: As in holotype.
Paratypes, 7 WAM 84-66 to 90-66. Block 1041, 800 m N of Quindalup Common, near Dunsborough, WA.
Remarks: Paratypes also deposited in the AM.

Engaewa similis Riek, 1967: 110, Fig. 4. Holotype, ♀ WAM 645-65. Locality: Augusta, WA.

Engaewa subcoerulea Riek, 1967: 107, Fig. 2, Pl. 1. Holotype, ♀ WAM 33-66.
Locality: Inlet R., 24 km NW of Walpole, WA.
Paratypes, 4 WAM 80-66 to 83-66. Locality: As in holotype.

Remarks: WAM 33-66 is misprinted in Riek (1965: 107) as WAM 33-36. WAM register and bottle label both record registration number as WAM 33-66. Paratypes also deposited in the AM.

Family Axiidae Huxley, 1879

Axius (Neaxius) waroona Poore and Griffin, 1979: 240, Fig. 10. Holotype, ♀ WAM 20-75. Locality: N side of Cape Naturaliste, WA, below lighthouse, building mud tubes under intertidal stones. Remarks: ♀ ovigerous.
Paratypes, many — WAM 174-31 Bathurst Pt, Rottnest I., WA, reef; WAM 432-73 Harding Rock, E side of Garden I., Cockburn Sound, WA; 2 WAM 9-75 Cowaramup Bay, WA, under intertidal rocks; WAM 73-75 Mannarup Beach, WA; WAM 130-75 near Bathurst Pt, Rottnest I., WA; 2 WAM 151-76 mouth of Big Horse Ck into Victoria R., NT.
Remarks: WAM 73-75 label reads 'In bottle (half buried) in tide pool. Two specimens moving together in tunnels in bottle. When placed in larger pool "they sought refuge always together"'.

Family Callianassidae Dana, 1852

Gourretia coolibah Poore and Griffin, 1979: 278, Figs 38-39. Holotype, ♀ WAM 66-75. Locality: 346 km ENE Troughton I., WA, 58 m, mud.

Family Upogebiidae Borradaile, 1903

Upogebia (Upogebia) giralia Poore and Griffin, 1979: 297, Fig. 49. Holotype, ♂ WAM 123-75. Locality: Learmonth, WA, mangroves.
Paratype, WAM 124-75. Locality: As in holotype.

Family Palinuridae Latreille, 1803

Panulirus cygnus George, 1962: 100, Pls I-II, Figs 1-4. Holotype, ♂ WAM 90-62. Locality: Radar Reef, Rottnest I., WA, reef flat, in eastern pool.
Paratypes, numerous — 4 WAM 9319 Dongara, WA; WAM 257-37 off Fremantle, WA; 3 WAM 258 to 260-37 off Fremantle, WA; juveniles WAM 64/5-53 off Cervantes, WA; juveniles WAM 40-50 9 m bank, W of Garden I., WA, caught in craypot; 5 juveniles WAM 41-58 off Beagle I., WA, in craypot; ♀ WAM 51-58 Pt Cloates, WA, approx. 1.8 m, also seen in shallow reef S of Whaling Station, hand speared; 1♂ + 1♀ WAM 53-58 N end of Garden I., WA; 2 juveniles WAM 54-58 W of Herald Heights, Dirk Hartog I., WA, 51 m; 4 juveniles WAM

69-58 Southern Gp, Abrolhos Is, WA, taken in craypots in west reef shallows; WAM 91-62 Radar Reef, Rottnest I., WA, reef flat in eastern pool; 3 WAM 92-62 Yanchep, WA, 7 WAM 93-62 Lighthouse Reef, North West Cape, WA; WAM 94-62 Ningalloo Stn, Pt Cloates, WA, 0.6 m, WAM 95-62 N end of Garden I., WA, ♀ WAM 96-62 Rottnest I., WA; WAM 97-62 Houtman Abrolhos Is, WA, WAM 98-62 Beagle I., WA, 60 m in craypot; WAM 99-62 5 km SE Hummock I., Pelsart Gp, Abrolhos Is, WA, 55 m in craypot; WAM 100-62, 101-62 Pelsart Gp, Abrolhos Is, WA, WAM 102-62 Lancelin I., WA; WAM 103-62 Pelsart Gp, Abrolhos Is, WA, shallows; WAM 104-62 Lancelin I., WA; 2 WAM 105-62 Geraldton, WA, 18-26 m; WAM 106-62 Dirk Hartog I., WA, 18-37 m; WAM 107-62 Sandy Cove (N Jurien Bay), WA, in Jewfish stomach; WAM 108-62 Pelsart Gp, Abrolhos Is, WA, shallows; WAM 109-62 Dongara, WA; WAM 110-62 Dirk Hartog I., WA, 18-37 m; WAM 111-62 South Passage, Shark Bay, WA; WAM 112-62 Wallabi I., Abrolhos Gp, WA; WAM 113-62 Pelsart Gp, Abrolhos Is, WA; 8 WAM 114-62 Fremantle area, WA; 4 WAM 115-62 Fremantle, WA; 6 WAM 116-62 Pt Moore reef, Geraldton, WA; 2 WAM 117-62 NE Pelsart Is, Southern Gp, Abrolhos Is, WA, WAM 118-62 Quinns Rock, WA; WAM 119-62 Pt Peron, WA, warm pool, 1 m water, WAM 120-62 Geraldton, WA, WAM 121-62 Entrance Rock, N end Garden I., Cockburn Sound, WA; ♂ WAM 122-62 Geraldton, WA; WAM 123-62 Strickland Bay, Rottnest I., WA, hand caught; WAM 124-62 Green I., near Cervantes, WA; WAM 125-62 North West Cape, WA, 0.6 m, beneath rocks (below lighthouse). Remarks: WAM 9319, 1 donated to Dr Kubo, Japan, 9.xii.60; WAM 257-37 1♂ sent to Dr Garth, University of Southern California, on exchange; WAM 53-58, 5 cm c.l.; WAM 95-62, premoult and very recently moulted; WAM 96-62 ♀ ovigerous; WAM 118-62, unusual colour pattern. white carapace; WAM 121-62, note with specimen reads 'This white has only 2 small spines on antennular plate behind the principal 2. Usual number is 4-8 I have seen one with 10 and another with 9', signed R.W. George; WAM 122-62, abnormal ♂ pleopod; WAM 124-82, white moulting to red.

Projasus bahamondei George, 1976: 27, Fig. 1 Pl. 1. Holotype, ♀ WAM 104-72. Locality. San Ambrosio I., SE Pacific, 26°21'S, 79°47'W; 175 m. Remarks: ♀ ovigerous, 71 mm c.l.

Family Porcellanidae Haworth, 1825

Pachycheles johnsonii Haig, 1965: 102, Fig. 1. Holotype, ♂ WAM 197a-60. Locality: Pt Gregory, NW side of Peron Peninsula, Shark Bay, WA, under stones on limestone reef flat at low tide. Paratypes, ♀ WAM 197b-60 Pt Gregory, NW side of Peron Peninsula, Shark Bay, WA;♂ WAM 227-30, ♀ WAM 228-30 Cape Leeuwin, WA;♂ WAM 33-62 Port

Hedland, WA; ♀ WAM 324-62 5 km W of Carnac I., WA, dredged, 29 m, on sponge.
Remarks: WAM 1976-60 ♀ ovigerous.

Polyonx maccullochi Haig, 1965: 114, Fig. 3.
Paratypes, ♂♂ WAM 334c-62. Locality: Shark Bay, WA.

Porcellana furcillata Haig, 1965: 110, Fig. 2. Holotype, ♀ WAM 344-62. Locality: 97 km NW of Bedout I., WA, dredged 46 m. Remarks: ♀ ovigerous. Paratypes, ♂ WAM 128c-60 3 km off Legendre I., Dampier Arch., WA, sponge and rubble; ♂ WAM 357-62 116 km NW of Bedout I., WA, dredged, 46 m. Remarks: WAM 357-62 bottle appears empty.

Family Albuneidae Stimpson, 1858

Albunea mariellae Seréne 1973: 261, Pl. I. Holotype, WAM 125-71. Locality: N of Ode Rowa, N of Nuhu Rowa, Kai; 27-37 m, sand and rubble, 5°32'S, 132°41'E.
Paratype, WAM 126-71. Locality: As in holotype.

Austrolepidopa trigonops Efford and Haig, 1968: 904, Figs 5-7. Holotype, ♀ WAM 62-62. Locality: 8 km N end of Rottnest I., WA, 36 m, sponge and sand.
Paratype, WAM 72-62. Locality: Near bar of South Passage, Shark Bay, WA, Honolulu dredge, 11 m, sand and silt.

Stemonopa insignis Efford and Haig, 1968: 908, Figs 8-10. Holotype, ♀ WAM 61-62. Locality: 8 km offshore, N of Maud Landing, WA, Honolulu dredge, 57 m, coral rubble.

Family Leucosiidae Samouelle, 1819

Leucosia levigena George and Clark, 1976: 306, Figs 5-7. Holotype, ♀ WAM 253-62. Locality: Yanchep Reef, WA, on shallow side of reef, 1 m.

Leucosia magna Tyndale-Biscoe and George, 1962: 86, Pl. I 4 and 5, Pl. II 4 and 5. Holotype, ♂ WAM 198-60. Locality: 48 km N of Dampier Arch., WA, 5 m, sand, Honolulu dredge.
Paratypes, WAM 199-60 11 km NNW of Anchor I., off Onslow, WA, 84 m, mud and gravel; juvenile WAM 200-60 11-13 km N of Long I., N of Onslow, WA, 51 m, sand and sponge.

Leucosia thysanotus George and Clarke, 1976: 304, Figs 1-4. Holotype, ♂ WAM 79-75. Locality: Norbill Bay, Rosemary I., WA, dredged 3 m, some weed. Remarks: Specimens in two bottles.

Paratypes, 4♂♂ + 2♀♀ + 2 juveniles WAM 16-63 Broome, WA, sand flats opposite jetty; ♂ WAM 124-64 1.6 km S of Delambre I., Dampier Arch., WA, dredged, 11 m; 3♂♂ WAM 80-75 near Rosemary I., Dampier Arch., WA.

Ixa acuta Tyndale-Biscoe and George, 1962: 72, Pl. Ii, Pl. IIi. Holotype, ♂ WAM 201-60. Locality: W side, Exmouth Gulf, WA, trawled.

Family Majidae Samouelle, 1819

Achaeus podocheloides Griffin, 1970b: 109, Figs 7a, 8, 14e-f. Holotype, ♂ WAM 95-67. Locality: NW of Jurien Bay, WA, beam trawl, 128-137 m, sponges and bryozoa, 30°00'S, 114°22'E.
Paratypes, ♀ WAM 331-67. Locality: SW of Pt Cloates, WA, beam trawl, 133 m, echinoids, starfish, molluscs, 23°39'S, 113°11'E.

Chlorinoides occidentalis Griffin, 1970a: 70, Figs 1b, 3, 4a, 4d-e. Holotype, ♂ WAM 319-67. Locality: NW of Rottnest I., WA, dredged, 155 m, some sponges.
Paratypes, many — ♀ WAM 17-67 W of Rottnest I., WA, beam trawl, 137-143 m, few fish and shells, no sponges, 32°00'S, 115°16'E; ♂ WAM 204-67 NW of Bluff Pt, Geraldton, WA, 128 m, MWT, bumped bottom, sponge and bryozoa, 27°40'S, 113°03'E; ♀ WAM 280-67 SW of Geraldton, WA, triangle dredge, 130-148 m, sponge and bryozoa, 29°05'S, 113°56'E; ♀ WAM 302-67 NW of Bluff Pt, Geraldton, WA, beam trawl, 131 m, sponge and bryozoa, 27°40'S, 113°20'E; ♂ WAM 318-67 NW of Rottnest I., WA, dredged, 183-188 m, on sponges; WAM 338-67 W of West End, Rottnest I., WA, dredged, 146 m, sandy; 17 WAM 339-67 W of Rottnest I., WA, beam trawl, 137-143 m, fish and shells, 32°00'S, 115°16'E; WAM 340-67 W of Lancelin I., WA, beam trawl, 113-122 m, bryozoa, 31°05'S, 114°55'E; WAM 341-67 NW of Rottnest I., WA, dredged, 183-188 m, on sponges; WAM 342-67 W of West End, Rottnest I., WA, dredged, 155-174 m; WAM 343-67 NW of Rottnest I., WA, dredged, 155 m, on sponges; WAM 344-67 WNW of Rottnest I., WA, 146-165 m.
Remarks: WAM 17-67, ♀ ovigerous; WAM 339-67, 3♂♂ + 1♀ ovigerous donated to the AM Reg. No. P16822.

Phalangipus trachysternus Griffin, 1973: 192, Figs 2d, 4g-h, 7h, 9g-h.
Paratypes, ♂ WAM 63-71 Stn 1540, collected by R.W. George on *Rama,* 1964; ♂ WAM 64-71 Broome, WA, sand bar opposite jetty; ♂ WAM 65-71 32 km, 320°, Darwin, NT; 1♂ + 2 juveniles WAM 66-71 Perry Harbour, Admiralty Gulf, WA, fry net, 9-11 m; 2♀♀ + 1 juvenile WAM 67-71 Ashburton area, Onslow, WA, trawled; ♀ WAM 70-71 23 km WNW of Darwin, WA, 24-26 m.
Remarks: WAM 70-71 ♀ ovigerous.

Family Atelecyclidae Ortmann, 1893

Kraussia bongensis Seréne, 1972: 56, Figs 19, 20, 23J, 24. Holotype, ♂ WAM 263-70A. Locality: 14 km and 130° from Bongas Light, Tawitawi Bay, Sulu Arch., dredged, 16-31 m, sandy.
Paratypes, ♂ WAM 36-71 (ex WAM 263-70B); ♂ WAM 37-71 (ex WAM 263-70C). Locality: As in holotype.

Kraussia marquesa Seréne, 1972: 53, Figs 14, 15, 23G-H. Holotype, ♂ WAM 264-70. Locality: Anaa Atoll, Marquesas I., depth 9-18 m.

Kraussia pelsartensis Seréne, 1972: 49, Figs 7, 8, 23D. Holotype, ♂ WAM 365-70. Locality: 5 km W of Hummock I., Pelsart Gp, Abrolhos Is, WA, Honolulu dredge, 37 m, coarse sand.
Paratypes, 2♂♂ WAM 268-70 Cape Vlaming, Rottnest I., WA; WAM 270-70 SW of Pt Cloates, WA, 113°39'30"E, 22°43'30"S; 2♂♂ WAM 274-70 11 km NW of Rat I., Abrolhos Gp, WA, Honolulu dredge, 46 m, coralline boulders.

Kraussia roycei Seréne, 1972: 50, Figs 9, 10, 23E. Holotype, ♂ WAM 269-70. Locality: Flying Foam Passage, Dampier Arch., WA; Honolulu dredge, 18 m, coral, sand and shell rubble.

Kraussia wilsoni Seréne, 1972: 46, Figs 5, 6, 23c. Holotype, ♂ WAM 278-70. Locality: N of Siasi I., Sulu Arch., 37-40 m, sponge, coral, sand.
Paratypes, WAM 143-71 N of Siasi I., Sulu Arch., 37-40 m, sponge, coral, sand; WAM 144-71 near Panglas I., off Bohol Is, Philippines, 82-128 m, mud and shells; 8 WAM 145-71 W of North West Cape, WA, beam trawl, 122-128 m, fish and crustacea, 21°48'S, 113°56'E; 2 WAM 146-71 Coronada Bay, Mindamao, Sulu Sea, 46-128 m, sand and mud.

Family Portunidae Rafinesque, 1815

Nectocarcinus spinifrons Stephenson, 1961: 92, Figs 1A, 2G, Pl. I Fig. 1, Pl. 4A. Holotype, ♂ WAM 47-60. Locality: NE side of Dirk Hartog I., Shark Bay, WA, dip net, night.
Allotype, ♀ WAM 47a-60. Locality: As in holotype.

Ovalipes georgei Stephenson and Rees, 1968: 234, Pls 36C, 39E, 39F, 40C, 42F, Figs 1F, 2E, 3E, 4E. Holotype, ♂ WAM 120-61. Locality: 9 km NW of Rottnest I. Main Light, WA, between 0000 and 0030 hrs, at surface, in N. 70 plankton net over 37 m.
Remarks: Colour pale grey anteriorly, five orange spots posteriorly. Dactyl of fifth leg with blood red spot.
Paratype, ♂ WAM 121-61. Locality: Off Cottesloe, WA, in prawn trawl.

Portunus curvipenis Stephenson, 1961: 106, Figs 1G, 3E, Pl. 2 Fig. 3, Pls 4E, 5B. Holotype, ♂ WAM 6-60. Locality: Exmouth Gulf, WA, trawled.

Portunus pseudoargentatus Stephenson, 1961: 109, Figs 2A, 3F, Pl. 2 Fig. 4, Pls 4F, 5D. Holotype, ♂ WAM 50-60. Locality: 8 km NW of Green I., South Group, Abrolhos Is, WA, Honolulu dredge, 57-64 m, coral rubble.

Portunus tenuicaudatus Stephenson, 1961: 114, Figs 2C, 3H, Pl. 3 Fig. 2, Pls 4H, 5C. Holotype, ♂ WAM 62(b)-60. Locality: 48 km N of Dampier Arch., WA, Honolulu dredge, 57 m, sand. Remarks: L and R pleopods ♂ tubed. Allotype, ♀ WAM 75(b)-60. Locality: 11-13 km N of Long I., near Onslow, WA, Honolulu dredge, 51 m, sand and sponge.

Family Parathelphusidae Alcock, 1910

Parathelphusa wasselli Bishop, 1963: 229, Figs 1A, 2D, 4, Pl. 1 Fig. 1.
Paratypes, ♂ + ♀ WAM 574-85. Locality: Port Stewart district, Cape York, Qld, under leaves on temporary freshwater lagoon hard bottom.
Remarks: Bott (1970) transferred this species to the genus *Holthuisana*, subgenus *Austrothelphusa*.

Family Ocypodidae Rafinseque, 1815

Ocypode mortoni George, 1980: 187, Figs 1c, 2c, Pl. 3 Fig. 3, Pl. 4. Holotype, ♂ WAM 2-81. Locality: Sai Wan, TaiLong Wan, E New Territories, Hong Kong.
Paratypes, 2♂♂ + 1♀ + 2 juveniles WAM 230-80, 1 juvenile WAM 2-82. Locality: As in holotype.
Paratype, ♀ WAM 1-82. Locality: Tong Fuk, Lantau I., Hong Kong.
Remarks: WAM 230-80, 1 (? juv.) damaged.

Uca elegans George and Jones, 1982: 22, Figs 14a, 15a, 16a, 17a-b, 18a, 37a-i, 55b. Holotype, ♂ WAM 52-76. Locality: Derby, WA, town jetty, 150 m landward of sea cliff. Remarks: Bottle 13, V174006; c.w. 2.17 cm.
Paratypes, numerous — 4 WAM 172-62 Broome, WA; ♂ WAM 182-62 Mundanbullengara, 64 km S of Port Hedland, WA, on edge of creek running into saltmarsh country, in sand or mud, in burrows; 2 WAM 655-65 Denham Hummock, Shark Bay, WA, from burrows near mangrove creek; WAM 659-65 Quarantine Pt, Broome, WA; 6 WAM 118-68 Fauré I., Shark Bay, WA; 3 WAM 124-68 Point Quobba, WA: WAM 44-76 Derby, King Sound, WA, V174008, Upper E flat, small boat jetty; WAM 49-76 Derby, King Sound, WA, near Blue Lagoon, W bank of Stokes Bay, HWS; 2♂♂ claws WAM 50-76 Derby, King Sound, WA, V174001; WAM 51-76 Derby, King Sound, WA, between V174005

and V174006, Bottle 2; WAM 53-76 Derby, King Sound, WA, V174006, Bottle 10. WAM 54-76 Derby, King Sound, WA, V174001, #5a Bottle 33; WAM 55-76 Derby, King Sound, WA, V174031 (or 011); WAM 56-76 Derby, King Sound, WA, V174011, #56 Bottle 34; WAM 57-76 Derby, King Sound, WA; WAM 58-76 Derby tidal flats, WA, washed into V174001; WAM 59-76 Derby tidal flats, WA, V174005, Bottle 24; WAM 126-76 Derby, WA, V 174005; ♂ WAM 18-77 Port Warrender, Admiralty Gulf, WA, on mudflat landward of mangroves; 8♂♂ claws WAM 22-77, 3♀♀ WAM 23-77, Vendoo Ck, S of Carnarvon, WA; 1♂ major chela WAM 1-78 Derby, King Sound, WA, mud flats; 3♂♂ major chelae WAM 12-78 Derby, WA, lagoon surface, tidal flats; WAM 90-78 Learmonth Barge, WA, creek mangroves; 1♂ major chela WAM 91-78 Derby, WA, V174008, Upper E flat; 3♂♂ WAM 92-78 Cascade Bay, Kimbolton, WA, 16°34'S, 123°38'E; 3♂♂ + 1♀ WAM 93-78 Port Warrender, Admiralty Gulf, WA, mangroves; 2♂♂ + 2♀♀ WAM 114-78 Rapid Ck, Nightcliff, Darwin, NT; 4♂♂ + 1♀ WAM 115-78 Ludmilla Ck, Darwin, NT, soft mud (overflow of main creek); 5♂♂ WAM 153-78 Buffalo Ck, Nhulunbuy, Gove, NT; ♀ WAM 181-78 Shark Bay or Exmouth Gulf, WA; 5♂♂ + 7♀♀ WAM 263-79 Rapid Ck, Nightcliff, Darwin, NT, ♂♂ c.w. 2.32-1.66 cm, ♀♀ c.w. 2.06-0.85 cm; 2♂♂ WAM 264-79 Ludmilla Ck, Darwin, NT, c.w. 1.52, 1.08 cm, muddy creek bed; 2♂♂ major chelae + 1♂ major dactyl WAM 278-79 MKO Beach, Cape Lambert, WA, 1 left and 1 right-handed chela, major ♂ dactyl left-handed; 3♂♂ + 4♀♀ WAM 280-79 Sams Ck, Cape Lambert, WA, ♂♂ c.w. 2.36-1.97 cm, all left-handed, ♀♀ c.w. 1.35-1.21 cm; 4♂♂ chelae + 2♂♂ WAM 282-79, mouth of Bittern's drain, Nickol Bay, Dampier, WA, 4♂♂ chelae, 2 left: 2 right-handed, ♂♂ c.w. 1.35, 0.90 cm, both left-handed; 4♂♂ WAM 289-79 Causeway, Finucane I., Port Hedland, WA, ♂♂ c.w. 1.40-0.75 cm, 2 right: 2 left-handed; 1♂ + 1♀ + 2♂♂ chelae WAM 293-79 Sting Ray Ck, Port Hedland, WA, ♂ c.w. 1.84 cm right-handed, 2♂♂ chelae right-handed, ♀ c.w. 1.49 cm; 3♂♂ + 4♀♀ WAM 295-79 Nickol Ck, Dampier, WA, ♂♂ c.w. 1.25-0.84 cm, 2 right: 1 left-handed, ♀♀ c.w. 1.24-1.05 cm; ♀ WAM 300-79 Sam's Ck, Cape Lambert, WA, middle sandbank, c.w. 1.86 cm; 2♂♂ + 1♀ WAM 316-79 SW Ck, Bay of Rest, Exmouth Gulf, WA, ♂♂ c.w. 1.35, 1.25 cm, 2 left-handed, ♀ c.w. 1.58 cm; 5♂♂ + 1♀ WAM 323-79 Bay of Rest, Exmouth Gulf, WA, ♂♂ c.w. 2.18-0.95 cm, 4 right: 1 left-handed, ♀ c.w. 1.07 cm; WAM 325-79 Bay of Rest, Exmouth Gulf, WA, c.w. 1.64 cm; 7♂♂ chelae WAM 330-79 Bay of Rest, Exmouth Gulf, WA, 4 right: 3 left-handed, clayey area landward of *Avicennia;* 7♂♂ + 5♀♀ WAM 332-79 Wapet Ck, Learmonth, Exmouth Gulf, WA, ♂♂ c.w. 1.45-0.62 cm, 3 right: 4 left-handed, ♀♀ c.w. 1.70-0.77 cm; 12♂♂ + 5♀♀ WAM 77-80 New Mangrove Bay, Bay of Rest, Exmouth Gulf, WA, ♂♂ c.w. 2.20-1.23 cm, 8 left-handed: 4 right-handed, ♀♀ c.w. 1.73-1.35 cm; 3♂♂ WAM 153-80 1.3 km N of Tourist Bureau, Broome, WA, ♂♂ c.w. 1.88-1.72 cm, 1 right: 1 left-handed; 5♂♂ WAM 154-80 Crab Ck, Broome, WA, ♂♂ c.w. 1.31-0.75 cm, 1 left: 4 right-handed; 8♂♂ WAM 158-80 Crab Ck,

Broome, WA, landward saltmarsh, ♂♂ c.w. 1.41-0.95 cm, 6 left: 2 right-handed; 3♂♂ + 4♀♀ WAM 196-80 N end of mangal, Broome, WA, saltmarsh, ♂♂ c.w. 1.79-1.01 cm, 1 left: 2 right-handed, ♀♀ c.w. 1.49-0.84 cm.

Remarks: WAM 50-76 dry material, skeletons on surface, washed into V 174001, one claw broken; WAM 55-76 dry material; WAM 57-76 dry material; WAM 58-76 regenerated claw; WAM 59-76 regenerated claw; WAM 23-77 ♂♂ claws broken; WAM 1-78 dry material; WAM 12-78 dry material; WAM 181-78 label reads 'on *Peron*, trawled.'; WAM 278-79 dry material; WAM 282-79 ♂♂ chelae broken; WAM 289-79 one regenerated claw; WAM 300-79 dry material.

Uca hirsutimanus George and Jones, 1982: 49, Figs 24c, 30b, 44a-g. Holotype, ♂ WAM 190-78. Locality: Derby, WA. Remarks: c.w. 1.30 cm, V174008, Zone 1.

Paratypes, numerous — WAM 61-76 Derby, WA, Zone 1, mangal, V174008A, south jetty, Bottle 17; WAM 69-76 Derby, WA, V174008 Upper E, small boat jetty, Bottle 36; WAM 76-76 Derby, WA, 30 m NW of V174006, Bottle 14; WAM 77-76 Derby, WA, V174008, Upper E, small boat jetty, Bottle 41; WAM 78-76 Derby, WA, V174008, Upper E flat, lower banks of tidal creek, Bottle 50; WAM 79-76 Derby, WA, V174008, Upper E, small boat jetty, Bottle 38; WAM 80-76 Derby, King Sound, WA, tidal flats, Bottles 12, 14, 16, 17, 19, 26; WAM 81-76 Derby, King Sound, WA, V174008, small boat jetty, Bottle 42; WAM 82-76 Derby, King Sound, WA, V174008, small boat jetty, Bottle 40; WAM 83-76 Derby, King Sound, WA, Upper E flat, small boat jetty; WAM 84-76 Derby, King Sound, WA, S jetty, Zone 1, Bottle 17; WAM 85-76 Derby, King Sound, WA, V174008A, Bottle 25; WAM 86-76 Derby, King Sound, WA, V174008, Upper E, small boat jetty, Bottle 38; WAM 87-76 Derby, King Sound, WA, V174008, S jetty, Zone 1, Bottle 19; WAM 88-76 Derby, King Sound, WA, sea cliff, V174008, Bottle 52; WAM 90-76 Derby, King Sound, WA, V174008, Zone 1, Bottle 18; WAM 91-76 Derby, King Sound, WA, V174011, #4 Bottle 32; WAM 124-76 Black Rocks, N of Derby, WA, Zone 2 mangal; WAM 125-76 Black Rocks, N of Derby, WA, Zone 3 mangal; 8♂♂ + 1♂ chela + 3♀♀ + 1 ovigerous ♀ WAM 33-77 Black Rocks area, N of Derby, WA, Zone 3 mangal; 3♂♂ + 1 ovigerous ♀ WAM 35-77 Black Rocks area, N of Derby, WA, front of mangal; 4♂♂ + 1♂ chela + 2 ovigerous ♀♀ WAM 36-77 Black Rocks area, N of Derby, WA, front of mangal; ♂ WAM 4-78 8 km S of Learmonth, Exmouth Gulf, WA; 7♂♂ + 7♀♀ + 1 ovigerous ♀ WAM 6-78 Derby, WA, Zone 1, S jetty, between Zone 3 and 4 Black Rocks and Zone 3 Black Rocks; 1♂ + 3♀♀ + 1 ovigerous ♀ WAM 74-78 Buffalo Ck, Darwin, NT, grey mud creek; WAM 81-78 Derby, WA, V174011, #3; 2♂♂ WAM 88-78 Derby, WA, V174011, #3; 7♂♂ + 4♀♀ WAM 135-78 Ludmilla Ck, Darwin, NT; ♂ WAM 136-78 Rapid Ck, Nightcliff, Darwin, NT; 2♂♂ WAM

137-78 Ludmilla Ck, Golf Course Rd, Darwin, NT; 5♂♂ + 6♀♀ WAM 138-78 boat ramp, Buffalo Ck, Darwin, NT; 2♂♂ + 1♀ WAM 139-78 boat ramp, near Hotel, Wyndham, WA; 16♂♂ + 8♀♀ WAM 140-78 boat ramp, near Hotel, Wyndham, WA; 13♂♂ + 3♀♀ WAM 141-78 Wyndham, WA, street opposite Hotel; 23♂♂ + 13♀♀ WAM 142-78 boat ramp, near Hotel, Wyndham, WA; 11♂♂ + 5♀♀ WAM 143-78 Wyndham, WA, level swamp between Meatworks Rd and creek; 10♂♂ WAM 144-78 Wyndham boat ramp, near Hotel, WA; 7♂♂ + 9♀♀ WAM 145-78 Crab Ck, Broome, WA; 1♂ + 1♀ + 1♂ chela WAM 163-78 Barred Ck, 30 km NW of Broome, WA; 7♂♂ + 3♀♀ WAM 164-78 Barred Ck, 30 km NW of Broome, WA, mangroves; 9♀♀ WAM 175-78 Barred Ck, 30 km NW of Broome, WA; 4♂♂ + 5♀♀ WAM 271-79 Saville St, Broome, WA, mangroves, ♂♂ c.w. 1.68-0.89 cm, ♀♀ c.w. 1.78-1.38 cm; 2♂♂ WAM 290-79 Sting Ray Ck, Port Hedland, WA, c.w. 1.14, 1.15 cm, 1 left and 1 right-handed; ♂ WAM 169-80 Broome Pearls Ck, Broome, WA, seaward end, c.w. 0.77 cm, right-handed; 1♂ + 1♀ WAM 174-80 Saville St, Broome, WA ♂ c.w. 1.28 cm, right-handed, ♀ c.w. 1.03 cm; ♀ WAM 184-80 Main Channel, Broome, WA, between Broome Pearls Ck and Roebuck Hotel Ck c.w. 1.27 cm; ♂ WAM 213-80 edge of Main Channel, Broome, WA, out from Streeter's jetty, c.w. 1.83 cm, right-handed; 2♂♂ WAM 226-80 Roebuck Hotel Ck, Broome, WA, landward edge, c.w. 1.80, 1.61 cm, 1 left: 1 right-handed; 1♂ + 1♀ WAM 123-81 Dampier Channel, Broome, WA, ♂ c.w. 1.42 cm, right-handed, ♀ c.w. 1.19 cm. Remarks: WAM 81-78 regenerated major chela; WAM 123-81 regenerated ♂ chela.

Uca pavo George and Jones, 1982: 25, Figs 19b, 20b, 38a-i, 55c, 55d. Holotype, ♂ WAM 189-78. Locality: Napier Terrace, Broome, WA.
Paratypes, numerous — 1♂ + 1♂ chela + 1♀ WAM 55-77 8 km S of Learmonth, Exmouth Gulf, WA, middle to seaward of mangrove; 10♂♂ + 2♀♀ WAM 56-77 Bay of Rest, Exmouth Gulf, WA; 1♂ + 1♀ WAM 60-77 Bay of Rest, Exmouth Gulf, WA, seaward of mangroves; 2♂♂ WAM 61-77 Ck N of Exmouth Station, Bay of Rest, Exmouth Gulf, WA; 2♂♂ + 4♀♀ WAM 121-78 Ludmilla Ck, Darwin, NT; 7♂♂ + 3♀♀ WAM 122-78 Ludmilla Ck, Darwin, NT; 2♀♀ WAM 123-78 Crab Ck, Broome, WA; 21♂♂ + 7♀♀ WAM 168-78 Napier Terr., Broome, WA, in mangroves; ♂ WAM 172-78 Saville St, Broome, WA, in mangroves; 12♂♂ + 2♀♀ WAM 261-79 Barred Ck, 30 km NW of Broome, WA, ♂♂ c.w. 2.92-1.53 cm, ♀♀ c.w. 1.75, 1.73 cm; 3♂♂ + 1 ovigerous ♀ WAM 312-79 SW Ck, Bay of Rest, Exmouth Gulf, WA, ♂♂ c.w. 2.67-1.75 cm, 2 right: 1 left-handed, ♀ c.w. 2.45 cm; ♂ WAM 314-79 Bay of Rest, Exmouth Gulf, WA, freshwater inlet, inner end, c.w. 3.04 cm, left-handed; ♂ WAM 163-80 edge of Main Channel, Broome, WA, out from Streeter's jetty, c.w. 2.07 cm, left-handed; ♂ WAM 170-80 Broome Pearls Ck, Broome, WA, seaward end, c.w. 2.32 cm, left-handed; 2♂♂ WAM 177-80 Saville St, Broome, WA, c.w. 1.77, 1.12 cm, both right-handed; ♂ WAM 180-80 Main Channel, Broome, WA, between

Broome Pearls Ck and Roebuck Hotel Ck, c.w. 2.67 cm, left-handed; ♂ WAM 194-80 Roebuck Ck, Broome, WA, landward end, c.w. 1.82 cm, left-handed; 4♂♂ + 3♀♀ WAM 205-80 Fisherman's Bend, Broome, WA, ♂♂ c.w. 2.0-1.54 cm, 4 left-handed, ♀♀ c.w. 1.94-1.65 cm; ♂ WAM 222-80 Fisherman's Bend, Broome, WA, c.w. 1.53 cm, left-handed.

Acknowledgements

Appendix

Professor Nicholls' collection

Uroctena affinis Nicholls, 1926b: 109, Pl. XIII Figs 10-15. ?Types (unregistered). Locality: Probably around Darlington and Mundaring, WA.
Remarks: Note on slide box reads '*Uroctena* spp. ?Types? R.W. George'. One labelled slide plus 3 unlabelled. Straskraba (1964: 133) synonymised this species with *Uroctena westralis* (Chilton, 1925).

Uroctena setosa Nicholls, 1926b: 107, Pl. XII Figs 1-6, Pl. XIII Figs 7-9. ? Types (unregistered). Locality: ? Reservoir at Katanning, WA.
Remarks: Note on slide box reads '*Uroctena* spp. ?Types? R.W. George'. One slide, unlabelled. Loose paper label says '*U. setosa* ♂ 1 slide only'. Three slides, unlabelled. Loose paper label says '*U. setosa* ♀ 3 slides'.

Uroctena yellandi Nicholls, 1926c: 113, Pl. XIV Figs 1-10, Text Fig. 1. ? Type (unregistered). Locality: ? a creek, some miles south of Armadale, WA.
Remarks: Note on slide box reads '*Uroctena* spp. ?Types? R.W. George'. Two slides, unlabelled. Loose paper label says '*U. yellandi*'. One box containing 8 slides, unregistered — a note in the box says '"in bundle of *Stenetrium* types — prob. part of the 3 species of Nicholls," R.W. George, 8.viii.61'.

Phreatoicus decipious Det. by G.E. Nicholls. ? Types, 4 WAM 278-64. Locality: Great Lake, Tasmania.

Remarks: Nicholls (1943) did publish *Mesacanthotelson decipiens* from the Great Lake, Tasmania, for which there was no type designated. It is possible that the WAM material is syntypic (G. Poore, pers. comm.).

J.L. Barnard material

Allorchestes murna morilla n. subsp. Det. by J.L. Barnard. Holotype, ♂ 8.5 mm WAM 138-71. Locality: Australia, 7. (i.e. W of Bunker Bay, Cape Naturaliste, WA); intertidal.

Remarks: Label says 'Figured'. The material was published as *Allorchestes compressa* subspecies W (Barnard, 1974: 48) and the figures referred to are on p. 46. WAM specimen is not a valid holotype, as Barnard did not publish a name for the subspecies. However, it is important that this material be identifiable as that figured and called 'subsp. W' by Barnard (H. Stoddart, pers. comm.).

Hyale crassicornis (Haswell) subsp. W (not yet named). Det. by J.L. Barnard. Holotype, ♂ 7.7 mm WAM 142-71. Locality: Australia 5, W of Bunker Bay, Cape Naturaliste, WA; intertidal.

Remarks: Label in bottle states that this material was originally determined by Barnard to be *Hyale iole arkoula* n. subsp. Material figured by Barnard, 1974 (Figs 33-35) as *Hyale crassicornis* (Haswell).

Mallacoota marilla Barnard, 1972: 249, Figs 146, 147 (part). Holotype, (Phenotype PS) ♂ 3 mm WAM 182-70. Locality: Pt Peron, WA; rock sand and seaweed washings.

Remarks: Label in bottle states that this material was originally determined by Barnard as *Maera marilla* n. sp. Barnard (1972: 249) published *Mallacoota marilla* with 2 'phenotypes', and used material of the 'PP' phenotype for the holotype of the species. He did not designate any type material for the 'PS' phenotype in the paper, although he did label the specimen WAM 182-70 as holotype. Lowry and Fenwick (1983: 228) recognised the 'PS' phenotype as a separate species (and at the same time put it into a different genus and family) and published *Hoho hirtipalma* (in the family Melitidae Bousfield, 1973, 1977 [emend.]) but did not use Barnard's material for the holotype. Although the WAM material is not type material it is important that it is recognised as the material Barnard used to represent his 'PS' phenotype (H. Stoddart, pers. comm.).

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Two new members of the *Lerista nichollsi* complex (Lacertilia: Scincidae)

G.M. Storr*

Abstract

Both species come from the arid mid-west of Western Australia. One, *Lerista gascoynensis*, is nearest to *L. nichollsi*, which it replaces in much of the middle and upper Gascoyne River valley. The other, *L. varia*, is nearest to *L. connivens*, which it replaces in much of the Shark Bay region.

Introduction

In a revision of the *Lerista nichollsi* complex (Storr 1984), I hesitated to include within *L. uniduo* three specimens that agreed with it in supraciliary formula but differed in being larger, relatively stouter and more boldly patterned. Recently G. Harold and D. Mead-Hunter collected additional specimens of the second form and demonstrated its sympatry with *L. uniduo*, which necessitated its description as a new species.

In the past (Storr 1972, 1984) specimens of a small, variably patterned *Lerista* from the Shark Bay region were identified as *L. lineopunctulata* (26725, 33373) or *L. connivens* (71090, 81340-1, 81383) according as the dorsal and upper lateral stripes were weakly or more strongly developed. Long series recently collected by P.G. Kendrick have shown that this *Lerista* is distinct from both *L. lineopunctulata* and *L. connivens* and it is herein described as new.

Systematics

Lerista gascoynensis sp. nov.

Figure 1

Holotype

R55971 in Western Australian Museum, collected by T.M.S. Hanlon and M. Peterson on 30 January 1977 at 16 km S Gascoyne Junction, Western Australia, in 25°10'S, 115°12'E.

Paratypes

North-West Division (WA)

Winderie (87616); 17 km SSW Gascoyne Junction (87565-74) and 16 km S (55975-6) and 20 km NNE (87617-21); 14 km SW Lyons River HS (87575-9, 87587-94); 2 km SE Dairy Creek HS (87645); 10 km SE Mt James HS (84217-9); 1 km E Mt Clere HS (84809).

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Diagnosis

A medium-sized member of the *L. nichollsi* complex with immovable eyelids, three supraciliaries (first and second separated by first supraocular) and narrow vertebral stripe. Distinguishable from *L. uniduo* by its greater size (maximum SVL 70 mm, *v.* 59), relatively stouter body and bolder pattern, and from both subspecies of *L. nichollsi* by its fewer supraciliaries (four in *L. n. nichollsi* and *L. n. petersoni*).

Description

Snout-vent length (mm): 36-70 (N 37, mean 57.6). Tail length (% SVL): 85-96 (N 10, mean 91.0).

Nasals in short to long contact. Supraoculars 3 with first two contacting frontal (N 36) or 4 with two (1). Supraciliaries 1 + 2 (except for 4 on one side of one specimen), last much the smallest. Loreals 2, second much the smaller and fused to prefrontal in five specimens. Presuboculars 1 (N 1) when first fused to second loreal, 2 (31) or 3 (5). Upper labials 6. Nuchals 1 (N 5), 2 (26) or 3 (6). Midbody scale rows 20 (N 34), 21 (1) or 22 (2). Lamellae under longer toe 10-14 (N 37, mean 11.8).

Coloration in alcohol. Dorsally brownish white except for brown edges and blotches on head shields and for narrow vertebral stripe (consisting of two rows

Figure 1 A paratype of *Lerista gascoynensis,* photographed by G. Harold.

of squarish blackish brown or dark brown spots, the space between them dark or pale brown). Broad blackish brown or dark brown upper lateral stripe, one and a half to two scales wide on body but narrowing on head. Lips vertically barred with blackish brown or dark brown. Ventrolateral and ventral surfaces whitish, except for brownish grey under toes.

Distribution

Interior of mid-western Western Australia, in the valley of the Gascoyne River from Winderie east to Mt Clere. See Figure 2.

Figure 2   Map of mid-western Western Australia showing location of specimens of *Lerista gascoynensis* and *L. varia*.

Remarks

It was originally thought possible (Storr 1984) that *L. gascoynensis* was an eastern variant of *L. uniduo*. However, typical *L. uniduo* has been subsequently

collected at 30 km SW Glenburgh (87626) and elsewhere within the range of *L. gascoynensis*. Actually, *L. gascoynensis* is very like *L. n. nichollsi*, from which it differs only in the fewer supraciliaries. As it appears to be allopatric to both *L. nichollsi* and *L. n. petersoni*, *L. gascoynensis* may eventually prove to be a subspecies of *L. nichollsi*.

Lerista varia sp. nov.

Figure 3

Holotype
R81341 in Western Australian Museum, collected by G. Harold and C.D. Winton on 18 June 1981 at Denham, Western Australia, in 25°55′S, 113°32′E.

Paratypes
North-West Division (WA)
Cape Peron (33373); Monkey Mia (89370-1, 91196-234); Denham (81340, 89372-3) and 6 km NE (81383) and 2 km NE (71090) and 2 km N (71081, 71083-9); Dirk Hartog I. (44549); 10 km S Useless Loop (26725); 17 km WSW Cooloomia (66371).

Diagnosis
A moderately large member of the *L. nichollsi* complex with movable eyelids, differing from *L. connivens* by its highly variable but generally much weaker pattern and by its fewer midbody scale rows (mostly 20, *v.* mostly 22); it is also smaller, has a darker dorsal ground colour and often has four (rather than only two) series of black dorsal spots. Unstriped specimens superficially similar to young *L. lineopunctulata*, but distinguishable by fewer supraciliaries (four with first much wider than high, *v.* five with first not wider than high), longer hindleg (12-18 % of SVL, *v.* 6-13 %), more numerous lamellae under longer toe (6-12, seldom fewer than 9; *v.* 4-11, seldom more than 9), and invariably having two toes (often only one in northern *lineopunctulata*).

Description
Snout-vent length (mm): 31-77 (N 57, mean 52.8). Tail length (% SVL): 64-87 (N 7, mean 79.1).

Nasals in short to long contact. Supraoculars 3 with first two contacting frontal (N 55) or 2 with one (2). Supraciliaries 4, first much the widest and last much the smallest. Loreals 2 (N 55) or 1 (1) when fused to each other. Presuboculars 2. Upper labials 6. Nuchals 1 (N 11), 2 (37) or 3 (2). Midbody scale rows 18 (N 5), 19 (1), 20 (36) or 22 (1). Lamellae under longer toe 6-12 (N 48, mean 9.8).

Coloration in alcohol. Head suffused or blotched with greyish brown. Back and tail brown or pale brown with or without a wide but usually indistinct stripe that encloses 0, 2 or 4 series of faint to moderately distinct brown spots. Upper lateral stripe narrow, indistinct or absent on body (rarely one scale wide and fairly sharp-edged, but usually narrower or represented only by dark edges to upper lateral scales), usually better developed on head as a loreo-temporal stripe. Lower lateral and ventral surfaces whitish except for brown vertical barring of lips and pale greyish-brown suffusion on chin.

Figure 3   Holotype of *Lerista varia*, photographed by G. Harold.

Distribution

Shark Bay region of Western Australia: Peron Peninsula, Dirk Hartog I., Edel Land and further south in the hinterland of the Zuytdorp Cliffs. See Figure 2.

Remarks

L. varia overlaps broadly with *L. lineopunctulata*. However, the insular and peninsular populations of *L. varia* lie outside the range of *L. connivens*, and it was at first believed that *L. varia* could be regarded as a subspecies of *L. connivens*, but this was precluded by the discovery of a specimen (66371) from well within the range of *L. connivens*.

Acknowledgement

References

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The holotypes of the Acari (Arthropoda: Arachnida) in the Western Australian Museum

L.E. Koch*

Abstract

Ninety-three recently lodged mite holotypes are listed with associated data.

Introduction

Information regarding the primary type specimens of the Arthropoda (excluding the Crustacea) lodged in the Western Australian Museum prior to 1980 has been presented by Koch (1980)†. These included a few Acari; viz. three mite holotypes (family Trombidiidae) and two tick holotypes and a syntype (family Ixodidae).

Since then large numbers of mite specimens have been added to the collection, and the 93 recently described holotypes are listed here.

The families, genera, subgenera and species are arranged alphabetically within each of the three represented groups: Astigmata, Mesostigmata, and Prostigmata. The generic names of the mites are those with which the specific names were originally combined. For each species or subspecies the information includes the sex, or stage, and WAM register number of the holotype, name of host specimen and of collector or expedition (Exp.), date, and locality of collection including latitude and longitude. Most of the Kimberley Exp. mites were collected by Dr F.S. Lukoschus. They were extracted usually within a few days after collection of the hosts, and the dates given here are those on the slide labels. Each holotype is mounted on a microscope slide. The nomenclature and classification of hosts have been updated.

The information in the present paper has been checked against the literature, records, labels, collectors' names and gazetteers, and where necessary by writing to the collectors and describers. It is believed that any discrepancies between the original papers and this list are due to errors in the former.

I thank Julianne Waldock for assistance.

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† Koch, L.E. (1980). The Primary Types of Arachnida, Chilopoda, Diplopoda, Insecta, Onychophora and Pycnogonida in the Western Australian Museum. *Rec. West. Aust. Mus.* 8 (2): 295-326.

List of types

Order Astigmata
Family Acaridae

Australhypopus flagellifer Fain and Friend, 1984; *Rec. West. Aust. Mus.* 11 (2): 106. Holotype, hypopus, WAM 82/1150. *Ex* scats of *Myrmecobius fasciatus* Waterhouse, 1836 (Marsupialia: Myrmecobiidae).* J.A. Friend; 8.vii.1981; Dryandra State Forest, WA; 32°44′S, 116°53′E.

Cosmoglypus angustus Fain and Friend, 1984; *Rec. West. Aust. Mus.* 11 (2): 102. Holotype, hypopus, WAM 82/1151. *Ex* scats of *Myrmecobius fasciatus* Waterhouse, 1836 (Marsupialia: Myrmecobiidae).* J.A. Friend; 8.vii.1981; Dryandra State Forest, WA; 32°44′S, 116°53′E.

Cosmoglyphus angustus distinctus Fain and Friend, 1984; *Rec. West. Aust. Mus.* 11 (2): 103. Holotype, hypopus, WAM 82/1152. *Ex* scats of *Myrmecobius fasciatus* Waterhouse, 1836 (Marsupialia: Myrmecobiidae).* J.A. Friend; 8.vii.1981; Dryandra State Forest, WA; 32°44′S, 116°53′E.

Ctenocolletacarus brevirostris Fain, 1984; *Rec. West. Aust. Mus.* 11 (2): 85. Holotype, hypopus, WAM 83/171. From *Ctenocolletes albomarginatus* Michener, 1965 (Hymenoptera: Stenotritidae). A.M. Douglas; 23.x.1947; Merredin, WA; 31°29′S, 118°16′E.

Ctenocolletacarus grandior Fain, 1984; *Rec. West. Aust. Mus.* 11 (2): 79. Holotype, hypopus, WAM 83/170. From *Ctenocolletes centralis* Houston, 1983 (Hymenoptera: Stenotritidae). T.F. Houston; 6, 7.ix.1981; Anketell, H.S. 12.5 km ENE of, WA; 28°02′S, 118°51′E.

Ctenocolletacarus longirostris Fain, 1984; *Rec. West. Aust. Mus.* 11 (2): 79. Holotype, hypopus, WAM 83/169. From *Ctenocolletes nicholsoni* Cockerell, 1929 (Hymenoptera: Stenotritidae). T.F. Houston; 20.viii.1971; Geraldton, 126 miles [200 km] N of, WA; 27°08′S, 114°38′E.

Tyroborus houstoni Fain, 1986; *Rec. West. Aust. Mus.* 12 (4): 409. Holotype, ♀, WAM 85/1168. *Ex* brood cell of *Paragia tricolor* Smith, 1850 (Hymenoptera: Vespidae). T.F. Houston; 30.iii.1983; Noble Falls, *c.* 30 km SW of Toodyay, WA; 31°45′S, 116°12′E.

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* The mites were probably associated with the termite diet of the host — Fain and Friend (1984, p. 101).

Family Atopomelidae

Austrochirus dorreensis Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 534. Holotype, ♂, WAM 80/342. From *Perameles bougainville* Quoy and Gaimard, 1824 (Marsupialia: Peramelidae). Fisheries and Wildlife Survey; 16.xi.1963; Dorre I., WA; 25°06'S, 113°06'E.

Dasyurochirus granulipes Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 544. Holotype, ♀, WAM 80/322. From *Sminthopsis granulipes* Troughton, 1932 (Marsupialia: Dasyuridae). W.K. Youngson; 10.iii.1973; Lake Grace, WA; 33°06'S, 118°28'E.

Dasyurochirus sminthopsis leucopus Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 538. Holotype, ♀, WAM 80/345. From *Sminthopsis leucopus* (Gray, 1842) (Marsupialia: Dasyuridae). P.A. Woolley; 5.xii.1974; Western Port, Vic.; 38°26'S, 145°08'E.

Dasyurochirus tapoatafa Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 542. Holotype, ♀, WAM 80/326. From *Phascogale tapoatafa* (Meyer, 1973) (Marsupialia: Dasyuridae). A. Frater; 12.xii.1974; Mahogany Creek, WA; 31°54'S, 116°08'E.

Murichirus (Murichirus) alatus Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 569. Holotype, ♂, WAM 80/346. From *Notomys alexis* Thomas, 1922 (Rodentia: Muridae). P.M. Lambert; 8.i.1975; Wanjarri Reserve, WA; 27° 24'S, 120°39'E.

Murichirus (Murichirus) alatus prosquamatus Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 571. Holotype, ♂, WAM 80/330. From *Pseudomys hermannsburgensis* (Waite, 1896) (Rodentia: Muridae). A.A. Burbidge; 12.iii. 1975; Disappointed Hill, WA; 28°03'S, 125°02'E.

Murichirus (Murichirus) dorsoscutatus Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 573. Holotype, ♂, WAM 80/349. From *Notomys alexis* Thomas, 1922 (Rodentia: Muridae). A.A. Burbidge; 16.iii.1975; Miss Gibson Hill, WA; 26°52'S, 126°20'E. [The discrepant data given by Fain and Lukoschus (1981) are incorrect – Fain, pers. comm.]

Murichirus (Murichirus) dorsostriatus Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 571. Holotype, ♂, WAM 80/353. From *Notomys alexis* Thomas, 1922 (Rodentia: Muridae). P.M. Lambert; 8.i.1975; Wanjarri Reserve, WA; 27°24'S, 120°39'E.

Murichirus (Murichirus) lobatitarsis Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 575. Holotype, ♂, WAM 80/354. From *Melomys* sp. (Rodentia: Muridae). Kimberley Exp.; 30.x.1976; Port Warrender, WA; 14°30'S, 125° 50'E.

Murichirus (Murichirus) mastacomys Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 579. Holotype, ♂, WAM 80/351. From *Mastacomys fuscus* Thomas, 1882 (Rodentia: Muridae). D. Wimbush [not Wimbosh] ; 11.ii.1958; Whites River (Munyang River), NSW; 36°19'S, 148°24'E.

Murichirus (Murichirus) quasimelomys Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 567. Holotype, ♂, WAM 80/328. From *Melomys* sp. (Rodentia: Muridae). Kimberley Exp.; 30.x.1976; Port Warrender, WA; 14°30'S, 125°50'E.

Murichirus (Murichirus) zyzomys Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 575. Holotype, ♂, WAM 80/356. From *Zyzomys argurus* (Thomas, 1889) (Rodentia: Muridae). Kimberley Exp.; 31.x.1976; Port Warrender, WA; 14°30'S, 125°50'E.

Notoryctobia notoryctes Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 556. Holotype, ♂, WAM 80/332. From *Notoryctes typhlops* (Stirling, 1889) (Marsupialia: Notoryctidae). E.J. Car [not T. Carr] ; 1968; Warburton Range, WA; 26°06'S, 126°40'E.

Petaurobia australiana Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 550. Holotype, ♀, WAM 80/324. From *Petaurus breviceps* Waterhouse, 1839 (Marsupialia: Petauridae). A.M. Douglas; 29.[not 20.]vi.1960; Kalumburu, WA; 14°18'S, 126°38'E.

Family Chirodiscidae

Alabidocarpus chalinolobi Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 524. Holotype, ♀, WAM 80/339. From *Chalinolobus gouldii* (Gray, 1841) (Chiroptera: Vespertilionidae). Kimberley Exp.; 25.viii.1976; Beagle Bay, WA; 16°59'S, 122°40'E.

Alabidocarpus parvulus Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 527. Holotype, ♀, WAM 80/341. From *Eptesicus douglasi* Kitchener, 1976 (Chiroptera: Vespertilionidae). Kimberley Exp.; 5.x.1976; Geikie Gorge, WA; 18°05'S, 125°43'E.

Alabidocarpus yandinae intersitus Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 523. Holotype, ♀, WAM 80/337. From *Eptesicus douglasi* Kitchener, 1976 (Chiroptera: Vespertilionidae). Kimberley Exp.; 20.ix.1976; Beverley Springs, WA; 16°35'S, 125°29'E.

Dentocarpus (Paradentocarpus) kimberleyensis Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 530. Holotype, ♀, WAM 80/344. From *Eptesicus douglasi* Kitchener, 1976 (Chiroptera: Vespertilionidae). Kimberley Exp.; 8.[not 20.]x.1976; Geikie Gorge, WA; 18°05'S, 125°43'E.

Labidocarpus australiensis Fain and Lukoschus, 1981; *Rec. West. Aust. Mus.* 8 (4): 518. Holotype, ♀, WAM 80/334. From *Hipposideros ater* Templeton, 1848 (Chiroptera: Hipposideridae). Kimberley Exp.; 6.x.1976; Geikie Gorge, WA; 18°05'S, 125°43'E.

Family Cytoditidae

Cytodites geopeliae Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 23. Holotype, ♀, WAM 79/930. From *Geopelia humeralis* (Temminck, 1821) (Columbiformes: Columbidae). Kimberley Exp.; 25.viii.1976; Beagle Bay, WA; 16°59'S, 122°40'E.

Family Glycyphagidae

Alabidopus muris Lukoschus, Janssen Duijghuijsen and Fain, 1979; *Rec. West. Aust. Mus.* 7 (1): 30. Holotype, hypopus, WAM 79/898. From *Rattus tunneyi* (Thomas, 1904) (Rodentia: Muridae). Kimberley Exp.; 30.x.1976; Port Warrender, WA; 14°30'S, 125°50'E. [Date and locality not as given by Lukoschus *et al.* (1979).]

Marsupiopus zyzomys Lukoschus, Janssen Duijghuijsen and Fain, 1979; *Rec. West. Aust. Mus.* 7 (1): 38. Holotype, hypopus, WAM 79/888. From *Zyzomys argurus* (Thomas, 1889) (Rodentia: Muridae). Kimberley Exp.; 12.ix.1976; Mount Hart, WA; 16°55'S, 125°05'E.

Family Hypoderidae

Caprimuldectes podargi Janssen Duijghuijsen, Lukoschus and Fain, 1979; *Rec. West. Aust. Mus.* 7 (1): 6. Holotype, hypopus, WAM 79/845. From *Podargus strigoides* (Latham, 1801) (Caprimulgiformes: Caprimulgidae). Kimberley Exp.; 24.viii.1976; Beagle Bay, WA; 16°59'S, 122°40'E.

Neottialges (Pelecanectes) grallinae Janssen Duijghuijsen, Lukoschus and Fain, 1979; *Rec. West. Aust. Mus.* 7 (1): 2. Holotype, hypopus, WAM 79/858. From *Grallina cyanoleuca* (Latham, 1801) (Passeriformes: Grallinidae). Kimberley Exp.; 29.viii.1976; Napier Downs, WA; 17°15'S, 124°44'E.

Family Knemidokoptidae

Neocnemidocoptes australiensis Fain and Lukoschus, 1979; *Mitt. hamb. zool. Mus. Inst.* 76: 392. Holotype, ♂, WAM 80/348. From *Poephila guttata* (Vieillot, 1817) (Passeriformes: Ploceidae). Kimberley Exp.; 2.x.1976; Brooking Springs, WA; 18°07'S, 125°39'E.

Family Laminosioptidae

Calamicoptes conopophilae Lukoschus and Lombert, 1979; *Rec. West. Aust. Mus.* 7 (3): 277. Holotype, ♀, WAM 80/366. From *Conopophila rufogularis* (Gould, 1842) (Passeriformes: Meliphagidae). Kimberley Exp.; 1.x.1976; Brooking Springs, WA; 18°07′S, 125°39′E.

Calamicoptes meliphagae Lukoschus and Lombert, 1979; *Rec. West. Aust. Mus.* 7 (3): 274. Holotype, ♀, WAM 80/364. From *Philemon citreogularis* (Gould, 1837) (Passeriformes: Meliphagidae). Kimberley Exp.; 26.viii.1976; Beagle Bay, WA; 16°59′S, 122°40′E.

Fainocoptes nixoni Lukoschus and Lombert, 1979; *Rec. West. Aust. Mus.* 7 (3): 268. Holotype, ♀, WAM 80/369. From *Geopelia humeralis* (Temminck, 1821) (Columbiformes: Columbidae). Kimberley Exp.; 25.viii.1976; Beagle Bay, WA; 16°59′S, 122°40′E.

Streetacarus australis Lukoschus and Lombert, 1979; *Rec. West. Aust. Mus.* 7 (3): 278. Holotype, ♀, WAM 80/358. From *Calyptorhynchus magnificus* (Shaw, 1790) (Psittaciformes: Psittacidae). Kimberley Exp.; 10.ix.1976; Mount Hart, WA; 16°55′S, 125°05′E.

Order Mesostigmata
Family Ascidae

Proctolaelaps spencerae Domrow, 1979; *Rec. West. Aust. Mus.* 8 (1): 99. Holotype, ♀, WAM 79/1206. From *Tarsipes rostratus* Gervais and Verreaus, 1842 (Marsupialia: Tarsipedidae). T. and R. Goldfinsh; 20.xi.1969; Jerdacuttup [not Ferdacuttup], WA; 33°42′S, 120°25′E.

Family Dermanyssidae

Laelaps angiodes Domrow, 1980; *Rec. West. Aust. Mus.* 8 (2): 225. Holotype, ♀, WAM 79/1521. From *Zyzomys woodwardi* (Thomas, 1909) (Rodentia: Muridae). Kimberley Exp.; 29.x.1976; Port Warrender, WA; 14°30′S, 125°50′E.

Laelaps elegans Domrow, 1980; *Rec. West. Aust. Mus.* 8 (2): 213. Holotype, ♀, WAM 79/1434. From *Pseudomys nanus* (Gould, 1858) (Rodentia: Muridae). Kimberley Exp.; 20.x.1976; Mitchell Plateau, WA; 14°53′S, 125°45′E.

Laelaps parameces Domrow, 1980; *Rec. West. Aust. Mus.* 8 (2): 222. Holotype, ♀, WAM 79/1511. From *Conilurus penicillatus* (Gould, 1842) (Rodentia:

Muridae). Kimberley Exp.; 28.x.1976; Port Warrender, WA; 14°30'S, 125°50'E.

Laelaps synnomus Domrow, 1980; *Rec. West. Aust. Mus.* 8 (2): 219. Holotype, ♀, WAM 79/1505. From *Zyzomys argurus* (Thomas, 1889) (Rodentia: Muridae). Kimberley Exp.; 28.x.1976; Port Warrender, WA; 14°30'S, 125°50'E.

Liponyssoides lukoschusi Domrow, 1979; *Rec. West. Aust. Mus.* 7 (4): 404. Holotype, ♀, WAM 79/1235. From *Podargus strigoides* (Latham, 1801) (Caprimulgiformes: Podargidae). Kimberley Exp.; 26.viii.1976; Beagle Bay, WA; 16°59'S, 122°40'E.

Family Macronyssidae

Ornithonyssus campester Micherdzinski and Domrow, 1985; *Int. J. Acarol.* 11 (3): 199. Holotype, protonymph, WAM 85/1492. From *Taphozous georgianus* Thomas, 1915 (Chiroptera: Emballonuridae). Kimberley Exp.; 30.viii.1976; Napier Downs, WA; 17°15'S, 124°44'E.

Ornithonyssus stigmaticus Micherdzinski and Domrow, 1985; *Int. J. Acarol.* 11 (3): 199. Holotype, protonymph, WAM 85/1843. From *Saccolaimus flaviventris* Peters, 1867 (Chiroptera: Emballonuridae). Kimberley Exp.; 10.ix.1976; Mount Hart, WA; 16°55'S, 125°05'E.

Ornithonyssus taphozous Micherdzinski and Domrow, 1985; *Int. J. Acarol.* 11 (3): 195. Holotype, ♀, WAM 85/1847. From *Taphozous georgianus* Thomas, 1915 (Chiroptera: Emballonuridae). Kimberley Exp.; 31.x.1976; Brooking Springs, WA; 18°07'S, 125°39'E.

Trichonyssus lukoschusi Micherdzinski and Domrow, 1985; *Int. J. Acarol.* 11 (2): 63. Holotype, ♂, WAM 85/1851. From *Eptesicus douglasi* Kitchener, 1976 (Chiroptera: Vespertilionidae). Kimberley Exp.; 5.x.1976; Geikie Gorge, WA; 18°05'S, 125°43'E.

Trichonyssus nixoni Micherdzinski and Domrow, 1985; *Int. J. Acarol.* 11 (2): 56. Holotype, ♂, WAM 85/1873. From *Chalinolobus nigrogriseus rogersi* Thomas, 1909 (Chiroptera: Vespertilionidae). Kimberley Exp.; 20.ix.1976; Beverley Springs, WA; 16°35'S, 125°29'E.

Trichonyssus streetorum Micherdzinski and Domrow, 1985; *Int. J. Acarol.* 11 (2): 55. Holotype, ♂, WAM 85/1901. From *Chaerephon jobensis* (Miller, 1902) (Chiroptera: Molossidae). Kimberley Exp.; 10.ix.1976; Mount Hart, WA; 16°55'S, 125°05'E.

Family Rhinonyssidae

Ptilonyssus condylocoxa Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 11. Holotype, ♀, WAM 79/918. From *Ramsayornis fasciatus* (Gould, 1843) (Passeriformes: Meliphagidae). Kimberley Exp.; 23.ix.1976; Beverley Springs, WA; 16°35′S, 125°29′E.

Ptilonyssus conopophilae Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 13. Holotype, ♀, WAM 79/920. From *Grantiella picta* (Gould, 1838) (Passeriformes: Meliphagidae). Kimberley Exp.; 3.ix.1976; Napier Downs, WA; 17°15′S, 124°44′E.

Ptilonyssus pentagonicus Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 18. Holotype, ♀, WAM 79/922. From *Manorina flavigula* (Gould, 1840) (Passeriformes: Meliphagidae). Kimberley Exp.; 10.ix.1976; Mount Hart, WA; 16°55′S, 125°05′E.

Ptilonyssus pseudothymanzae Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 15. Holotype, ♀, WAM 79/921. From *Meliphaga flavescens* (Gould, 1839) (Passeriformes: Meliphagidae). Kimberley Exp.; 17.ix.1976; Beverley Springs, WA; 16°35′S, 125°29′E.

Order Prostigmata
Family Cheyletidae

Orinthocheyletia [= Ornithocleyletia] lichmerae Smiley, 1984; *Int. J. Acarol.* 10 (4): 239. Holotype, ♀, WAM 83/322. From *Lichmera indistincta* (Vigors and Horsfield, 1827) (Passeriformes: Meliphagidae). Kimberley Exp.; 24.viii.1976; Beagle Bay, WA; 16°59′S, 122°40′E.

Ornithocheyletia lonchurae Smiley, 1984; *Int. J. Acarol.* 10 (4): 240. Holotype, ♀, WAM 83/323. From *Lonchura castaneothorax* (Gould, 1837) (Passeriformes: Ploceidae). Kimberley Exp.; 13.ix.1976; Mount Hart, WA; 16°55′S, 125°05′E.

Family Demodicidae

Demodex bicaudatus Kniest and Lukoschus, 1981; *Rec. West. Aust. Mus.* 9 (2): 111. Holotype, ♂, WAM 80/311. From *Macroglossus minimus* (Geoffroy, 1810) (Chiroptera: Pteropodidae). Kimberley Exp.; 19.x.1976; Mitchell Plateau, WA; 14°53′S, 125°45′E.

Demodex macroglossi Desch, 1981; *Rec. West. Aust. Mus.* 9 (1): 41. Holotype, ♂, WAM 80/743. From *Macroglossus minimus* (Geoffroy, 1810) (Chiroptera: Pteropodidae). Kimberley Exp.; 19.x.1976; Mitchell Plateau, WA; 14°53′S, 125°45′E.

Ophthalmodex australiensis Woeltjes and Lukoschus, 1981; *Rec. West. Aust. Mus.* 9 (3): 308. Holotype, ♂, WAM 80/320. From *Rhinonycteris aurantius* (Gray, 1845) (Chiroptera: Hipposideridae). Kimberley Exp.; 9.x.1976; Geikie Gorge, WA; 18°05′S, 125°43′E.

Ophthalmodex wilsoni Woeltjes and Lukoschus, 1981; *Rec. West. Aust. Mus.* 9 (3): 311. Holotype, ♀, WAM 80/316. From *Eptesicus pumilus* (Gray, 1841) (Chiroptera: Vespertilionidae). Kimberley Exp.; 9.x.1976; Geikie Gorge, WA; 18°05′S, 125°43′E.

Family Ereynetidae

Boydaia (Boydaia) podargi Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 21. Holotype, ♀, WAM 79/928. From *Podargus strigoides* (Latham, 1801) (Caprimulgiformes: Caprimulgidae). Kimberley Exp.; 24.viii.1976; Beagle Bay, WA; 16°59′S, 122°40′E.

Neospeleognathopsis (Pteropignathus) pteropus Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 58. Holotype, ♀, WAM 79/1070. From *Pteropus scapulatus* Peters, 1862 (Chiroptera: Pteropodidae). Kimberley Exp.; 7.x.1976; Brooking Springs, WA; 18°07′S, 125°39′E.

Family Myobiidae

Acanthophthirius (Acanthophthirius) acinipus Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 66. Holotype, ♂, WAM 79/932. From *Scotorepens greyii* (Gray, 1843 [not 1858]) (Chiroptera: Vespertilionidae). Kimberley Exp.; 23.ix.1976; Beverley Springs, WA; 16°35′S, 125°29′E.

Acanthophthirius (Acanthophthirius) intercalatus Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 67. Holotype, ♂, WAM 79/938. From *Nyctophilus arnhemensis* Johnson, 1959 (Chiroptera: Vespertilionidae). Kimberley Exp.; 19.ix.1976; Beverley Springs, WA; 16°35′S, 125°29′E.

Acanthophthirius (Myotimyobia) alatus Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 69. Holotype, ♂, WAM 79/942. From *Eptesicus douglasi* Kitchener, 1976 (Chiroptera: Vespertilionidae). Kimberley Exp.; 4.x.1976; Geikie Gorge, WA; 18°05′S, 125°43′E.

Australomyobia dasycercus antechinus Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (3): 293. Holotype, ♀, WAM 79/1018. From *Antechinus bilarni* Johnson, 1964 (Marsupialia: Dasyuridae). Kimberley Exp.; 20.ix.1976; Beverley Springs, WA; 16°35′S, 125°29′E.

Australomyobia dasyurus Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (3): 296. Holotype, tritonymph, WAM 79/1026. From *Dasyurus hallucatus* Gould, 1842 (Marsupialia: Dasyuridae). Kimberley Exp.; 20.x.1976; Mitchell Plateau, WA; 14°53′S, 125°45′E.

Australomyobia phascogale Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (3): 290. Holotype, ♀, WAM 79/1012. From *Phascogale calura* Gould, 1844 (Marsupialia: Dasyuridac). D.G. Bathgate, 16.xii.1960; Lake Grace, WA; 33°06′S, 118°28′E.

Binuncus fortis Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 80. Holotype, ♂, WAM 79/1002. From *Pteropus scapulatus* Peters, 1862 (Chiroptera: Pteropodidae). Kimberley Exp.; 1.x.1976; Brooking Springs, WA; 18°07′S, 125°39′E.

Ewingana (Ewingana) bispinosa longispina Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 74. Holotype, ♂, WAM 79/951. From *Chaerephon jobensis* (Miller, 1902) (Chiroptera: Molossidac). Kimberley Exp.; 13.ix.1976; Mount Hart, WA; 16°55′S, 125°05′E.

Hipposiderobia belli Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 73. Holotype, ♀, WAM 79/950. From *Rhinonycteris aurantius* Gray, 1845 (Chiroptera: Hipposideridae). Kimberlcy Exp.; 8.x.1976; Geikie Gorge, WA; 18°05′S, 125°43′E.

Pteracarus microdorsalis Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 78. Holotype, ♀, WAM 79/980. From *Nyctophilus* sp. (Chiroptera: Vespertilionidae). Kimberley Exp.; 20.ix.1976; Beverley Springs, WA; 16°35′S, 125°29′E.

Pteropimyobia pahangensis quinquedens Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 79. Holotype, ♀, WAM 79/983. From *Macroglossus minimus* (Geoffroy, 1810) (Chiroptera: Pteropodidae). Kimbcrley Exp.; 19.x.1976; Mitchell Plateau, WA; 14°53′S, 125°45′E.

Radfordia (Radfordia) australiana Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (3): 313. Holotype, ♀, WAM 79/1040. From *Rattus tunneyi* Thomas, 1904 (Rodentia: Muridae). Kimberley Exp.; 10.ix.1976; Mount Hart, WA; 16°55′S, 125°05′E.

Radfordia (Syconycterobia) latior Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (3): 310. Holotype, ♀, WAM 79/1063. From *Conilurus penicillatus* (Gould, 1842) (Rodentia: Muridae). Kimberley Exp.; 31.x.1976; Port Warrender, WA; 14°30′S, 125°50′E.

Radfordia (Syconycterobia) mastacomys Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (3): 304. Holotype, ♂, WAM 79/1046. From *Mastacomys fuscus* Thomas, 1882 (Rodentia: Muridae). D. Wimbush, 11.ii.1958; Whites River (Munyang River), NSW; 36°19′S, 148°24′E.

Radfordia (Syconycterobia) notomys Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (3): 306. Holotype, ♀, WAM 79/1048. From *Notomys* sp. (Rodentia: Muridae). R.B. Humphries; 13.v.1965; Kalbarri, WA; 27°42′S, 114°12′E.

Radfordia (Syconycterobia) vesca Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (3): 312. Holotype, ♀, WAM 79/1064. From *Pseudomys nanus* (Gould, 1858) (Rodentia: Muridae). Kimberley Exp.; 20.x.1976; Mitchell Plateau, WA; 14°53′S, 125°45′E.

Radfordia (Syconycterobia) zyzomys Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (3): 308. Holotype, ♀, WAM 79/1054. From *Zyzomys argurus* (Thomas, 1889) (Rodentia: Muridae). Kimberley Exp.; 30.viii.1976; Napier Downs, WA; 17°15′S, 124°44′E.

Ugandobia australiensis Fain and Lukoschus, 1979; *Rec. West. Aust. Mus.* 7 (1): 75. Holotype, ♂, WAM 79/961. From *Saccolaimus flaviventris* Peters, 1867 (Chiroptera: Emballonuridae). Kimberley Exp.; 18.ix.1976; Beverley Springs, WA; 16°35′S, 125°29′E.

Family Psorergatidae

Psorergatoides australiensis Giesen, Lukoschus and Fain, 1982; *Rec. West. Aust. Mus.* 9 (4): 316. Holotype, ♀, WAM 81/570. From *Eptesicus pumilus* (Gray, 1841) (Chiroptera: Vespertilionidae). Kimberley Exp.; 23.x.1976; Mitchell Plateau, WA; 14°53′S, 124°45′E. [The discrepant data given by Giesen, Lukoschus and Fain (1982) are incorrect — Lukoschus, pers. comm.].

Family Trombiculidae

Ascoschoengastia deficiens Lester, 1984; *Proc. Linn. Soc. NSW* 107 (4): 493. Holotype, larva, WAM 84/877. From *Dasyurus hallucatus* Gould, 1842 (Marsupialia: Dasyuridae). P.J.A. Presidente; 18.vii.1982; Mitchell Plateau, WA; 14°53′S, 125°45′E.

Ascoschoengastia setosa Goff, 1979; *Rec. West. Aust. Mus.* 8 (1): 86. Holotype, larva, WAM 79/1577. From *Zyzomys argurus* (Thomas, 1889) (Rodentia: Muridae). Kimberley Exp.; 30.ix.1976; Brooking Springs, WA; 18°07′S, 125°39′E.

Chiroptella (Neosomia) geikiensis Goff, 1979; *Rec. West. Aust. Mus.* 8 (1): 93. Holotype, larva, WAM 79/1578. From *Rhinonycteris aurantius* (Gray, 1845) (Chiroptera: Hipposideridae). Kimberley Exp.; 8.x.1976; Geikie Gorge, WA; 18°05'S, 125°43'E.

Cotrombicula lukoschusi Goff, 1983; *Int. J. Ent.* 25 (1): 71. Holotype, larva, WAM 83/567. From *Taphozous georgianus* Thomas, 1915 (Chiroptera: Emballonuridae). Kimberley Exp.; 2.ix.1976; Napier Downs, WA; 17°15'S, 124°44'E.

Cotrombicula mitchellensis Goff, 1983; *J. med. Ent.* 20 (2): 134. Holotype, larva, WAM 83/570. From *Taphozous georgianus* Thomas, 1915 (Chiroptera: Emballonuridae). Kimberley Exp.; 23.x.1976; Mitchell Plateau, WA; 14°53'S, 125°45'E.

Cotrombicula rugosa Goff, 1979; *Rec. West. Aust. Mus.* 8 (1): 89. Holotype, larva, WAM 79/1579. From *Zyzomys argurus* (Thomas, 1889) (Rodentia: Muridae). Kimberley Exp.; 31.x.1976; Port Warrender, WA; 14°30'S, 125°50'E.

Guntheria kethleyi Goff, 1979; *Rec. West. Aust. Mus.* 8 (1): 88. Holotype, larva, WAM 79/1580. From *Zyzomys argurus* (Thomas, 1889) (Rodentia: Muridae). Kimberley Exp.; 31.viii.1976; Napier Downs, WA; 17°15'S, 124°44'E.

Guntheria platalea Domrow, 1984; *J. Aust. ent. Soc.* 23 (3): 214. Holotype, larva, WAM 84/874. From *Rattus fuscipes fuscipes* (Waterhouse, 1839) (Rodentia: Muridae). W. Gibb; 16.viii.1979; Pemberton, WA; 34°27'S, 116°02'E.

Guntheria weedunnarti Goff, 1980; *J. med. Ent.* 17 (5): 478. Holotype, larva, WAM 80/430. From *Sminthopsis leucopus* (Gray, 1842) (Marsupialia: Dasyuridae). P.A. Woolley; 5.xii.1974; Western Port, Vic.; 38°26'S, 145°08'E.

Schoengastia gutekunsti Goff, 1981; *Rec. West. Aust. Mus.* 8 (4): 585. Holotype, larva, WAM 80/213. From *Ctenotus inornatus* (Gray, 1845) (Squamata: Scincidae). Kimberley Exp.; 10.ix.1976; Mount Hart, WA; 16°55'S, 125°05'E.

Schoutedenichia empusa Domrow, 1984; *J. Aust. ent. Soc.* 23 (3): 218. Holotype, larva, WAM 84/875. From *Zyzomys woodwardi* (Thomas, 1909) (Rodentia: Muridae). P.J.A. Presidente; 22.vii.1982; Mitchell Plateau, WA; 14°53'S, 125°45'E.

Schoutedenichia mimema Domrow, 1984; *J. Aust. ent. Soc.* 23 (3): 219. Holotype, larva, WAM 84/876. From *Zyzomys woodwardi* (Thomas, 1909) (Rodentia: Muridae). P.J.A. Presidente; 22.vii.1982; Mitchell Plateau, WA; 14°53'S, 125°45'E.

Zyzomyacarus arguri Goff, 1979; *Rec. West. Aust. Mus.* 8 (1): 82. Holotype, larva, WAM 79/1581. From *Zyzomys argurus* (Thomas, 1889) (Rodentia: Muridae). Kimberley Exp.; 31.viii.1976; Napier Downs, WA; 17°15′S, 124°44′E.

Zyzomyacarus napierensis Goff, 1979; *Rec. West. Aust. Mus.* 8 (1): 84. Holotype, larva, WAM 79/1582. From *Zyzomys argurus* (Thomas, 1889) (Rodentia: Muridae). Kimberley Exp.; 31.viii.1976; Napier Downs, WA; 17°15′ S, 124°44′E.

Life cycle stages of mites of the genus *Ctenocolletacarus* Fain (Acari: Acaridae) associated with *Ctenocolletes* bees in Australia

A. Fain* and T.F. Houston†

Abstract

The first known life cycle stages (other than the hypopus) for the genus *Ctenocol-letacarus* are described. They comprise the female, egg, larva, and protonymph of *C. longirostris*, and the tritonymph and adults (female and homomorphic and heteromorphic males) of *C. brevirostris*. They were collected from brood cells of their hosts or reared from hypopi.

Additional host records for hypopi of the two species are provided and *Cteno-colletes nigricans* is newly recorded as a host for *C. brevirostris*.

Introduction

Fain (1984) erected the genus *Ctenocolletacarus* for three new species of acarid mites then known only from heteromorphic deutonymphs (hypopi) phoretic on bees of the genus *Ctenocolletes* (Stenotritidae) in Western Australia. Houston (1984) noted that female bees carried the hypopi in specialised pouches on the abdomen and surmised that there is a mutualistic association between bees and mites. More recently, he excavated nests of *Ctenocolletes albomarginatus* Michener and *C. nicholsoni* Cockerell and obtained series of mites from the brood cells. Nests of *C. nicholsoni* yielded gravid females, eggs, larvae and protonymphs. Some of the protonymphs were reared to hypopi which were identified as mostly *C. longirostris* Fain and a few *C. grandior* Fain. Moreover, hypopi of *C. brevi-rostris* Fain taken from adult bees were reared to tritonymphs and adults of both sexes.

This paper describes these newly discovered life cycle stages and provides a basis for a forthcoming account of the biology of the mites.

Most of the material examined is lodged in the Western Australian Museum with duplicates in the Institut royal des Sciences naturelles de Belgique, Bruxelles, the British Museum (Natural History), London, and the Museum of Zoology, University of Michigan, Ann Arbor.

All dimensions are given in μm.

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Systematics

Genus *Ctenocolletacarus* Fain, 1984

Type species
  C. longirostris Fain, 1984.

Characters of adults and immatures may now be added to the definition of this genus, originally based on hypopi only.

Female

Body of ovigerous individuals (containing about 12 eggs) strongly dilated; cuticle soft with small propodonotal shield; sejugal furrow poorly developed; epimeres I fused in a short sternum, others free; vulva longitudinal (I-shaped) and situated between coxae III-IV; genital suckers normally developed; anus very close to vulva; copulatory orifice ventroterminal, close to midline; legs appearing relatively small in dilated female; all tarsi ending in claw with long straight base completely embedded in membranous pretarsus.

Chaetotaxy of body: setae *ve* very small, situated along lateral margin of shield directly behind *vi;* setae *s cx* very short and thin, not barbed; setae *sc i* short and thin; *sc e* long with thick bases; *d1, d2, l1* and *l2* very short and thin; *d3-d5* and *l3-l5* thick but in *C. longirostris* all are broken close to their bases except *l5* which is long and entire (in *brevirostris,* at least *d3, d5* and *l5* long); ventrally, setae *cx I, cx III, sh* and the three pairs of genitals short and thin, *h* about twice as long; three pairs of short anal setae and two pairs of chitinous ringlets represent vestigial anal setae.

Chaetotaxy of legs: tarsus I with 13 setae of which six are short apical or preapical spines, three are preapical pedunculate foliate setae (two large laterals and one smaller dorsal), and four are median setae (two spines and two spinous setae); tarsus II as in I but with one spinous median seta (*ba* seta) lacking; tarsus III with seven spines (six on apical third and one on median third) and three subapical pedunculate foliate setae; tarsus IV with eight spines and two pedunculate foliate setae (one dorsal, one anterior); tibiae I-IV with 2-2-1-1 spines; genua with 2-2-1-0 spines; femora with 1-1-0-1 thin setae; trochanters with 1-1-1-0 setae.

Solenidiotaxy: tarsus I with three solenidia, *w3* being apical; all tibiae with one solenidion; genua I with two unequal solenidia; genua II-III each with one solenidion.

Male

General characters as in female and sexual dimorphism little developed. Males are of two kinds: a homomorphic male with legs III normal, and a heteromorphic

male with legs III modified (leg thicker than normal and tarsus prolonged into a very strong conical ventrally recurved process). Both kinds of males with adanal suckers absent and replaced by pair of chitinous ringlets; tarsus IV with two small suckers.

Tritonymph

Only one free tritonymph was observed (the others being enclosed by the hypopial skin). Legs reduced, claws smaller and setae shorter than in adults. Setae $d3$-$d5$ much shorter than in adults; $d5$ curved with a tooth on basal third. Some of the enclosed tritonymphs contained a fully developed male or female. Thus, it appears that the tritonymph is a non-motile stage that remains within the hypopial exuvium. Our one free specimen probably was expelled accidentally.

Protonymph

Dorsal setae mostly spinous and subequal in length. Some protonymphs contained a fully developed hypopus.

Larva

Chaetotaxy as for protonymph but genitals, anals, $l4$ and $l5$ lacking. Coxa I with pair of long Claparéde organs. Some larvae contain a protonymph.

Remarks

The genus *Ctenocolletacarus* differs from other genera of Acaridae by characters of the hypopi (Fain 1984) and the following: male lacking adanal suckers; female with anus situated anteriorly close to vulva and anal chaetotaxy reduced to three pairs instead of usual five or six pairs; both sexes with strong development of setae $d5$ and $l5$ which are very long and have very thick bases.

Ctenocolletacarus longirostris Fain, 1984
#### Figures 1-6, 11-17

Although we are using the above name for the females, eggs, larvae and protonymphs obtained from brood cells of *Ctenocolletes nicholsoni*, it is possible that some of them are really *C. grandior*. This is because both species are represented amongst 22 hypopi reared from one cell (17 *longirostris*, 5 *grandior*). Presumably some of the protonymphs from that cell (and perhaps individuals from other cells) are *grandior*. However, we could not distinguish two kinds in any stage other than the hypopus and, because all hypopi carried by female bees occupying the nests were *longirostris*, we elect to use this name for all individuals. We may be dealing with sibling species distinguishable only by their hypopi.

Female (Figures 1-6)

Our two females are broadly ovoid and contain 12 and 14 eggs; cuticle broken in posterior third so dimensions of idiosoma are estimated as (length x width) 1260 x 960 and 1200 x 800.

Dorsum: well developed tegmen covers base of gnathosoma; lengths of setae are *ve* and *s cx* 6-10; *vi* 50, *sc i* 50, *sc e* 200, *d1*, *d2*, *l1* and *l2* 20-30; *l4* at least 50 long.
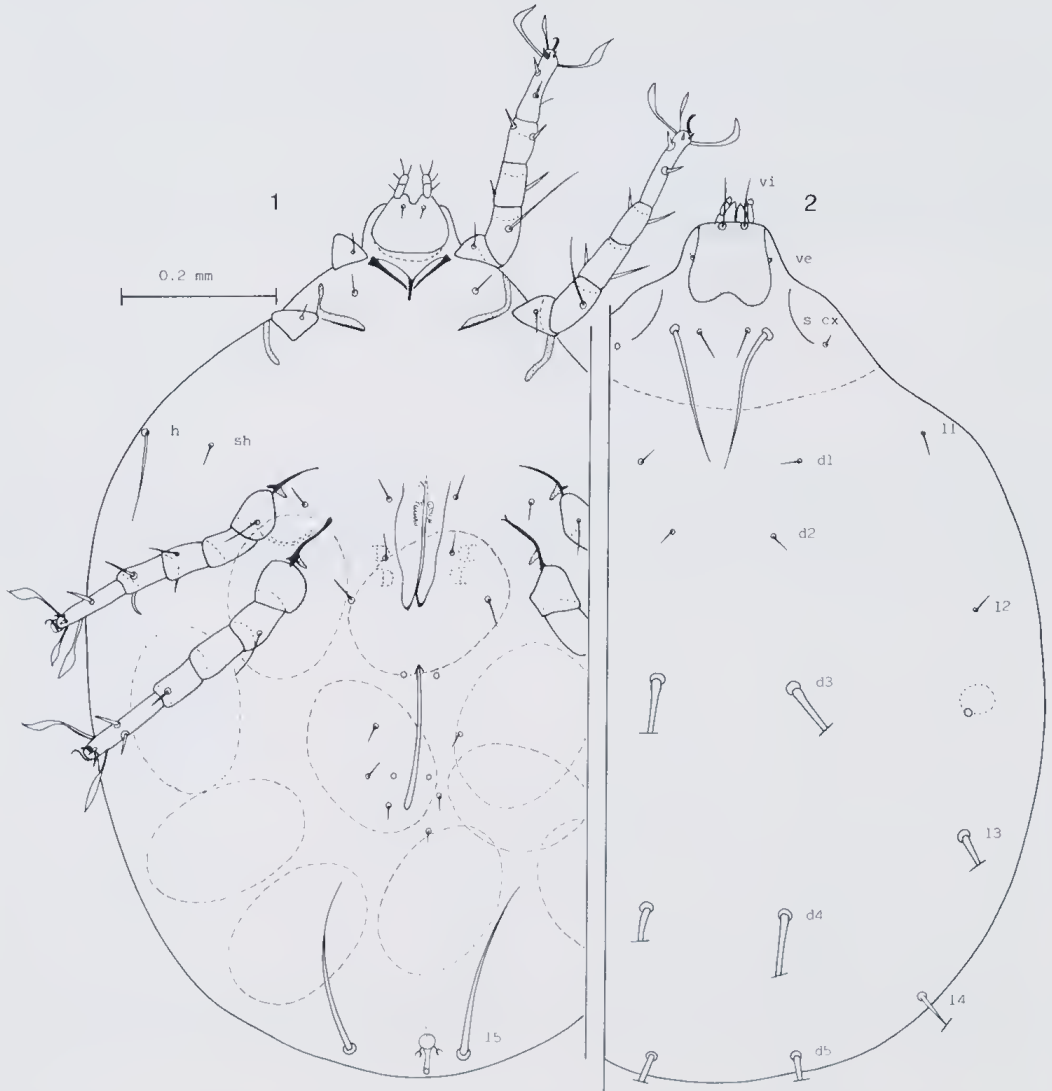
Figures 1, 2   *Ctenocolletacarus longirostris*. Gravid female, ventral and dorsal views, respectively.

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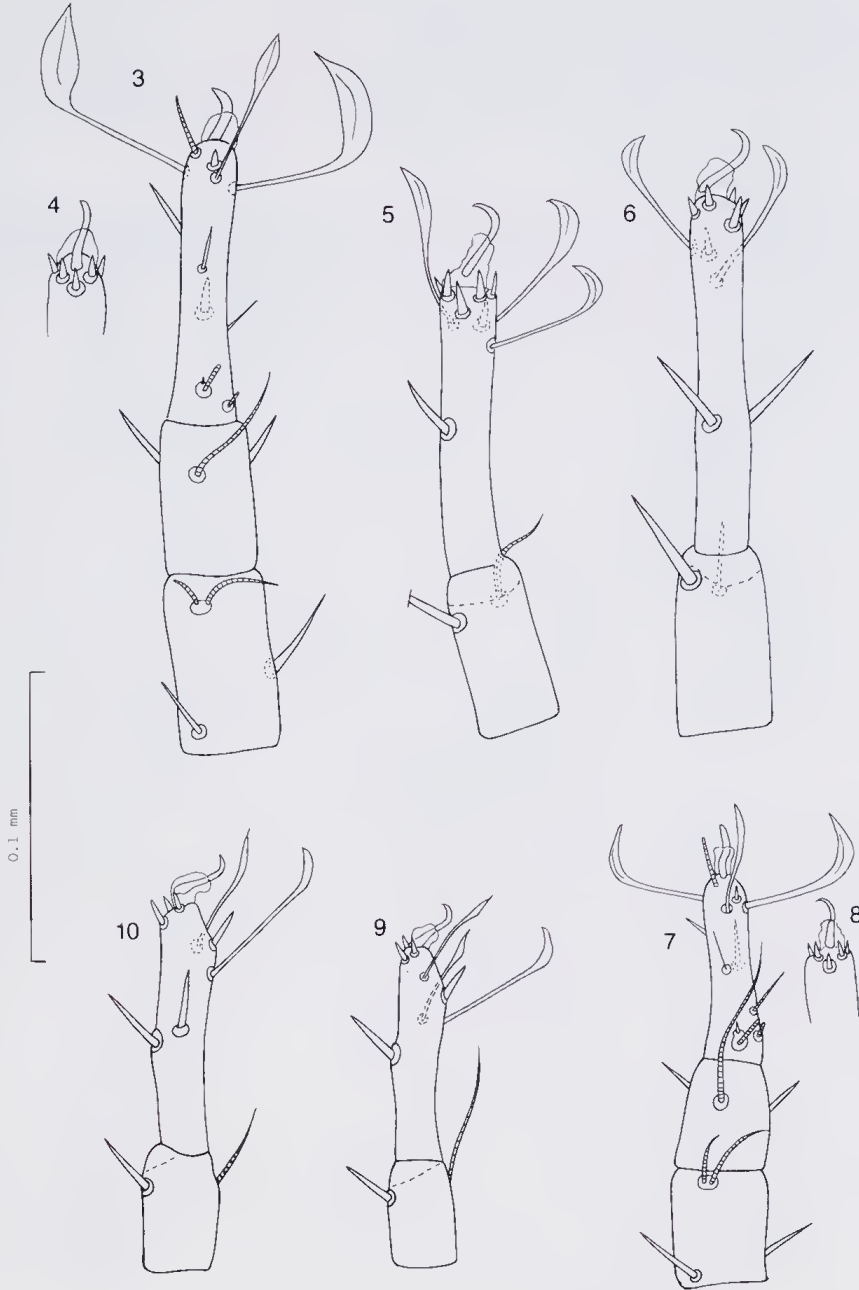
Figures 3-10   Legs of *Ctenocolletacarus* females. (3-6) *C. longirostris:* (3) leg I, dorsal view;
(4) apex of tarsus I, ventral view; (5) tibia and tarsus III; (6) tibia and tarsus IV.
(7-10) *C. brevirostris:* (7) leg I, dorsal view; (8) apex of tarsus I, ventral view;
(9) tibia and tarsus III; (10) tibia and tarsus IV.

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Venter: setal lengths are *h* 135, *sh* 30, *l5* 250, *cx I, cx III* and genitals 30-40, anals (very thin) 12-15.

Legs: lengths of tarsi I-IV are 102, 105, 108 and 130, respectively.

Protonymph (Figures 11-16)

Idiosoma of freshly emerged specimens measure (length x width) from 390 x 240 to 420 x 255 (n 5) and of fully fed specimens from 450 x 280 to 600 x 420 (n 5); one pair of genital suckers, one pair of genital setae and three pairs of anal
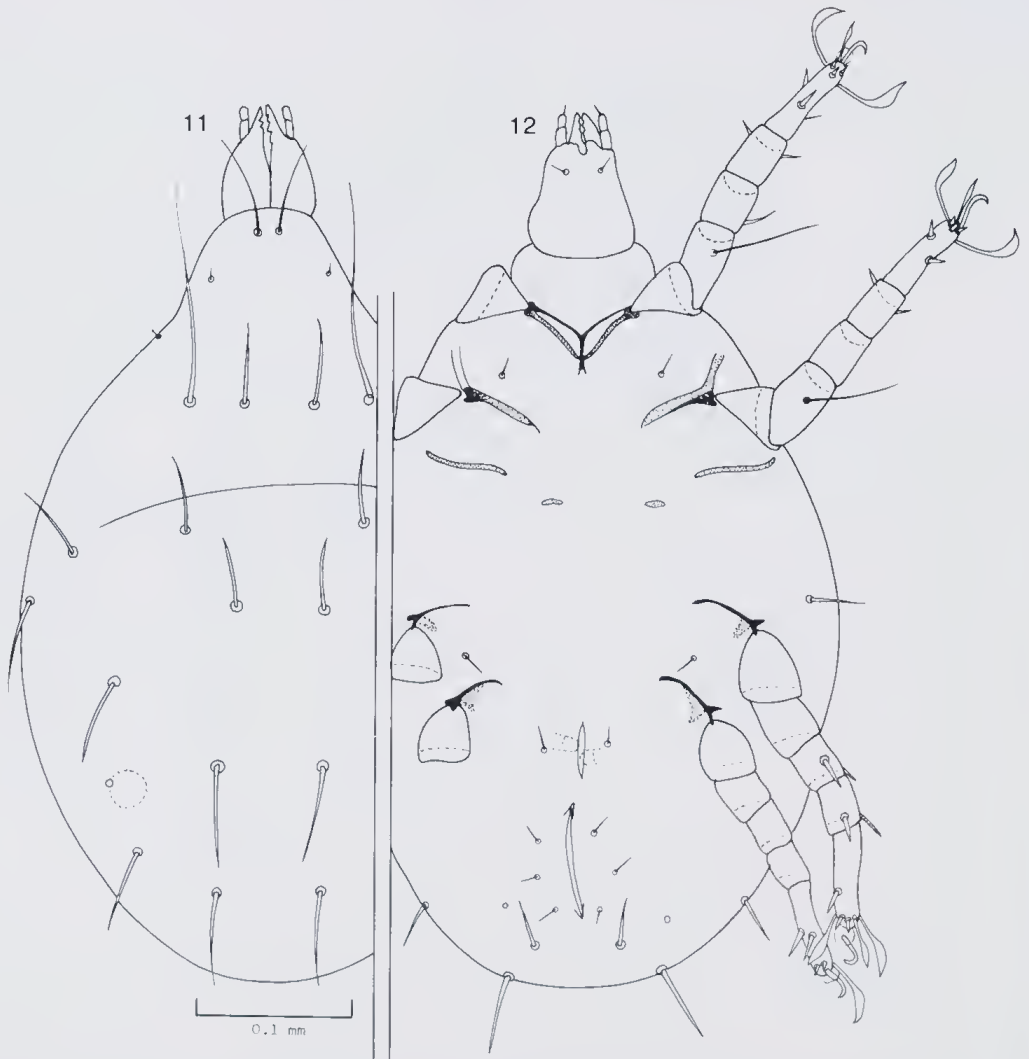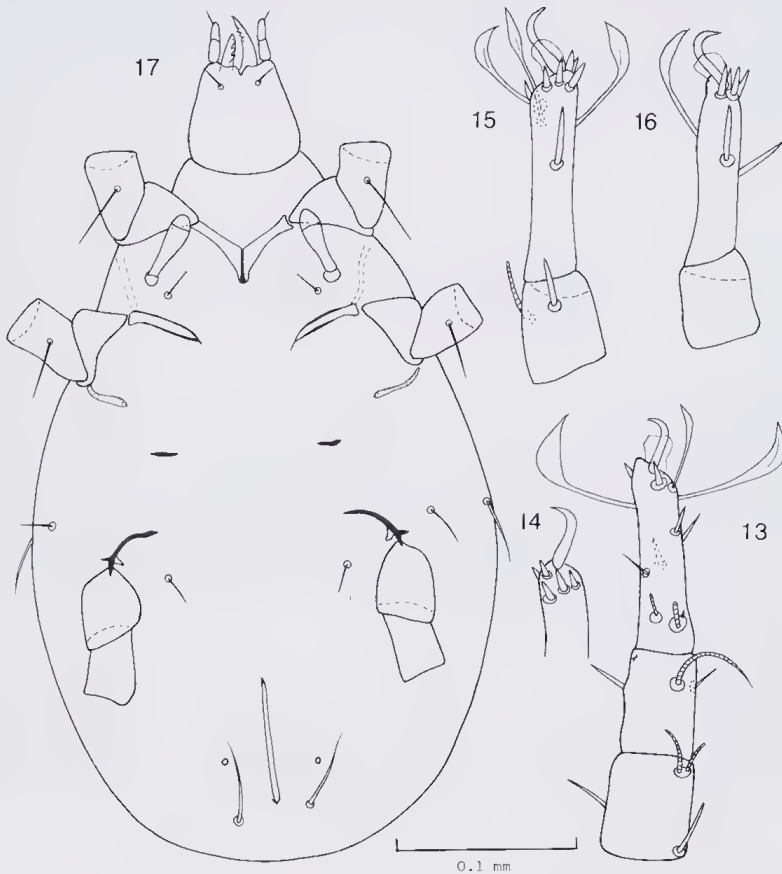

Figures 11, 12 *Ctenocolletacarus longirostris.* Protonymph, dorsal and ventral views, respectively.

setae present; hysteronotal setae 45-60 long; lengths of other setae are *vi* 55, *ve* 10, *s cx* 6, *sc i* 70, *sc e* 140, and (on venter) *d5* 35 and *l5* 40; legs well developed each ending in large claw; tarsi I-IV with 13-12-10-7 setae; tarsus IV bearing six spines and one dorsal foliate seta; tibiae I-IV with 2-2-1-0 setae, genua with 2-2-1-0 and femora with 1-1-0-0; trochanters bare; tarsus I with only two solenidia (*w1* and *w2*).

Larva (Figure 17)

Length and width of idiosoma of four specimens are 420 x 270, 390 x 245, 360 x 240 and 344 x 225; body shape as in protonymph; ventrally, genital suckers and genital and anal setae absent; coxae I bear setae *cx I* 35 long; setae *sh, cx III* and *d5* present; chaetotaxy of legs I-II as for protonymph; leg III as in protonymph but with one foliate seta of tarsus replaced by spine.

Figures 13-17 *Ctenocolletacarus longirostris.* (13-16) protonymph: (13) leg I in dorsal view; (14) apex of tarsus I viewed ventrolaterally; (15) tibia and tarsus III; (16) tibia and tarsus IV. (17) Larva, ventral view.

Egg

Ellipsoidal; eggs still enclosed in female measured from 225 x 150 to 235 x 159 (dimensions possibly exaggerated through compression), those deposited on cell wall from 180 x 110 to 190 x 120; chorion smooth, glossy and colourless.

Material examined

In alcohol unless indicated otherwise. All from Western Australia.

Associated with *Ctenocolletes nicholsoni*, from 13 km S of Wannoo (26°49'S, 114°37'E), 24-28 August 1984, collected by T.F. Houston and B.P. Hanich. *Ex* brood cells: WAM 85/426-427, 2 ovigerous ♀; WAM 85/428, eggs attached to cell wall; WAM 85/429, 200-300 larvae and protonymphs (*c.* 70 on 8 slides); WAM 85/430, *c.* 200 protonymphs and few larvae (25 proto-nymphs on 4 slides); WAM 85/431, 250-300 larvae and protonymphs (*c.* 60 on 8 slides); WAM 85/432-433, *c.* 30 protonymphs containing hypopi (22 on 7 slides); WAM 85/434, 6 hypopi reared from protonymphs with 5 hypopi of *C. grandior* (on slide); WAM 85/435, 11 hypopi reared from protonymphs (2 slides). *Ex* tergal pouches of two female bees (WAM 85/411-412) collected at nests: WAM 85/436-437, *c.* 60 hypopi (23 on 3 slides).

Associated with *Ctenocolletes centralis* Houston, from 21 km ENE of Beyondie HS (24° 47'S, 120°02'E), collected 17 and 20 August 1984 by T.F. Houston and B.P. Hanich. *Ex* tergal pouches of four female bees (WAM 85/405-408): WAM 85/422-425, *c.* 200 hypopi (*c.* 50 on 12 slides).

Ctenocolletacarus brevirostris Fain, 1984

(Figures 7-10, 18-27)

Female (Figures 7-10, 18-19)

Our three specimens were freshly emerged, non-gravid, and poorly sclerotised; lengths and widths of idiosomas 400 x 225, 420 x 240 and 435 x 250; dorsal shield very weakly punctate; chaetotaxy as in *C. longirostris* female; lengths of some setae are *vi* 25, *sc i* 20, *sc e* 200, *d3* 230 (*d4* incomplete, at least 75), *d5* 280-300 and *h* 110; venter as in *longirostris* but setae *l5* 300 long and legs shorter, lengths of tarsi I-IV being 63-66-72-93.

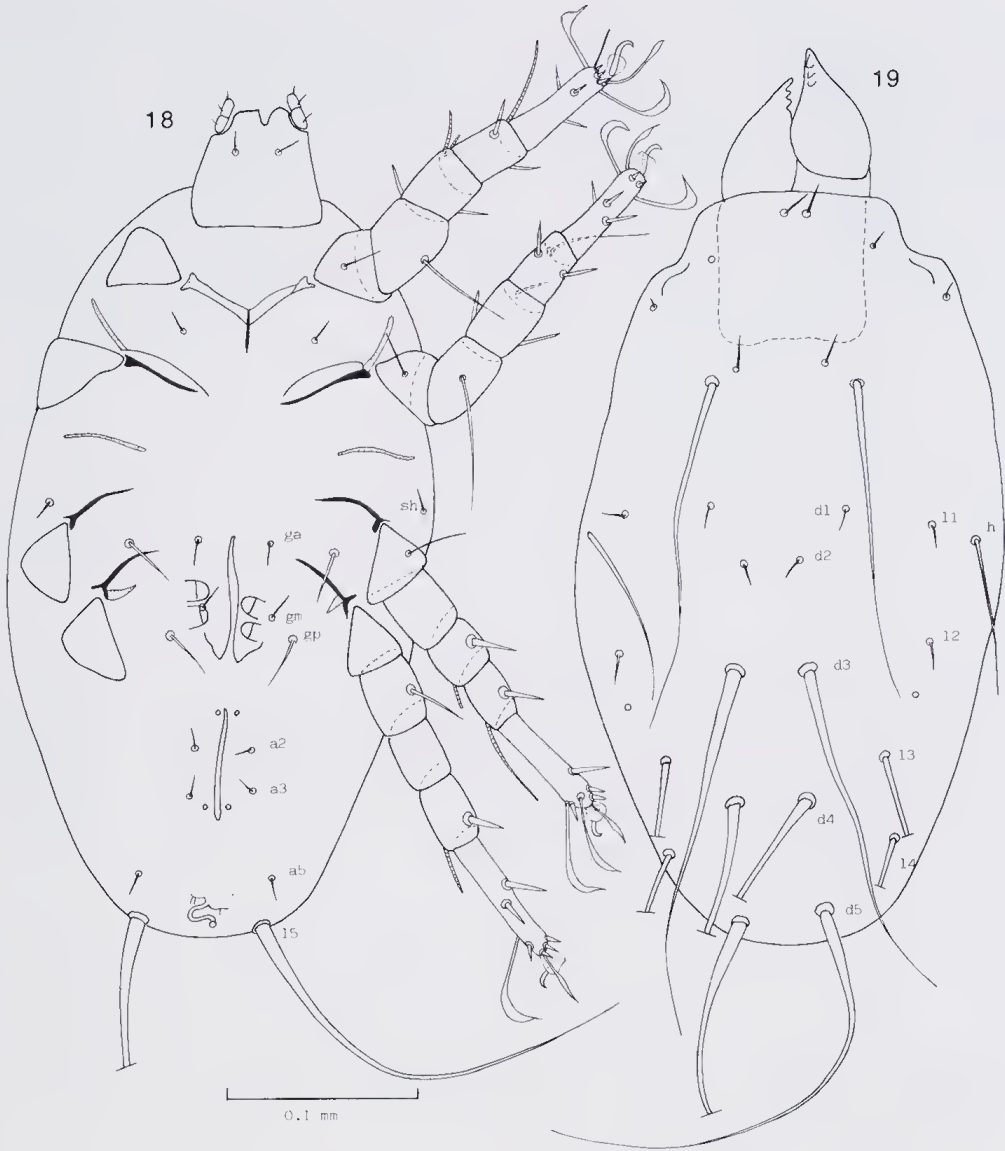Male (homomorphic) (Figures 20-23)

Idiosoma length 420, width 240; dorsum as in female; genital slit between coxae IV; anus close to genital slit; penis triangular, attenuated anteriorly; three pairs of anal setae present; legs I-III as in female; tarsi IV with seven spines and one pedunculate foliate seta.
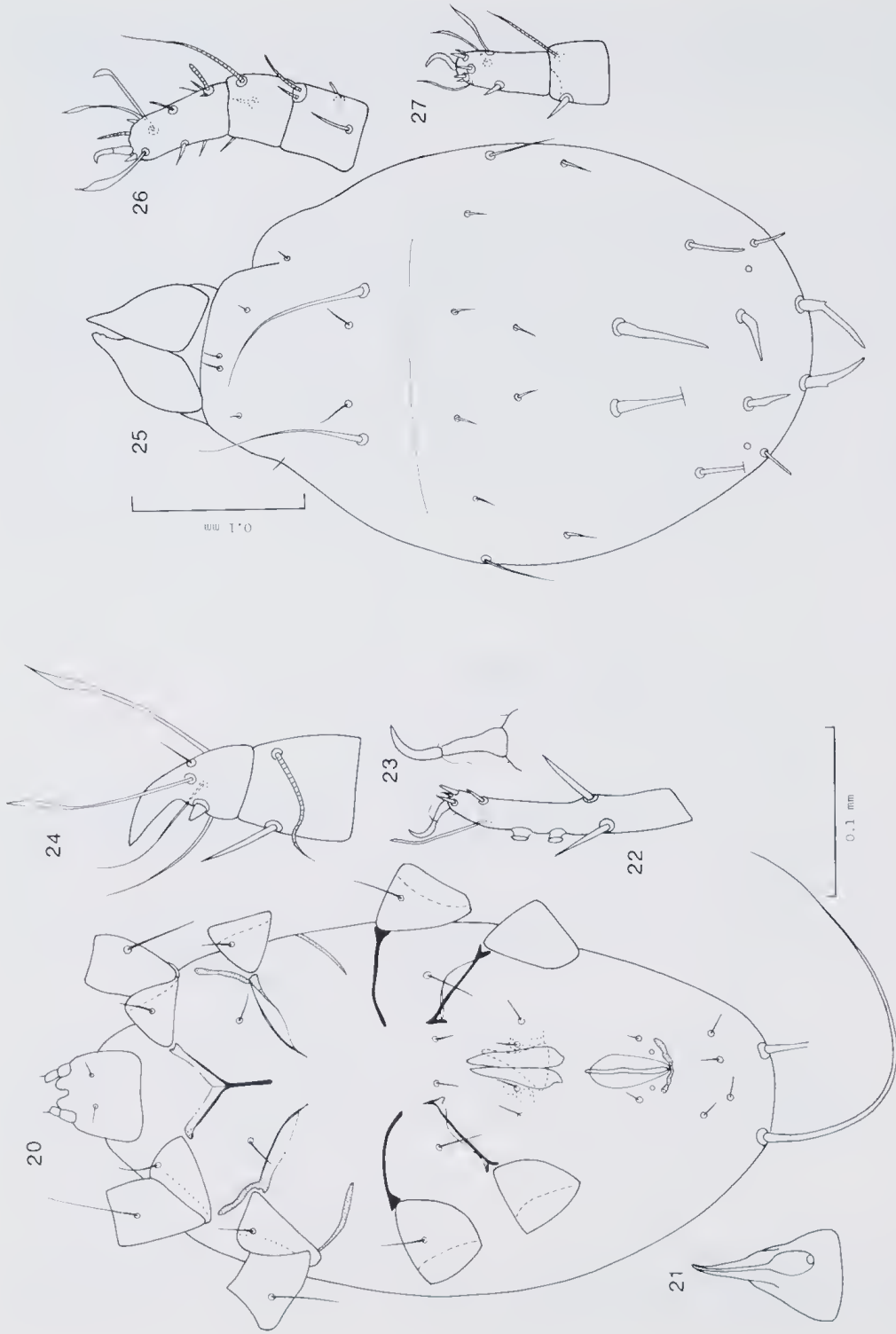
Male (heteromorphic) (Figure 24)

Idiosoma length 435, width 225; tarsus III bearing one blunt preapical spine, three long pedunculate foliate setae, one long thin ventral seta, and one short thin dorsal seta.

Tritonymph (Figures 25-27)

Our one free tritonymph has an idiosoma 370 long and 265 wide; dorsal chaetotaxy as in adult; *l5* strong spines, 30 long; legs short with tarsi I-IV 45-45-36-45 long.

Figures 18, 19 *Ctenocolletacarus brevirostris.* Newly emerged female, ventral and dorsal views, respectively.

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Figures 20-24 *Ctenocolletacarus brevirostris.* (20-23) Homomorphic male: (20) ventral view; (21) penis; (22) tarsus IV; (23) claw of tarsus IV. (24) Tibia and tarsus III of heteromorphic male.

Figures 25-27 *Ctenocolletacarus brevirostris* tritonymph: (25) body, dorsal view; (26) leg I; (27) leg III.

0.1 mm

Remarks

Females of *brevirostris* differ from those of *longirostris* as follows: legs shorter (cf. tarsal lengths); some setae shorter (e.g. *vi* and *sc i*) but *l5* longer; solenidion *w2* more apical than *w1* (more basal in *longirostris*); solenidia of tibiae relatively longer.

Material examined

In alcohol unless indicated otherwise. All from Western Australia.

Associated with *Ctenocolletes albomarginatus*, from East Yuna Nature Reserve, 34 km WNW of Mullewa. *Ex* brood cells (excavated on 13-16 September 1984 by T.F. Houston): WAM 85/438, hypopus containing completely developed tritonymph moulting to male (slide). Reared from hypopi *ex* tergal pouches of female bee (WAM 85/413) (collected 13-16 September 1984 by T.F. Houston): WAM 85/439, 2♀, 2♂ (homomorphic and heteromorphic), one free tritonymph, hypopi in moulting stage (9 slides).

Associated with *Ctenocolletes nigricans* Houston, from East Yuna Nature Reserve, 34 km WNW of Mullewa, 23-24 September 1983, collected by C.A. and T.F. Houston. *Ex* tergal pouches of four female bees (WAM 83/552, 83/561-563): WAM 85/418-421, *c.* 250 hypopi (*c.* 50 on 11 slides).

Acknowledgements

References

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Houston, T.F. (1984). Biological observations of bees in the genus *Ctenocolletes* (Hymenoptera: Stenotritidae). *Rec. West. Aust. Mus.* 11 (2): 153-172.

The eleotrid fishes of Lake Kutubu, Papua New Guinea
with descriptions of four new species

Gerald R. Allen* and Douglass F. Hoese†

Abstract

The eleotrid fishes of Lake Kutubu in the Southern Highlands district of Papua New Guinea are reviewed. Six species, including *Mogurnda variegata* Nichols, *Oxyeleotris fimbriata* (Weber), and four new species of *Mogurnda* described herein, were collected by the senior author during a visit to the lake in 1983. *Mogurnda kutubuensis* sp. nov. is related to a close knit complex of species restricted to New Guinea and northern Australia. It differs from the members of this group by a combination of features which include coloration and counts for fin rays and scales. The three remaining new species, *M. furva*, *M. spilota*, and *M. vitta* are allied to *M. variegata*. They differ from each other primarily with regards to their distinctive colour patterns and from other species of *Mogurnda* by having a more elongate snout which except for *M. vitta* has a distinctive concave profile. All species except *Oxyeleotris fimbriata* are apparently endemic to Lake Kutubu. Diagnoses, descriptions and illustrations are provided for both new taxa and previously described species.

Introduction

The family Eleotridae, commonly known as gudgeons or sleepers is represented by about 120 species belonging to approximately 30 genera. They typically dwell in brackish or freshwater environments, primarily in tropical and subtropical regions. Most marine species, formerly assigned to this family are now included in Gobiidae. The largest number of species inhabit the Indo-Pacific region. Because of extensive speciation in fresh waters of Australia and New Guinea, about 70 species or nearly 60 per cent of all eleotrids are found there.

The present paper is the second in a series dealing with the exclusively freshwater eleotrids of Australia-New Guinea. The genus *Hypseleotris* Gill of Western Australia was treated in the first paper (Hoese and Allen 1983). We now deal with the eleotrid fauna of Lake Kutubu situated in the Southern Highlands district of Papua New Guinea (Figure 1). Nichols (1951) described an eleotrid, *Mogurnda variegata*, which was collected at this locality (although mis-spelt Lake Katuba

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by Nichols) in 1936 by the Archibold Expedition from the American Museum of Natural History. Munro (1964) reported 15 additional specimens procured at the lake by a government patrol officer in 1955. He remarked on the unusual variability in colour pattern and body shape exhibited by this series and provided drawings of five specimens. He also mentioned that the native population at Lake Kutubu had at least eight names for the various colour phases.

The senior author had an opportunity to visit Lake Kutubu during September 1983. Two rotenone collections and seining activities yielded a number of diverse eleotrids, which largely agreed with the varieties of *M. variegata* illustrated by Munro. Subsequent examination of this material revealed that five species were represented including *M. variegata* and four new taxa which are described herein. In addition, a sixth eleotrid, *Oxyeleotris fimbriata* was collected at the lake and is reported on here.

Lake Kutubu (Figure 1), one of the largest lakes in New Guinea, is situated approximately 370 kilometres north-west of Port Moresby or 40 kilometres south-west of Mendi, the nearest large population centre. It is about 19 kilometres in length and 2-3 kilometres in width, being situated in a limestone basin surrounded by high mountains. According to Bayly *et al.* (1970) the lake was formed by volcanic damming of the basin during the Pleistocene between 10,000-500,000 years ago. The maximum and mean depths are about 70 and 36 metres respectively. Mean annual rainfall at Lake Kutubu is 450 cm. The lake is drained by the Soro River which joins the Hegigio River, a tributary of the Kikori River system, which ultimately flows into the Gulf of Papua. The lake lies at an elevation of 800 metres above sea level and can be reached only on foot or by chartered aircraft. There are about 15 small villages in the area and all inhabitants speak the Foe (pronounced 'foy') language.

The fish fauna of Lake Kutubu as presently known consists of 12 species including the six eleotrids, a plotosid *(Oloplotosus torobo* Allen), an atherinid *(Craterocephalus lacustris* Trewavas), a melanotaeniid *(Melanotaenia lacustris* Munro), a teraponid *(Hephaestus adamsoni* Trewavas), and a gobiid *(Glossogobius* sp.). All except *Oxyeleotris fimbriata* and the introduced mosquitofish, *Gambusia affinis*, appear to be endemic.

The data for our collections from Lake Kutubu are as follows: Station 1 — Soro River, about 30 metres in width, near north-west end of lake, at end of walking track from Moro landing strip (approximately 6°23'S, 143°14'E), rotenone and seine, G. Allen, J. Paska, and B. Crockford, 26 September 1983; depth 0-3 m, water clear, soft mud bottom with abundant vegetation, water temperature 26.0°C, pH 8.3. Station 2 — west shore of lake opposite Wesame Island at mouth of small tributary stream (approximately 6°24'S, 143°18'E), rotenone and seine, G. Allen, J. Paska, and B. Crockford, 27 September 1983; depth 0-2 m, water clear, soft mud bottom with abundant vegetation, water temperature 23.8°C, pH 7.8.

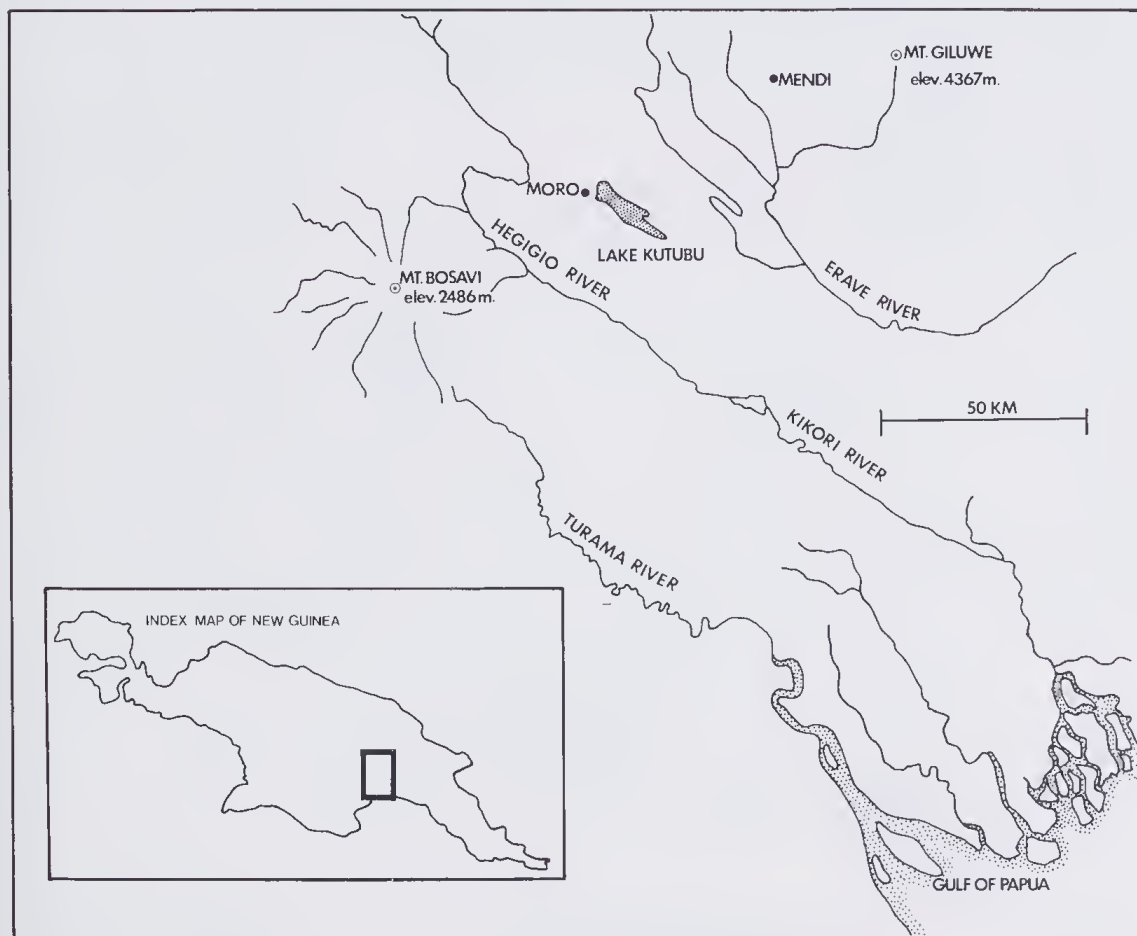All CSIRO specimens included in this paper were collected at Lake Kutubu by C.E.T. Terrell in March 1955.

Figure 1   Map of Lake Kutubu region of southern Papua New Guinea.

Methods

Methods for counts and measurements mainly follow those of Hubbs and Lagler (1958). The longitudinal scale count or scales in lateral series was taken from the upper pectoral base obliquely to the midline and then horizontally to the end of the hypural. The transverse scale row count was taken from the origin of the second dorsal fin downward and backward to the anal base. The post-dorsal count is taken from the end of the second dorsal fin to the caudal base mid-dorsally. Gill raker counts include all rudiments. The last ray of the anal and second dorsal fins is split at the base and is counted as a single element.

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Sex was determined by examination of the genital papilla (Figure 2). Colour when fresh was taken from Ektachrome transparencies of dead specimens photographed within 15-30 minutes of capture. The abbreviation SL refers to standard length. Counts and measurements that appear in parentheses refer to the range for paratypes if differing from the holotype. Institutional abbreviations are as follows: AMNH — American Museum of Natural History, New York; AMS — Australian Museum, Sydney; CSIRO — Commonwealth Scientific and Industrial Research Organisation, Division of Fisheries and Oceanography, Hobart, Australia; PNG — Kanudi Fisheries Research Laboratory, Port Moresby, New Guinea; WAM — Western Australian Museum, Perth.
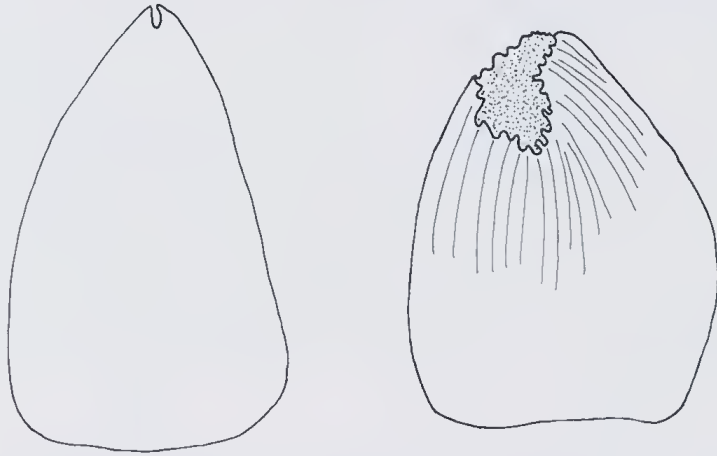

Figure 2   Camera lucida drawing of genital papilla of *Mogurnda kutubuensis:* (A) male, and (B) female. Height of papillae about 3.0 mm.

Systematics

Key to the eleotrid fishes of Lake Kutubu

1a Scales in lateral series 55-60; predorsal scales 28-40; soft anal rays 8-10; colour dark brown, often with series of darker chevron-shaped markings along side and black spot at base of upper caudal fin rays . . . . *Oxyeleotris fimbriata*

1b Scales in lateral series 36-43; predorsal scales 11-27; soft anal rays 10-13; colour not as in 1a 2

2a Snout relatively short and blunt (Figure 7), its length 7.8-9.8 in head length, but usually less than 9.2 . . . *Mogurnda kutubuensis* sp. nov.

2b Snout relatively elongate and pointed (Figures 4, 9, 11 and 13). Its length 9.1-11.3 in head length 3

3a Pectoral rays 14; scales in lateral series 42-43; a broad,
white stripe (series of white blotches in young) along
middle of side . . . . *Mogurnda vitta* sp. nov.

3b Pectoral rays 15-16; scales in lateral series 36-40; white
stripe along middle of side absent 4

4a Colour of body and fins black without distinguishing
marks . . . . *Mogurnda furva* sp. nov.

4b Colour of body and fins not uniformly black, consisting
of well contrasted light and dark blotches 5

5a Transverse scale rows 12-13; head dark with white
bands radiating from rear portion of eye; body greenish-
brown with large white blotches on side . . . . *Mogurnda spilota* sp. nov.

5b Transverse scale rows 14-15; head tan or light brown with
darker bands radiating from rear portion of eye and dark
mottling on dorsal surface; body mottled with large dark
brown spots . . . . *Mogurnda variegata*

Mogurnda furva sp. nov.

Figures 3 and 4

Holotype
  WAM P28158-009, female, 65.2 mm SL, Lake Kutubu, Papua New Guinea — Station 1.

Paratypes
  WAM P28158-011, 2 specimens, 19.0-31.0 mm SL, collected with holotype.

Diagnosis
A species of *Mogurnda* Gill differing from most members of the genus by an elongate, pointed snout and a blackish colour. It is most closely allied to *M. spilota*, *M. variegata*, and *M. vitta*, all of Lake Kutubu, which have a similar snout shape, but differs from them in lacking distinguishing marks (blotches, spots, or stripes), on the head, body, and fins. It further differs from *M. vitta* in being deeper bodies (depth at pelvic fin origin 23-24 per cent of SL v. 19.3-21.3 per cent), in having 15 or 16 rather than 14 pectoral rays, 39 scales in mid-lateral series compared with 42-43, and having a concave rather than straight snout profile. It also has a lower transverse scale count than *M. variegata* (12 or 13 v. 14 or 15).

Description

Dorsal rays IX-I, 11 (VIII or IX-I, 11 or 12); anal rays I, 13 (I, 10 to 12); pectoral rays 15 (15 or 16); segmented caudal rays 15 (14 or 15); branched caudal rays 13 (9 and 13); scales in lateral series 39; transverse scale rows 13 (12 or 13); predorsal scales 20; postdorsal scales 11 or 12; gill rakers on first arch $3 + 9 = 12$ ($2 + 8 = 10$); vertebrae 33.

Body elongate, laterally compressed, more strongly posteriorly; body depth at pelvic fin origin 23.2 per cent of SL; body depth at anal fin origin 21.2 per cent of SL. Head somewhat pointed with elongate, concave snout; nape strongly arched. Head length 35.5, snout length 9.5, eye width 7.1, interorbital width 7.4, all as percentage of SL. Mouth forming an angle of about 40 degrees with longitudinal axis of body; jaw extending to level about midway between front of eye and anterior edge of pupil; teeth of jaws numerous in dense bands, teeth of outer row enlarged; palate edentulous; tongue, palate, and floor of mouth with numerous small melanophores. Gill opening extends well forward of posterior
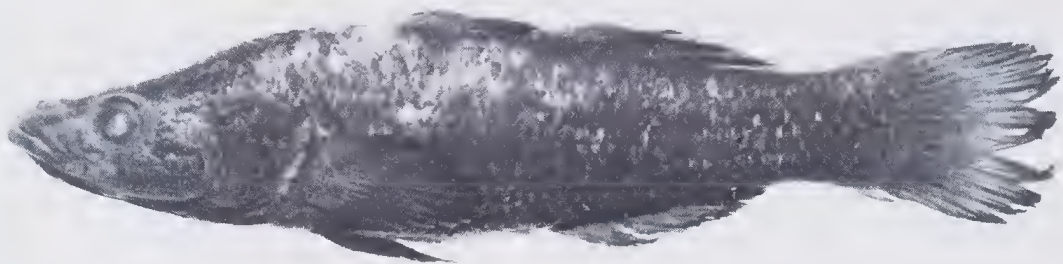

Figure 3   *Mogurnda furva*, holotype, 65.2 mm SL, Lake Kutubu.

Figure 4   Camera lucida drawing of head of *Mogurnda furva*, holotype, showing tracks of sensory papillae (stippled).

margin of preopercle. Head with numerous sensory papillae arranged in tracks as illustrated in Figure 4.

Scales of head, predorsal region, and bases of caudal and pectoral fins cycloid, remainder of body scales finely ctenoid (Figure 5). Head entirely scaled except lips, snout tip, preorbital region, lower jaw and chin; preopercle scales smaller than body scales and tend to be embedded.
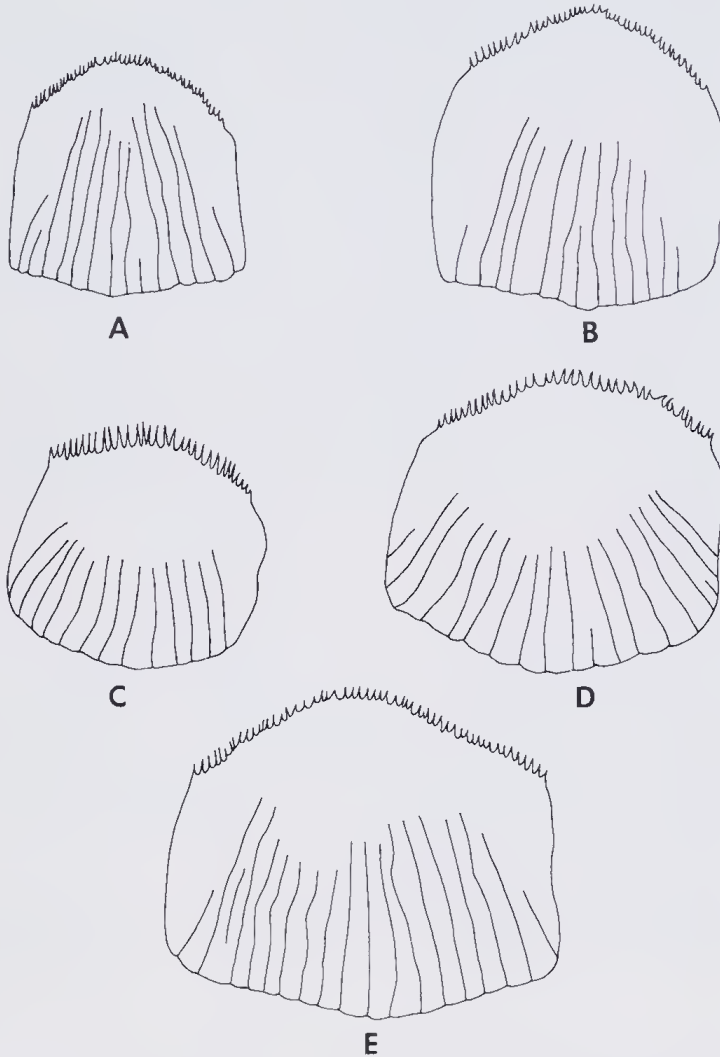

Figure 5   Camera lucida drawing of scales of *Mogurnda* from Lake Kutubu. All scales were taken from the same position (seventh scale of mid-lateral scale row) and are shown at the same magnification: (A) *M. furva,* 65.2 mm SL, (B) *M. kutubuensis,* 71.0 mm SL, (C) *M. variegata,* 68.0 mm SL, (D) *M. vitta,* 104.0 mm SL, and (E) *M. spilota,* 89.6 mm SL.

Second dorsal fin taller than first dorsal fin; fifth or sixth spine of first dorsal fin tallest; pectoral fins 21.5 per cent of SL; pelvic fins 19.9 per cent of SL; pectoral fins more or less rounded; pelvic fins pointed, the depressed tips nearly reaching anus. Caudal peduncle relatively elongate, its length 23.6 per cent of SL, and depth 12.6 per cent of SL; caudal fin rounded, its length 21.5 per cent of SL.

Colour when fresh: overall black, including fins except narrow white margin on dorsal and pelvic fins.

Colour in alcohol: overall dark brown, nearly black except anus and genital papilla white; fins blackish. Juvenile paratypes much lighter than holotype; whitish with dense covering of melanophores (except where scales are missing) giving overall dusky effect; fins blackish.

Remarks

A male specimen (CSIRO C2246, 114.1 mm SL) illustrated by Munro (1964: Figure 21-C) as *M. variegata* and examined by us, probably represents an adult of *M. furva*. We base this opinion on meristic characters and the following colour pattern features which it shares with *M. furva*, and which are lacking in other *Mogurnda* from Lake Kutubu: (1) although the specimen is overall light brown becoming darker dorsally, close inspection under magnification reveals a dense covering of pepper-like melanophores without any whitish or non-pigmented areas, even on the ventral surface; (2) absence of spoke-like bands radiating from rear or bottom edge of eye; (3) absence of banding or spotting on the dorsal and caudal fins. In addition, all median fins and the pelvics are dusky, although not as dark as in the types of *M. furva*. The following counts and measurements were recorded for this specimen: dorsal rays VIII-I, 11; anal rays I, 11; pectoral rays 15; segmented and branched caudal rays 15; scales in lateral series 39; transverse scale rows 13; predorsal scales 26; gill rakers on first arch 3 + 8 = 11. The following proportions are percentage of the standard length: body depth at pelvic fin origin 23.7; body depth at anal fin origin 23.5; head length 34.3; snout length 10.5; eye width 5.7; interorbital width 8.8, pectoral fin length 18.4; pelvic fin length 20.0; caudal peduncle length 21.7; caudal peduncle width 14.1; caudal fin length 19.5 (damaged).

The local inhabitants call this fish 'sabkisiwabo'. We name the species *furva* (Latin: dark, swarthy, or black) with reference to the characteristic coloration.

Mogurnda kutubuensis sp. nov.

Figures 6 and 7

Holotype
WAM P28159-011, female, 87.0 mm SL, Lake Kutubu, Papua New Guinea — Station 2.

Paratypes

AMS I25781-001, 12 specimens, 19.0-82.0 mm SL, collected with holotype; PNG un-registered, 9 specimens, 21.0-57.0 mm SL, collected with holotype; WAM P28158-008, 30 specimens, 21.4-67.8 mm SL, Lake Kutubu — Station 1; WAM P28159-008, 112 specimens, 16.0-77.0 mm SL, collected with holotype.

Diagnosis

A species of *Mogurnda* with a short, rounded snout, allied to *M. mogurnda* (Richardson) from Australia and several undescribed species from New Guinea. It differs from them in colour pattern (strongly mottled or overall dark instead of having series of large blotches midlaterally or vertical banding) and the following combination of characters: dorsal rays VII or VIII-I, 10 to 12; anal rays I, 11 to 13; scales in lateral series 36 to 38; transverse scale rows 13; predorsal scales 18 to 20; vertebrae 33; gill opening ends below posterior margin of preopercle; small scales present between supraorbital papillae and eye.

Description

Dorsal rays VIII-I, 11 (VII or VIII-I, 10 to 12); anal rays I, 11 (I, 11 to 13); pectoral rays 15 (15 or 16); segmented caudal rays 15; branched caudal rays 15 (14 or 15); scales in lateral series 38 (36 to 38); transverse scale rows 13; predorsal scales 20 (18 to 20); postdorsal scales 12 (11 or 12); gill rakers on first arch 2 + 10 = 12 (2 + 8 to 10 = 10 to 12); vertebrae 33.

Body elongate, laterally compressed, more strongly posteriorly; body depth at pelvic fin origin 28.2 per cent (27.0-29.9) of SL; body depth at anal fin origin 23.0 per cent (24.0-25.7) of SL. Head rounded with relatively short snout, its profile straight or slightly concave; nape strongly arched. Head length 35.6 (32.2-36.0), snout length 9.1 (7.8-9.8), eye width 8.2 (7.1-8.3), interorbital width 12.6 (9.7-12.6), all as percentage of SL. Mouth forming an angle of about 52 degrees with longitudinal axis of body; jaw extending to level of anterior edge of pupil; teeth of jaws numerous in dense bands, teeth of outer row enlarged; palate edentulous; tongue, palate, and floor of mouth pale with numerous melanophores. Gill opening extends to below posterior margin of preopercle. Head with numerous sensory papillae arranged in tracks as illustrated in Figure 7.

Scales of head, predorsal region, and bases of caudal and pectoral fins cycloid, remainder of body scales ctenoid (Figure 5). Head entirely scaled except lips, snout tip, preorbital region, lower jaw and chin; preopercle scales smaller than body scales and tend to be embedded.

Second dorsal fin significantly taller than first dorsal fin; sixth or seventh spine of first dorsal fin tallest; pectoral fins 22.2 per cent (21.4-23.1) of SL, shorter than pelvic fins 18.4 per cent (18.8-24.3) of SL; pectoral fins rounded, pelvic fins pointed, the depressed pelvic fin tips falling well short of genital papilla. Caudal peduncle relatively elongate, its length 23.8 per cent (21.9-25.6) of SL, and depth 12.6 per cent (13.4-14.6) of SL; caudal fin rounded, its length 24.5 per cent (22.8-25.0) of SL.

Figure 6   *Mogurnda kutubuensis*, holotype (upper), 87.0 mm SL, and paratype, 55.2 mm SL, Lake Kutubu.
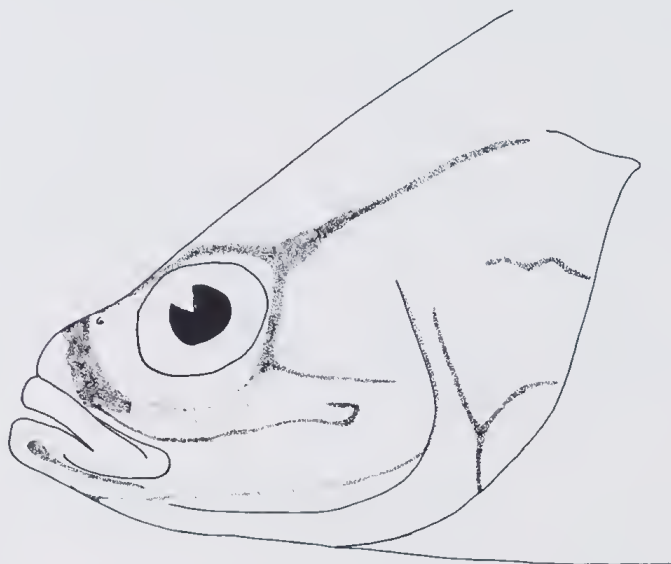

Figure 7   Camera lucida drawing of head of *Mogurnda kutubuensis*, 73.0 mm SL, showing tracks of sensory papillae (stippled).

Colour when fresh: dark reddish-brown on upper part of body and top of head; sides with large irregular red-brown blotches with intervening areas light blue-green; underside of head, breast, and belly region yellowish or tan; head with three relatively broad stripes radiating from eye, first from lower edge of eye to lower edge of opercle, second from lower posterior corner of eye to middle of opercular margin, third (sometimes obscure) from upper posterior corner of eye to upper opercular margin and continued on to upper half of pectoral fin base; areas between light blue-green; fins dusky red-brown, dorsal, caudal, and anal fins with small brown to reddish spots.

Colour in alcohol: large specimens (in excess of about 75 mm SL) mainly dark brown with faint indication of dark spotting on side as described above; head with three dark brown stripes radiating from eye to edge of operculum as described above; fins dark brown to blackish with faint spots on dorsal and caudal fins. Juveniles under about 40 mm SL, have a series of approximately 10 to 12 brown eye-sized blotches along the middle of the sides on a tan ground colour, grading to dark brown dorsally. Intermediate specimens (40-75 mm SL) have the sides covered with numerous interconnected, irregular, brown blotches on a tan ground. The two dorsal fins, caudal and anal fins are frequently covered with numerous small dark brown spots. These individuals also show a pair of short stripes from the front edge of the eye to the upper lip.

Remarks

M. kutubuensis belongs to a group of closely related species which we refer to as the *Mogurnda mogurnda* complex, based on their similarity to this widespread Australian species. The group contains several new taxa from New Guinea which will be treated in a forthcoming review of *Mogurnda* by the present authors. The species are distinguished mainly by fin ray and scale counts in combination with colour pattern features. *Mogurnda kutubuensis* has a colour pattern unlike that of any other member of the complex, consisting of numerous, interconnected, irregular-shaped blotches, rather than having a series of relatively few large blotches along the side or alternating light and dark bars. It further differs from an undescribed species from the Fly and Digul rivers in having fewer lateral scale rows ((36-38 v. 45-52) and fewer soft dorsal and anal rays (usually 11 or 12 v. 14 or 15). Another undescribed species from the Port Moresby area has a slightly lower lateral scale row count (34-36) and has a series of squarish blotches or bars along the side.

M. kutubuensis and *Oxyeleotris fimbriata* were the most abundant eleotrids in our collections from Lake Kutubu. Both species were common along the vegetated shallow margin of the lake and immediate tributaries.

There are no obvious sex differences related to fin shape or colour pattern in *M. kutubuensis,* although sex is easily determined by examining the genital papilla (Figure 2). This feature is useful for specimens as small as 38-40 mm SL.

Munro (1964: Figure 21-E) illustrated a large (102 mm SL) male with an overall dark brown colour as a variety of *Mogurnda variegata*. Examination of this fish (CSIRO C2251) reveals it is *M. kutubuensis*. It has the characteristic short, rounded snout (see Figure 7) and in this respect Munro's illustration is inaccurate. The dark coloration is typical of several large adults in the type series.

We name the species *kutubuensis* with reference to the type locality. The local name for this fish is 'anaku'.

Mogurnda spilota sp. nov.

Figures 8 and 9

Holotype

WAM P28159-010, male, 89.6 mm SL, Lake Kutubu, Papua New Guinea — Station 2.

Paratypes

CSIRO C2249, female, 92.8 mm SL; CSIRO C3175, female, 125.5 mm SL; CSIRO C3176, female, 125.5 mm SL, CSIRO C3189, male, 91.0 mm SL; CSIRO C3190, female, 91.4 mm SL; WAM P28158-010, female, 55.5 mm SL; Lake Kutubu, Papua New Guinea — Station 1.

Diagnosis

A species of *Mogurnda* differing from most members of the genus by an elongate, pointed snout and colour pattern consisting of large white blotches on a greenish-brown ground and with white spoke-like bands radiating from rear portion of eye. It is most closely allied to *M. furva, M. variegata,* and *M. vitta,* all of Lake Kutubu, which have a similar snout shape, but differs from them in colour. It further differs from *M. vitta* in being deeper bodied (depth at pelvic origin 21.4-27.0 per cent [average 24.5] of SL v. 19.3-21.3 per cent [average 20.3]) in having 15 rather than 14 pectoral rays, 37-40 scales in mid-lateral series compared with 42-43, and having a concave rather than straight snout profile. It also differs from *M. variegata* in having a lower transverse scale row count (12-13 v. 14-15).

Description

Dorsal rays VIII-I, 11 (VII or VIII-10 to 12); anal rays I, 12 (12-13); pectoral rays 15; segmented caudal rays 15; branched caudal rays 14 (14 or 15); scales in lateral series 37 (37-40); transverse scale rows 13 (12 or 13); predorsal scales 18 (20-23); postdorsal scales 12 (11 or 12); gill rakers on first arch 2 + 9 = 11 (2 or 3 + 8 or 9 = 11); vertebrae 33.

Body elongate, laterally compressed, more strongly posteriorly; body depth at pelvic fin origin 25.9 per cent (21.4-27.0) of SL; body depth at anal fin origin 22.3 per cent (20.2-23.0) of SL. Head somewhat pointed with elongate, concave snout; nape strongly arched. Head length 36.3 (35.7-37.0), snout length 10.6 (9.6-11.3), eye width 7.4 (5.7-6.8), interorbital width 10.2 (8.7-11.1), all as

percentage of SL. Mouth forming an angle of about 38 degrees with longitudinal axis of body; jaw extending to level of anterior edge of pupil; teeth of jaws numerous in dense bands, teeth of outer row enlarged; palate edentulous; tongue, palate, and floor of mouth with numerous melanophores. Gill opening extends well forward of posterior margin of preopercle. Head with numerous sensory papillae arranged in tracks as illustrated in Figure 9.

Scales of head, predorsal region, and bases of caudal and pectoral fins cycloid, remainder of body scales ctenoid (Figure 5). Head entirely scaled except lips, snout tip, preorbital region, lower jaw and chin; preopercle scales smaller than body scales and tend to be embedded.

Second dorsal fin significantly taller than first dorsal fin; sixth spine of first dorsal fin tallest; pectoral fins 20.6 per cent (18.7-23.0) of SL; pelvic fins 23.4 per cent (15.0-22.0, most damaged) of SL; pectoral fins rounded; pelvic fins pointed, the depressed pelvic fin tips reaching beyond base of genital papilla.
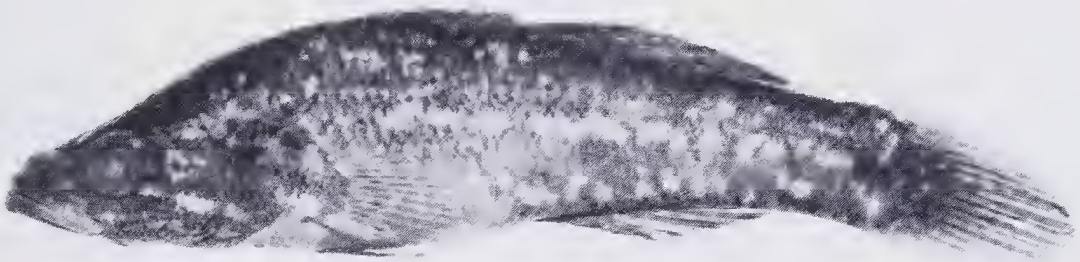

Figure 8   *Mogurnda spilota*, holotype, 89.6 mm SL, Lake Kutubu.
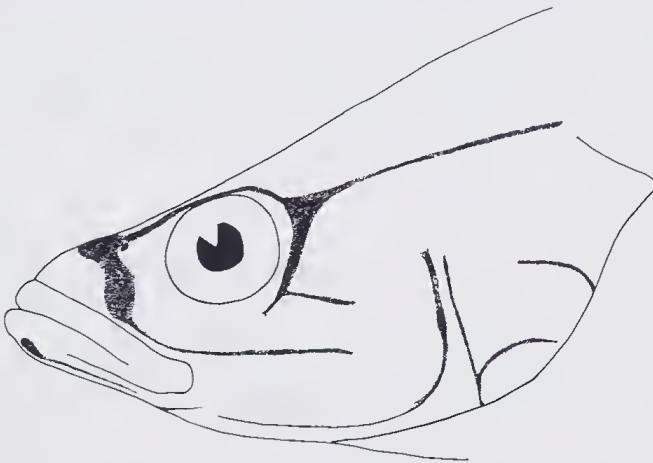

Figure 9   Camera lucida drawing of head of *Mogurnda spilota*, holotype, showing tracks of sensory papillae (stippled).

Caudal peduncle relatively elongate, its length 22.3 per cent (23.1-26.1) of SL, and depth 13.4 per cent (11.8-13.1) of SL; caudal fin rounded, its length 25.4 per cent (18.7-25.2, most damaged) of SL.

Colour when fresh: overall dark greenish-brown grading to whitish on underside of head, breast, and belly; lower side of head and pectoral region golden brown; lips and chin dusky brown; series of about 10 irregular-shaped white blotches (about eye size) along middle of side from upper corner of operculum to base of caudal fin; second series of similar, although less well defined blotches from lower pectoral fin base to lower caudal base; 2-3 similar, but fainter blotches on side of nape; upper surface of head and nape with dense whitish mottling; head with three broken white stripes, first from below eye to lower preopercular margin, second from lower posterior corner of eye to lower opercular margin, third across middle of operculum and continued on base of pectoral fin; dorsal fins and anal fin whitish with several dark brown stripes; caudal fin dark brown on basal half with irregular white bars, faintly spotted with brown distally; pelvic fins slightly dusky brown; pectoral fins translucent with brown rays and light brown spotting.

Colour in alcohol: similar to above coloration except golden-brown not apparent on lower sides. After 30 years in preservative the CSIRO paratypes are overall light brown with some darker brown mottling, grading to dusky whitish or tan ventrally, with faint indications of white blotches described above. The dorsal, caudal, anal, and pectoral fins on most of these individuals are spotted.

Remarks

This species was illustrated by Munro (1964: Figure 21-B). He gave the native name of 'feferigugisabo'. There does not appear to be any sexual dimorphism other than the difference in genital papilla structure (Figure 2).

We name this species *spilota* Greek: stained or spotted with reference to the colour pattern.

Mogurnda variegata Nichols

Figures 10 and 11

Mogurnda variegata Nichols, 1951: 1, Figure 1 (Lake Katuba [Kutubu], Papua New Guinea).

Diagnosis

A species of *Mogurnda* differing from most members of the genus by an elongate, pointed snout, and colour pattern consisting of a maze of large dark brown blotches on a tan or yellowish ground, with dark brown spoke-like bands radiating from lower and posterior edge of eye. It is most closely allied to *M. furva, M. spilota,* and *M. vitta,* all of Lake Kutubu, which have a similar snout shape, but differs from them in colour. It further differs from these species in having 14 or

15 transverse scale rows, and from *M. vitta* in being deeper bodied (depth at pelvic origin 22.0-26.2 per cent [average 24.4] of SL v. 19.3-21.3 per cent [average 20.3]), having 15 rather than 14 pectoral rays, 36-40 scales in mid-lateral series compared with 42-43, and having a concave rather than straight snout profile.

Description

Dorsal rays VII or VIII-I, 10 to 12; anal rays I, 11 to 13; pectoral rays 15; segmented caudal rays 15; branched caudal rays 13 to 15; scales in lateral series 36 to 40; transverse scale rows 14 or 15; predorsal scales 19 to 24; postdorsal scales 11 or 12; gill rakers on first arch 2 to 4 + 8 or 9 = 10 to 13; vertebrae 33 (rarely 32).

Body elongate, laterally compressed, more strongly posteriorly; body depth at pelvic fin origin 22.0-26.2 per cent of SL; body depth at anal fin origin 20.2-24.4 per cent of SL. Head somewhat pointed with elongate, concave snout; nape strongly arched. Head length 35.2-41.4, snout length 9.1-11.1, eye width 5.2-7.9, interorbital width 7.7-9.6, all as percentage of SL. Mouth forming an angle of about 40 degrees with longitudinal axis of body; jaw extending to level about midway between front of eye and anterior edge of pupil; teeth of jaws numerous in dense bands, teeth of outer row enlarged; palate edentulous; tongue, palate, and floor of mouth pale with few melanophores. Gill opening extends well forward of posterior margin of preopercle. Head with numerous sensory papillae arranged in tracks as illustrated in Figure 11.

Scales of head, predorsal region, and bases of caudal and pectoral fins cycloid, remainder of body scales ctenoid (Figure 5). Head entirely scaled except lips, snout tip, preorbital region, lower jaw and chin; preopercle scales smaller than body scales and tend to be embedded.

Second dorsal fin significantly taller than first dorsal fin; fifth or sixth spine of first dorsal fin tallest; pectoral fins 17.5-25.4 per cent of SL (some damaged); pelvic fins 18.0-24.0 per cent of SL; (some damaged); pectoral and pelvic fins pointed, the depressed pelvic fin tips reaching beyond base of genital papilla. Caudal peduncle relatively elongate, its length 21.5-26.2 per cent of SL, and depth 12.1-13.9 per cent of SL; caudal fin rounded, its length 23.2-25.4 per cent of SL.

Colour when fresh: overall pale yellowish-tan with large mottled, dark brown spots covering upper two-thirds of body; head with two dark brown bands radiating from back of eye, across preopercle; upper surface of head and nape strongly mottled; both dorsal fins and caudal fin pale yellow with dark brown spots; remaining fins pale yellow, but anal fin with narrow brown stripe at base and dark brown or blackish margin, more pronounced posteriorly.

Colour in alcohol: overall tan with brown mottling on body and spots on fins as described above. After 30 years in preservative the CSIRO paratypes are generally lighter and more yellowish ventrally. The dark mottling on most of the specimens is not as well defined as on the fresher material, but the characteristic

maze-like mottling on the top of the head is clearly evident particularly on the larger (110-126 mm SL) specimens.
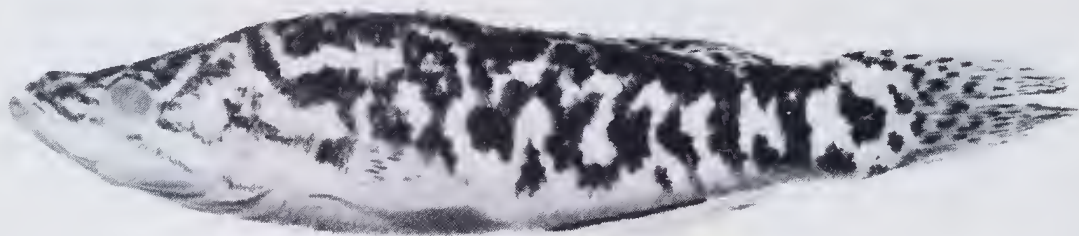
Figure 10   *Mogurnda variegata*, 70.5 mm SL, Lake Kutubu.
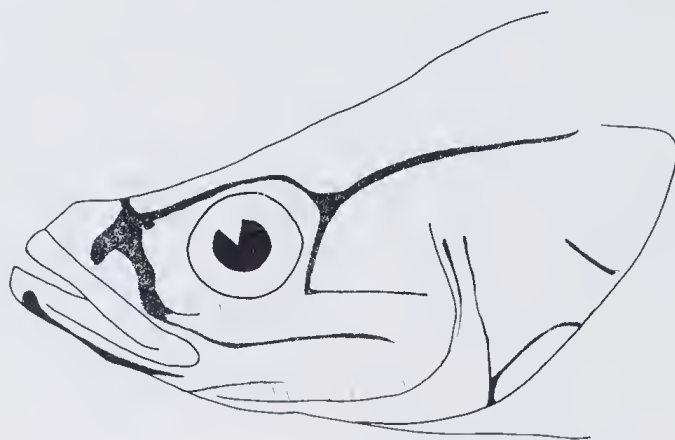
Figure 11   Camera lucida drawing of head of *Mogurnda variegata*, 70.5 mm SL, showing tracks of sensory papillae (stippled).

Remarks

This species was illustrated by Munro (1964, Figure 21-A), although our 1983 material lacks the spots which were shown on the anal fin. According to Munro the native name for the spotted anal variety is 'ikiguabi' and the pale finned variety is known as 'seragate', the latter name was also used by the hired canoeists for the specimens we collected.

Except for the structure of the genital papilla (Figure 2) there is a lack of pronounced sexual dimorphism. The CSIRO and WAM material consists of six males, 67.0-125.8 mm SL, and eight females, 50.5-110.0 mm SL.

Material examined

AMNH 18576, holotype, 75.0 mm SL, Lake Kutubu; AMNH 15101, paratypes, 10 specimens, 45.0-81.0 mm SL, Lake Kutubu; CSIRO A2134-35, 2 specimens, 72.4-76.1 mm SL;

CSIRO C2248, 125.8 mm SL, CSIRO C2250, 110.0, mm SL; CSIRO C3184-85, 2 specimens, 93.2-110.0 mm SL; WAM P28158-007, 7 specimens, 50.5-73.6 mm SL, Lake Kutubu, Papua New Guinea — Station 1; WAM P28159-007, 55 mm SL, Lake Kutubu — Station 2.

Mogurnda vitta sp. nov.

Figures 12 and 13

Holotype

WAM P28159-012, male, 104.0 mm SL, Lake Kutubu, Papua New Guinea — Station 2.

Paratypes

CSIRO IA8086, female, 120.7 mm SL; CSIRO C2247, female, 88.2 mm SL; CSIRO C3188, male, 95.5 mm SL; WAM P28159-013, 55.0 mm SL, collected with holotype.

Diagnosis

A species of *Mogurnda* differing from most members of the genus by an elongate, more or less rounded snout (Figure 13), and pattern consisting of a brownish colour on the upper two-thirds of the body and a broad white mid-lateral stripe (series of white blotches in young specimens), with brown spoke-like bands radiating from lower and posterior edge of eye. It is most closely allied to *M. furva, M. spilota,* and *M. variegata,* all of Lake Kutubu, which have a similar, although more pointed, snout shape, but differs from them in colour. It is further distinguished from these species in having a more slender body (depth at pelvic origin 19.3-21.3 per cent [average 20.3] of SL v. 21.4-27.0 per cent [average 23.0-24.5], having 14 rather than 15 pectoral rays, 42-43 scales in mid-lateral series compared with 36-40, and having a straight rather than concave snout profile.

Description

Dorsal rays VIII (VII)-1, 11; anal rays 1, 11 (10-13); pectoral rays 14; seg-mented caudal rays 15 (14 to 16); branched caudal rays 15 (13 to 15); scales in lateral series 43 (42); transverse scale rows 13 (12 to 13); predorsal scales 23 (21 to 27); postdorsal scales 13 (12 to 14); gill rakers on first arch 2 + 9 = 11; vertebrate 33 (33 or 34).

Body elongate, laterally compressed, more strongly posteriorly; body depth at pelvic fin origin 20.0 per cent (19.3-21.3) of SL; body depth at anal fin origin 18.4 per cent (18.3-20.0) of SL. Head rounded with elongate snout, its profile straight; nape gently arched. Head length 33.1 (31.5-36.4), snout length 9.2 (8.5-11.3), eye width 5.9 (5.7-7.6), interorbital width 8.9 (7.6-10.0), all as per-centage of SL. Mouth forming an angle of about 32 degrees with longitudinal axis of body; jaw extending to level of anterior edge of pupil; teeth of jaws numerous in dense bands, teeth of outer row enlarged; palate edentulous; tongue,

palate, and floor of mouth pale with few melanophores. Gill opening extends well forward of posterior margin of preopercle. Head with numerous sensory papillae arranged in tracks as illustrated in Figure 13.
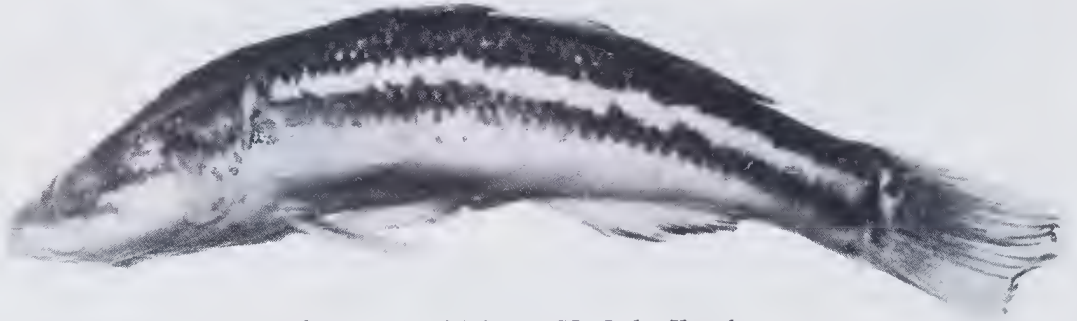
Figure 12   *Mogurnda vitta*, holotype, 104.0 mm SL, Lake Kutubu.

Figure 13   Camera lucida drawing of head of *Mogurnda vitta*, holotype, showing tracks of sensory papillae (stippled).

Scales of head, predorsal region, and bases of caudal and pectoral fins cycloid, remainder of body scales ctenoid (Figure 5). Head entirely scaled except lips, snout tip, preorbital region, lower jaw and chin; preopercle scales smaller than body scales and tend to be embedded.

Second dorsal fin significantly taller than first dorsal fin; sixth spine of first dorsal fin tallest; pectoral fins 19.2 per cent (17.8-21.3) of SL, pelvic fins 18.5 per cent (16.8-24.9, all but smallest damaged) of SL; pectoral fins rounded; pelvic fins pointed, the depressed pelvic fin tips reaching beyond base of genital papilla in smallest paratype, but considerably shorter in holotype and other paratypes. Caudal peduncle relatively elongate, its length 21.8 per cent (21.8-24.6) of SL, and depth 11.0 per cent (10.4-11.8) of SL; caudal fin rounded, its length 21.6 per cent (18.5-24.9, damaged in most) of SL.

Colour when fresh: greenish-brown on back and dorsal half of head; broad white stripe from upper edge of operculum to base of caudal fin, bordered above and below with dark brown stripes, nearly equal in width to white stripe and joining at caudal base; lower portion of head and body pale yellow to whitish, two stripes radiating from eye, one from bottom part of eye to middle section of cheek, the other from lower posterior corner of eye to upper margin of preoperculum; anterior portion of lips dusky brown; intense dark brown spot (nearly equal to pupil) above upper edge of preopercle; dorsal fins translucent with faint brown spotting; caudal fin slightly dusky brown with scattered brown spots basally; anal fin yellow-white with black submarginal band and narrow white margin; pelvic fins whitish; pectoral fins translucent with yellow hue and brown pigment covering upper half of base. Juvenile paratype (male, 55.0 mm SL) similar overall except white mid-lateral stripe replaced by series of nine white blotches and caudal fin more heavily spotted.

Colour in alcohol: similar to fresh coloration, basically dark brown dorsally with whitish mid-lateral stripe and ventral region. After 30 years in preservative the CSIRO specimens still retain the characteristic striped pattern, but are generally lighter with the mid-lateral stripe and ventral part of the head and body yellowish or tan.

Remarks

This species was illustrated by Munro (1964: Figure 21-D). He gave the native name of 'kaigibu'. We name this species *vitta* (Latin: ribbon, band, or stripe) with reference to the distinctive colour pattern.

Oxyeleotris fimbriata (Weber)

Figures 14 and 15

Eleotris fimbriata Weber, 1908: 254 (Etna Bay, southern New Guinea).

Diagnosis

A species of *Oxyeleotris* differing from other members of the genus by a combination of features which include: soft rays in second dorsal fin 10 or 11; soft anal rays 8 to 10; scales in lateral series 55 to 65; predorsal scales 28 to 40; colour generally dark brown, often with series of darker chevron-shaped markings along side and large blackish spot at base of upper caudal fin rays.

Description

Dorsal rays VI-I, 10 or 11; anal rays I, 8 to 10; pectoral rays 15; segmented caudal rays 16 to 18; branched caudal rays 15 or 16; scales in lateral series 55 to 60; transverse scale rows 18 to 21; predorsal scales 34 to 40; postdorsal scales 15 to 18; gill rakers on first arch 2 + 9 or 10 = 11 or 12; vertebrae 28 (rarely 29).

Body elongate, laterally compressed in posterior portion more or less cylindrical anteriorly; body depth at pelvic fin origin 21.8-24.9 per cent of SL; body depth at anal fin 17.1-20.4 per cent of SL. Head blunt and depressed with elongate, rounded snout; nape gently arched. Head length 37.6-40.4, snout length 9.1-10.6, eye width 5.2-6.3, interorbital 9.1-10.9, all as percentage of SL. Mouth forming an angle of about 30-35 degrees with longitudinal axis of body; jaw extending to level of posterior part of eye; lips fimbriate, teeth of jaws numerous in dense bands, teeth of outer row enlarged; palate edentulous. Gill opening extends well forward of posterior margin of preopercle. Head with numerous sensory papillae arranged in tracks as illustrated in Figure 15.
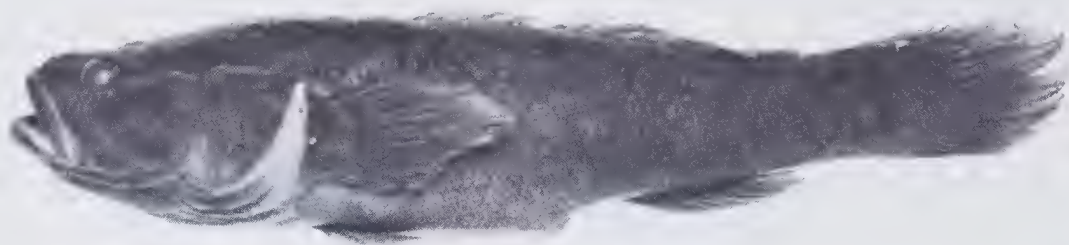
Figure 14   *Oxyeleotris fimbriata*, 125.0 mm SL, Lake Kutubu.
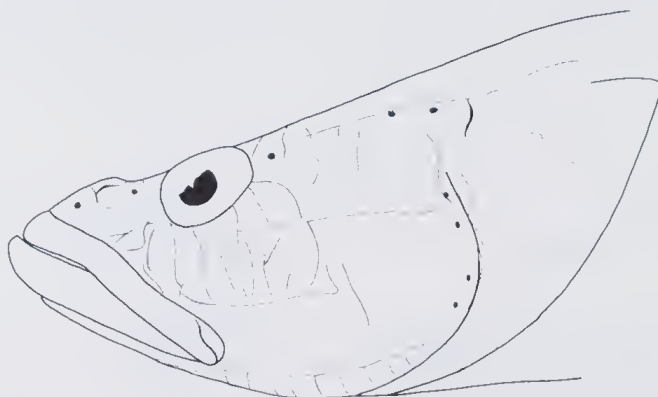
Figure 15   Camera lucida drawing of head of *Oxyeleotris fimbriata*, 105.0 mm SL, showing tracks of sensory papillae (stippled).

Scales of head, predorsal region, anterior part of body, and bases of caudal and pectoral fin cycloid, remainder of body scales ctenoid. Head entirely scaled except lips, snout, preorbital region, lower jaw and chin; predorsal scales extending to mid-interorbital; preopercle scales smaller than body scales and tend to be embedded.

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Second dorsal fin significantly taller than first dorsal fin; third or fourth spine of first dorsal fin tallest; pectoral fins 19.7-22.7 per cent of SL; pelvic fins 17.7-19.0 per cent of SL; pectoral fins rounded; pelvic fins short and pointed, the depressed pelvic fin tips falling well short of base of genital papilla. Caudal peduncle relatively elongate, its length 20.1-21.7 per cent of SL, and depth 12.0-14.0 per cent of SL; caudal fin rounded, its length 22.5-23.8 per cent of SL.

Colour when fresh: overall dark brown, lighter brown on underside of head and on breast and belly region; series of about 15 faint, narrow dark chevron markings, with their apex directed anteriorly, on side of body; head with three broad dark brown stripes with lighter brown spaces between them, first from maxillary to lower edge of preopercle, second from bottom of eye to lower edge of preopercle, third from lower posterior corner of eye to angle of pre-opercle; fins dark brown with narrow whitish borders, except bottom half of pectoral lighter brown.

Colour in alcohol: adults similar to above description, but sometimes lacking chevron markings, some with small, dark brown spots dorsally on head and body. Juveniles (under about 70 mm SL) are generally lighter brown and have more vivid chevron markings on the side, and an intense black spot on the upper caudal fin base. Also the dorsal and caudal fins are prominently spotted. The juvenile markings gradually fade into the more sombre adult coloration with increased growth, although the chevron markings along the side are often faintly evident in adults.

Remarks

There is an urgent need for revision of the New Guinea species of *Oxyeleotris*. The species previously recogniscd as *O. fimbriata* is probably divisible into at least three species. Another member of this complex, *O. wisselensis* Allen and Boeseman, 1982 inhabits the Wissel or Paniai Lakes of Irian Jaya (western New Guinea). We provisionally identify the Lake Kutubu specimens as the nominal *O. fimbriata* as the counts for lateral scale rows and predorsal scales (55-60 and 34-40 respectively) agree with specimens from a broad arca of southern New Guinea including the type locality near Etna Bay, Irian Jaya. The species has been reported from both southern and northern New Guinea by Koumans (1953). However, specimens from the Sepik Basin of northern New Guinea appear to be distinct with regard to lateral scale row counts (71-85). Another population from the Vogelkop Peninsula of far western New Guinea has a similar scale count, but differs from the Sepik population in shape and colour pattern.

The Lake Kutubu people refer to this species as 'nafa'. It was previously reported from this locality by Munro (1964).

Material examined

WAM P28158-006, 11 specimens, 58.0-140.0 mm SL, Lake Kutubu — Station 1; WAM P28159-006, 31 specimens, 18.0-157.0 mm SL, Lake Kutubu — Station 2.

Acknowledgements

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A new generic name for *Anchisomus multistriatus* Richardson 1854 (Tetraodontidae), with notes on its toxicity and pufferfish biting behaviour

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and James C. Tyler‡

Abstract

A poorly known pufferfish, *Anchisomus multistriatus* Richardson, is redescribed from 25 specimens from northern Australian coastal waters, and placed in a new monotypic genus, *Feroxodon*. It differs from other tetraodontid genera with a similar nasal organ structure (tube with two nostrils) in aspects of frontal and sphenotic osteology. The species has been implicated in unprovoked biting incidents and in a well documented case of fish poisoning fatality.

Introduction

During the tenure of the senior author's fellowship at the Smithsonian Institution, the collections of the National Museum of Natural History in Washington, DC, were examined for their holdings of pufferfishes from the coast of China and adjacent regions. This revealed a relatively large pufferfish (306 mm SL) from Queensland, Australia, that was unknown to either the first (JS) or last listed (JCT) authors.

Not only was the distinctive colour pattern of the specimen unfamiliar, but also its generic affinity was problematic. A letter to numerous colleagues describing the essential features of the fish resulted in positive responses from: J. Barry Hutchins (Western Australian Museum), who had collected and photographed in life during 1978 a specimen from Learmonth, Western Australia (photograph reproduced here); Graham S. Hardy, who identified the fish as *Anchisomus multistriatus* Richardson, 1854 and agreed to collaborate in a redescription of it; and Douglas F. Hoese (Australian Museum), who also identified it as *A. multistriatus*.

In this paper *Anchisomus multistriatus* Richardson is redescribed and placed in a new genus, with detailed comparisons to related genera. In addition, aspects

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of the toxicity of *A. multistriatus* and of biting behaviour in it and in other tetraodontids are presented.

Methods and abbreviations

Measurements were taken by dial caliper and recorded to the nearest 0.1 mm, following the methods of Dekkers (1975), Hardy and Hutchins (1981) and Hardy (1981, 1983), while the osteological usage follows Tyler (1980). Fin ray counts include all visible rays, both branched and unbranched, and in the pectoral fin the small uppermost element that is reduced to a nubbin in adults. Fin ray lengths were determined by measurements from the embedded base. Most of the specimens were radiographed and half of them were cut open along the cheek on the right side to count gill rakers. All counts and measurements are from preserved specimens, and the osteological illustrations are based on photographs of the two specimens cleared and stained.

The following abbreviations are used in the text and tables: SL — standard length; HL — head length; N — number of specimens examined; $\bar{x}$ — average value; D — dorsal fin; A — anal fin; P — pectoral fin; V — vertebrae; PV — precaudal vertebrae; CV — caudal vertebrae; GR — gill rakers; QM — Queensland Museum, Brisbane; AMS — Australian Museum, Sydney; MAGNT — Museum and Art Galleries of the Northern Territory, Darwin; NMNZ — National Museum of New Zealand; USNM — United States National Museum of Natural History, Washington, DC.

Systematics

Five of the seven species first listed in *Anchisomus* by Richardson (1854, based on ms. of J.J. Kaup), i.e. *geometricus* (= *annulatus*), *angusticeps*, *reticularis* (= *nephelus*), *spengleri*, and *turgidus* (= *maculatus*), clearly are assignable to *Sphoeroides* (Shipp, 1974). A sixth species, *scalaris*, listed by name only, does not appear to have been formally described at any time. It is here considered a *nomen nudum*. Under normal circumstances, the seventh species, *multistriatus*, might have remained in *Anchisomus*, a valid generic name despite its inadequate description by Richardson, owing to its distinctive characteristics which preclude allocation to any other tetraodontid genus (see below). However, Jordan (1919), acting as first reviser, selected *Tetrodon spengleri* Bloch as the logotype of *Anchisomus*, thus making *Anchisomus* a junior subjective synonym of *Sphoeroides*. Consequently, we propose the new generic name *Feroxodon* for *Anchisomus multistriatus* Richardson.

Feroxodon new genus

Type species
  Anchisomus multistriatus Richardson, 1854.

Diagnosis

Feroxodon is a heavy bodied, monotypic genus of tetraodontid fishes, belonging to the group of genera characterised by a nasal sac with two nostrils. It differs uniquely from the other genera included therein by having the frontals broadly expanding from a point just anterior to the lateral ethmoids, thereby contributing greatly to a postcrolaterally directed postorbital wing, in association with a correspondingly reduced sphenotic. The eyes of *Feroxodon* are small, positioned high on the head and are enclosed in a relatively small and bony orbital rim. The anal fin origin is well behind the dorsal fin base. *Feroxodon* further differs from other genera in which, like it, the eye rim is adnate only dorsally, in lacking a ventrolateral skinfold (present in *Torquigener* and *Amblyrhynchotes*); lacking trituration teeth (present in *Tylerius, Sphoeroides, Takifugu* and *Amblyrhynchotes*); possessing medial prootic prongs (absent in *Takifugu, Javichthys, Amblyrhynchotes* and, usually, in *Torquigener*); possessing a lower lateral line posterior to the pectoral fin (absent or remnants only in *Sphoeroides*); and in having the frontals extending anterior to the anterior margins of the lateral ethmoid lobes (not so in *Torquigener, Javichthys* and *Amblyrhynchotes*).

Description

See following description of *F. multistriatus,* the only known species.

Etymology

From the Latin *ferox* = ferocious, and *odon* = teeth, in allusion to the fierce biting habits of the single species, *multistriatus;* to be treated as masculine.

Feroxodon multistriatus (Richardson, 1854)

(Striped Toado)

Figures 1-5; Colour Plate 1

Anchisomus multistriatus Richardson, 1854: 160-161, pl. 30.
Tetrodon multistriatus — Gunther 1870: 285.
Anchisomus multistriatus — Gill 1892: 708; Gunther 1910: 460; Hardy 1983: 8; Gloerfelt-
  Tarp and Kailola 1984: 293, 363.
Spheroides multistriatus — Ogilby 1915: 128-129; Ogilby1918: 103; McCulloch and Whitley
  1925: 178; McCulloch 1929: 429.
Sphaeroides multistriatus — Whitley 1936: 50-51; Whitley 1964: 59.
Sphoeroides multistriatus — Marshall 1964: 495.
Geneion multistriatum — Le Danois 1959: 188-189 (in part); Le Danois 1961: 469 (in part).

Description

The following meristics and measurements are based on 25 specimens, 52.8-320 mm SL, unless otherwise stated. See Table 1 for frequency distributions of meristic features.

Table 1   *Feroxodon multistriatus* meristics

Dorsal fin rays						Anal fin rays		
10	11	12	N	$\bar{x}$		9	N	$\bar{x}$
2	22	1	25	11.0		25	25	9.0

Pectoral fin rays						Caudal fin rays		
R.+15	R.+16	R.+17	N	$\bar{x}$		11	N	$\bar{x}$
9	14	2	25	R.+15.7		25	25	11.0

Precaudal vertebrae					Caudal vertebrae				
9	10	N	$\bar{x}$		10	11	12	N	$\bar{x}$
16	5	21	9.2		2	18	1	21	11.0

Total vertebrae					Gill rakers				
19	20	21	N	$\bar{x}$	9	10	11	N	$\bar{x}$
1	15	5	21	20.2	6	5	2	13	9.7

Head length 2.27-2.86 ($\bar{x}$ 2.51) times in SL; snout to origin of dorsal fin 1.42-1.60 ($\bar{x}$ 1.52) times in SL; snout length 1.61-1.97 ($\bar{x}$ 1.76) times in HL; anterior edge of nasal tube to end of snout 2.26-2.79 ($\bar{x}$ 2.46) times in HL; posterior edge of base of nasal tube to anterior edge of eye 5.53-9.43 ($\bar{x}$ 6.56) times in HL; gill slit length 2.93-4.52 ($\bar{x}$ 3.83, 24 specimens) times in HL; caudal peduncle length 4.16-8.12 ($\bar{x}$ 5.76) times in SL; caudal peduncle depth 7.37-10.22 ($\bar{x}$ 9.09) times in SL and 1.18-2.00 ($\bar{x}$ 1.61) in caudal peduncle length; dorsal fin origin to anal fin origin 3.03-3.90 ($\bar{x}$ 3.54, 24 specimens) times in SL; nasal tube base width (diameter) 9.00-16.17 ($\bar{x}$ 12.58, 24 specimens) times in snout length and 17.71-28.75 ($\bar{x}$ 22.29, 24 specimens) in HL; nasal tube height 1.32-3.41 ($\bar{x}$ 2.31, 24 specimens) times in nasal tube base width; nasal tube base width 1.65-3.33 ($\bar{x}$ 2.28, 24 specimens) times in distance between nasal tubes; horizontal diameter of eye 4.98-8.77 ($\bar{x}$ 6.35) times in HL and 1.02-2.73 ($\bar{x}$ 1.43) times in bony interorbital width; bony interorbital width great, 8.87-13.45 ($\bar{x}$ 11.17) times in SL and 3.21-5.35 ($\bar{x}$ 4.47) times in HL; dorsal fin elongate and pointed, longest ray 3.98-5.99 ($\bar{x}$ 4.70) times in SL; anal fin elongate and pointed, origin well behind dorsal fin base, longest ray 4.57-6.08 ($\bar{x}$ 5.23) times in SL; pectoral fin rounded, longest ray 4.80-6.16 ($\bar{x}$ 5.55) times in SL; caudal fin slightly rounded, longest ray 2.93-3.97 ($\bar{x}$ 3.42) times in SL.

Body robust, rounded, tapering to a narrow caudal peduncle; mouth small, terminal; lips thick, covered with numerous short papillae. *Eyes* small, positioned

PLATE 1

Feroxodon multistriatus, lateral view reproduced from an Ektachrome slide by J. Barry Hutchins of a specimen of 240 mm SL, WAM P. 26184-001, caught on handline from the FV *Courageous* anchored off Learmonth, Exmouth Gulf (22°15′S, 114°05′E), Western Australia, 9 May 1978.

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Figure 1   *Feroxodon multistriatus,* dorsal and ventral views of the same specimen, 82.5 mm SL, AMS I.21832-003, Arafura Sea, Northern Territory, 14-16 November 1980.

high on head, lower border well above level of corner of mouth, enclosed in a relatively small orbital rim, dorsally adnate. *Nasal apparatus* a short tube on each side, anterior to eye, two nostrils (medial and lateral), lateral nostril the larger; inner surface of apparatus with several well developed olfactory lamellae. *Lateral lines* distinct; upper line encircling eye with an anterodorsal branch almost meeting in midline anterior to nasal organ; preopercular branch dropping to lateral limit of belly, extending along body to about halfway along caudal peduncle; mid-dorsal branch of lateral line above pectoral fin base not meeting in midline; second lateral line dropping behind mouth corner, extending along

Figure 2 *Feroxodon multistriatus*, lateral view of entire skeleton, 306 mm SL, USNM 176752, Brisbane, Queensland, April-May 1952.

ethmoid
palatine
vomer
ethmoid
parasphenoid
lateral ethmoid
frontal
pterosphenoid
sphenotic
prootic
pterotic
epiotic
exoccipital
basioccipital
supraoccipital
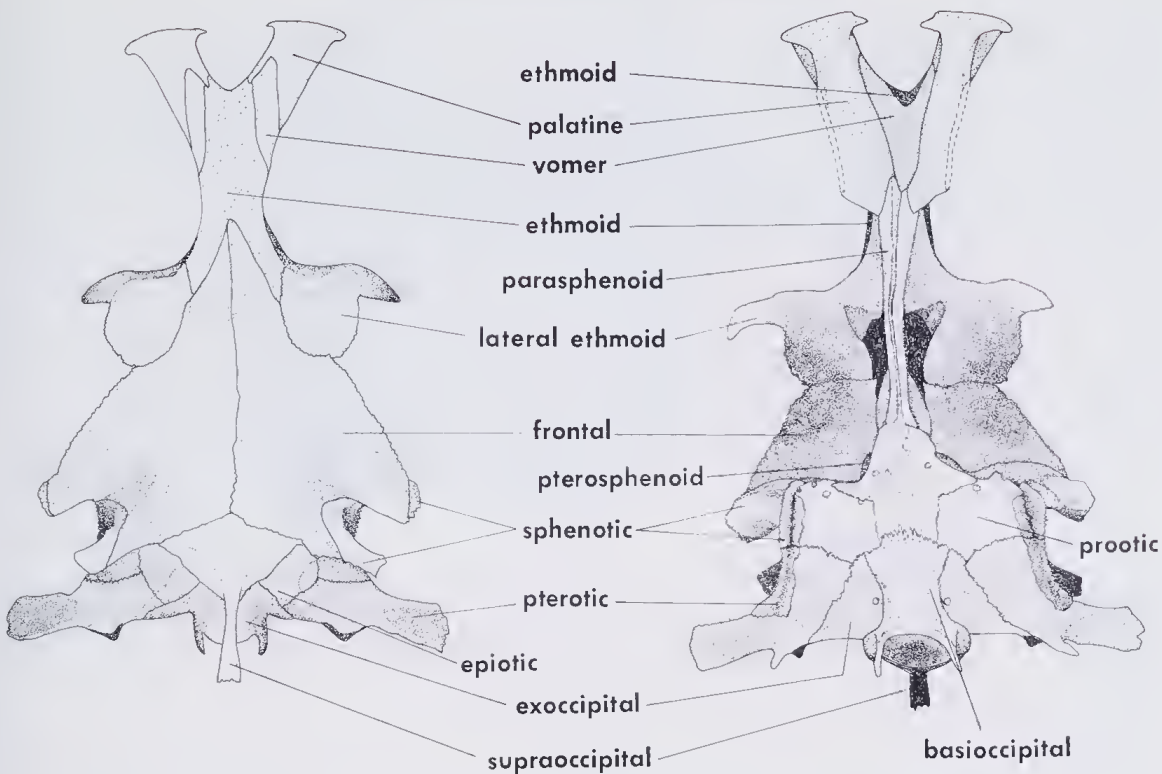
Figure 3   *Feroxodon multistriatus,* dorsal (left) and ventral view of the skull, 306 mm SL, USNM 176752, Brisbane, Queensland, April-May 1952.

lateral region of belly almost to caudal fin base, except for a break ventral to pectoral fin. *Ventrolateral skinfold* absent. *Spines* few, relatively large, on dorsum from nasal tubes to dorsal fin, on belly from chin to anus, and behind pectoral fin; absent from caudal peduncle; 4-11 ($\bar{x}$ 6.4) spines on interorbital region; 11-37 ($\bar{x}$ 15.5) lateral head spines, those of larger specimens fewer and more deeply embedded; 2-8 ($\bar{x}$ 5.2) spines on anterior margin of gill slit.

Colour pattern notes made by GSH on NMNZ P. 9937 after several days in formalin but with much colour still remaining are as follows: body pattern anterior to dorsal fin base comprising alternating dark olive and brown lines, these extending forward diagonally onto sides of body and head and longitudinally between eyes and nostrils; body pattern posterior to dorsal fin base with olive lines anastomosing ventrally and enclosing elongate brown spots; large rounded brown spots on lower half of body sides and caudal peduncle, on a pale background, the spots continuing onto lateral regions of belly but becoming less distinct; belly dirty yellowish; chin with grey smudges on either side; pale around pectoral fin base, but with olive and brown striations; pectoral fin pale; dorsal, anal and caudal fins greyish.

Figure 4   *Feroxodon multistriatus,* lateral view of last five caudal vertebrae, 306 mm SL, USNM 176752, Brisbane, Queensland, April-May 1952.
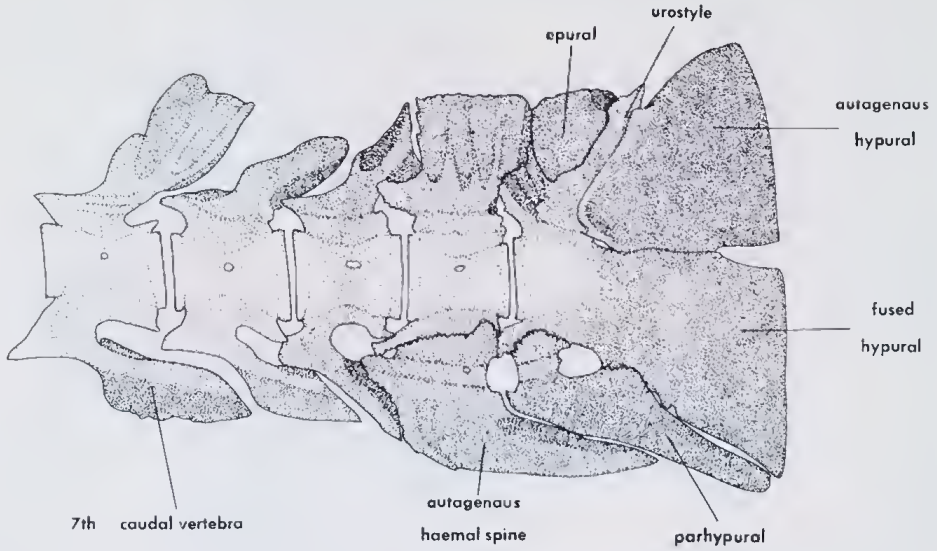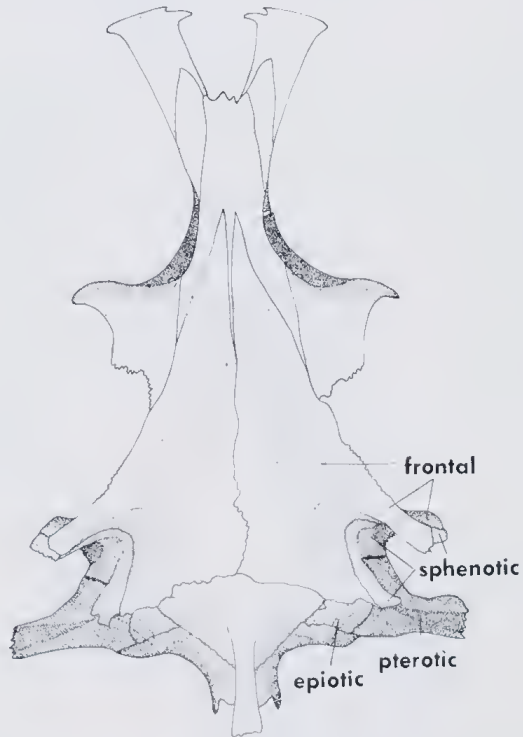

Figure 5   *Feroxodon multistriatus,* dorsal view of the skull, 121 mm SL, QM I.15993, Princess Charlotte Bay, Queensland, 23 February 1979.

Colour in life (based on a 35 mm Ektachrome slide of a fresh specimen of about 240 mm SL from Learmonth, Western Australia). Sides of head with medium brown stripes on pale background, bending obliquely posterodorsally over pectoral fin base and continuing onto dorsal fin base; lateral surface under dorsal fin with large brown ocellated oval spots on pale background, the spots or blotches tending to be anteroventrally elongate and with thin brown lines often helping to outline the ocellations within a reticulate network; belly pale; dorsal, anal and (least so) pectoral fins with a slight yellowish brown cast.

Distribution

Feroxodon multistriatus ranges in shallow inshore waters along the northern half of Australia, from Exmouth Gulf in Western Australia to as far south as Caloundra, just north of Brisbane, in south-east Queensland.

Remarks

All references given above under the names *Anchisomus, Tetrodon* or *Sph[a, o]eroides multistriatus* refer to that species alone, as redescribed here. However, the reference to *Geneion multistriatum* (in Le Danois 1959, 1961), as indicated by the included synonyms (*mela-plathié, multistriatus, leschenaultii, marmorata, spinosissimus, pleurospilus, whitleyi, marleyi*) and references, represents at least six distinct species (see Jordan and Edwards 1887; Fraser-Brunner 1943; Shipp 1974; Hardy 1982, 1983).

Le Danois' (1959: 188, Figure 151) illustration of the body conceivably could be based on *multistriatus,* since the specimen is shown as having few but large spines and relatively large blotches on the caudal peduncle, and somewhat vertical stripes on the cheek. However, the cheek stripes in Le Danois' illustration are not as narrow nor as sharply defined as those shown by Richardson for *multistriatus* or observed by us. Furthermore, her illustration of the body shows a prominent skin fold on the ventrolateral edge of the caudal peduncle, unlike the *multistriatus* of Richardson and of our specimens. Her illustration of dorsal craniology (Figure 152) does not show the heavy anteroventral flanges of the lateral ethmoids and the prominent posterolateral flanges of the sphenotics observed by us.

The illustrations by Le Danois (1959, Figures 151-152) purportedly are based on the type specimen of *Epipedorhynchus leschenaulti* Duméril, 1855 (Bibron ms.), according to her note on p. 189. No locality for this species was given by Duméril (1855: 278), who simply listed 'Leschenaulti, Bib', without description of any kind. Le Danois (1961: 469) later indicated that MNHN B. 1493 was the specimen originally described as '*Tetraodon melaplathié*' Leschenault de la Tour manuscript 1818 (on which *Epipedorhynchus leschenaulti* Duméril, Bibron ms., was based), giving 'Ile Maurice' as the type locality.

However, MNHN B. 1493 has not been dissected (examined by GSH through the courtesy of M.L. Bauchot). Therefore, it could not have been the basis for

Le Danois' (1959) Figure 152 skull illustration, nor for her Figure 151 of the complex colour pattern on the body, for the specimen is totally devoid of pigmentation. Indeed, the status of MNHN B. 1493 is entirely questionable. Dr M.L. Bauchot (pers. comm.) has indicated that there is no basis from which we can determine whether or not the specimen is the fish described, in the first instance, by Leschenault in his manuscript or by subsequent workers, for no trace of an original label now remains.

The identity of MNHN B. 1493 remains uncertain. It apparently belongs to the *Torquigener*-like group of genera, but has large, well-formed triturating teeth. The condition of the specimen precludes more precise identification at this stage, but it is not an example of the subject of this paper.

The lack of descriptive characters for *Epipedorhynchus leschenaulti,* not to mention the totally inconclusive status of the purported holotype, lead us to regard *E. leschenaulti* as a *nomen nudum.* The name has no direct relevance to the nomenclatural history of *Anchisomus multistriatus* Richardson.

Osteological notes

Osteological features of *Feroxodon multistriatus* are illustrated in Figures 2-5. The following notes concentrate on features that are either unusual in *F. multistriatus* or of special significance in the eventual establishment of tetraodontid relationships. Branchial and pharyngeal characteristics, which cannot be seen in the illustrations provided, also are described here.

Branchiostegal rays $2 + 4 = 6$, with distal end of uppermost ray extending back to edge of gill slit, behind which a small flap of skin protrudes, disrupting otherwise uniform edge of opercular covering. Branchial arches typical of Tetraodontidae, with 3 basibranchials, 3 hypobranchials, 5 ceratobranchials (fifth toothless), 4 epibranchials and 3 pharyngobranchials, 3 gills, no gill slit between gill-less fourth and fifth arches and no gill rakers along posterior edge of fourth arch or on either side of fifth arch. Gill rakers all relatively short and stubby, simple, unbranched, with minute denticulations. First pharyngobranchial with a lunate plate-like portion exposed on roof of mouth, completely covered with fine denticles, these denticulations not easily distinguishable as clusters of individual units in the larger (306 mm SL) cleared and stained specimen, but clearly seen to consist of numerous closely but irregularly arranged separate units in the smaller (121 mm SL) cleared and stained specimen. Second and third pharyngobranchials with exposed surface on roof of mouth slightly shorter but much narrower than that of first pharyngobranchial, and bearing relatively large conical teeth set in individual basal cups (about 20 on second pharyngeal and 10 on third pharyngeal in larger cleared and stained specimen, 12 to 15 on second and 5 to 8 on third in smaller specimen), those of smaller specimen with slightly more sharply pointed distal ends.

Last caudal vertebra with parhypural, lower hypural plate fused to centrum and upper autogenous hypural plate articulated immovably to dorsal edge of

lower fused hypural plate and to posterior edge of urostyle; single epural, oriented vertically and obliquely posterodorsally; haemal spine of penultimate vertebra autogenous.

Eleven dorsal fin basal pterygiophores; supraneural element articulated to anterodorsal end of first pterygiophore; six anal fin basal pterygiophores.

The most noteworthy features of the cranium are: well developed lateral ethmoids with heavy downturned anteroventral flanges forming a strong rim around front of eye; great width posteriorly of frontals and their broad contact with lateral ethmoids as they become narrower anteriorly and taper to points overlying ethmoid at level of anterior ends of lateral ethmoids; posterolateral expansion as wings or prongs above skull surface of extreme posterolateral ends of sphenotic (in conjunction with most posterior portions of frontals); sphenotic wing directed toward postcrolateral expansions of pterotic; well developed dorsal flange of parasphenoid in interorbital septum making contact dorsally on undersurface of skull with ventromedial edges of frontals; medial prongs from anterior edges of prootics at entrance to myodome relatively well developed; relative large size of the strongly ossified head.

The skeletal structure of the smaller (121 mm SL) of the two cleared and staincd specimens is not markedly different from that described above, and illustrated mainly on the basis of the larger (306 mm SL) spccimen. The main differences are that the smallcr specimen does not yet have the frontals as wide over the orbit or as massively expanded postcrolaterally as in the larger specimen, nor are the posterolateral wings of the sphenotic quite as extended laterally.

Comparisons with other genera

In addition to thc distinctive features of its colour pattern, which make the species easy to recognise (along with its large maximum size, heavy body, small eye, and restricted northern Australian distribution), *Feroxodon multistriatus* is unique in its particular combination of 18 external and internal features considered especially significant as generic level diagnostic and phylogenetic indicators for tetraodontids. Thcse features arc summarised in Table 2, comparing the conditions in *Feroxodon* with those of 13 other Indo-Pacific genera with a nasal apparatus consisting of a tube with two nostrils. The more salient of these 18 characters in the other appropriate genera as compared to *Feroxodon* are discussed below.

One of the most significant features of *Feroxodon* is the anterior tapering of the frontals in comparison to their very considerable lateral development in the postorbital region. In addition, the anal fin origin is well behind the dorsal fin base, whereas in all of the remaining genera, with the exception of *Tylerius* in which it is just behind, the anal fin originates under the dorsal fin base. The eyes of *Feroxodon* are small, highly positioned on the head, and are enclosed

Table 2   Summary of major anatomical features of *Feroxodon* and related genera

	Feroxodon	Polyspyna	Reicheltia	Marilyna	Colomesus	Torquigener	Tylerius	Contusus	Lagocephalus	Sphoeroides	Takifugu	Amblyrhyn-chotes	Javichthys	Tetractenos
Eye condition	dorsally adnate	completely adnate	completely adnate	completely adnate	completely adnate	dorsally adnate	dorsally adnate	completely adnate	dorsally adnate	dorsally adnate	dorsally adnate	dorsally adnate	dorsally adnate	completely adnate
Ventrolateral skinfold	absent	absent	present	present	absent	present	absent	absent	present	usually absent	present or absent	present	absent	present
Lower lateral line posterior to pectoral fin	present	absent	absent	present	present	present	present	absent	present	absent, or remnants only	present	present	present	present
Anal fin origin	well behind dorsal	under dorsal	under dorsal	under dorsal	under dorsal	under dorsal	just behind dorsal	under dorsal	under dorsal	under dorsal	under dorsal	under dorsal	under dorsal	under dorsal
Epural orientation	oblique	oblique	oblique	oblique	oblique	oblique	oblique	oblique	horizontal	oblique	oblique	oblique	oblique	oblique
Interhyal	present	absent	absent	absent	absent	absent	absent	absent	present	usually absent	absent	absent	absent	absent
Triturating teeth	absent	small or absent	absent	small or absent	present	small or absent	present	absent	present	present	present	present	absent	absent
Last basal pterygiophore posterior prongs	absent	absent	absent	absent	absent	absent	absent	absent	moderate to well developed	absent	absent	absent	absent	absent
Medial prootic prongs	well developed	absent	absent	absent	present	absent to moderately developed	present	absent	moderate to well developed	absent to well developed	absent	absent	absent	absent
Frontal width over orbit	broad	moderately narrow	broad	broad	broad	narrow	broad	broad	broad	narrow to broad	broad	broad	narrow	broad
Lateral ethmoid contact with palatine	no	yes	no	yes	yes	yes or no	no	yes	no	no	yes or no	yes	no	yes
Lateral post-orbital expansion of frontal	extensive	small	moderate	nil	nil	small	nil	small	moderate to extensive	nil	small	small	nil	small
Dorsal hypohyal	present	present	present	present	present	present	present	present	usually absent	usually present	absent	absent	present	present
Parasphenoid dorsal lobe in orbit	present	present	present	present	present or absent	present	present	present	usually present	usually absent	present	present	present	present
Supraoccipital/sphenotic contact	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
Ethmoid	long	short	short	moderately long	long	long	short	short	long	long	short to moderate	long	long	short
Frontal position relative to anterior margin of prefrontal lobe	in front	behind	in front	behind	behind	behind	in front	in front	in front or behind	in front or behind	in front	behind	behind	level
Posterior margin of nostrils relative to eyes	well forward	just forward	level	level	level	well forward	well forward	well forward	well forward	well forward	well forward	just forward	well forward	just forward

in a relatively small bony orbital rim, comparatively far smaller than in the other genera. While examination of the anatomical features included in Table 2 indicates a diverse array of characters defining the various genera, it also shows that those genera with the eye rim completely adnate share, as a group, rather fewer characters with *Feroxodon* than do the remaining genera.

The incompletely adnate eye condition appears to be a specialisation within the Tetraodontinae (a completely adnate eye rim characterises both the Canthigasterinae and also the nearest outgroup, the Diodontidae). It follows, therefore, that *Feroxodon,* which has the eye dorsally adnate only, should first be compared with those genera similarly characterised, and from within which group its closest relation is likely to be found; i.e. *Lagocephalus, Torquigener, Javichthys, Sphoeroides, Takifugu, Tylerius* and *Amblyrhynchotes.*

Lagocephalus — Although *Lagocephalus* is the genus most closely similar to *Feroxodon* in the degree of frontal contribution to the postorbital wing, *Lagocephalus* differs from *Feroxodon* in several cranial features. The six species of *Lagocephalus* illustrated by Tyler (1980: Figures 197, 263-264) have the posterolateral wings of the frontals more slender and elongate (in comparison to the straighter, upraised posterior edge of the frontal in *Feroxodon*), and a marked depression in the dorsal surface of the frontal as it approaches the postorbital association with the sphenotic. The shape and orientation of the lateral ethmoids in *Feroxodon,* featuring a heavy and strongly downturned anterolateral wing, differ in *Lagocephalus,* in which the lateral ethmoids may be relatively broad (as in *lagocephalus, lunaris* and *spadiceus*) or tapering anterolaterally (as in *sceleratus*), but are not especially heavy or thick and downturned anterolaterally. *Feroxodon* lacks a median dorsal exposure of the vomer, while in *Lagocephalus* the vomer is usually prominently exposed on the dorsal surface of the anterior end of the skull between the palatines and in front of the ethmoid. Additional features present in *Lagocephalus,* but absent in *Feroxodon,* include well developed posterior prongs from the last basal pterygiophores of the dorsal and anal fins, triturating teeth, and a ventral skinfold. Dorsal hypohyals, which usually are absent in *Lagocephalus,* are present in *Feroxodon.* Overall, *Lagocephalus* has a more elongate and streamlined body, in keeping with a pelagic or semi-pelagic existence, than the chunkier, more deep-bodied *Feroxodon* found in inshore coastal regions.

Torquigener and *Javichthys* — Both of these genera have the frontals narrow over the orbit, in direct contrast to *Feroxodon.* Also, in *Torquigener* and *Javichthys* the frontals fail to extend anterior to the anterior margins of the lateral ethmoid lobes and have either no postorbital expansion of the frontals toward the sphenotic or only a moderate expansion, whereas in *Feroxodon* the frontals extend well anterior to the anterior margins of the lateral ethmoid lobes and have a well developed posterolateral flange from the frontals directed toward the lateral ends of the pterotics. Medial prootic prongs, well developed in *Feroxodon,*

are absent from *Javichthys* and in most species of *Torquigener*. *Torquigener* further differs from *Feroxodon* in possessing a ventrolateral skinfold.

Sphoeroides — Differs from *Feroxodon* in having a minimal postorbital lateral development of the frontals, the presence of triturating teeth, and the absence (usually) of an interorbital dorsal lobe of the parasphenoid contacting the frontal. The lower lateral line, which if present at all in some species of *Sphoeroides* is represented only by remnants, in *Feroxodon* is distinctly present, although faint.

Takifugu and *Tylerius* — Both of these genera have short, or at best only moderate, dorsal exposure of the ethmoid, compared with the larger ethmoid more fully exposed dorsally in *Feroxodon*. In addition, the frontals of *Takifugu* and *Tylerius* have only a minimal postorbital development laterally, and both genera have triturating teeth, which are absent in *Feroxodon*. Medial prootic prongs, present in *Feroxodon* and *Tylerius,* are absent from *Takifugu.*

Amblyrhynchotes — The structure of the dorsal surface of the skull in *Amblyrhynchotes* bears little resemblance to that of *Feroxodon*. The frontals in *Amblyrhynchotes,* which taper progressively to a point just behind the anterior margins of the lobes of the lateral ethmoids, have limited postorbital lateral expansion, and are somewhat reduced posteriorly. The lateral ethmoids in *Amblyrhynchotes* are spade-like and flattened, unlike the strongly downturned elements in *Feroxodon*. The ethmoid is extensive in *Amblyrhynchotes,* but whereas the lateral ethmoids and palatines fail to contact in *Feroxodon*, they do so extensively in *Amblyrhynchotes*. In addition, triturating teeth are present and medial prootic prongs are absent in *Amblyrhynchotes,* conditions opposite to those in *Feroxodon*. The general countenance of the two genera is also rather different, particularly regarding the anterodorsal orientation of the jaws in *Amblyrhynchotes,* which also has a ventrolateral skinfold, whereas in *Feroxodon* the jaws are in the normal terminal position and there is no skinfold.

All of the genera with the eye completely adnate *(Tetractenos, Contusus, Polyspina, Reicheltia, Marilyna* and *Colomesus)* have a dorsal cranial configuration significantly different from *Feroxodon*. Of these six genera only *Colomesus* has medial prootic prongs and a longish ethmoid, but the complete or almost complete domination of the supraorbital rim by the lateral ethmoid and sphenotic bones in *Colomesus,* a condition most closely paralleled by *Marilyna,* is strikingly different in *Feroxodon*. The possession in these six genera of other characters in common with *Feroxodon* varies discordantly amongst all of them (see Table 2), leading to the conclusion that none of this group of six genera are particularly closely related to *Feroxodon.*

Of a much different group of tetraodontid genera, characterised by a divided nasal organ comprising one or two lobes, the single-lobed *Omegophora,* revised by Hardy and Hutchins (1981), bears some resemblance to *Feroxodon* in the configuration of the head and snout profile (particularly regarding the long ethmoid region and small, highly positioned eye). However, major differences

occur in some body proportions, fin shape, lateral line, shape of the frontal rim over the orbit, and spination. It appears that any superficial similarities between *Omegophora* and *Feroxodon* are most likely to have arisen from convergence within groups phyletically distinct on the basis of the fundamental nature of the nasal apparatus.

Remaining tetraodontid genera in groups with highly unusual plate-like or open plicated disk nasal apparatuses, including the highly specialised *Pelagocephalus, Chonerhinos* and *Xenopterus,* bear no significant resemblances to *Feroxodon,* over the basic tetraodontid characteristics, and are accordingly omitted from this discussion.

Material examined

Total of 25 specimens (52.8-320 mm SL). QM I.1462, Townsville, Queensland; QM I.12330, off Prudhoe I., Queensland; QM I.10277, Exmouth Gulf, Western Australia; QM I.15993 (3 specimens), Princess Charlotte Bay, Cape York, Queensland; QM I.15907, 1-9 km E of Capt. Billy Creek, Cape York, Queensland; QM I.16759, Torres Straits, Queensland, 10°02'S, 142° 28'E; QM I.16758, Torres Straits, Queensland; QM I.20496 (2 specimens), off Cairns, Queensland; QM I.4049, off Caloundra, Queensland; AMS I.21832-003, I.21839-009, I.21830-009, all from the Arafura Sea, Northern Territory; AMS I.20958-015, Princess Charlotte Bay, Cape York, Queensland; AMS I.20771-031 (3 specimens), 1-12 km E of Capt Billy Creek, Cape York, Queensland; MAGNT S.10031-087 (2 specimens), N of Smith Point, Cobourg Peninsula, Northern Territory; MAGNT S.10266-001, Shoal Bay, Northern Territory; MAGNT S.10938-018, Groote Eylardt, Northern Territory; USNM 176752, Brisbane, Queensland; NMNZ P.9937, Gove, Melville Bay, Northern Territory.

Stomach contents and gonads

Among the identifiable contents in the stomachs of the specimens examined were: remains of an elongate fish with many fin rays per vertebral segment and no scales, perhaps an eel (an opinion shared by Victor G. Springer, pers. comm.) in one specimen of QM I.15993, while another specimen from the same lot had the remains of a large crab-like crustacean and the same eel-like fish in addition to ctenoid scales; remains of a crustacean and a fish with a forked caudal fin in QM I.20496; crustacean remains and ctenoid scales in AMS I.20771-031; large crustacean fragments in NTMS 10938-018.

We have found both ripe males and females among the specimens examined, without any sexual dimorphism apparent to us in colour pattern or morphometrics.

Toxicity

Because of its rare details of the symptoms preceding death, and the pathological conditions included, we present in its entirety the pers. comm. of Dr J.M.N. Hilton, Forensic Pathologist, Queen Elizabeth II Medical Centre, Nedlands, Western Australia, concerning a recent fatality resulting from consumption of *Feroxodon multistriatus.*

'Briefly, the deceased was a 71 year old Philippino (sic) visiting Australia, living in a caravan in a small town in the far north west of the State (Onslow). Sometime in the afternoon of the 10th December 1984 he caught a fish which he left under a rock for a couple of hours before retrieving it, cleaning and cooking parts thereof. It is believed he ate the fish at about 2400 hours. Within half an hour it is said he became weak, nauseated, gagging. He was taken to the local hospital where he was seen by a nursing sister, diagnosed as having an anaphylaetic reaction to fish, she having been informed that the fish in question was a sting-ray. She noted his weakness and gagging. No doctor lives in the district and there was telephone contact with the nearest practitioner. Treatment commenced, but he suffered a cardiac arrest and died at 0315 hours. The total time lapse between ingestion and death did not much exceed three hours.

His body was flown to Perth for post mortem examination, accompanied by part of the skin of the fish and some liver and roe said to be from the fish. The skin was identified by Barry Hutchins.

Post mortem examination of the deceased showed marked congestion and gross oedema of the lungs; the coronary arteries showed moderate atherosclerosis of the short segments and moderate narrowing of each major branch without occlusion. There was a vene puncture wound present in the left antecubital fossa with an 8 cm area of bruising around it and further puncture wounds present in the right antecubital fossa. These were iatrogenic. There were no other abnormal findings on macroscopic examination. Micro examination of the tissues from the various organ systems showed intense pulmonary oedema and moderate congestion.'

Biting habits of *Feroxodon multistriatus* and other tetraodontoid species

Two unprovoked attacks upon humans in 1979 near Proserpine, Queensland, are almost certainly attributable to *F. multistriatus* (Jeffrey W. Johnson, pers. comm.). In one of these attacks, a girl lost three toes, attesting to the considerable biting power of large tetraodontids. Similar mutilation suffered by a youngster, reported in 'The West Australian' newspaper (17 April 1977), is believed attributable to the silver toadfish, *Lagocephalus sceleratus* (J. Barry Hutchins, pers. comm.).

Such opportunistic 'feeding' behaviour in tetraodontids is indicative of a sometimes highly aggressive predatory nature, which can be likened to a feeding frenzy. Personal experience of such a frenzy, by the small blowfish *Torquigener pleurogramma,* was reported to us by J. Barry Hutchins, and local belief in potentially fatal mass attacks by the large and mainly freshwater dwelling *Xenopterus naritus* was mentioned by Day (1875). The report of triggerfishes fatally attacking soldiers during World War II (Straughan 1958) is unsubstantiated, unlike the author's observations on *Balistes vetula* attacking sharks, and the

biting power of *B. carolinensis* (= *capriscus*). Wood (1953) described an attack upon a mating loggerhead turtle by several *B. carolinensis*, directed toward the erected penis and most aggressive following periods of profuse bleeding.

Further reports of the opportunistic biting of humans, including the mutilation of male genital organs, by pufferfishes are given by Salanoue-Ipin (1910), Gimlet (1923), and Tirant (1929). Indeed, genital mutilation led to the unsubstantiated suggestion by Buddle (1930), repeated by Caras (1946), that local consumption of pufferfishes in Singapore, despite the dangers of tetrodotoxin poisoning, continued in the belief of special aphrodisial properties.

In addition to reports on opportunistic biting, are those on biting ability and power: e.g. Allan *in* Darwin (1845) and Adams (1848), both citing *Diodon*, and Boulenger (1907), on *Tetraodon fahaka* (= *lineatus*). More recently, Hutchins (1980) and Hutchins and Thompson (1983) have commented on nuisance biting of fishermen and bathers.

Of a different nature, biting between conspecific pufferfishes, particularly around the flanks, belly and anus of the female, generally is attributed to breeding behaviour. First reported by Uno (1955) for *Fugu niphobles*, and since elaborated upon by other Japanese workers (see Honma *et al.* 1980), such behaviour apparently is widespread among marine and freshwater pufferfish species. Thus, Feigs (1955), Merckens (1958), Breder and Rosen (1966), and Chlupaty (1962) reported induction of spawning by biting in the African freshwater species *Tetraodon schoutedeni*, while Klausewitz (1957a, b), Hass (1959), Richter (1982), and Leipzig (1982) reported similarly for the south-east Asian freshwater species *Carinotetraodon somphongsi* (= *lorteti*). On the other hand, Roberts (1982) attributed bite marks on *Chonerhinus nefastus* to conspecific fin snipping as a food item and to agnostic behaviour rather than to breeding ritual.

Among marine pufferfishes, adult females of *Sphoeroides* (especially *S. maculatus*) often have belly scars (Shipp 1966), these being particularly numerous on individuals apparently in prime spawning condition. Similar marks on the deepwater species *S. pachygaster*, at first believed attributable to cephalopod suckers (Shipp 1974) are now thought to have resulted as well from spawning-related, conspecific biting (Robert L. Shipp, pers. comm.). Examination of museum holdings have disclosed bite scars, predominantly around the flanks and anus, which we believe also related to spawning behaviour, but present on both males and females in *S. testudineus, S. annulatus, Takifugu oblongus, Xenopterus naritus* (JS and JCT, pers. obs.) and several species of *Torquigener, Contusus* and *Tetractenos* (GSH, pers. obs.).

We conjecture that snout nudging on the flanks of female balistoids, ostracioids and diodontids during breeding behaviour (Clark 1950; Sakamoto and Suzuki 1978; Moyer 1979; Lobel and Johannes 1980; Kawabe 1984) may in fact be considered a behavioural precursor of flank biting in tetraodontids.

In this paper, reference is made to *Takifugu* in place of *Fugu*, upon the recommendation of K. Matsuura, pers. comm.

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Diagnosis of the *Lerista bipes* species-group (Lacertilia: Scincidae), with a description of a new species and an updated diagnosis of the genus

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Abstract

The *bipes* species-group of *Lerista* is diagnosed; its most significant feature is a reduction in the number of cervical vertebrae from eight to seven. A new species in the group is described as *L. praefrontalis;* it is unique in the group in having retained prefrontal scales and in having lost one phalange in the fourth toe of the pes. An updated key is provided for the *bipes* group. The genus *Lerista* is rediagnosed *vis-à-vis* the *Sphenomorphus* group of lygosomine skinks.

Introduction

The genus *Lerista* is a species-rich group of small to medium-sized sand-swimming, lygosomine skinks occurring in the arid and semi-arid areas of mainland Australia wherever there are sandy substrates. Forty-five species are known at present and many of these have only been described recently; presumably many more await discovery.

Within *Lerista,* there is a group of eight species that share a very distinctive morphology and are associated with areas of fine, loosely consolidated sand substrates – mainly dunes. The group has not been recognised before and the purpose of this paper is to diagnose this group and describe a new species in it. An existing, informal name, '*bipes* species-group', is used for the group, but it should be noted that its use here differs by being more restrictive than in previous usage (Storr 1972; Storr *et al.* 1981).

Lerista bipes species-group

Diagnosis

The *bipes* species-group differs from all other *Lerista (sensu* Greer 1967 and Storr 1972, 1976) in the following combination of derived *(vis-à-vis* other *Lerista)* character states: nasals slightly enlarged; frontoparietals fused to each other and to interparietal; preocular single; presuboculars absent; supraciliaries 0 + 2; primary temporal contacts parietal broadly.

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Snout region of skull constricted at premaxillary — maxillary suture; pre- and postfrontals meet above orbit.

Front limb reduced to basal nubbin of humerus, not visible externally; rear limb didactyl, phalanges reduced to 0.0.3.5.0 or less, metatarsals 1 and 2 absent; third distal tarsal fused to astragalus.

Venter lacks colour.

Presacral vertebrae $\geqslant$ 41; postsacral vertebrae $\leqslant$ 43; cervical vertebrae seven.

Sternal ribs two, from eighth and ninth vertebrae; mesosternum absent; complete inscriptional chevrons $\geqslant$ 8.

The reduction of the cervical vertebrae from eight to seven is especially significant in identifying the *bipes* group as monophyletic because it is not known to occur elsewhere in the family except in the African scincine lineage *Melanoseps — Typhlacontias — Scolecoseps — Feylinia,* in the African lygosomine *Eumecia,* and in the Australian lygosomine *Anomalopus brevicollis.*

Remarks

The following seven described species of *Lerista* show this combination of character states or states derived from them: *bipes* (Fischer, 1882); *greeri* Storr, 1982; *griffini* Storr, 1982; *ips* Storr, 1980; *labialis* Storr, 1972; *simillima* Storr, 1984b and *vermicularis* Storr, 1982. For identification aids for these species see Storr (1984b) and Storr *et al.* (1981).

The group occurs throughout arid and semi-arid Australia in areas of fine, loosely consolidated sand. The group's centre of abundance is in north-western Australia.

The relationships of the *bipes* group as conceived here are unclear. Previously, members of this group have been allied with the species *connivens, humphriesi, nichollsi, onsloviana, praepedita* and *uniduo* (Storr, 1972, 1984a; Storr *et al.,* 1981). However, the derived character states recognised to date for this expanded group ('no fore-legs and never more than two toes; snout flat and very protrusive' — Storr *et al.* 1981) are neither extensive nor unusual and even an expanded comprehensive diagnosis such as that given above for the *bipes* group would only consist of modifications common in many sand-swimming lineages; there are no unique or unusual character states such as the reduced number of cervical vertebrae which diagnoses the *bipes* group *(sensu stricto).* This extended concept of the *bipes* group, therefore, may well represent a polyphyletic assemblage of sand-swimmers.

Among the species previously associated with the *bipes* group *(sensu stricto),* four share an unusual character which may be indicative of their close relationship: *connivens, nichollsi, onsloviana* and *uniduo* all have very loosely attached scales. These 'tear-away scales', which may be a predator-escape device, occur otherwise in skinks only in a few *Ctenotus.* Recently Storr (1984a) recognised these *Lerista* species as the *nichollsi* group but the diagnosis comprised only primitive character states (possession of prefrontals and a forelimb groove).

Perhaps tear-away scales are more indicative of the monophyly of the *nichollsi* complex. The wider relationships of this group, like those of the *bipes* group, remain to be discovered.

Lerista praefrontalis sp. nov.

Figures 1 and 2

Holotype

Western Australian Museum R 80580: King Hall Island, WA; 16°05′S, 123°25′E; Fisheries and Wildlife Department expedition; 27 June 1982; 'in litter among sand at base of cliff'.

Diagnosis

Differs from all other members of the *bipes* species group *(sensu stricto)* in each of the following characters: prefrontals distinct, and phalanges of fourth toe of pcs four instead of five.

Description

Snout depressed and projecting, lower jaw countersunk; rostral scale crescentic anteriorly and trilobed posteriorly with medial lobe attaining level of nostril and narrowing contacting frontonasal, and two lateral lobes almost reaching level of posterior edge of nasal; supranasals absent; frontonasal trapezoidal, slightly wider than long, smoothly rounded on posterior lobe; prefrontals present, separated, each divided obliquely; frontal longer than wide, broadly and smoothly rounded posteriorly; supraoculars three, first two on each side contacting frontal, first one reaching orbit; frontoparietals and interparietal fused into a single scale with a clear area just posterior of centre through which parietal eye is evident; parietals meeting behind fused frontoparietal-interparietal; pairs of transversely enlarged nuchals two.

Nasal shaped like bishop's hat, with medial apex tilted forward and nostril just behind anterior suture at level of 'hat's' bulge; loreals two, posterior fused to single preocular; supraciliaries two, first projecting medially between second and third supraoculars; suboculars represented by only two postsuboculars; postocular single; lower eyelid movable with clear window; primary temporal single, large, in broad contact with parietal; secondary temporals two, upper much larger than and overlapped by lower; supralabials five, third subocular; postsupralabial single; external ear opening very small.

Mental with little dorsal upturning; infralabials five; postmental single, in contact with first two infralabials on each side; enlarged pairs of chin scales three, members of first two pairs separated by one scale row, members of third pair by three scale rows.

Longitudinal scale rows at midbody 20; paravertebral scales 99; subdigital lamellae of largest (fourth primitively) toe 8-9.
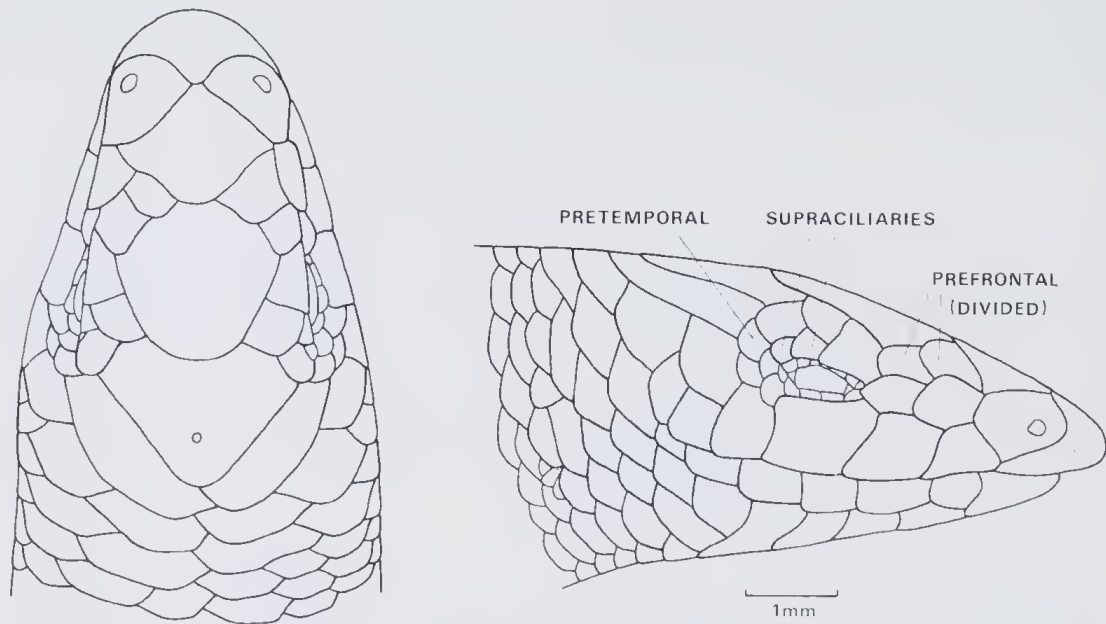
Figure 1   Head of the holotype of *Lerista praefrontalis* (WAM R 80580).

Figure 2   Photograph of the holotype of *Lerista praefrontalis* (WAM R 80580).

Snout-vent length 67 mm; no external trace of front limbs; rear limbs didactyl, 11.9 per cent of SVL; tail 58 mm, 16 mm of which is regenerated.

Colour in preservative sandy beige above with a dark brown lateral stripe extending from canthus to base of tail and a row of dark brown dashes running through centre of each paravertebral row from neck on to base of tail; opalescent below dark lateral stripe.

Presacral vertebrae 45; sternal ribs two; complete inscriptional chevrons 10; phalangeal formula of pes: 0.0.3.4.0/0.0.2.4.0 (i.e. bilaterally asymmetric).

Distribution

Only known from a single specimen from King Hall Island in the Kimberley of Western Australia.

Figure 3   Map showing the distribution of *Lerista praefrontalis* (dark triangle).

Etymology

The species name derives from the unique retention of the prefrontals within the *bipes* species-group.

Key to the species of the *Lerista bipes* species-group

1 Prefrontals present, distinct .... *praefrontalis*
 Prefrontals fused to loreal or absent 2

2 Supralabials six, fourth subocular 3
 Supralabials five, third subocular 5

3 Supraoculars three 4
 Supraoculars two 7

4 Supraciliaries present .... *greeri*
 Supraciliaries absent .... *ips*[1]

5 Preocular distinct .... *bipes*
 Preocular fused to posterior loreal 6

6 Supraoculars three, first two contact frontal; supraciliaries
 present; lower secondary temporal present .... *griffini*
 Supraoculars two, first only contacts frontal; supraciliaries
 absent; lower secondary temporal absent .... *vermicularis*

7 Two supraoculars contact frontal .... *simillima*
 One supraocular contacts frontal .... *labialis*

Diagnosis of the genus *Lerista*

Recent morphological surveys of the species of *Lerista* using x-rays and cleared and double-stained specimens, plus a better understanding of character state polarities in skinks in general, permits a more comprehensive diagnosis of *Lerista* than available previously (Greer 1967, Storr 1972 and 1976).

The genus *Lerista* is a member of the *Sphenomorphus* group *(sensu* Greer 1979) of lygosomine skinks *(sensu* Greer 1986) but differs from all other members of that group in the following combination of derived character states: prefrontals separated; lower eyelid with clear window; lower secondary temporal overlaps upper; external ear opening small, without projections.

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[1] I interpret Storr's (1980) single supraciliary in *ips* as the third supraocular; compare this scale in *ips* with the scale of similar size and position in *labialis* which Storr (1972) calls a supraocular.

Premaxillary teeth ≤ 7; postorbital absent; vomers fused; pterygoid teeth absent; palatal rami of pterygoids squared off, in medial contact; process from ectopterygoids excluding palatal rami of pterygoid from infraorbital vacuity.

Presacral vertebrae ≥ 31.

Visceral fat bodies absent; parietal peritoneum lacking pigment.

For a list of included species see Cogger *et al.* (1983) and Storr (1984a-b, 1985).

Acknowledgements

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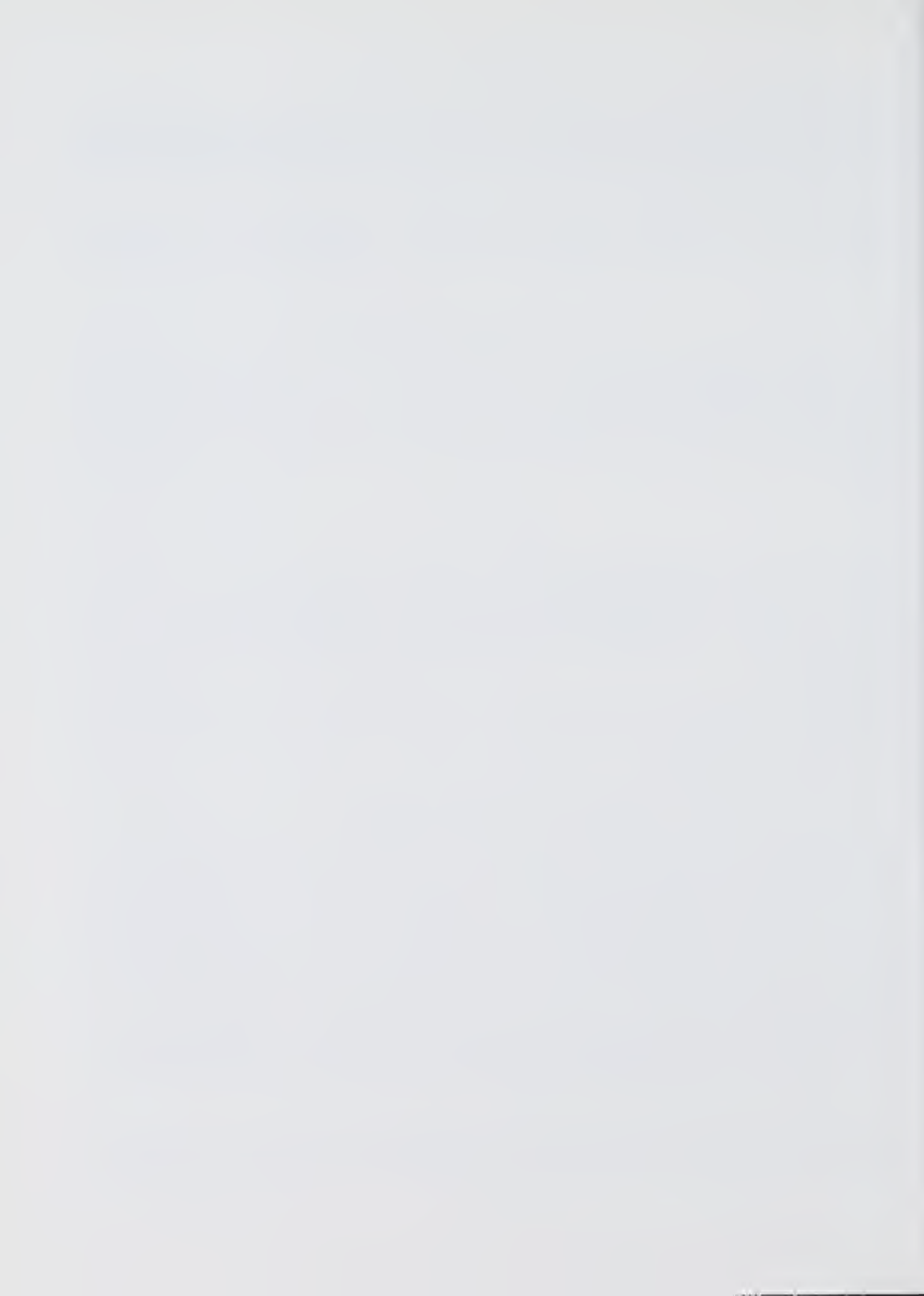
A new species of *Gastrosaccus* (Mysidacea) from Western Australia

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Abstract

A new species of *Gastrosaccus* (Crustacea, Mysidacea) from Western Australia is described and illustrated. *Gastrosaccus sorrentoensis* sp. nov. is readily character-ised by the fringe of filaments on the posterodorsal edge of the carapace and the prominent spinous process on the posterodorsal edge of the fifth abdominal somite. *Gastrosaccus spinifer* (Goes, 1864) is the only other member of the genus possessing both these characteristics, but in *G. sorrentoensis* the fringe of filaments extends around the entire border of the carapace emargination. Other morphological features separating the two species are noted.

Introduction

In a recent review on the biology of mysids, Mauchline (1980) commented on the general paucity of information on distributions in southern latitudes and noted that many new species probably remained to be described. This was de-monstrated by Băcescu and Udrescu (1982) who recorded eight species in samples collected from coastal waters of Queensland and New South Wales, Australia, five of which were new to science.

Recent work by the second author (McLachlan and Hesp 1985) on sandy beaches near Perth in Western Australia has revealed a further undescribed species. It was collected in large numbers in the surf zone of Sorrento beach using a hand net in water of about 1 m depth.

Systematics

Gastrosaccus sorrentoensis sp. nov.

Figures 1-4

Holotype
WAM 343-86. Adult male collected November 1983 off Sorrento Beach near Perth by A.M. Length 9.3 mm.

Paratypes
WAM 344-86. Males and females. Collection data as for holotype.

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Diagnosis

The only Australian species of *Gastrosaccus* with a fringe of spine-like filaments extending around the posterodorsal edge of the carapace and with a prominent spinous process on the posterodorsal edge of the fifth abdominal somite. The only other member of the genus possessing both these characteristics is *G. spinifer,* but in *G. sorrentoensis* the fringe of filaments extends around the entire border of the carapace emargination. (See Table 1 for summary of features distinguishing these two species and comments under Remarks.)

Description

The morphological characteristics described below refer to both sexes, unless otherwise stated.

Total length of adult females 8.5-11.3 mm (20 specimens); adult males, 7.0-9.3 mm (20 specimens). Carapace short, leaving last thoracic somites exposed in dorsal view. Anterior margin of carapace produced into blunt rostrum between bases of eyestalks (Figure 1A). Posterior dorsal margin of carapace deeply emarginate, each side of emargination split with posterior margin overlapping the anterior. Emarginated border fringed with many slender spine-like filaments; these number about 25 along edge of carapace between lobes (Figure 1A). Further fringe of smaller filaments posterior to each lobe which decrease progressively in size away from the split. Towards extremity of carapace fringe represented by small undulations only. In lateral view carapace extends posteriorly to cover whole of thorax.

Abdominal somites almost cylindrical with no marked indication of lateral compression and without ridge or keel along mid-dorsal line of any somites. Fifth somite bears a prominent spinous process on posterodorsal edge (Figure 1B). Antennule (Figure 1C), first segment of peduncle equal in length to second and third combined, second with two strong spines set obliquely across outer lateral margin. Third segment bears a finger-shaped process on dorsal side near origin of outer flagellum. This flagellum swollen at the base and in the female, fringed with a row of setae. In the male this lobe extremely hirsute.

Antennal scale (Figure 1D) slightly more than three times as long as broad and almost reaching anterior edge of second segment of its peduncle. Lateral margins of scale straight, outer edge terminating in strong spine which does not extend beyond rounded apex. Inner margin bears *c.* 20 plumose setae. Setation of peduncle as shown (Figure 1D).

Mandible (Figure 1E) with three-segmented palp, proximal segment short and without setae. The second and third segments bear spinous setae as illustrated. Distal end of last segment with a comb-like process.

Maxillule (Figure 1F) bearing three long and two shorter spines on lobe of first segment. Shorter spines armed with spinules along entire length; longer

spines bear spinules in distal half only. Basal endites with *c.* 18 stout and serrate spines.

Maxilla (Figure 2A) similar in form to that of other members of genus with exopodite bearing 13 plumose setae along outer border. Terminal segment of endopod spinose along inner and distal margins. Palp, coxal and basal endites heavily spinose as illustrated.

Endopod of first thoracic limb (Figure 2B) short and densely setose, particularly along inner lateral margin. First exopod segment expanded, outer distal angle without a tooth. Remaining 13 segments bear one or two long plumose setae. Second thoracic limb similar in structure although endopod is larger and setation appears less dense. First exopod segment with small tooth on outer distal angle.

Third to eighth thoracic limbs similar in form, carpus and propodus of endopods fused and divided into subsegments. Number of subsegments varies between 14 and 16 in the eighth pair (Figure 2C) and decreases progressively in the more anterior limbs. In third pair there are *c.* eight subsegments. Each subsegment bears a brush of small setae and two small spines. No nail on terminal segment. First exopod segment of third to eighth thoracic appendages expanded and armed with small tooth on outer distal corner on all except the eighth pair. Exopod flagella with 14 to 16 segments, each segment with two long, plumose setae.

First pleopod of female (Figure 3A) with long slender sympod, armed proximally with one plumose seta and distally with six spinose setae. Exopod about three times as long as broad, bearing three spine-like setae and two small plumose setae distally. Lateral margins fringed with five or six plumose setae. Endopod nearly four times as long as its mid-width, tapering distally and bearing row of five spinose setae. Second pleopod of female (Figure 3B) in form of an unjointed plate, five times as long as wide. Margins of distal half armed with nine spinose setae and *c.* five plumose setae which vary in length. Remaining pleopods of female small and similar in form to second pair.

Male first pleopod (Figure 3C) with swollen sympod, outer margin fringed with 11 plumose setae. Endopod small and un-segmented, bearing three spine-like setae at distal end. Remaining setation as shown. Exopod 10-segmented, each segment bearing two long plumose setae.

Second male pleopod (Figure 3D) with rectangular sympod. Endopod nine-segmented, slightly shorter than sympod and bearing well developed pseudo-branchial lobe on first segment. Lobe bearing eight setae as shown. Remaining endopod segments each with two setae. Exopod more robust, 10-segmented and longer than endopod. Setae on outer margin longer than those along inner border. Outer setae on segments two to five are distinctly thicker proximally, their profiles irregular in form along the thickened part.

Endopod of third male pleopod (Figure 3E) nine-segmented and as long as rectangular sympod. Pseudobranchial lobe on first segment, setation as shown. Exopod eight-segmented, slightly more than three times length of endopod.
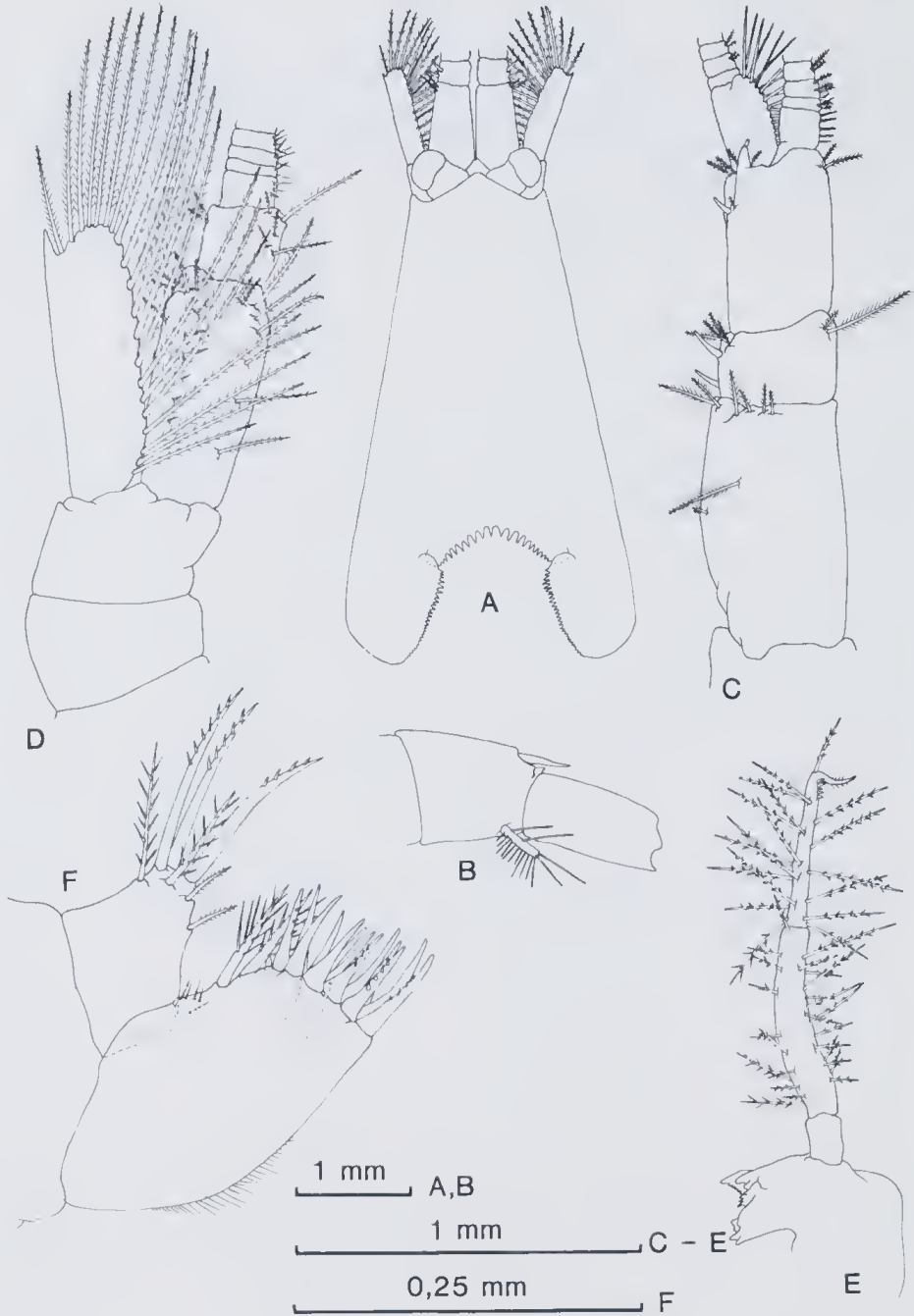
Figure 1   *Gastrosaccus sorrentoensis* sp. nov. A. Carapace in dorsal view. B. Fifth abdominal somite in lateral view. C. Female antennule. D. Antennal peduncle and scale. E. Mandible. F. Maxillule.
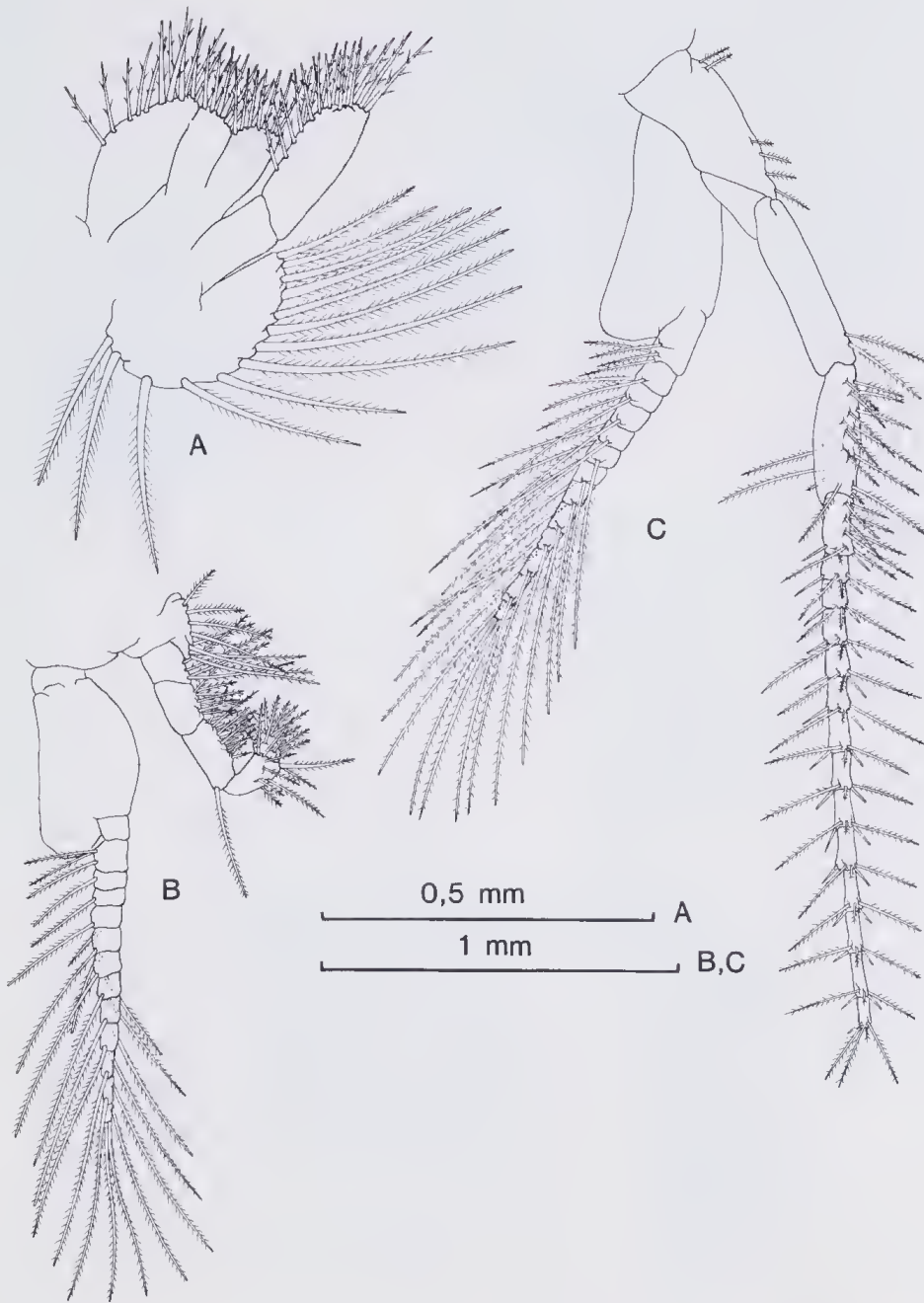
Figure 2   *Gastrosaccus sorrentoensis* sp. nov. A. Maxilla. B. First thoracic appendage. C. Eighth thoraci appendage.
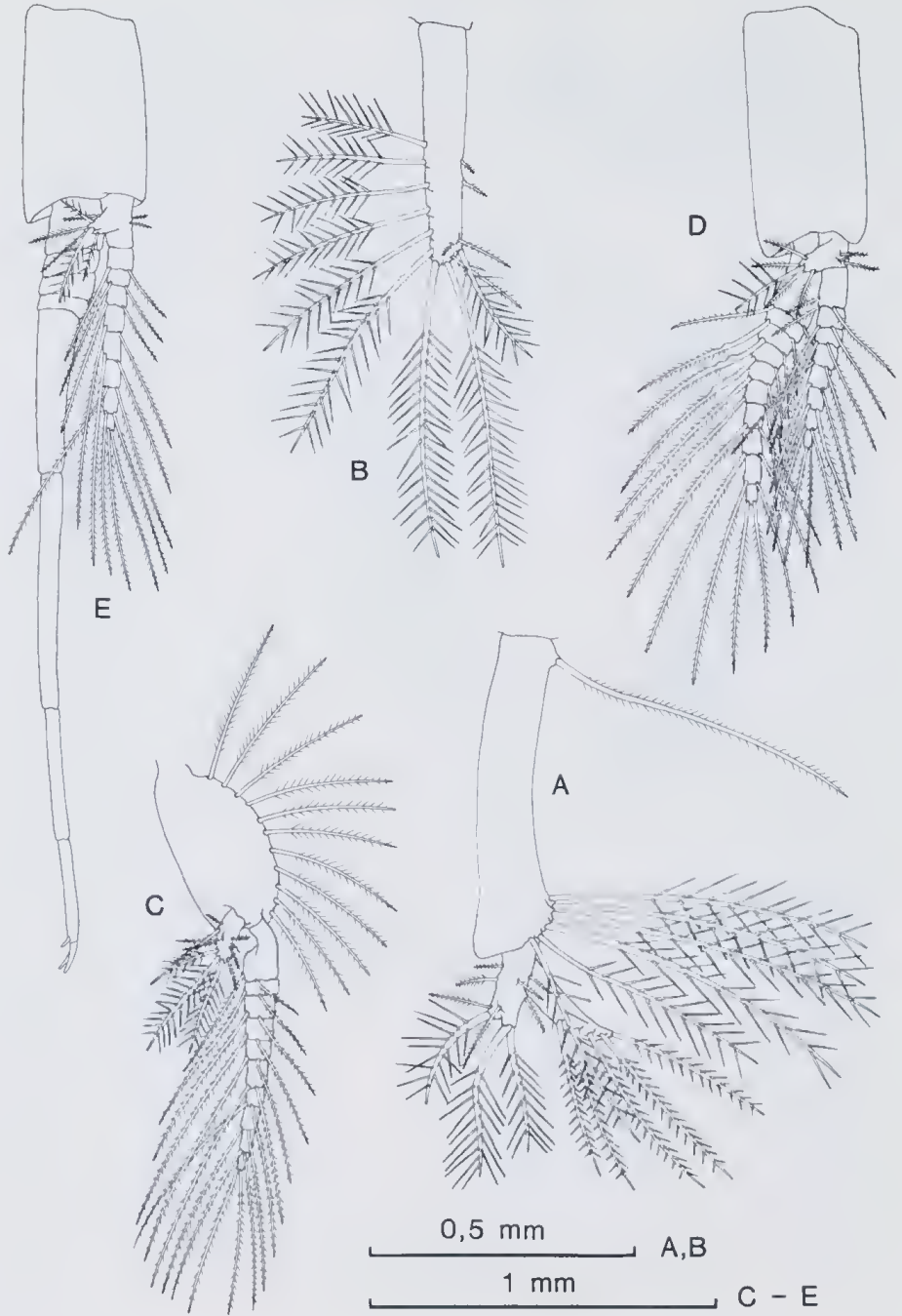
Figure 3   *Gastrosaccus sorrentoensis* sp. nov. A. First pleopod of female. B. Second pleopod of female. C. First pleopod of male. D. Second pleopod of male. E. Third pleopod of male.

First four segments extend to midlength of the endopod. Fifth segment shorter than sixth which is equal to combined length of remaining segments. Apex armed with two strong claws and a smaller spine sub-terminally.

Uropod (Figure 4A) extending beyond telson, exopod subequal in length to endopod and bearing 14 robust spines which are finely plumose along posterior margin. Apex of these spines with short, curved protrusion. Endopod tapering distally, inner border armed with five or six spines irregularly spaced among the setae, first located opposite edge of statocyst. Two groups of *c.* four and eight small setae near base and on inner and outer edge of endopod respectively.

Telson (Figure 4B) two and a half times as long as basal width. Margins armed with seven and occasionally eight strong spines on either side. Terminal spines markedly longer than others. Cleft one-sixth length of telson and armed with 15 to 18 small graduated spines on either side. In females a small pigment spot opposite each of the fifth lateral spines. A single robust spine on median antero-ventral line of telson (Figure 4C).

1 mm
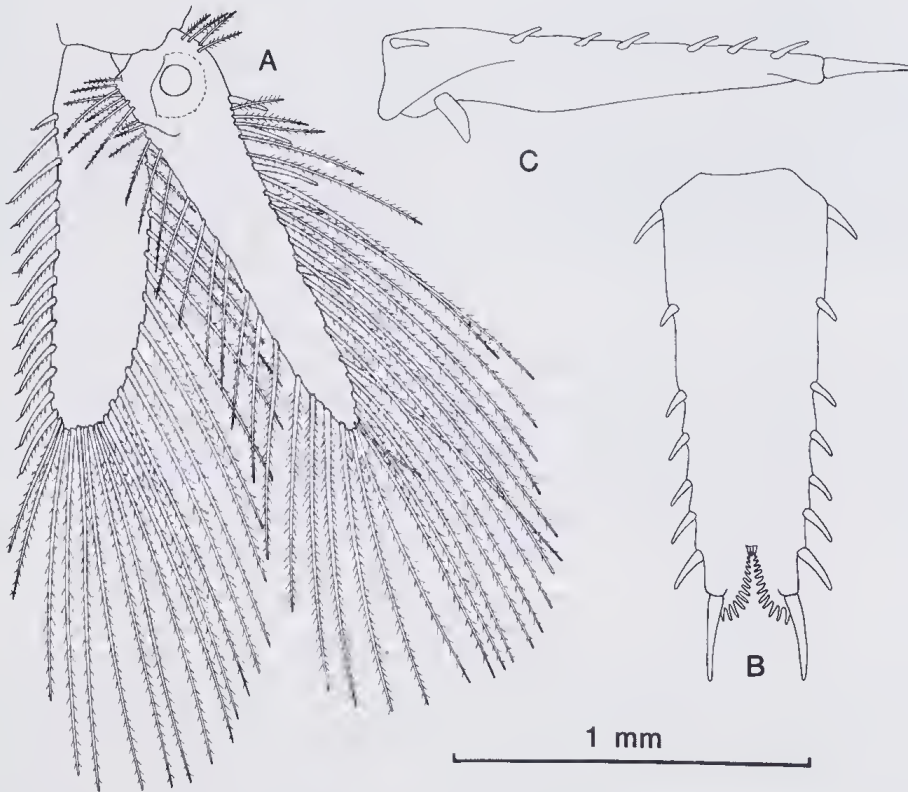
Figure 4   *Gastrosaccus sorrentoensis* sp. nov. A. Uropod. B. Telson in dorsal view. C. Telson in lateral view.

Remarks

The genus *Gastrosaccus* from Australian waters is currently represented by seven species, four of these being endemic to the continent. Those with a wider geographical range are *G. australis* W. Tattersall, 1923 which has been recorded from Spirits Bay, New Zealand (Tattersall 1923); *G. indicus* Hansen, 1910 recorded from the East Indian Archipelago, the north-east of Madagascar, the coasts of India, the Philippine Islands, Java and Port Stephens in New South Wales (Tattersall 1940, Ii 1964); *G. bengalensis* Hansen, 1910 (synonymous with *G. philippinensis* [Ii 1964, Pillai 1972]) from the Bay of Bengal, the Andaman Islands, between Ceylon and New Guinea, off Formosa, Taiwan and from Moreton Bay in Queensland (Băcescu and Udrescu 1982).

Gastrosaccus dakani W. Tattersall, 1940 is known from Australian waters only and was originally recorded from Lake Illawarra and from the estuary of the Brisbane river (Hodge 1963). Descriptions of *G. daviei, G. brisbanensis* and *G. queenslandiensis* were published only recently (Băcescu and Udrescu 1982),

Table 1   Summary of the morphological characteristics which separate *G. spinifer* (from Tattersall and Tattersall, 1951) and *G. sorrentoensis* sp. nov.

Gastrosaccus spinifer	*Gastrosaccus sorrentoensis*
Eight or nine spine-like filaments along posterodorsal edge of carapace. No filaments posterior to overlapping lobes on either side of emargination.	Spine-like filaments anterior to overlapping lobes on either side of emargination are closely set and number about 25. Posterior to lobes a further 50 smaller filaments or undulations on either side. These decrease progressively in size posteriorly.
Marked lateral compression of fourth and fifth abdominal somites.	No marked lateral compression of fourth and fifth abdominal somites.
Longitudinal keel along mid-dorsal line of fourth and fifth abdominal somites.	No keel along mid-dorsal line of fourth and fifth abdominal somites.
Three spines on outer margin of second segment of antennular peduncle.	Two spines on outer margin of second segment of antennular peduncle.
Inner margin of endopod of uropod armed with about 10 long slender spines.	Inner margin of endopod of uropod armed with five or six spines.
Spines arming outer margin of exopod of uropod set in distal two-thirds of segment.	Spines arming outer margin of exopod of uropod set along entire length of segment.
Terminal spines of telson not markedly longer than others. Cleft more than one-quarter length of telson.	Terminal spines of telson markedly longer than others. Cleft one-sixth length of telson.

while Dexter (1984) recorded an undescribed species of *Gastrosaccus* from the eastern regions of the continent. Future research will undoubtedly reveal further new species as well as wider geographical ranges.

Gastrosaccus sorrentoensis is the first recorded member of the genus from Western Australia and shows distinct characteristics which separate it from other Gastrosaccinae. Of particular significance is the fringe of filaments along the posterodorsal edge of the carapace and the spine located on the fifth abdominal somite. No other species of *Gastrosaccus* currently known from Australia possesses this fringe, although *G. brisbanensis* has the spine on the fifth abdominal somite. Of the remaining 36 species known worldwide (Mauchline and Murano 1977, Wooldridge 1978, Băcescu and Udrescu 1982, Wooldridge and McLachlan 1986), only four have the fringe of filaments – *G. muticus* W. Tattersall, 1915, *G. simulans* W. Tattersall, 1915, *G. spinifer* (Göes, 1864) and *G. namibensis* Wooldridge and McLachlan, 1986. *G. spinifer* is the only one with both a fringe and a spine on the fifth segment of the abdomen, although this spine is apparent in immature *G. simulans* (Tattersall, 1915). The former species is widespread in waters around Britain and Europe, and more recently, from West Africa (Tattersall and Tattersall 1951).

Finally, the prominent spine present on the anteroventral surface of the telson should be noted. No reference to this spine could be found in the literature for other members of the genus, although observations have shown it to be present in *Gastrosaccus psammodytes* O. Tattersall, 1958, a mysid common along sandy beaches in South Africa (Brown and Talbot 1972; Wooldridge 1983). It is possible that the presence of this spine has been overlooked by many authors and that it is not unique to *G. sorrentoensis* and *G. psammodytes*.

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First record of *Sminthopsis psammophila* (Marsupialia: Dasyuridae) from Western Australia

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Abstract

Five specimens, one female and four males, of *Sminthopsis psammophila* Spencer, 1895 were caught at a site in the south-western corner of the Great Victoria Desert (29°58′S, 123°38′E). This discovery considerably increases the known modern range of the species. Previously only five *S. psammophila* have been collected; a single specimen from south-western Northern Territory and four from southern South Australia. The Western Australian animals differ significantly in some skull and external characters from the previous specimens. The habitat of the animals is compared with previous descriptions.

Introduction

Five specimens of *Sminthopsis psammophila* Spencer, 1895 were collected in the Great Victoria Desert within 15 km of 29°58′S, 123°38′E from 19 June to 2 July 1985. Four were caught in drift line pit traps of 160 x 550 mm PVC pipe and one was caught in an Elliott trap (after Biological Surveys Committee 1984). The specimens are lodged in the Western Australian Museum.

Five specimens of this species have previously been collected; one from Lake Amadeus (south-western Northern Territory) in 1895, and four from two sites on the Eyre Peninsula (southern South Australia) in 1969. These specimens have been discussed by Aitken (1971) and Archer (1981). Archer also discusses material from owl deposits of unknown age collected from Ayers Rock, which is near Lake Amadeus.

The new specimens have been examined and compared with published descriptions of the previous specimens.

The specimens

Skull and external measurements (as for Aitken *op. cit.*) are given in Table 1. We are able to compare 23 skull measurements in the four Western Australian males with those of the two males described by Aitken *(op. cit.)*. Nineteen of

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the measurements are shorter in the Western Australian animals but only 10 are significantly different (t-test, $p < 0.05$). We are able to compare the whole body measurements of the four Western Australian males with three males from Aitken *(op. cit.)*. The body and tail lengths of the Western Australian males are shorter and the foot and ear lengths are longer, but only body and ear length are significantly different ($p < 0.01$, $p < 0.05$, respectively).

The Western Australian specimens agree with the description of skull and teeth given by Archer (1981).

The colour and external morphology of the Western Australian specimens agree with those in Aitken (1971) except as follows (colours follow Ridgway [1912]):

Character	Aitken's specimens	Western Australian specimens
Dorsal hairs	Medium 3 mm drab grey	Tilleul buff
Dorsal spines	Basal 8 mm dark mouse grey, thickened apical 10 mm fuscous black	Lengths reversed
Dorsal fur	Drab, brindled	Chaetura drab to hair brown, brindled
Ear	An antero-external patch of fuscous black bristles	Bristles black in one male, white with black tips in other specimens
External inter-digital pad on hind foot	Horseshoe-shaped	Two parallel lobed, one considerably larger
Dorsal tail colour	Brindled, drab-grey with vinaceous buff toning	Vinaceous buff speckled fuscous black, not brindled
Terminal crest of tail	Hairs fuscous black, drab grey with fuscous black tips, or vinaceous buff with fuscous black tips	Similar, or wholly vinaceous buff. The dorsal and ventral hairs are dissimilar in four specimens
Mystacial vibrissae	Black	Black dorsally and posteriorly. White ventrally and anteriorly
Facial vibrissae	Two, black	Two groups. A dorsal pair which are dark brown but variable. A ventral set of two, three or four; variable in colour but typically one brown and the others white.

Table 1 Skull and whole body measurements (mm) and weights (g) of *Sminthopsis psammophila* from Western Australia.

Specimen no.	Animals				
	M23226	M23230	M23228	M23229	M23227
Sex	♀	♂	♂	♂	♂
Parameter					
Greatest length of skull (from tip of pre-maxilla)	31.7	33.5	32.5	34.2	32.0
Basilar length	28.1	30.3	29.1	30.6	29.4
Zygomatic breadth	16.5	18.6	17.1	17.7	18.8
Cranial breadth	13.1	14.0	13.0	13.6	13.6
Least interorbital constriction	6.3	6.6	6.0	6.5	6.4
Rostral breadth	4.2	4.5	4.2	4.5	4.2
Greatest width across upper molars	10.1	10.7	10.2	10.6	10.3
Depth of cranium	11.9	12.6	11.6	12.1	12.1
Palatilar length (inc. spine)	17.7	18.6	19.0	19.1	18.3
Greatest breadth of alisphenoid bulla	4.7	4.8	4.6	4.9	4.8
Length of incisive foramen	-	4.1	4.1	3.8	4.0
Length of anterior palatine foramen	3.9	3.8	4.1	3.8	4.3
Length of posterior palatine foramen	1.3	1.5	1.4	1.1	1.1
Width of posterior palatine foramen	1.6	1.6	1.6	1.6	1.5
Length of nasals	13.1	13.4	13.5	14.0	13.1
Greatest width of nasals	2.5	3.1	2.2	2.2	2.4
Dorsal length of pre-maxilla	8.6	8.2	8.1	9.0	8.7
Length of mandible (exc. teeth)	24.4	25.9	24.7	25.7	24.9
Crown length of I^1	0.6	0.6	0.6	0.6	0.6
Crown length of I^{2-4} (inc.)	2.0	1.85	1.9	1.95	1.9
Crown lengths of P 1/1	1.5/1.5	1.35/1.4	1.4/1.45	1.3/1.25	1.4/1.4
P 3/3	1.6/1.8	1.6/1.65	1.6/1.7	1.6/1.6	1.6/1.55
P 4/4	1.7/1.5	1.8/1.5	1.7/1.4	1.8/1.5	1.7/1.45
Crown heights of P 1/1	1.15/1.1	1.3/1.3	1.1/1.2	1.2/1.1	1.25/1.2
P 3/3	1.3/1.4	1.5/1.3	1.3/1.4	1.25/1.4	1.4/1.4
P 4/4	1.6/1.3	1.9/1.3	1.7/1.35	1.6/1.35	1.9/1.55
Crown length of M^{1-3} (inc.)	6.2	6.0	6.0	6.1	6.0
Crown length of M^{1-4} (inc.)	6.85	6.85	6.9	6.9	6.85
Body length	85	93	97	100	99
Tail length	107	114	120	118	110
Length of hind foot (inc. claw)	25.5	26.5	27	26.5	25
Length of ear (from notch)	25	26.5	28	28	28.5
Weight	25.7	32.7	26	35.0	29.8

The single Western Australian female is in good condition, nulliparous and non-pregnant. The nipples are in two opposed semicircles of four each side, narrowly separated, so that the eight nipples almost form a circle.

The five Western Australian specimens appear to be adult; they all had fully erupted dentition and slight to moderate tooth wear.

The anterior half of the external skin of the ear is black in the Western Australian animals and forms a broad stripe.

Habitat

The area where the Western Australian animals were caught is a mosaic of woodland of *Eucalyptus gongylocarpa* and mallee, both over spinifex *(Triodia basedowii)* and some shrubs. Smaller areas of other vegetation units are present throughout the area. The soils are deep sand (mostly yellow but with some red) and small areas of heavier earths. The landscape is flat to gently undulating with some sand ridges. The ridges are generally low but there are occasional large, well-defined sand dunes.

The five animals were caught at four sites as follows:

1. (29°53'20"S, 123°35'00"E) Two animals were caught in a small area (a few hectares) of low *Melaleuca uncinata* shrubland. The shrubs were up to 2.5 m tall and had a projected foliage cover of greater than 30 per cent. *Triodia basedowii* was present but represented only about 1 per cent cover. Also present were scattered emergent mallees (5-7 m) and *Acacia colletioides* (to 1.5 m). The soil was a deep yellow-red sand. No sand ridges were nearby.

2. (29°53'40"S, 123°30'30"E) One animal was caught in *Eucalyptus gongylocarpa* woodland. The trees were up to 6 m tall with odd individuals to 15 m, and gave about 1 per cent cover. *Triodia basedowii* gave less than 30 per cent cover. Mallees gave 10-30 per cent cover. *Acacia* spp. and other shrubs were also present. The soil was deep yellow sand. A low sand ridge was adjacent.

3. (29°55'30"S, 123°31'40"E) One animal was caught in an open mallee of *Eucalyptus leptophylla* and *E. concinna*. The mallees were 2-4 m high and gave less than 10 per cent cover. *Triodia basedowii* gave about 20 per cent cover. *Melaleuca uncinata* and other shrubs were present but scattered. The soil was deep yellow sand. A low sand ridge was adjacent.

4. (30°01'20"S, 123°46'10"E) One animal was caught in a mallee of *Eucalyptus leptophylla*. The mallee was 2.5-3 m tall and had a cover of 10-30 per cent. *Triodia basedowii* gave a cover of 30 per cent. *Acacia* spp. and other shrubs were present but scattered except for *Acacia jutsonii* which gave 10-30 per cent cover. The soil was deep yellow sand. No sand ridges were nearby.

All these trapsites had about 50 per cent bare ground.

Two trapsites were placed on well-defined sand dunes and two on small areas of heavier soils, but no *S. psammophila* were caught there.

The vegetation was in poor condition with few species flowering, but small mammals appeared to be present in large numbers. Two factors may be relevant. The area had not been burnt for at least eight years. There are no complete weather records in the general area, but from an examination of incomplete and unofficial figures collected by the Bureau of Meteorology (Perth) there has been at least one major summer rainfall in each of the three preceding summers. While these recorded rainfalls are not exceptionally high they do indicate that the total annual rainfall has at least been moderate for the three years preceding these captures.

The spinifex was in small clumps, on average, about 30 cm high.

Discussion

The discovery of *S. psammophila* in Western Australia considerably increases the known range of the species.

The quantitative results for the skull and whole body measurements show that the Western Australian animals are smaller than other specimens in most measurements. The Western Australian specimens are significantly larger only in ear length. Aitken (1971) gives a cranial depth of at least 12 mm as 'diagnostic' but in the Western Australian animals the range is 11.6 to 12.6 mm and the mean is only 12.1 mm. The length of the upper molars does not overlap between the Western Australian and other specimens, regardless of age or sex. Our specimens and those of Aitken (1971) suggest that females are slightly smaller than males but there are insufficient data to analyse this. Archer (1971) thought that the Northern Territory specimen was smaller than the South Australian specimens and speculated on a wet-dry cline, but from Aitken's measurements the Northern Territory specimen is smaller only in body length. It easily exceeds all of the Western Australian specimens in body length.

The three known localities of *S. psammophila* are approximately 1000 km from each other and the differences reported here in colour and surface anatomy cannot be assessed.

The habitat of the Western Australian *S. psammophila* is sandy country but not restricted to sand ridges. They were caught in woodland, mallee and shrubland, with spinifex present in all cases.

Aitken (1971, 1983) has described the habitat of previous captures. In both cases the habitat was sand ridge country with spinifex, with interdunal vegetation of scattered Desert Oak groves in the Northern Territory and mallee/*Melaleuca uncinata* open scrub in South Australia.

The habitat of the Western Australian specimens agrees well with that described by Aitken, except that sandy soil rather than sand ridges would appear

to be sufficient, and the range of vegetation types is now woodland, mallee, shrubland and spinifex, but with spinifex present in all cases.

The conservation status of *S. psammophila* is uncertain. Potentially suitable habitat is widespread, but there has been very little animal trapping in the Great Victoria Desert (Burbidge *et al.* 1976, McKenzie and Burbidge 1979, Morris and Rice 1981) and the results are inadequate to describe the distribution or abundance of the species in Western Australia.

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A new species of *Lerista* (Lacertilia: Scincidae) with two subspecies from central Australia

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Abstract

A new species, *Lerista aericeps*, closely related to the Western Australian species *L. separanda* and *L. xanthura*, is described from the Northern Territory and south-western Queensland. It is divided into two subspecies.

Introduction

Over the last few years Alice Springs herpetologists have collected several specimens of two *Lerista* related to the western species *L. separanda* and *L. xanthura* (both of Storr 1976). Believing them to be new, M.W. Gillam and his colleagues in the Conservation Commission of the Northern Territory sent me live and preserved specimens for description (catalogue numbers prefixed with CAWC). Also examined were two specimens in the Western Australian Museum (WAM), and three from the Queensland Museum (QM) loaned by J. Covacevich.

Systematics

Lerista aericeps aericeps sp. et subsp. nov.

Figure 1

Holotype

R1565 in Central Australian Wildlife Collection, Alice Springs, collected by A. Kerle at 25 km S Alice Springs, Northern Territory, on 5 November 1985.

Paratypes

Northern Territory

71 km W Barry Caves (WAM R55381-2); Kurundi Station in 20°37'S, 134°50'E (CAWC R1140); 27 km N Alice Springs (CAWC R1573); Ewaninga (CAWC R50); Andado (CAWC R379).

Queensland

Cluny (QM J34137); Durrie (QM J39572); Cuddapan (QM J26502).

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Diagnosis

A small slender *Lerista* with four fingers, four toes and immovable eyelid (a large transparent disc), distinguishable from *L. separanda* and *L. xanthura* by its coppery head, faintly spotted back and tail, and single preocular (rather than two). Further distinguishable from *L. separanda* by its yellow (rather than red) tail and five (rather than four) supraciliaries. Distinguishable from *L. aericeps taeniata* by lack of dark upper lateral stripe.

Description

Snout-vent length (mm): 34-49 (N 10, mean 40.4). Length of tail (% SVL): 118-133 (N 3, mean 125.3).

Nasals in short contact or narrowly separated. Prefrontals widely separated. Frontoparietals in short to long contact, usually a little smaller than interparietal. Nuchals 1-4 (N 10, mean 2.3). Supraoculars 3, first two in contact with frontal. Supraciliaries 5, second and fifth smallest. Loreals 2, first much the larger. Preocular much smaller than second loreal (absent in one specimen). One presubocular. Temporals 3. Upper labials 6. Midbody scale rows 18. Lamellae under longest toe 13-15 (N 10, mean 14.2), each finely keeled.

Coloration of holotype in life. Head coppery red. Back pale greyish brown, tinged with copper and olive, scales finely dark-edged and faintly flecked with

Figure 1   Holotype of *Lerista aericeps aericeps,* photographed in life by R.E. Johnstone.

dark brown. Tail (regenerated) yellowish brown with coppery tinge. Upper lateral stripe represented by dark dots on body and by a diffuse blackish-brown stripe from orbit through lore to side of rostral. Legs pale greyish brown, faintly smudged with dark greyish brown. Lower surface whitish, scales finely dark-edged.

Most paratypes darker than holotype and more heavily spotted (including top of head and side of body). Some have upper labials barred and ventrals more widely dark-edged.

Distribution

Arid eastern interior of Northern Territory, north nearly to Barkly Tableland, and arid south-western Queensland. See map, Figure 2.

Figure 2   Map of Northern Territory and western Queensland, showing location of specimens of *Lerista a. aericeps* (spots) and *L. a. taeniata* (circles).

Derivation of name

From Latin *aes* (copper) and *ceps* (head).

Lerista aericeps taeniata subsp. nov.

Figure 3

Holotype

R1566 in Central Australian Wildlife Collection, Alice Springs, collected by S.R. Morton at 20 km E of The Granites, Northern Territory, in 20°34'S, 130°38'E, on 15 November 1985.

Paratypes

Northern Territory

Tanami Desert in 20°15'S, 131°45'E (CAWC R1043); 20 km E The Granites (CAWC R1567-72, 1574-76); Sangsters Bore (20°53'S, 130°24'E) (CAWC R1314).

Diagnosis

Distinguishable from *L. a. aericeps* by its dark upper lateral stripe, larger preocular and more numerous midbody scale rows (mostly 20, v. 18), and from *L. orientalis* (DeVis) by its coppery head and yellow tail and very different habitat (red desert sands, v. subhumid woodlands).

Description

Snout-vent length (mm): 21.5-44 (N 12, mean 34.3). Length of tail (% SVL): 116-142 (N 5, mean 123.8).

Nasals in short contact. Prefrontals widely separated. Frontoparietals in long contact, usually a little smaller than interparietal. Nuchals 2-4 (N 12, mean 2.3). Supraoculars 3, first two in contact with frontal. Supraciliaries 5, second and fifth smallest. Loreals 2, first much the larger. Preocular as high as second loreal but narrower. One presubocular. Temporals 3. Upper labials 6. Midbody scale rows 18 (N 3) or 20 (N 8). Lamellae under longest toe 14-17 (N 11, mean 15.7), each finely keeled.

Coloration of holotype in life. Head and neck coppery red. Back pale coppery olive-brown, still paler in narrow strip next to upper lateral stripe; dorsals finely dark-edged and faintly flecked with blackish brown, marks tending to form four longitudinal lines of dots (paravertebral strongest). Tail greenish yellow, finely and faintly flecked with black. Blackish-brown upper lateral stripe, one and a half scales wide on body, narrowing as it passes through orbit and lore to side of rostral. Legs pale greyish brown, smudged with blackish brown. Lower surface whitish.

Upper lateral stripe narrower (one scale wide) in some paratypes, and meeting its opposite number at tip of snout in others.

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Figure 3   Holotype of *Lerista aericeps taeniata*, photographed in life by R.E. Johnstone.

Distribution

Arid western interior of Northern Territory (Tanami Desert). See map, Figure 2.

Derivation of name

From Latin *taeniatus* (striped).

Reference

Storr, G.M. (1976). Revisionary notes on the *Lerista* (Lacertilia, Scincidae) of Western Australia. *Rec. West. Aust. Mus.* **4**: 241-256.

A new species of *Hydrophis* (Serpentes: Hydrophiidae) from north-west Australian waters

L.A. Smith*

Abstract

A new species of sea snake *(Hydrophis geometricus)* from north-west Australian waters is described. It is compared with *H. macdowelli* Kharin and *H. ocellatus* Gray.

Introduction

Until recently most of the Western Australian Museum's hydrophiid collection comprised specimens found derelict along the Western Australian coast. Only a small part of it has been collected at sea, mostly by interested fishermen.

In an effort to improve the collection the Department of Ornithology and Herpetology of the Western Australian Museum has enlisted the help of marine biologists in the Western Australian Museum and the Western Australian Department of Fisheries with the result that in the last six years three valuable collections have been made off the north-west coast of Western Australia. Although the collections only totalled 48 specimens they represented 10 species, including three specimens of a new species of *Hydrophis* which is described below.

Systematics

Hydrophis geometricus sp. nov.

Figure 1

Holotype
   R76484 in Western Australian Museum collected by the late N.N. Sinclair on 9 March 1981 at 84 km NW of Dampier, Western Australia in 20°10'S, 116°06'E.

Paratypes
   140 km NNE of Dampier (76481), 130 km NNW of Dampier (73663).

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Diagnosis

A small-headed *Hydrophis* with a slender neck and deep, compressed body. Distinguishable from *Hydrophis ocellatus* by its colour pattern of very regular pentagons on flanks (rather than ellipses or spots) and the absence of a nasal cleft (present in *H. ocellatus*).

Description

A moderately large snake (up to 1237 mm long) with a small head (1.6-1.8 times as long as wide), slender neck and a very deep, compressed body. Tail 11.7-17.6% of snout-vent length.

Head shields entire. Rostral as wide as high. Nasals large, in contact throughout their length. Nasal cleft absent. Prefrontals small. Frontal 1.5-1.9 times as long as wide (mean 1.7). Preocular one, postoculars two (three on one side of one specimen). Anterior temporals mostly one, sometimes two. Upper labials seven or eight, second in contact with preocular, third and fourth or third to fifth entering orbit. Lower labials eight or nine, usually first three or four entire, remainder with small fragments at lip.

Figure 1 *Hydrophis geometricus* (R76481). Photographed by N.N. Sinclair

Ventrals 288-304 (N 3, mean 293.6), smooth, occasionally divided (especially posteriorly). Dorsals juxtaposed, with a short keel. Scale rows at midbody 51-58 (N 3, mean 54.6); at neck 31-34 (N 3, mean 32.3, decreasing by 19-24); before vent 43-52 (N 3, mean 47.0, decreasing by 5-12).

Head greyish or greyish black. Lips olive. Body greyish black with narrow, regular (one scale wide) white bars across back which fork on upper flanks to form apical angle of 34 to 35 contiguous pentagons. Lower flanks blackish or grey, flecked yellowish or whitish. Tail with yellowish-grey elliptic blotches separated by narrow yellowish-white bars.

Distribution
Continental shelf off the north-west Australian coast (Figure 2).

Figure 2   Map showing location of specimens of *Hydrophis geometricus* off the north-west coast of Western Australia.

Remarks
Hydrophis macdowelli Kharin and *H. ocellatus* Gray are the only two species of sea snake from north-west Australian waters which have small heads and deep, compressed bodies (at least posteriorly). Neither species has a flank pattern anything like the regular pentagons of *H. geometricus* (three approximately longitudinal series of small dark grey marks in *H. macdowelli;* elliptic or circular spots in *H. ocellatus*).

R73663 was trawled in 93-103 m at 1650 hrs.

Two new species of desert burrowing frogs of the genus *Neobatrachus* (Anura: Myobatrachidae) from Western Australia

M.J. Mahony* and J.D. Roberts†

Abstract

Species of the genus *Neobatrachus* are an important part of the frog fauna of Western Australia, occurring in the sub-humid, semi-arid and arid zones. They are desert burrowing frogs with very similar external morphology, and without mating call data they are difficult to distinguish. Two new species of *Neobatrachus*, *N. fulvus* and *N. kunapalari*, are described from Western Australia. Specimens of these species previously have been misidentified as *N. centralis* (Parker). The two new species can be distinguished by the structure of the inner metatarsal tubercle and the attachment of the skin between the legs and flank of the body. In *N. fulvus* the inner metatarsal tubercle is rectangular shaped with rounded edges, and the skin of the flank extends across to the knee so that the groin is not distinct. In *N. kunapalari* the tubercle is semi-circular in shape and the skin extends only slightly from the side of the body to encompass the groin. *N. fulvus* is diploid (2n = 24) and *N. kunapalari* tetraploid (4n = 48). Differences in chromosome morphology enable these species to be distinguished from diploid and tetraploid congeners. Mating calls are a soft trill in these species. Differences in pulse number and rate enable *N. kunapalari* to be distinguished from congeners in the same geographic range. The mating call of *N. fulvus* differs from the only other species of *Neobatrachus* (*N. sutor*) that is found in the same geographic region, but its call is very similar to a number of other species of *Neobatrachus*.

Introduction

Australian frogs of the genus *Neobatrachus* are a conspicuous element of the Western Australian frog fauna, particularly in the semi-arid and arid zones. Five species are currently recognised as occurring in Western Australia: *N. aquilonius* Tyler, Davies and Martin, *N. centralis* (Parker), *N. pelobatoides* (Werner), *N. sutor* Main and *N. wilsmorei* (Parker). Features of the biology of these species have been the subject of numerous studies, including habitat and breeding biology (Main *et al.* 1959; Main 1968), male mating calls (Littlejohn and Main 1959), physiology (Bentley *et al.* 1958), and karyology (Mahony and Robinson 1980).

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The external morphology of these species shows little variation, due presumably to the strong selective pressures which determine optimum body shape for water storage and the minimisation of water loss in the harsh desert environment. Several of the species are sympatric over large areas, but without biological information such as mating call or karyotype they are often difficult to distinguish morphologically.

The karyology of this genus is particularly interesting due to the occurrence of bisexual polyploidy in several species (Mahony and Robinson 1980). During chromosomal studies aimed at determining the origin of polyploidy and the relationship between species in this genus, it has become apparent that differences between specimens currently referred to *N. centralis* warrant recognition at the species level. Here we describe two new species previously referred to *N. centralis*.

Materials and methods

Material cited here is deposited in the following collections: Australian Museum, Sydney (AM), British Museum (Natural History), London (BMNH), Western Australian Museum, Perth (WAM).

Measurements of specimens follow Tyler *et al.* (1981), except that foot length (FL) was measured from the proximal end of the inner metatarsal tubercle to the tip of the fourth toe.

Mating calls

Calls were recorded on a Sony TC-510-2 reel to reel tape recorder with a Beyer M101 microphone using a tape speed of 19 cm s^{-1}. Oscillographs were prepared on a SanEi SM28 Oscillograph for analysis of temporal pattern in call structure. Pulse durations and dominant frequencies were analysed on a Norland 3001 Processing Digital Oscilloscope. Six call characteristics were analysed: call duration (s), pulse duration (ms), pulse rate (pulses s^{-1}), pulse number, dominant frequency (Hz) and pulse rise time as a percentage of pulse duration. Rise time for pulses was measured as the time from pulse initiation to maximum amplitude. Pulses in calls of *Neobatrachus* are simple with no internal amplitude modulation (Roberts 1978, see Figure 4) so this parameter simply gives a measure of the sharpness of the attack phase of the pulse.

Calls from frogs in the Exmouth area were recorded by H. Ehmann using a National Panasonic RQ 339 recorder with inbuilt condenser microphone. For analysis these recordings were played back on a Sony TC-D5 Pro cassette recorder.

Three calls were analysed for each frog. For frequency and pulse characteristics two pulses were analysed from the centre of each call. Pulse rate was measured over pulses 7-10 following Roberts (1978).

All data from an individual frog were averaged and each frog therefore contributes only one datum to overall averages reported later. Sample sizes are given in Table 2.

Cytology

Due to the unusual form of chromosome evolution and speciation involving polyploidy in several species of the genus *Neobatrachus*, the karyotypes of live specimens were examined and the ploidy of preserved specimens determined using cytological techniques outlined by Mahony and Robinson (1980).

Systematics

Neobatrachus fulvus sp. nov.

Figures 1-4

Holotype

WAM R52994, an adult female of 48.0 mm S-V collected at Exmouth, near North West Cape, WA (21°56'S, 114°07'E) by G. Harold and G. Barron on 8 March 1976.

Paratypes

There are 12 paratypes: WAM R93494-96, and AM R119438-39, collected at Learmonth by H. Ehmann on 22 May 1984; WAM R76583, collected 18 km E of Gnaraloo (23°49'S, 113°41'E) by G. Harold and C. Winton on 21 May 1982; and WAM R52937-42 collected at Exmouth by G. Harold and G. Barron on 10 March 1976. The series AM R119438-39 and WAM R76583 have been karyotyped and the ploidy level of two preserved specimens WAM R52938-39 determined. One of these paratypes, an adult female, WAM R76583, is photographed (Figure 1).

Diagnosis

(1) Adults moderate to large (males 38-42 mm; females 42-48 mm S-V) and of robust habitus; (2) hind limb short (T/S-V mean 0.34), with a large inner metatarsal tubercle, rectangular shaped with rounded edges and with a black keratinised cap; (3) mating call consisting of a short high-pitched trill; (4) dorsal coloration chocolate brown with small spots or variegations of mustard yellow particularly posteriorly and on flanks; (5) karyotypically diploid ($2n = 24$). Most closely related in appearance to *N. aquilonius* which is a slightly larger species (males 48-54 mm) with a tetraploid chromosome number ($4n = 48$).

Description of holotype

Head deep and semi-circular when viewed from above, and rounded in profile. Snout high. Eye large and prominent, its diameter (5.9 mm) equivalent to one and one-half times eye-to-naris distance (4.1 mm). Pupil vertical. Palpebral membrane with a yellow pigmented upper border. Canthus rostralis poorly defined and slightly curved. Nostrils inclined antero-dorsally and separated from one another

Figure 1   Photograph of paratype WAM R76583 of *N. fulvus* in life.

by a distance (4.35 mm) slightly greater than eye-to-naris distance (E/IN 1.11). Tympanum not visible.

Tongue broad and circular. Choana small, oval, and vomerine teeth (directly between choana) in a relatively long row divided medially.

Fingers cylindrical, unwebbed and without lateral fringes; in decreasing order of length 3>1>2>4 (Figure 2). Moderately developed subarticular and palmar tubercles. Foot wide and moderately long (FL 17.0 mm) with an inner metatarsal tubercle but no outer metatarsal tubercle. Inner metatarsal tubercle prominent with a keratinised black cap which is broad and slightly flattened in profile (Figure 2). Tips of first and second fingers with a small, black, keratinised cap. Toes flattened slightly and with very small subarticular tubercles and approximately one half webbed (Figure 2). Toes in decreasing order of length 4>5 = 3>2>1. Hind limbs short and very robust (TL 15.9 mm, TL/S-V 0.34).

Ventral surface of body and limbs entirely smooth. Short row of raised tubercles extending from above posterior margin of mandibular joint angled downwards to above arm.

Dorsal surface including limbs and thighs chocolate brown with lighter yellowish variegation. Dark interorbital bar and a distinct large unvariegated butterfly-shaped area in post-scapular region.

Ventral surface of body white except for diffuse light brown markings beneath mandibular articulation and around mandibular margin.
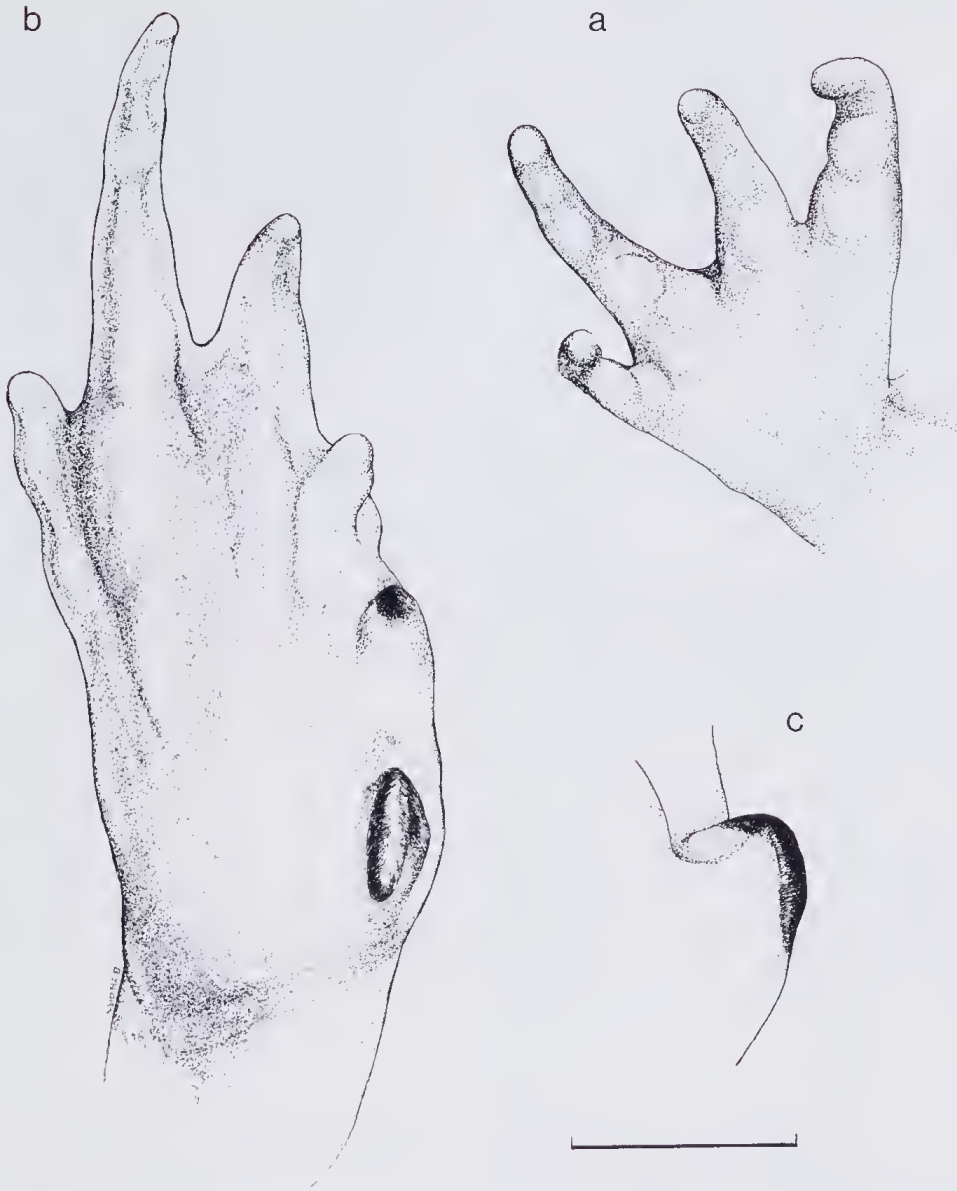
Figure 2   Diagram of (a) hand, (b) foot, and (c) metatarsal tubercle of *N. fulvus*. Bar 1 mm.

Variation

S-V length of adult males 38.2-42.0 mm, females 42.7-48.2 mm. Body round and globose, hindlegs very short (TL/S-V 0.34) (Table 1). Ratios of head measurements show little variation between specimens. Eyes large and prominent (E/EN 1.38). Males with diffuse nuptial pads extending from base of first and second fingers to tips.

Table 1   Proportions of 10 *N. fulvus* from Exmouth.

Ratio	Mean	Range (mm)
Head width/Head length	1.46	1.39 - 1.60
Eye/Eye-naris	1.38	1.34 - 1.50
Eye-naris/Internarial span	1.11	0.94 - 1.23
Head length/Snout-vent length	0.27	0.24 - 0.30
Tibia length/Snout-vent length	0.34	0.30 - 0.37
Foot length/Snout-vent length	0.39	0.34 - 0.43

Skin of side of body extends across to knee so that groin is not distinct. (see Figure 5 of Roberts 1978).

All 12 paratypes similar to holotype in dorsal markings. A faint, interrupted mid-dorsal line apparent in several specimens.

In life, ground colour of dorsal surface dull claret, variegated with small light yellow reticulations. Darker inter-orbital band and a post-scapular butterfly-shaped area. Bright yellow band bordering superior edge of palpebral membrane. Under surface of limbs white, upper surface variegated with yellow and brown. Ventral surface of body white, mandibular edge diffuse brown.

Mating call

Only one frog was recorded with sufficient clarity to allow detailed analysis. However, there were numerous calls (from several frogs) in the background chorus and these do not differ qualitatively from those analysed.

The call consists of 13-14 pulses repeated relatively slowly giving a call duration of just over 0.75 sec. Dominant frequency is about 1.5 kHz. Pulse durations are relatively long, and the pulse has a soft sound as rise and decay times are approximately equal.

Details of call structure are given in Table 2. A representative oscillogram is given in Figure 3a.

Table 2   Call structure data for trilling species of *Neobatrachus* from Western Australia. Values given are mean ± S.E. When only one frog has been recorded no error data are given. For *N. kunapalari*, temperature range is 21.2−21.5°C. For *N. pelobatoides*, temperature range is 12.0−12.5°C.

Species	n	Pulse number	Pulse rate (s⁻¹)	Pulse duration (ms)	Call duration (s)	Dominant frequency (Hz)	Rise time as % pulse duration	Water temperature (°C)
N. aquilonius[1]	1	11.0	18.3	25.0	.565	1500	-	25.5
N. aquilonius[2]	1	14.7	18.2	16.1	.773	1750	43	24.0
N. fulvus	1	13.7	14.2	16.6	.780	1503	50	23.2
N. kunapalari	4	19.6 ± .6	23.4 ± .4	10.7 ± .8	.820 ± .07	1224 ± 27	18.8 ± 1.1	21.4 ± .1
N. pelobatoides[3]	3	59.8 ± 7.6	18.9 ± 1.6	11.2 ± .9	3.230 ± .32	816 ± 28	48.3 ± 3.8	12.3 ± .2

[1] Data from Tyler *et al.* (1981). [2] Recorded 2.8 km SE of Turner River on North West Coastal Highway, 11.i.83. [3] Recorded on Brookton Highway, 42 km WSW of Beverley, 23.vi.78.
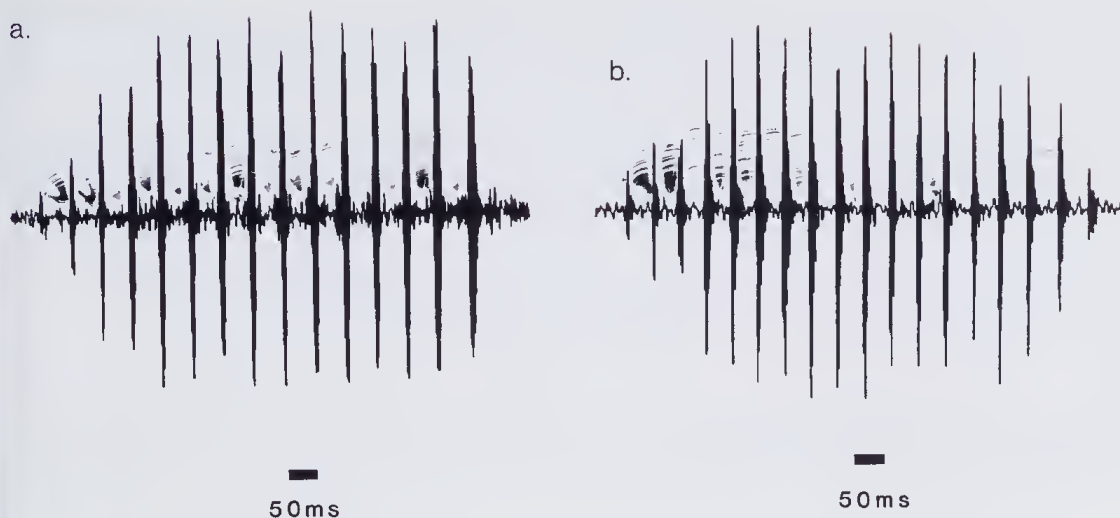
Figure 3   Oscillograms of *Neobatrachus* calls. (a) *N. fulvus*, (b) *N. kunapalari*.

Distribution

Currently known only from Exmouth, Learmonth and Gnaraloo in the North West Cape area of Western Australia.

Breeding biology

Following rain on 28 May 1984, H. Ehmann observed this species breeding in large flooded claypans. Details of the number of eggs laid or larval life are not known. *Neobatrachus sutor* and a *Cyclorana* species (probably *C. maini*) were breeding in the same body of water.

Habitat

Specimens collected at Learmonth were breeding in flooded claypans, and one specimen was foraging on red soil dunes. Specimens from Exmouth were foraging on a cleared area of red soil with surrounding vegetation of open mulga over dense grass. The Gnaraloo specimen was in an area of open *Acacia* and spinifex on pale brown sandy loam (G. Harold and G. Barron, field notes).

Karyotype

N. fulvus is diploid (2n = 24) (Figure 4), and the chromosome relative lengths and centromere positions are very similar to those of both diploid and tetraploid species of this genus (see Mahony and Robinson 1980). It can be distinguished readily from diploid congeners by the distinctive terminal location of the nucleolar organiser region (NOR) on the long arm of chromosome 5.

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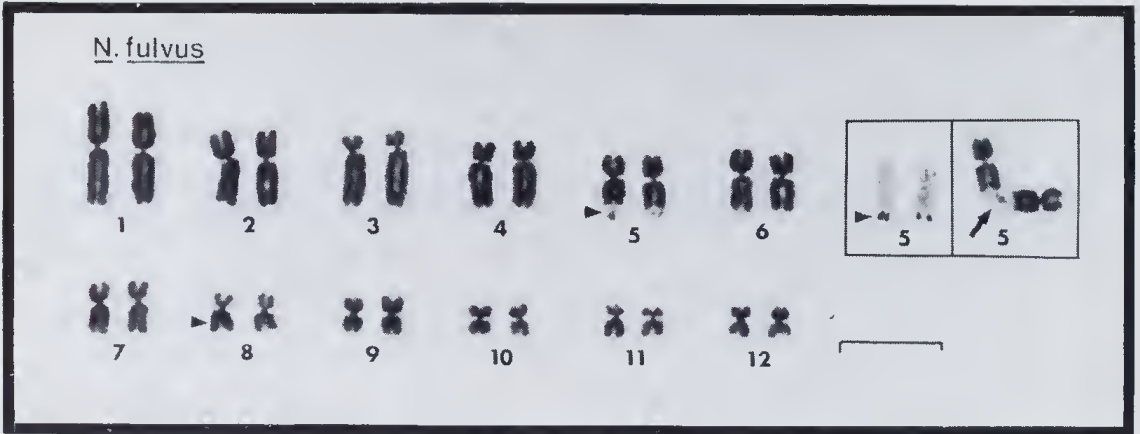
Figure 4   Karyotype of *N. fulvus*. Inset, silver-stained NOR. Bar 10 μm.

Comparison with other species

N. aquilonius is larger (S-V length: 59 mm compared with 48.00 mm) and tetraploid. Based on the information given in the type description of *N. aquilonius* and one additional recording of *N. aquilonius*, the calls of *N. fulvus* and *N. aquilonius* are similar (Table 2, Figure 3). Without additional data there is no way of reliably differentiating the calls of these two species.

N. pelobatoides is only slightly shorter but it is a less robust animal. Its dorsal surface is covered by numerous small even tubercles, its metatarsal tubercle is rounded and not strongly keratinised, and the upper legs are not enclosed within a skin fold. The call has a much higher pulse number, probably a higher pulse rate (when allowance is made for temperature effects; see Roberts 1978) and a dramatically lower dominant frequency (Table 2).

N. sutor is slightly smaller but of similar habitus. It can be distinguished clearly by its dorsal pattern and coloration which is golden overall or light brown with small dark spots or circles. Its inner metatarsal tubercle is shorter and less robust. The call is a single note repeated rapidly rather than a trilling sound (Littlejohn and Main 1959). At present this is the only congener recorded within the geographic range of *N. fulvus*.

N. wilsmorei is distinguished readily by its characteristic chocolate brown colour with, on each side, a pair of diverging, bright yellow stripes commencing behind the eye. It is larger (S-V length: 63 mm compared with 48 mm). Call is a single note of about 0.04 s duration repeated at 1.4 s intervals (Littlejohn and Main 1959).

N. kunapalari (= *N. centralis* in part, see below) is larger (males 48-58 mm, females 53-59 mm) with a distinctive inner metatarsal tubercle (Figure 6). Dorsal surface is yellowish to bronze with darker markings rather than chocolate brown with yellowish variegation. The call has a higher pulse number than that of *N.*

fulvus, a higher pulse rate and lower frequency. The form of the repeated pulse also differs (Table 2, Figure 3).

Etymology

From Latin *fulvus* meaning 'reddish yellow or tawny', thus describing the colour of this species.

Neobatrachus kunapalari sp. nov.

Figures 3, 5-7

Holotype

WAM R93485, an adult male of 51.0 mm snout-vent length collected 8.9 km S of Merredin, WA (31°33'S, 118°15'E) by J.D. Roberts and D. Cale on 26 May 1985. A photograph of the holotype in life is presented in Figure 5.

Paratypes

There are 11 paratypes: WAM R93486-92, AM R119436-37 collected between 7 and 18 km S of Merredin by J.D. Roberts and D. Cale on 26 May 1985; and WAM R93493, AM R118104, two adult males collected 15.1 km SSW of Narembeen, WA by J.D. Roberts on 25 January 1982.

Diagnosis

(1) Adults moderate to large (males 48-58 mm; females 53-59 mm S-V) and of robust habitus; (2) hind limb short (T/S-V mean 0.33), with a large inner meta-tarsal tubercle, of semi-circular shape in profile and invariably with a black keratinised cap; (3) mating call consisting of a relatively short high-pitched trill; (4) dorsal surface of males, particularly on anterior half of body, covered with numerous, fine, small tubercles which are spinose in breeding males; (5) dorsal coloration variable but usually yellowish to dull bronze variegated with irregular dark patches of black; (6) karyotypically tetraploid (4n = 48). Distinguished from related species by either its distinctive call, karyotype or shape of metatarsal tubercle.

Description of holotype (Figure 5)

Head deep and semi-circular viewed from above, and slightly flattened in profile. Nostrils inclined dorsally, internarial span (3.6 mm) slightly less than eye-to-naris distance. Eye large and prominent, its diameter (7.5 mm) equivalent to one and three-quarters times eye-to-naris distance (4.2 mm) (Table 3). Pupil vertical in life; iris two-toned, upper half golden and lower silver, and covered with fine black lines. Tympanum not readily visible externally but present and roughly circular. Vomerine teeth in a straight row, divided medially; their posterior margin in line with anterior margin of choanae which are small and oval. Tongue broad and circular.

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Figure 5   Photograph of holotype of *N. kunapalari* (WAM R93485) in life.

Fingers short and cylindrical; in decreasing order of length 3>1>2>4 (Figure 6). No interdigital webbing; second and third fingers fringed slightly (Figure 6). Nuptial pads extend from base of first and second fingers to tip. Subarticular tubercles well developed, with two large, flat palmar tubercles.

Hind limbs short with tibia averaging one-third of snout-vent length (Table 3). Foot long (FL 22.3 mm) being 43 per cent of snout-vent length. Toes short, slightly flattened and in decreasing order of length 4>3>5>2>1. Subarticular tubercles poorly developed except on 3 and 4. No outer metatarsal tubercle, but large, semi-circular shaped, inner metatarsal tubercle, edged with black (Figure 6). Webbing between toes extensive, extending to tip of each toe, although as a fringe past last joint.

Dorsal surface covered by numerous, fine, small warts, which are spinose, particularly on head, eyelids and scapular region. Ventral surface, top of foot, femur and under side of arm smooth. Above articulation of jaw and extending back to above arm a roughly linear line of tubercles partly fused and forming a distinct stripe. Ventral surface smooth. Dorsal surface in preservative light yellowish grey with numerous dark rounded and separate patches of black, occasionally lighter coloured centrally. A distinct interorbital bar but no mid-dorsal stripe. Upper surface of arms and legs mottled but ground colour darker

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than dorsum. In life bright yellow background with black spots. Ventral surface white, but chin grey, and ventral surface of foot, arms and hand plum colour. Skin extending only slightly from side of body to encompass groin.
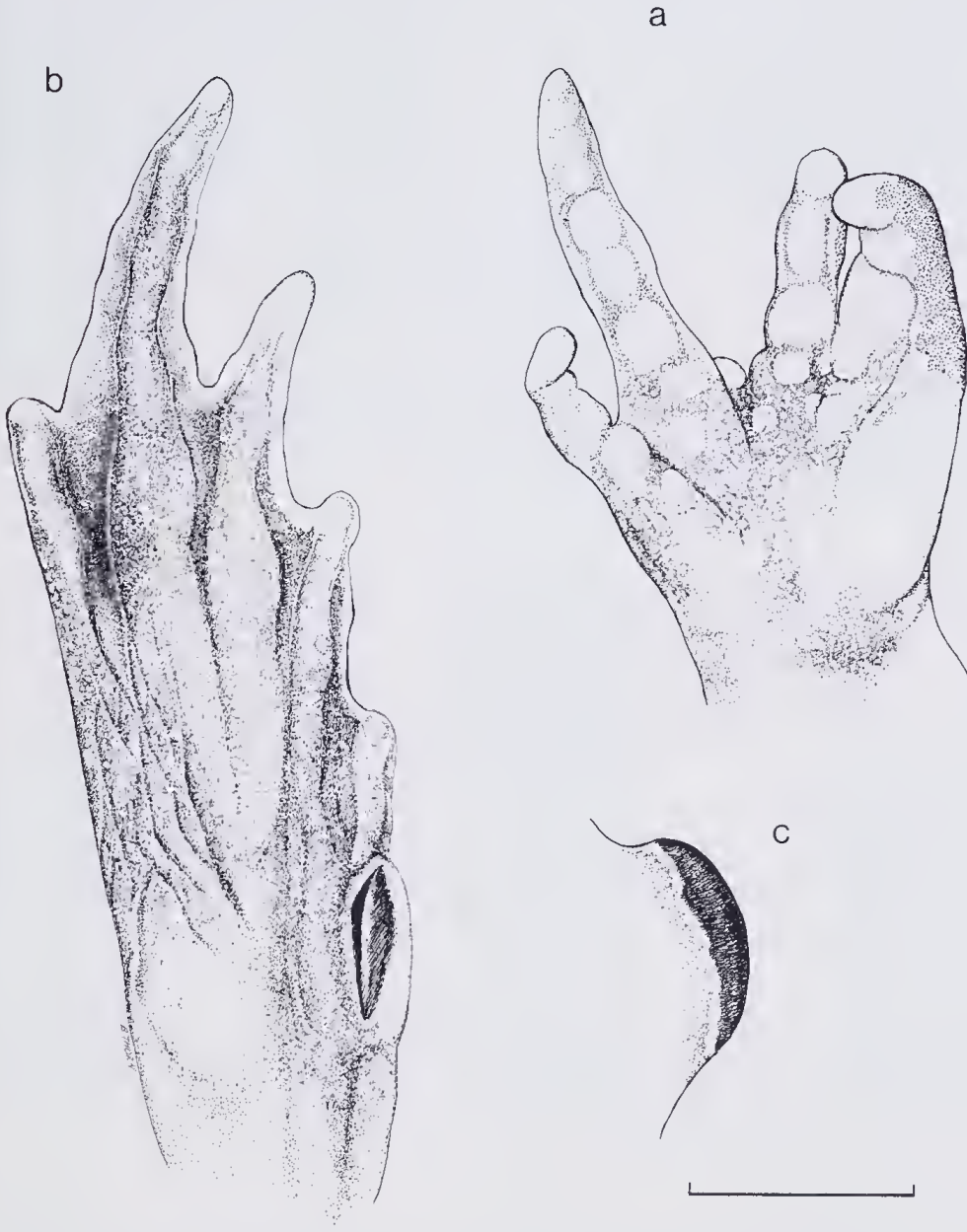

Figure 6   Diagram of (a) hand, (b) foot, and (c) metatarsal tubercle of *N. kunapalari*. Bar 1 mm.

Table 3   Proportions of 6 *N. kunapalari* from near Merredin.

Ratio	Mean	Range (mm)
Head width/Head length	1.43	1.39 - 1.54
Eye/Eye-naris	1.78	1.67 - 2.02
Eye-naris/Internarial span	1.16	0.94 - 1.18
Head length/Snout-vent length	0.28	0.24 - 0.30
Tibia length/Snout-vent length	0.33	0.31 - 0.36
Foot length/Snout-vent length	0.43	0.38 - 0.44

Variation

The type series consist of seven males and three females. Females having numerous small warts or smooth dorsally and lacking small spines present in breeding males. Skin between posterior side of body and upper leg enclosing groin looser than in males.

Background colour yellowish to dull bronze with dark black or brown blotches. Dark interorbital bar variable in size. A pale, narrow mid-vertebral stripe in two specimens.

Mating call

Calls were not recorded when the holotype was collected. However, call data are available from two paratypes and from two other frogs recorded on the same occasion. These recordings were made on 25 January 1982, 15.1 km SSW of Narembeen, Western Australia at approximately 70 km south of the type locality.

The call of *N. kunapalari* consists of 18-21 slowly repeated pulses giving a call duration of about 0.8 s. Dominant frequency is about 1.2 kHz. Pulse durations are low and the pulse has a sharp sound as the rise time is short relative to the decay time.

Details of call structure are given in Table 2 and a representative oscillogram is given in Figure 3b. These calls are similar to those figured and analysed by Littlejohn and Main (1959) as *N. centralis*.

Distribution

This species is distributed widely in the semi-arid and arid zones of Western Australia south of about latitude 25°S and into the south-west on the eastern side of Darling Range. Virtually all records of *N. centralis* in south-western Australia (e.g. Main 1965, 1968; Tyler *et al.* 1984) are likely to refer to this species. However, without details of call or karyotype identification of preserved material is difficult (see below) so we cannot be more precise in defining the range. This species was not found in the Port Hedland area (Mahony and Roberts, unpublished data), or in the region of North West Cape (H. Ehmann, unpublished data), following suitable rains in which other frog species, including several

belonging to *Neobatrachus* bred. Similarly, in the vicinity of Ayers Rock and the Olgas in south-western Northern Territory this species was not detected (Mahony, unpublished data). Lindgren and Main (1961) did not detect this species at Jigalong (23° 22'S, 120° 47'E) following summer rains, and the northern localities depicted for this species (as *N. centralis*) by Tyler *et al.* (1984) may represent *N. aquilonius*. The boundaries of the distribution of this species to the north and east are therefore somewhat uncertain.

Breeding biology

One of the paratype females laid 1096 eggs on 30 May 1985. The diameter of a sample of 10 ova averaged 1.6 mm and the capsule diameters averaged 2.5 mm. Main (1968) gives details of the general breeding biology and habitat of this species (as *N. centralis*), including details of egg deposition sites, and length of larval life.

Karyotype

N. kunapalari is a tetraploid (4n = 48) (Figure 7). The chromosomes of this species have been figured and discussed by Mahony and Robinson (1980), but referred incorrectly to *N. sutor*. *N. kunapalari* can be distinguished readily by the distinctive location of the NOR, medially on the long arm of chromosome 7, whereas in all the other congeners it is on chromosome 5.
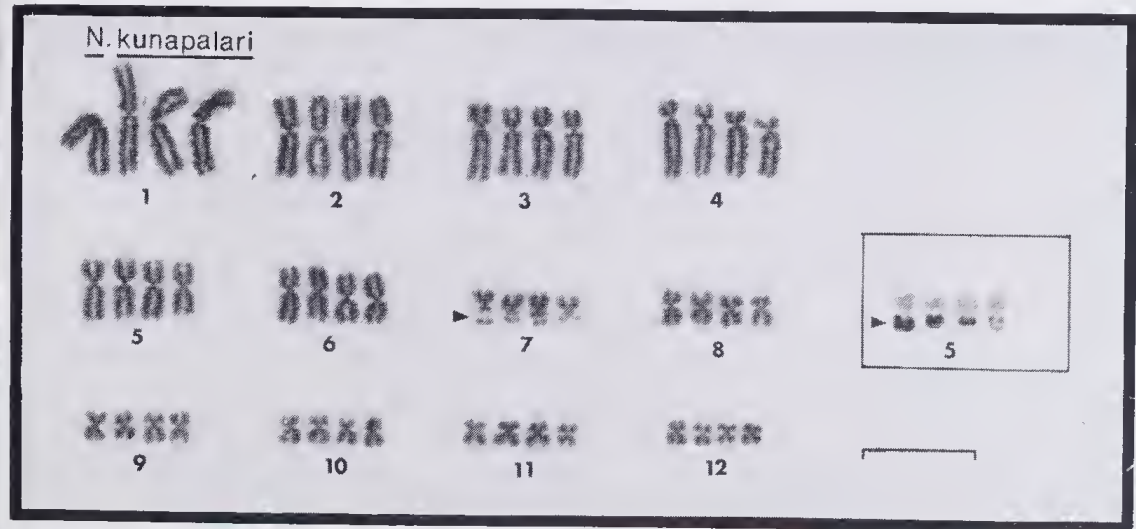

Figure 7   Karyotype of *N. kunapalari*. Inset, silver-stained NOR. Bar 10 μm.

Comparison with other species

N. aquilonius differs in aspects of chromosome morphology, particularly location of the NOR (both species are tetraploid) and mating call. The groin area is enclosed by skin from the flank.

N. pelobatoides is smaller (S-V, 44 mm compared with 51 mm), with a longer mating call (Table 2; Littlejohn and Main 1959), and is karyotypically diploid.

N. sutor is of similar size but usually is more robust in appearance, with the skin of the side of the body enclosing the groin. The dorsal surface is smooth and males do not have small spinose tubercles on the dorsum. Its metatarsal tubercle is pointed rather than semi-circular and its call is a distinctive short tap repeated at approximately 0.4 s intervals rather than a trill. It is diploid karyotypically. The dorsal markings and coloration of *N. sutor* and *N. kunapalari* are often similar, and caution should be exercised when identifying preserved specimens of these two species.

N. wilsmorei is distinctive in size, dorsal coloration and mating call, and is diploid (see comparison with *N. fulvus*).

N. fulvus is smaller, has a distinct coloration and call and is diploid. The metatarsal tubercle is also distinct (Figures 2 and 6) and the eye/eye-naris ratio is larger (1.38 compared to 1.78, Tables 1 and 3).

Etymology

The name applied to this species by Aborigines of the Gugadja tribe (Peile 1978).

Discussion

Desert frogs are typically robust animals with rounded bodies and short limbs, which represents the most adaptive morphology for a life which contains long periods beneath the surface. External morphology therefore shows very little variation, and it is often difficult to delimit species by traditional means such as external features and body measurements. Furthermore, remoteness and inaccessibility during suitable weather conditions have meant that field observations and the recording of mating calls, which may distinguish species, are not readily obtained. In view of all this the use of karyotypic data has proved to be most valuable in distinguishing different species of *Neobatrachus*. This approach has been particularly useful because of the unusual form of chromosomal evolution involving polyploidy, observed in several species.

Recognition of the two new species described here relies in particular on the correct identification of *N. centralis* (Parker). This species was formerly considered to have an extensive distribution in the semi-arid and arid zones of Australia (from the west coast through central Australia to north-western Victoria, western New South Wales and south-western Queensland, Barker and Grigg 1977, Cogger 1983, Cogger *et al.* 1983, and Tyler *et al.* 1984). The precise locality from which the holotype of *N. centralis* was collected is uncertain, but, Ledo and Tyler (1973) indicate that it was most likely in the vicinity of Coopers Creek where it is crossed by the Birdsville Track, in the north-east of South Australia. Karyotypic examination of specimens from various localities in this

area, including two specimens collected on the Birdsville Track near Marree (approximately 50 km S of Coopers Creek), indicates that only one species of *Neobatrachus* occurs there. It is tetraploid (4n = 48) and can be distinguished from Western Australian specimens referred to *N. centralis*, by differences in chromosome morphology, particularly the location of the NOR. The external morphology of these specimens agrees closely with that of the holotype of *N. centralis* (BMNH 1905. 10. 31. 47), which we have examined, and is different to that of Western Australian specimens included here in *N. kunapalari*. We note that Tyler *et al.* (1984) also felt *N. centralis* from Western Australia was morphologically distinct from *N. centralis* in South Australia.

Roberts (1978) considered that *N. centralis* may be a junior synonym of *N. sudelli*. We do not address that issue here. We have both call and karyotype data (unpublished) to suggest that two distinct tetraploid forms occur in south and eastern Australia.

The chromosome number and morphology of specimens referred to *N. centralis* from Western Australia previously have been discussed by King *et al.* (1979) and Mahony and Robinson (1980). Both reports indicated that animals so identified were diploids (2n = 24). Following morphological examination of the holotype of *N. sutor* (WAM R3892), and the karyotypic analysis of material identified by mating call to be *N. sutor,* it is apparent that both reports actually referred to *N. sutor.*

An adequate understanding of the distributions and life histories of both newly described species will require extensive field work in the semi-arid and arid zones of Western Australia.

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CONTENTS

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Descriptions of three new species and one subspecies of freshwater hardyhead (Pisces: Atherinidae: *Craterocephalus*) from Australia

Walter Ivantsoff*, L.E.L.M. Crowley* and Gerald R. Allen†

Abstract

Three new species and a new subspecies belonging to the atherinid genus *Cratero-cephalus* are described. The fish from south-eastern Australia previously recognised as *C. fluviatilis* is described as a subspecies of the more northerly occurring *C. stercusmuscarum*. The two subspecies are distinguished by differences in colour pattern and vertebral counts. A new name, *C. stercusmuscarum fulvus* is proposed because *fluviatilis* is regarded as a junior synonym of *C. eyresii*. A hardyhead from the Northern Territory which has been erroneously identified as *C. marjoriae* is described as a new species — *C. marianae*, based on differences in transverse scale counts, position of the anus, gill raker shape, and colour pattern. Two additonal new species, *C. helenae* and *C. lentiginosus* are described from the Kimberley region of Western Australia. The former species is closely allied to *C. marianae* but differs in counts of midlateral scales, vertebrae, and gill rakers. *Craterocephalus lentiginosus* is most closely related to *C. stercusmuscarum*, but differs from it in having consistently lower meristic counts and by the presence of a lateral process on the premaxilla.

Introduction

The family Atherinidae contains approximately 170 species. These relatively small, silvery fishes occur worldwide mainly in marine or estuarine habitats but several genera including *Craterocephalus* McCulloch of Australia and New Guinea is primarily found in fresh water. Ivantsoff (1978) reviewed the status of all the nominal species in this genus, recognising 10 as valid. However, some of his findings were inconclusive. A new study of the genus by Ivantsoff and Crowley, encompassing osteology and electrophoresis is currently in progress.

Recent collections in north-western Australia have resulted in the discovery of two new species of *Craterocephalus* (Allen, 1982). In addition, the fish from the Northern Territory previously identified as *Craterocephalus marjoriae* Whitley

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(1948), is described here as another new species. Ivantsoff (1978) indicated that a species of fish known as *Craterocephalus fluviatilis* McCulloch (1913), is different in coloration but indistinct morphologically from *C. stercusmuscarum* (Günther, 1867). In the present paper these forms are recognised as distinct subspecies on the basis of their allopatric distribution and slight differences in meristics and morphology.

Methods for counts and measurements are based on Munro (1967), but modified in several instances as described by Prince *et al.* (1982) and Patten and Ivantsoff (1983). In *Craterocephalus* the second dorsal and anal fins may or may not have an unbranched ray preceding the branched rays. For the sake of uniformity, the first ray following the spine in both these fins was not considered as part of the branched ray count. Radiographs were utilised to obtain vertebral counts. The number of specimens examined, their provenance and where presently held is indicated in relevant sections. Measurements and counts are recorded for all type specimens. Specimens examined have been borrowed from or deposited in the following institutions: American Museum of Natural History, New York, field registrations (AMNH − DR); Australian Museum, Sydney (AMS); British Museum of Natural History, London (BMNH); California Academy of Sciences, San Francisco (CAS); Macquarie University, Sydney (MQU); Queensland Museum, Brisbane (QM); Museum of Zoology, University of Michigan, Ann Arbor, USA (UMMZ); and Western Australian Museum, Perth (WAM).

Systematics

Craterocephalus stercusmuscarum fulvus subsp. nov.

Figure 1

Craterocephalus fluviatilis McCulloch, 1913: 49 (in part) (Narrandera, New South Wales).

Holotype

AMS I.25480-001, 40.7 mm SL, Wirrabilla Lagoon, Wirrabilla Station, Collarenebri, New South Wales, 29°33′S, 148°35′E, collected by D.G. Stead, 3 May 1910. Method of collection unknown.

Paratypes

AMS IB.784 (41, of which only 20 measured and counted), (21.5-40.2 mm SL), Wirrabilla Lagoon, Wirrabilla Station, as above.

Diagnosis

A subspecies of the atherinid genus *Craterocephalus* differing from the nominal *C. stercusmuscarum stercusmuscarum* by lacking a spotted colour pattern and possessing a slightly higher vertebral count (31-36 v. 35-38). It is distinguished from *C. eyresii* by a lower number of horizontal scale rows on the body (usually 7 v. 10-18), and by having thick rather than thin lips. *Craterocephalus stercus-*

muscarum fulvus is distinguished from all other species and subspecies of *Cratero-cephalus* by a combination of characters that includes the following: relatively small, slender fish with 7.0-7.5 rows of scales along side of body; spots on side of body absent, black band through snout, midlateral band black, gold or silvery; mouth small, gape restricted, and lips thick.
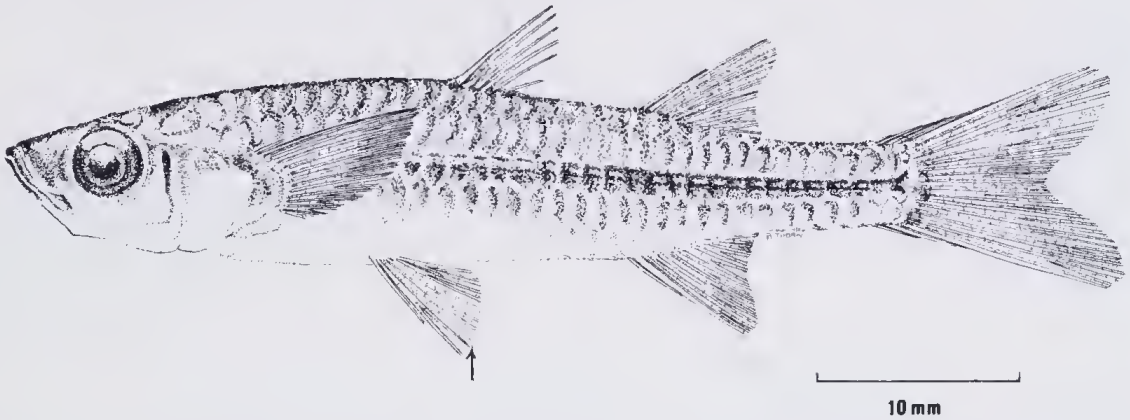
Figure 1   *Craterocephalus s. fulvus* AMS I.25448-001 Sandy Creek, Northern New South Wales, 53.4 mm SL. Arrow near ventral fin indicates position of anus.

Description
    Small fish not known to exceed 63 mm SL. Mouth small, protrusible, with gape restricted by fusion of lips. Premaxilla short, not reaching vertical through anterior margin of orbit, its free edge slightly concave anteriorly and convex posteriorly. Dorsal process of premaxilla long and pungent but not reaching into interorbital space. Ramus of dentary highly elevated posteriorly. Minute teeth in several rows in both jaws. Other bones in mouth edentulous. Preopercle and opercle scaled. Body scales large, dorsoventrally oval, with circuli complete and concentric. Scales in seven distinct rows along side of body. Gill rakers in first lower gill arch short and tubercular, less than half diameter of pupil. Large specimens often with shallow interorbital trough and with head sloping obliquely towards snout.

Colour: Live specimens bright golden yellow (Namoi River, NSW) or greenish gold (Fraser Island, Queensland); frequently dull yellow in captivity. Black band originating from tip of snout, extending through eye and continuing as black, gold or silvery midlateral band to hypural joint. Female with black blotch around vent when reproductively mature.
    Preserved specimens yellow to brown with band as described above. Upper half of body darker than abdomen. Dorsum of head often black. Body scales with fine speckling at edges. No large regular spots along side of body as in *C. s. stercusmuscarum.*

Etymology: fulvus, pertaining to yellow or tawny hue which is the usual coloration of this subspecies. This fish is commonly referred to as the Mitchellian Hardyhead.

Remarks

McCulloch's (1913) account of *C. fluviatilis* is based on the holotype and five paratypes from Narrandera and 20 specimens from the Barwon and Namoi River Junction. McCulloch found that the 20 specimens from the Barwon and Namoi, had seven scale rows, whereas those from Narrandera, the type locality, had scale row counts ranging from 7-10.

Examination of the type material of *C. fluviatilis* indicates more than nine scale rows along the side of the body in the holotype and two paratypes. These have been reidentified as *C. eyresii* (Steindachner, 1884), a species in which the scale row count varies from 10 to 18 (Ivantsoff 1980). The remaining three paratypes from Narrandera, including McCulloch's (1913) figured specimen, are conspecific with the designated types of *C. s. fulvus* from Wirrabilla Lagoon. In these, there are never more than seven scale rows along side of body although McCulloch (1913) sometimes counted eight, presumably because of a difference in the technique of counting.

It appears that McCulloch (1913) had difficulty in distinguishing between *C. fluviatilis* and *C. eyresii* and in 1918, McCulloch and Waite stated that the two species were very closely related. As the holotype of *C. fluviatilis* cannot be distinguished from *C. eyresii*, it is now regarded as its junior synonym.

The account of *C. stercusmuscarum* from south-eastern Australia by Ivantsoff (1980: 134) refers to the new subspecies.

Initial results of electrophoretic studies by Crowley (unpublished) indicate that the unspotted *(C. s. fulvus)* and spotted *(C. s. stercusmuscarum)* subspecies show no differences in the 16 loci examined electrophoretically. Nor can they be distinguished on meristic (other than vertebral counts) and morphometric values and must therefore be regarded as conspecific.

Juvenile and smaller specimens of either subspecies of *C. stercusmuscarum* from the Northern Territory may be unspotted as recorded by Taylor in 1964 (all under 37 mm SL and identified as *C. fluviatilis*). Similar observations have been made in other populations in the range considered to be occupied by *C. s. stercusmuscarum*. We conclude, therefore, that juveniles of the two subspecies cannot be distinguished by any of the external characters considered in this study.

C. s. fulvus is not uncommon in most parts of the Murray-Darling drainage system in New South Wales, Victoria and South Australia. It occurs in central Australia and extends as far north as Maryborough, Queensland.

Additional material examined

AMS IB.787 (6), Mungabarina, Murray River; MQU 75-16 (20) Wabby Lake, Fraser Island, Queensland; AMS I.18532-001 (2), Namoi River, Manilla, New South Wales; AMS IB.786 (3) Hart's Island, Murray River, South Australia; AMS IB.785 (3) Barwon River near Collarenebri,

New South Wales; AMS I.12458 (1), AMS IB.783 (3) Junction of Barwon and Namoi Rivers, New South Wales; AMS I.25448-001 (3) Sandy Creek, New South Wales; MQU 75-20 (1) Macintyre River, Goondiwindi, Queensland. Measurements expressed as proportions and counts for 63 specimens are presented in Table 1.

Other material examined, but not used for measurements and counts: AMS I.12457 (3) North Yanko Creek, Narrandera, New South Wales (paratypes of *C. fluviatilis*); AMS I.690 (2) Cudjegong River, New South Wales; AMS IA.7180 (5) Condamine River, Queensland; AMS IB.4164 (2) Wentworth, Murray River, New South Wales; AMS I.6200-001 (3) Albury, Murray River, New South Wales; AMS I.17898-001 (2) Lake Cargelligo, New South Wales; AMS 16908-003 (6) Dixon Dam, New South Wales; AMS I.18514-001 (9), AMS I.18539-001 (20) Wabby Lake, Fraser Island, Queensland; AMS I.19062-003 (2) Borah Creek, New South Wales; MQU 77-2 (4) Keepit Dam, New South Wales; QM I.13980 (2) Kobble Creek near Samford, Queensland; QM I.13981 (2) North Pine River, Dayboro, Queensland; QM I.13982 (2) Enoggera Creek, The Gap, Brisbane, Queensland; QM I.13938 (2) Pullen Pullen Creek near Kenmore, Queensland; QM I.13921 (2) Gold Creek, Brookfield near Brisbane, Queensland. Size range 19.0-63.0 mm SL.

Craterocephalus lentiginosus sp. nov.

Figure 2

Holotype

WAM P25029-003, 43.3 mm SL Derris powder over sandstone bottom at depths to 2 m, Upper Roe River, 70-80 km upstream from the sea, Kimberley, Western Australia (approx. 15°31'S, 125°38'E), collected by G.R. Allen, 18 August 1974.

Paratypes

Nineteen specimens: WAM P25029-003 (6), data as for holotype; WAM P25029-003 (2) prepared alizarin specimens, data as for holotype; AMS I.24115-001 (4) data as for holotype; AMS I.24115-002 (2) prepared alizarin specimens, data as for holotype. WAM P25028-003 (6), derris powder over sandstone and mud bottom in a quiet pool (approximately 10 by 60 m) at depths to 2 m, Wyulda Creek, about 2 km above junction with Roe River, Kimberley, Western Australia (approximately 15°31'S, 125°38'E) collected by G.R. Allen, 17 August 1974. Size range 21.9-43.3 mm SL. Measurements expressed as proportions and counts for the holotype and 19 paratypes are presented in Table 2.

Diagnosis

A species of the atherinid genus *Craterocephalus* most closely allied to *C. stercusmuscarum*, but differing in counts for midlateral scales (29-31 v. 32-35 for *stercusmuscarum*), predorsal scales (12-15 v. 11-17) and vertebrae (32-33 v. 31-38). It is further distinguished from all other species and subspecies of *Craterocephalus* by a combination of characters that includes the following: relatively small, slender fish with 5-7 rows of large, almost rectangular scales along side of body; spots on upper four rows of scales only, black band extending from snout through opercle and continuing as midlateral band to hypural joint; midlateral scales 29-31; vertebrae 32-33; lateral process of premaxilla well developed, its upper tip pointing posteriorly.

10 mm
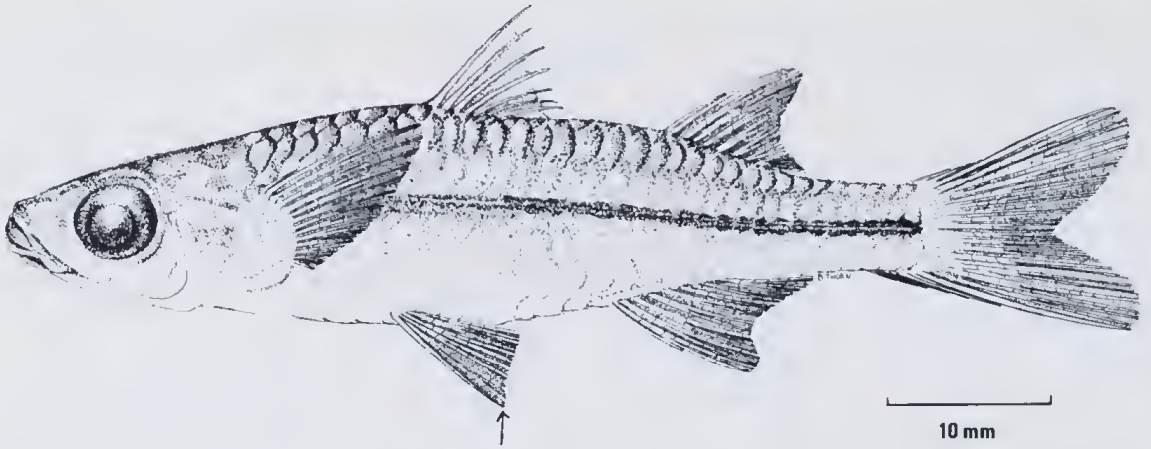
Figure 2   *Craterocephalus lentiginosus*, holotype, WAM P.25029-003, Upper Roe River, Kimberley, Western Australia, 43.3 mm SL.

Description

Slender fish, maximum known size 43.3 mm SL. Mouth small, protrusible, gape restricted by fusion of lips. Lips moderately thick. Premaxilla short, not reaching vertical through anterior margin of orbit, its free edge concave anteriorly and slightly convex posteriorly. Dorsal process of premaxilla long and pungent, extending to just past vertical through anterior margin of orbit. Lateral process of premaxilla well developed, falcate, with dorsal tip pointing backwards. Ramus of dentary highly elevated posteriorly. Well formed teeth in two rows on anterior half of both jaws. Other bones in mouth edentulous. Body scales large, dorsoventrally elongated almost rectangular with concentric circuli anteriorly, incomplete posteriorly. Scales in five or six regular rows along side of body. Preopercle with 4-5 scales. Opercle also scaled. Small, spinule covered, tubercular gill rakers on first lower gill arch.

Colour: Preserved specimens yellow to dusky brown. Dark brown band originating on snout, extending through eye, opercle and continuing as dark punctate midlateral band to hypural joint. Pigment in large spots in centre of each scale of upper four rows (including midlateral row) forming discontinuous bands of varying intensity along side of body. Juveniles and smaller fish with less pigmentation and lighter in appearance. Upper half of body in adults dusky with fine peppering of melanophores concentrated on each scale. Ventral half of body almost devoid of pigment below fourth scale row. Head, snout and lips dark. All fins dusky. Dark pigmentation at bases of fins. Middorsal and midventral line of pigment apparent in posterior half of body.

Etymology: lentiginosus, referring to the freckled or spotted appearance of this species. We recommend the common name Freckled Hardyhead.

Remarks

The account of *C. worrelli* Whitley from the Roe River by Allen (1975) represents a misidentification of *C. lentiginosus.* In addition Allen (1982) referred to it as *Craterocephalus* species B.

This species is thus far known only from the Roe River in the western Kimberley, Western Australia.

Craterocephalus helenae sp. nov.

Figure 3

Holotype

WAM P25456-003, 56.5 mm SL, down stream from Gibb River Road, Kimberley, Western Australia, 15°41'S, 126°32'E. Sand and rocky bottom. Rotenone, collected by J.B. Hutchins, 31 August 1975.

Paratypes

Twenty-eight specimens: WAM P25456-003 (8) data as for holotype; WAM P25406-009 (2) Drysdale River Channel near Mogurnda Creek, Kimberley, Western Australia, 15°02'S, 126° 55'E. Sand and rocky bottom. Rotenone, collected by J.B. Hutchins, 5 August 1975; WAM P25424-008 (2) and alizarin preparations (2), Drysdale River, small channel near Fern Gully Creek, Kimberley, Western Australia, 14°39'S, 126°57'E. Sand and rocky bottom. Rotenone and seine net, collected by J.B. Hutchins, 19 September 1975. WAM P25873-010 (8) Drysdale River, Kimberley, Western Australia, 15°39'S, 126°21'E, collected by G.R. and C. Allen and G. Evans, 16 September 1977; AMS I.25436-001 (5) data as for WAM P25873-010; AMS I. 25449-001, alizarin preparation (1), data as for WAM P25424-008. Measurements expressed as proportions and counts for 26 paratypes and the holotype are presented in Table 4. Size range 35.4-61.3 mm SL.

Diagnosis

A species of the atherinid genus *Craterocephalus* closely allied to *C. marjoriae* Whitley and *C. marianae* sp. nov., but differing from them by a combination of

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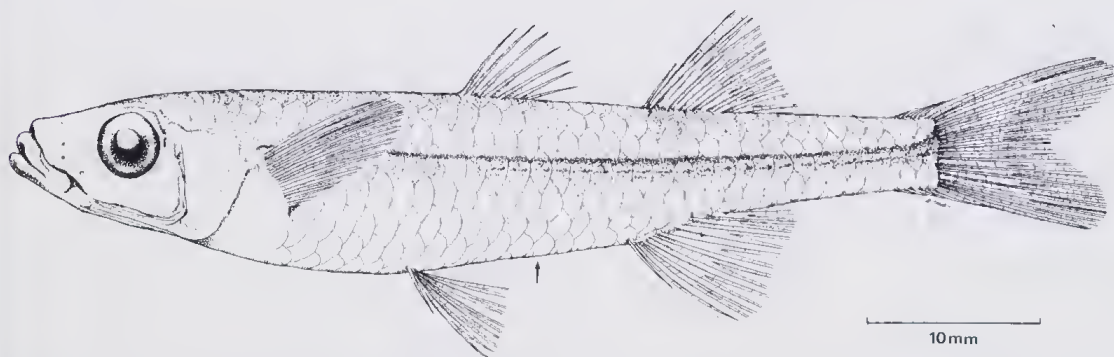
Figure 3   *Craterocephalus helenae*, holotype, WAM P.25456-003 Drysdale River, Kimberley, Western Australia, 56.5 mm SL.

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characters that includes a low gill raker count (8-10; $\bar{x}$ = 8.9 v. 10-12; $\bar{x}$ = 11.1-11.2), a higher mean count for midlateral scales (30-32; $\bar{x}$ = 29.4 v. 27-30; $\bar{x}$ = 28.4 and 29.4), and a higher mean count for vertebrae (32-33; $\bar{x}$ = 32.9 v. 29-34; $\bar{x}$ = 30.2 and 31.6). Further comparisons of the members of this closely related group are indicated in Table 6.

Description

Small but moderately robust fish, presently known maximum size about 61.3 mm SL. Head relatively rounded and truncate. Mouth small, gape restricted by fusion of lips. Lips moderately thick. Mouthparts protrusible with upper jaw extending slightly over lower when extended forward. Premaxilla longer than in other species presently described but not quite reaching vertical through anterior margin of orbit. Anterior free edge of premaxilla concave, posterior half covered by lips. Dorsal process of premaxilla long and pungent extending almost to vertical through anterior margin of orbit. Posterior ramus of premaxilla wide and culminating in round eminence. Ramus of dentary highly elevated posteriorly, curving forwards at dorsal end. Upper jaw with fine teeth pointing posteriorly and almost at right angles to free edge of premaxilla. Lower jaw expanding anteriorly to form wide, edentulous plate. Other elements of mouth also edentulous. Body scales large, sturdy, dorsoventrally elongated, almost rectangular and scalloped anteriorly; circuli restricted to anterior half of scale. Scales in about 5.5 distinct rows along side of body. Four scales on preopercle and four large scales on opercle. First 4-5 scales on dorsum of head rectangular and large. Gill rakers in angle of first lower gill arch short and leaf-like, those following, reduced to slight elevations covered with fine spinules.

Colour: Preserved specimens yellow brown. Midlateral band, about one-third of scale width, extending from origin of pectoral to caudal base, its upper edge marked by concentration of fine melanophores forming thin, streaky line. Upper half of body more dusky than lower, with greater concentration of very fine melanophores, particularly at posterior edge of scales. Dorsum of head dark; snout, premaxilla and opercle speckled with chromatophores in various concentrations and sizes. Lower half of body speckled but less so than upper half, with ventral surface almost unpigmented. All fins finely peppered with melanophores.

Etymology: helenae is named in honour of the senior author's wife Helena. We recommend the common name Helena's Hardyhead.

Remarks

The records of *C. marjoriae* by Lake (1978, in part) and Hutchins (1977) from the Northern Territory and Kimberley respectively are referrable to *C. helenae*. Allen (1982) identified it as *Craterocephalus* species A.

This species is known only from the Drysdale River in the north-central Kimberley, Western Australia.

Craterocephalus marianae sp. nov.

Figure 4

Holotype

AMS I.18523-001, 55.4 mm SL, Magela Creek, Jabiru, Northern Territory, 12°41'S, 132° 55'E, collected with seine by D. Pollard and M. Mann, June 1972.

Paratypes

Thirty specimens measured and counted, AMS I.18523-001 (7) data as for holotype; AMS I.18541-001 (11) data as for holotype, but collected in July 1972; AMS I.16859-001 (12), data as for holotype but collected in July 1972.

Designated as paratypes but not included in measurements and counts: WAM P.28195-001 (10) data as for AMS I.16859-001; BMNH 1983. 12.8.1-5.(5) data as for AMS I.16859-001; CAS 53748 (5) data as for AMS I.16859-001; UMMZ 212.147 (5) data as for AMS I. 16859-001. Size range 36.4-59.4 mm SL.

Diagnosis

A species of the atherinid genus *Craterocephalus* belonging to the *eyresii* species complex as defined by Ivantsoff (unpublished) and closely allied to *C. marjoriae* Whitley and *C. helenae* sp. nov. It appears closest to *C. helenae*, but is distinguished from that species by lower counts of midlateral scales (27-30 v. 30-32) and vertebrae (29-31 v. 32-33), higher gill raker counts (8-10 v. 10-11), the presence of a row of spots below the midlateral scales, and a more rounded snout. It differs from *C. marjoriae* in having less horizontal scale rows below the midlateral band (2.5 v. 3.5), in having the anus at or in front of the tips of the ventral fins rather than behind them, and in possessing low, rudimentary gill rakers rather than well formed tubercular rakers. Further comparisons are indicated in Table 6.
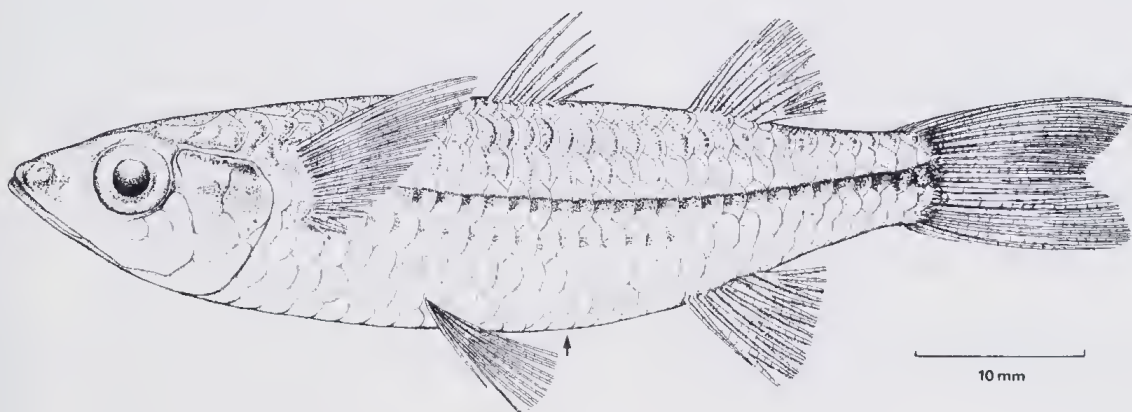
Figure 4   *Craterocephalus marianae*, holotype, AMS I.18523-001 Magela Creek, Jabiru, Northern Territory, 55.4 mm SL.

Description

The following description is based on measurements and counts taken from the holotype and 30 paratypes unless otherwise indicated (Table 5). Live specimens collected in the Magela Creek, Northern Territory, were utilised for colour variability and patterns.

Small, moderately robust fish, maximum known size about 60 mm SL. Dorsum of head above snout convex and sloping towards mouth. Mouth small, gape restricted by fusion of lips. Lips moderately thick. Mouthparts protrusible, upper jaw slightly overlying lower, when extended forward. Premaxilla longer than in other species of *Craterocephalus,* just reaching vertical through anterior margin of orbit. Anterior free edge of premaxilla markedly concave, posterior half slightly convex and covered by fleshy lip. Dorsal process of premaxilla long and pungent, extending to vertical through anterior margin of orbit. Posterior ramus of premaxilla wide and culminating in round eminence. Ramus of dentary highly elevated posteriorly, curving forwards at dorsal end. Upper jaw with fine teeth pointing posteriorly and almost at right angles to free edge of premaxilla. Lower jaw expanding anteriorly to form wide edentulous plate. Other elements of mouth also edentulous. Body scales large, sturdy, dorsoventrally elongated, ellipsoid to rectangular, scalloped anteriorly. Circuli restricted to anterior half of scale. Scales always in 5.5 scale rows along side of body. Preopercle with three scales. Opercle with four large scales. Scales on dorsum of head rectangular and large. Gill rakers in angle of first lower gill arch short and leaf-like, those following, reduced to elevations covered by spinules.

Colour: Live specimens sandy yellow, translucent, with thin black midlateral stripe more prominent on posterior half of body. Upper half of body darker than lower. Peritoneum clearly visible, outlining abdominal cavity. Dorsum and sides of head darker than body, opercular region reddish or opalescent. Rows of spots below midlateral band often present. Fins hyaline and unpigmented. Preserved specimens various hues of yellow. Midlateral band, brown, about half scale width, more prominent in posterior half of body and frequently punctuated by darker spot on each scale. Scales on upper half of body often edged by melanophores, those below with no such marking. Often with two rows of spots below midlateral band, fading away towards hypural joint. Dorsum of head dark, eyes black, peritoneum visible as black mark ventrally, in front and behind ventral fins. Fins clear and unpigmented.

Etymology: marianae is named in honour of the senior author's daughter Mariana. We recommend the common name Mariana's Hardyhead.

Remarks

This species has frequently been misidentified as *C. marjoriae* Whitley by previous workers including Pollard (1974), Lake (1978, in part), and Ivantsoff (1980, in part).

Preliminary biochemical analysis by the second author indicates there are genetic differences between *C. marianae* and *C. marjoriae* at 8 of 16 loci examined. The enzymes encoded by these loci were *Malic enzyme, 6 Phosphogluconate dehydrogenase, Fumarase, Phosphoglucomutase, Superoxide dismutase, Mannosephosphate isomerase, Phosphoglucose isomerase* and *Glutamate oxaloacetate transferase.*

C. helenae, C. marianae are quite distinct from *C. marjoriae* whilst the similarity between *C. helenae* and *C. marianae* makes them more difficult to separate. It would appear that geographic isolation between the Kimberley and the rest of northern Australia which has made *C. lentiginosus* distinct within the *stercusmuscarum* complex, has also allowed for independent paths of evolution for *C. marianae* and *C. helenae* within the *eyresii* complex.

C. marianae (identified as *C. marjoriae* by Ivantsoff 1978, 1980) has been the subject of intensive biological investigation by Bishop *et al.,* (in press) and by Ivantsoff *et al.,* (in press). Its abundance has allowed the above authors to determine the fishes' habitat preferences and preferred physical parameters, spawning sites, breeding seasonality, fecundity, embryo and larval development, feeding habits and growth rates. Its mortality curves during the 'dry' season in the Magela Creek have been examined by Ward (1982). *C. marianae* is therefore one of the best studied small, non-commercial freshwater fish in Australia.

This species is known only from the Magela Creek drainage of the East Alligator River System, Northern Territory.

Additional material examined

Mudginbarri Lagoon, Northern Territory, 12°26'S, 132°52'E, AMS I.16857-001 (27); isolated pool, 4 km south of South Alligator River crossing, Northern Territory, 12°23'S, 132°58'E, AMS I.17726-001 (20); Pine Creek, Oenpelli Road, South Alligator River, Northern Territory, approximately 12°21'S, 133°02'E, AMNH-DR 1969-112 (13).

Abbreviations used in all tables: SL, standard length; Pec L, length of longest pectoral rays; H max, greatest body depth; H min, least body depth at caudal peduncle; Sn, snout; OD1, origin of first dorsal fin; OD2, origin of second dorsal fin; OV, origin of ventral fin; TPec, tips of pectoral fins; TV, tips of ventral fins; OA, origin of anal fins; TA, point of last ray insertion of anal fin. Position of fins and anus is expressed as a number of scales in front (F) or behind (B) the point of reference. S D, standard deviation.

Table 1   Measurements expressed as proportions and counts of the holotype and other 62 specimens including 20 paratypes of *Craterocephalus stercusmuscarum fulvus*.

SL	Holotype 40.7 mm	Paratypes and 42 other 19.0-63.0 mm		
		For all specimens:		
		mean	range	SD
In SL				
Head	3.3	3.5	(3.2-4.0)	.18
Pec L	6.3	6.2	(3.7-9.0)	.96
H max	4.6	5.2	(4.4-6.0)	.39
H min	12.5	12.5	(10.2-15.0)	1.2
Sn-OD1	1.9	2.0	(1.9-2.3)	.08
Sn-OD2	1.3	1.4	(1.3-1.5)	.04
Sn-OV	2.0	2.1	(1.9-2.3)	.10
Sn-TV	1.6	1.7	(1.6-1.8)	.05
Sn-OA	1.4	1.4	(1.3-1.5)	.05
Sn-TA	1.2	1.2	(1.1-1.3)	.05
In Head				
Eye	3.3	3.2	(2.5-3.8)	.26
Interorbital	2.8	3.0	(2.2-3.7)	.32
Postorbital	2.2	2.4	(2.0-2.8)	.16
In Eye				
Snout	1.2	1.3	(0.9-1.7)	.23
Premaxilla	1.2	1.3	(1.0-1.6)	.14
Dorsal process of premaxilla	1.5	1.5	(1.0-2.1)	.22
Scale Counts				
Midlateral	32	33.4	(32-35)	.86
Transverse	7	7.0	(7.0-7.5)	.14
Predorsal	15	14.0	(11.0-17.0)	1.34
Interdorsal	7	7.1	(6.0-8.0)	.65
Fin Elements				
First dorsal spines	6	6.4	(4.0-8.0)	.75
Second dorsal rays	5	6.3	(5.0-9.0)	.69
Anal rays	7	7.5	(6.0-9.0)	.68
Pectoral rays	11	12.1	(11.0-14.0)	1.12

Table 1 (continued)

SL	Holotype 40.7 mm	Paratypes and 42 other 19.0-63.0 mm		
		For all specimens:		
		mean	range	SD
Position of Fins				
OD1 to TV	F4.5	F4.5	(F3-F6)	.83
OD1 to TPec	B2.0	B1.9	(0-B3.5)	.88
OV to TPec	0	F0.6	(F3-B2)	1.70
Other Values				
Gill rakers in first				
lower gill arch	11	11.3	(10-13)	.87
Position of anus to TV	0	F0.3	(F1.5-B1.0)	.61
Vertebrae	33	34.5	(31-36)	.93

Table 2   Measurements and counts for 15 specimens (holotype and paratypes) of *Cratero-cephalus lentiginosus* (unless otherwise indicated #)

SL	Holotype 43.3 mm		15 paratypes 21.9-43.3 mm		
			For all specimens:		
			mean	range	SD
In SL					
Head	3.5		3.5	(3.2-3.7)	.14
Pec L	5.7	#14	6.1	(5.3-6.9)	.47
H max	4.8		5.0	(4.6-5.4)	.25
H min	10.8		11.1	(9.9-12.5)	.69
Sn-OD1	2.0		2.1	(2.0-2.2)	.07
Sn-OD2	1.4		1.4	(1.4-1.5)	.05
Sn-OV	2.3		2.2	(2.0-2.4)	.1
Sn-TV	1.7		1.7	(1.6-1.7)	.04
Sn-OA	1.4		1.4	(1.4-1.5)	.05
Sn-TA	1.3		1.2	(1.2-1.3)	.05
In Head					
Eye	3.4		3.2	(3.0-3.5)	.15
Interorbital	2.9		3.0	(2.6-3.3)	.16
Postorbital	2.4		2.5	(2.4-2.7)	.10
In Eye					
Snout	1.1		1.3	(1.0-1.5)	.16
Premaxilla	1.1		1.3	(1.1-1.6)	.12
Dorsal process of					
premaxilla	1.8		1.6	(1.4-1.8)	.15

Table 2 (continued)

SL	Holotype 43.3 mm		15 paratypes 21.9-43.3 mm		
			For all specimens:		
			mean	range	SD
Scale Counts					
Midlateral	30		29.7	(29-31)	.60
Transverse	6		6.1	(5-7)	.52
Predorsal	14		13.2	(12-15)	.94
Interdorsal	7		6.8	(6-7)	.40
Fin Elements					
First dorsal spines	6		6.9	(6-8)	.50
Second dorsal rays	7		6.4	(6-7)	.51
Anal rays	7		7.4	(7-8)	.50
Pectoral rays	12		11.7	(11-13)	.60
Position of Fins					
OD1 to TV	F5		F5.3	(F4-F6)	.60
OD1 to TPec	B2	#14	B1.2	(0-B3)	.89
OV to TPec	0	#14	F0.8	(0-F2)	.58
Other Values					
Gill rakers in first					
lower gill arch	9		9.4	(8-11)	1.15
Position of anus to TV	0		F1.1	(0-F2)	.69
Vertebrae	32		32	(32-33)	.26

Table 3   Meristic values distinguishing *C. lentiginosus, C. s. stercusmuscarum* and *C. s. fulvus*. Data for *C. s. stercusmuscarum* taken from Ivantsoff (1978).

	C. lentiginosus		*C. s. stercus-muscarum*		*C. s. fulvus*	
	mean	range	mean	range	mean	range
Midlateral scales	29.7	(29-31)	32.9	(32-34)	33.4	(32-35)
Transverse scales	6.1	(5-7)	7.0	(6.5-7)	7.0	(7-7.5)
Predorsal scales	13.2	(12-15)	16.1	(12-18)	14.0	(11-17)
Vertebrae	32.0	(32-33)	36.7	(35-38)	34.5	(31-36)

Table 4 Measurements expressed as proportions and counts for 26 specimens (holotype and paratypes) of *Craterocephalus helenae* (unless otherwise indicated #).

SL	Holotype 56.5 mm		25 paratypes 35.4-61.3 mm For all specimens:		
			mean	range	SD
In SL					
Head	3.4		3.3	(3.2-3.6)	.11
Pec L	4.9		4.8	(4.1-5.0)	.32
H max	4.2		4.3	(4.0-4.7)	.17
H min	11.0		10.4	(9.4-11.1)	.50
Sn-OD1	2.1		2.1	(2.0-2.1)	.05
Sn-OD2	1.4		1.4	(1.3-1.4)	.02
Sn-OV	2.3		2.2	(2.0-2.3)	.08
Sn-TV	1.7		1.6	(1.5-1.7)	.06
Sn-OA	1.5		1.4	(1.4-1.5)	.03
Sn-TA	1.2		1.2		
In Head					
Eye	3.7		3.4	(3.2-3.8)	.20
Interorbital	3.2		3.1	(2.7-3.3)	.17
Postorbital	2.5		2.5	(2.4-2.7)	.08
In Eye					
Snout	0.9		1.0	(0.8-1.2)	.11
Premaxilla	0.9		1.0	(0.9-1.2)	.08
Dorsal process of premaxilla	1.0		1.1	(0.9-1.3)	.11
Scale Counts					
Midlateral	31		31.2	(30-32)	.63
Transverse	5.5		5.6	(5.5-6.0)	.17
Predorsal	11		11.4	(10-13)	.80
Interdorsal	6		7.4	(6-8)	.58
Fin Elements					
First dorsal spines	7		5.8	(5-7)	.63
Second dorsal rays	8		6.3	(5-7)	.67
Anal rays	8		6.3	(5-7)	.63
Pectoral rays	12		12.3	(12-13)	.45
Position of Fins					
OD1 to TV	F5.5		F4.4	(F3-F6)	.70
OD1 to TPec	F1		F1.0	(0-F2.0)	.57
OV to TPec	F2		F2.6	(F1.5-F4.0)	.64
Other Values					
Gill rakers in first lower gill arch	8		8.9	(8-10)	.67
Position of anus to TV	F1		F0.9	(0-F1.5)	.39
Vertebrae	33	#24	32.9	(32-33)	.33

Table 5   Measurements and counts for 31 specimens (holotype and paratypes) of *Cratero-cephalus marianae* (unless otherwise indicated #).

SL	Holotype 55.4 mm		30 paratypes 36.4-59.4 mm		
			For all specimens:		
			mean	range	SD
In SL					
Head	3.2		3.2	(3.0-3.4)	.11
Pec L	4.8		4.8	(4.4-5.3)	.24
H max	4.2		4.4	(4.0-4.8)	.16
H min	9.1		9.1	(8.7-10.2)	.38
Sn-OD1	2.0		2.0	(1.9-2.1)	.06
Sn-OD2	1.4		1.4	(1.3-1.4)	.07
Sn-OV	2.1		2.2	(2.1-2.3)	.07
Sn-TV	1.6		1.6	(1.6-1.7)	.02
Sn-OA	1.4		1.4	(1.3-1.4)	.02
Sn-TA	1.2		1.2	(1.2-1.3)	.02
In Head					
Eye	3.1		3.3	(3.0-3.7)	.15
Interorbital	2.9		2.9	(2.5-3.1)	.13
Postorbital	2.5		2.6	(2.4-2.8)	.11
In Eye					
Snout	1.1		1.0	(0.8-1.2)	.10
Premaxilla	1.0		1.0	(0.8-1.2)	.08
Dorsal process of premaxilla	1.0		1.1	(0.9-1.3)	.10
Scale Counts					
Midlateral	29		28.4	(27-30)	.61
Transverse	5.5		5.5		
Predorsal	13		11.7	(11-13)	.70
Interdorsal	6		6.2	(6-7)	.38
Fin Elements					
First dorsal spines	6		6.0	(5-7)	.48
Second dorsal rays	5		5.1	(5-6)	.34
Anal rays	6		6.0	(5-7)	.26
Pectoral rays	13		12.6	(11-14)	.72
Postion of Fins					
OD1 to TV	F4		F4.4	(F3.5-F5.5)	.46
OD1 to TPec	F0.5		F0.2	(B1-F1.5)	.48
OV to TPec	0		F1.8	(F1-F3.5)	.59
Other Values					
Gill rakers in first lower gill arch	11		11.2	(10-12)	.58
Position of anus to TV	F1		F1.0	(0-F2)	.46
Vertebrae	29	#45	30.2	(29-31)	.59

Table 6   Characters distinguishing three closely related species of *Craterocephalus*.
           *Data from Ivantsoff, 1978.

	C. marjoriae		C. helenae		C. marianae	
	mean	range	mean	range	mean	range
Pectoral fin in SL	5.5	(4.9-6.4)	4.8	(4.1-5.0)	4.8	(4.4-5.3)
Snout in eye	1.2	(0.9-1.6)	1.0	(0.8-1.2)	1.0	(0.8-1.2)
Premaxilla in eye	1.2	(1.0-1.5)	1.0	(0.9-1.2)	1.0	(0.8-1.2)
Dorsal process of premaxilla in eye	1.4	(1.1-1.7)	1.1	(0.9-1.3)	1.1	(0.9-1.3)
Midlateral scales	29.4	(28-30)	31.2	(30-32)	28.4	(27-30)
Scales below mid-lateral band	3.5		2.5		2.5	
Gill rakers in first lower gill arch	11.1	(10-12)	8.9	(8-10)	11.2	(10-12)
Vertebral count	31.6	(30-34)	32.9	(32-33)	30.2	(29-31)
Gill raker shape	tubercular		reduced		reduced	
Position of anus in relation to tips of ventral fins	usually behind		at or in front		at or in front	
Colour patterns	dark blotch below midlateral band and above vent in NSW populations		no live specimens available		4th, 5th row with spots along side of body, patch absent	
Dorsal head scale	ovoid		rectangular		rectangular	
Premaxilla length	not reaching vertical through anterior margin of orbit		almost reaching vertical		reaching vertical	

Acknowledgements

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A second contribution to the biology of *Ctenocolletes* bees (Hymenoptera: Apoidea: Stenotritidae)

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Abstract

Field observations of adult behaviour (particularly foraging and mating) and nests of five species of *Ctenocolletes* are presented and compared with earlier observations. All studied species are solitary and ground-nesting. Nests are unusual in lacking tumuli and those of *C. albomarginatus* and *C. nicholsoni* are remarkably deep (2.7-3.2 m).

C. fulvescens is unusual in the genus in having a summer/autumn (rather than a winter/spring) flight season and in exhibiting matinal foraging in females and a bimodal flight pattern in males.

Conjugate flight of mating pairs and territorial hovering and darting flights of males are recorded for additional species. Meloidae (Coleoptera) are confirmed as cleptoparasites in nests of *C. nicholsoni* and a *Crassifoenus* species (Hymenoptera: Gasteruptiidae) is recorded from nests or nesting areas of four *Ctenocolletes* species.

Introduction

In a previous paper (Houston 1984), I recorded the first details of the bionomics of bees in the genus *Ctenocolletes.* Nests of only one species (*C. ordensis* Michener) were described and much of the information on adult behaviour was fragmentary, providing only a very incomplete picture of the bionomics of the genus as a whole.

The observations presented here were made opportunistically during field work at various Western Australian localities in 1983-1985 and are similarly fragmentary. Nevertheless, they augment and significantly extend earlier observations. Examination of the nests of several species has revealed some significant interspecific differences and discovery of the nests of *C. albomarginatus* Michener and *C. nicholsoni* Cockerell provided the first opportunity to study the life histories of acarid mites associated with the bees. The mite-bee symbiosis will be the subject of a forthcoming paper and the present paper provides the necessary background.

The nomenclature employed here follows Houston (1985). Specimens taken as vouchers in the course of my studies are lodged in the Western Australian Museum.

In respect of brood cells, I use the terms 'proximal' to mean near the opening (or cell plug) and 'distal' to mean near the closed (blind) end.

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Observations

Ctenocolletes albomarginatus Michener

Nests

A nesting area of this species adjacent to the eastern margin of East Yuna Nature Reserve (*c.* 34 km WNW of Mullewa) was examined first on 13-16 September 1984. It was on the crest of a sandy rise in a farm paddock that had lain fallow for some years. Areas of bare, wind-eroded sand were interspersed with areas of herbs and shrub regrowth and bordered on natural *Banksia* shrubland and heath in the reserve.

The persistent flight of *albomarginatus* males over an area of level bare sand attracted my attention initially and the arrival of pollen-laden females confirmed the presence of nests there. The females alighted at barely discernible pits in the ground and quickly burrowed out of sight through loose sand. About 10 burrows were thus revealed in an area about 7 x 15 m but more may have been present. Tumuli were totally absent from the nest entrances.

One burrow was excavated and was so deep and required so much time and effort to expose that I was unable to excavate more. The excavation pit went to a depth of 3.3 m through uniform but increasingly more compacted yellow sand. To a depth of 2.6 m the sand was soft and damp but below this it became dry and hard and near 3 m depth could only be chipped with a spade.

The entrance shaft extended at an angle of 13° below horizontal for 27 cm and near the entrance was filled with loose sand (Figure 1). At its lower end it turned vertically and descended to a depth of 295 cm. Here the shaft turned obliquely for 11 cm, made two lateral turns and terminated in an open empty cell at a depth of 305 cm (23 cm to one side of the vertical shaft line). The shaft was 8.5 mm in diameter, uncemented and unlined.

Three closed cells apparently associated with this nest were exposed at depths of 308-316 cm. They were 20-28 cm from the vertical shaft axis and spanned 100° of arc about it. All were cut through before they were discovered and no details of their closures were obtained. The internal shape of the cells was ovoid (although the lower side was flatter than the upper) and their long axes dipped about 30-45° below the horizontal. Their walls did not appear to be built-in nor any harder than the mortar-like matrix and were the same colour internally as the matrix. Only the distal half of each cell was varnished and waterproof; the walls nearer the cell plug readily absorbed droplets of water and the interstices between sand grains forming the walls there were seen to be open under the microscope.

Several old cells were cut through in the lower reaches of the excavation but they were compactly filled with sand and were difficult to detect.

The entrance shaft of a second nest was like that of the first but extended only 18 cm before turning vertically. It had an 8 cm barricade of loose sand

and fine litter within the entrance.

Each of the three closed cells from the nest fully excavated contained a pollen mass surmounted by an egg (Figure 4). The pollen provision was soft and moist and could not be handled without distortion.
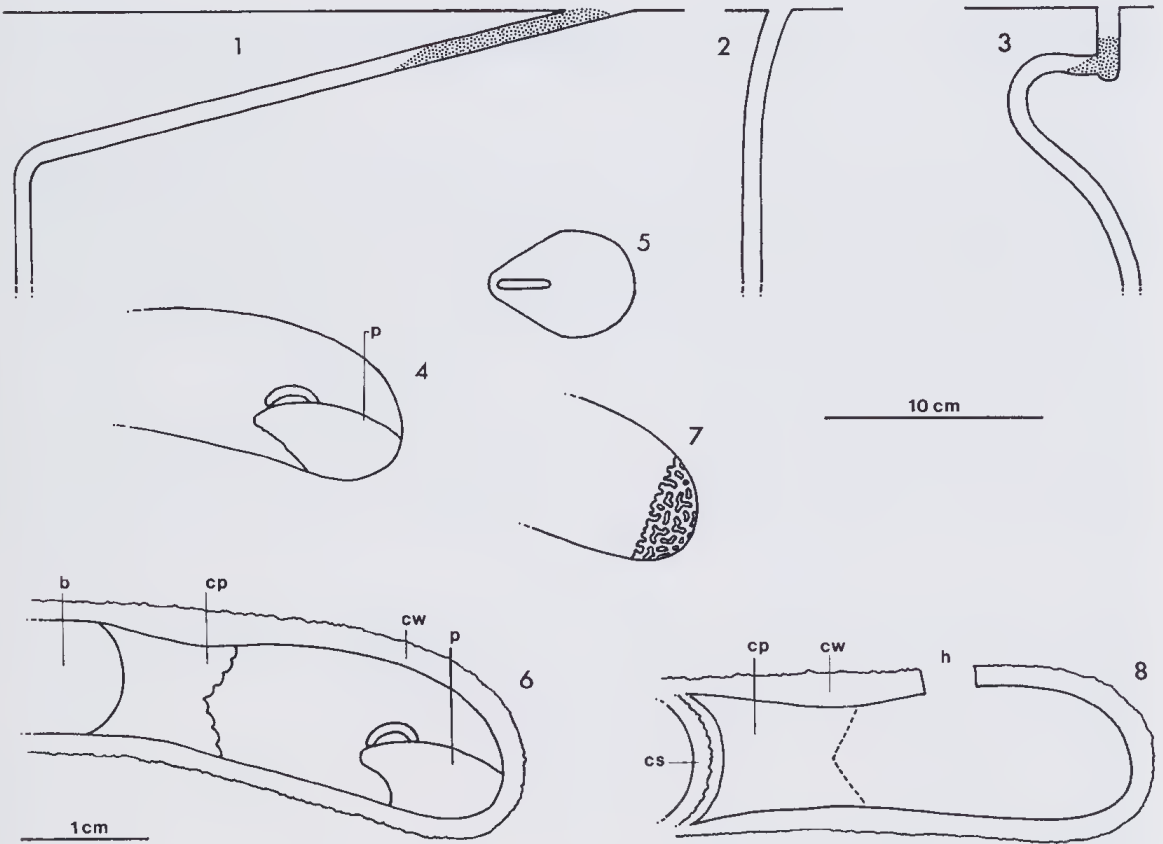
Figures 1-8   Nest details of *Ctenocolletes* species. (1-3) Profiles of entrance galleries of (1) *C. albomarginatus*, (2) *C. nicholsoni* and (3) *C. smaragdinus* (loose soil stippled). (4, 5) *C. albomarginatus*: profile of brood cell (closure lost in excavation) and provision mass (4) and top view of provision mass and egg (5). (6, 7) *C. nicholsoni*: profile of brood cell and provision mass (6) and profile of faecal mass in distal end of cell (7). (8) Profile of old soil-filled brood cell of *C. smaragdinus* with hole in ceiling presumably made by an emerging parasite (original orientation of cell not shown). Upper scale line refers to Figures 1-3, lower to Figures 4-8.

Legend: b, soil barricade; cp, cell plug; cs, concave septum; cw, built-in cell wall; h, hole; p, provision mass surmounted by egg.

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Associated organisms

All four cells contained 2-6 acarid mites or their exuviae and these will be discussed in a forthcoming paper. A few gasteruptiid wasps (*Crassifoenus* sp.) were observed searching the ground at the nesting area but none was seen to enter a nest.

Adult behaviour

On a brief visit to the East Yuna Reserve on 29 August 1984, I first noted males coursing over the bare sand (there were only two of them) and collected both sexes at flowers. On a return visit on 13-16 September 1984, more males (about 12 at any one time) were patrolling the nesting area. They flew errati-cally within 10 cm of the surface and their paths interwove. Occasionally two would engage in circling or chasing one another but there appeared to be no territoriality at the site. Some spots seemed to elicit more attention from males than others. Males would hover near them and almost alight. One spot (a tiny mound with an ant nest entrance hole to one side) received close attention from several males for over an hour but the reason was not apparent.

When a pollen-laden female flew in and approached her burrow 50 cm from this 'hot spot', the males immediately converged on her. She quickly became enveloped in a ball of grappling males that tumbled about on the ground while other males hovered about. After a few seconds the female mounted by a male struggled free and the pair flew conjugately up and over adjacent shrubbery out of sight. A similar sequence of events occurred when a second female approached her burrow. A third female that was pursued by a single male was netted. The pursuing male persisted about the net bag and followed as I moved it some metres. Males showed no response to flying insects other than their own species or to small objects flicked past or dangled near them.

Further observations of adult behaviour were made at the site on 24-26 August 1985. In mild overcast conditions, the males patrolled from about 11 am to 4.30 pm each day. They were more widely dispersed than previously and only about half of them flew close to the ground. The remainder flew rapidly 40-60 cm above it and frequently circled a patch of *Ricinocarpus* shrubs. On this visit I had hoped to observe females burrowing but only one female was seen entering the ground and she did not reappear. One mating as described above was observed at the site.

Ctenocolletes centralis Houston

Recent collection records of this species indicate that its chief forage plants are *Acacia* species and *Thryptomene maisonneuvii*. Pollen loads of five females collected at flowers of the latter plant proved to be composed of *Acacia* pollen in four cases and myrtaceous (probably *Thryptomene*) pollen in the fifth. *Thryptomene* apparently serves primarily as a nectar source. The only other plant genera visited are *Baeckea* and *Dicrastylis*.

Males have been observed at several localities engaging in fast wide-ranging flight over *Thryptomene maisonneuvii* flowers. Numerous individuals crossed paths and there was no evidence of aggression. However, on 28 July 1983, at least 20 males were found defending territories amongst *Triodia* hummocks in a flat sandy interdune swale 17 km west of Wiluna. Males maintained hover stations about 20-50 cm above the ground and made frequent forays out from them. This activity was observed at midday in fine sunny conditions. No females were observed in the area, nor could I find any nest burrows. The area and surrounds were dry and flowerless.

Ctenocolletes fulvescens (Houston)

Recent collection records (Houston 1985) confirm that this species is unique in the genus in its adult activity being confined to late summer and early autumn (January-March). Of 21 males and four females collected on 26 February-4 March 1984, most showed little or no wing wear and few showed extensive emargination. The one female collected in January (21, 1970) had entire wing margins. This suggests that emergence of young adults may occur from late January through February.

All individuals collected or observed were at flowers of mallee *(Eucalyptus gracilis* and *E. oleosa)*. Both sexes took nectar and females collected pollen (verified by microscopic examination of two pollen loads). Flowers of other plants such as *Amyema, Banksia* and *Melaleuca* were available but were not visited.

Females exhibited a matinal activity pattern and foraged from about 7.30-10.30 am (Western Standard Time) with a peak of activity between 8 and 9 am. Males exhibited a bimodal activity pattern, flying about the mallees from 6.55-11.45 am and 5.50-7.10 pm (sunrise 6.20-6.30 am; sunset 7.00-7.10 pm). The one female collected in January was flying at sunrise during extremely hot weather.

Males spent most of their time flying very rapidly from tree to tree and were difficult to net as they seldom alighted or hesitated. Occasional chases between males were noted but none was observed to hover in or defend a territory.

Several copulating pairs were encountered during morning. They flew conjugately and ponderously about the blossoms and settled intermittently. The females foraged and some carried pollen. Males were mounted above and behind the females much as described for *C. smaragdinus* (Houston, 1984: 159) but held their antennae erect. Initiation of copulation was observed twice: each time a male swooped in near a feeding female, hovered momentarily while orientating, then pounced on her. The pairs fell from the foliage, buzzing loudly but quickly took flight conjugately.

This species' habitat consists of mallee eucalypt woodland over sandy loam soil with calcrete outcrops.

Ctenocolletes nicholsoni Cockerell

Nests

A populous nesting colony of this species was discovered 13 km south of Wannoo (or about 209 km north of Geraldton) on 24 August 1984 and studied over the next three days. It was in a sandy flat between sand ridges which had been burnt at least two years previously. The vegetation consisted almost entirely of waist-high *Acacia* and *Grevillea* shrubs providing about 30 per cent ground cover. The ground surface was largely bare except for some leaf litter beneath the shrubs.

Nest entrances were simple holes in the ground and were identifiable only when females entered or departed. Hundreds were scattered irregularly over an area at least 50 m across (the full extent of the aggregation was not determined). Some were in open bare ground but most were partly concealed beneath shrubs or litter. Tumuli were completely absent and entrances were open, the galleries descending vertically or obliquely (Figure 2).

Only two nests were excavated. Their considerable depth and the amount of labour required to expose them precluded more being tackled. The soil was 'red' sand to a depth of 3 m where it gave way to gravel and stone. It was soft near the surface and increasingly more compacted with depth so that below 1.5-2.0 m it could be cut in blocks. It was damp to a depth of 2.7 m.

The first burrow excavated had an elliptical entrance 10 x 12 mm and descended vertically, narrowing to a diameter of 8.5 mm below about 20 cm. The unlined uncemented shaft descended vertically with only slight deviations. Eleven separate brood cells apparently associated with this shaft were exposed at depths of 2.4-2.7 m. Their access burrows were compactly soil-filled and untraceable. The cells were distributed around the shaft axis, 8-20 cm from it, except for one directly beneath the shaft. A few cells were in close proximity to one another but no cells were in linear sequence.

In general form, the cells resembled those described and figured for *C. ordensis* (Houston, 1984) but the following differences were noted: long axes of cells inclined from almost horizontal to almost vertical, most dipping steeply (distal ends lowermost); inner walls shiny and waterproof only in distal end, grading to matt and absorbent near plug; closures consisting only of soil plug and barricade of sand and fine gravel (no concave partitions although outer surface of plug was smooth and concave) (Figure 6). Cells were detectable during excavation by their hardened gritty walls.

The second nest excavated had an entrance hidden beneath litter, an oblique entrance gallery 5 cm long and, proceeding from this, a vertical shaft descending to a depth of 2.4 m. At the lower end of the shaft was a soil plug beneath which an open burrow extended obliquely for 30 cm then horizontally for a further 5 cm ending in an open cell. The cell contained mouldy amorphous pollen meal and had obviously been abandoned. Ten freshly closed cells were exposed at

depths of 2.4-2.7 m within 20 cm of the shaft axis. Not all need have been associated with the one nest for a second shaft ran parallel to and only 6 cm from the first. The structure and arrangement of the cells were essentially as for the first nest.

Over half of the cells found contained immatures on provisions. In each case the provision was a soft, very moist mass of pollen making broad contact with the lowest part of the cell and moulded to a peak facing the cell plug. Eggs, when present, rested atop the provision touching it only by their ends (Figure 6). Larvae from hatchlings to middle instars rested on the provisions, ventral surface down and head towards the cell plug, and fed on the peaked proximal surface. They thus appeared to be sedentary.

Two cells contained post-defaecating larvae and khaki faecal material formed hemispherical masses in the distal ends of the cells (Figure 7). These meconia were dry and firm and riddled with minute passages. Two fully fed defaecating larvae were also found and passed copious quantities of orange faecal material as long pasty extrusions which fused into a mass or were smeared about as the larvae writhed.

Almost all cells of nest 1 contained larvae ranging from newly hatched to post-defaecating. One damaged cell had probably contained an egg and another had an early stage meloid larva in place of the bee immature. Most cells of nest 2 contained provisions with either bee eggs (3 cells) or meloid larvae (5 cells); only one contained a post-defaecating bee larva. All post-defaecating larvae rested with their heads towards the cell plug, otherwise their orientation was not recorded.

Numerous old soil-filled cells were encountered at depths of 2.3-2.8 m while excavating the fresh cells. They were harder and more easily removed than the latter. None contained any conspicuous traces of faecal material.

Associated organisms

As mentioned above, at least six cells contained meloid larvae. One recently closed provisioned cell must have received two triungulins: when opened it contained a second instar meloid larva on a dead flaccid bee egg, a dead triungulin and a triungulin exuvium. Other cells contained older meloid larvae up to fully developed size.

Adult meloids were not obtained from the nests but some *Zonitis* adults were collected on bushes at the nesting area and on the forage plants. Triungulins attached to the bees' pubescence are commonplace (6 of 20 females collected at nests carried 1-3 triungulins and one female carried six on the metanotum and propodeum).

Numerous adults of both sexes of a *Crassifoenus* species (Hymenoptera: Gasteruptiidae) hovered close to the ground at the nesting area. Females occasionally inspected nest entrances but I saw none enter. However, a dead specimen was found in a burrow from a previous season.

All cells closely inspected contained at least some individuals of the acarid mite *Ctenocolletacarus longirostris* Fain. Details will appear in a forthcoming paper.

Several cells were returned to the laboratory in vials and microscopic examination of their inner walls revealed numerous tiny nematodes writhing in a film of moisture. Also, hundreds of minute black fungal bodies peppered the walls in a broad band around the proximal half of each cell. These were identified as pycnidia (spore bodies) of a *Sphaeronaema* species, form class Coelomycetes (R.N. Hilton, pers. comm.). Each spherical pycnidium, measuring 30-40 μ in diameter, was embedded in or situated beneath the secreted wall lining and extended a single bristle up to 0.3 mm long into the cell lumen. In some cases, heavy growths ruptured the wall lining but otherwise the fungus appeared to cause no harm to the bees or their provisions. Greenish globules of yeast also developed on the walls of these cells while they were kept moist.

Adult activity

One adult female bee was recovered from each of the excavated nests and no more than one female was observed at any other burrow. Clearly the species is solitary.

Adult activity was not closely monitored but following a cold night (min. temp. 2.5°C) and in sunny conditions, females began leaving their burrows at about 9.18 am (sunrise at 7.05 am, WST). They were heard returning to or leaving their burrows intermittently throughout the day and a peak of activity was noted from 4.30-6.00 pm as hundreds of females returned from their final foraging trip. Activity then trailed off to zero following sunset at about 6.05 pm. Females returning to their burrows did so swiftly and entered without hesitation. Departures were also swift and without warning.

Males were not encountered at the nests but, judging by sounds heard intermittently throughout the day, some patrolled the nesting area flying fast just above the tips of the foliage.

Twenty-five females collected as they returned to nests during my 1984 visit were rated as to the degree of wear of their wing margins and mandible apices as a guide to age of the population. Wing wear varied from moderate to heavy indicating that the population had been active for some weeks and was more or less in phase. Mandible wear was far more variable (from nil to heavy) and did not correlate as clearly with wing wear as would be expected if all females burrowed and foraged to the same extent during their lives: several females with moderate to heavy wing wear exhibited little or no mandible wear. This could be explained if some females in the population re-use burrows from an earlier generation or usurp those of other females and thereby avoid a major part of excavation work.

The nesting site was revisited twice in July and August 1985 in the hope of observing earlier stages of nesting activity. Conditions appeared to be conducive

to activity but none was observed on either visit nor were any burrows evident. Although adults were absent at the nesting area on the first visit (28 July-3 August), numerous freshly emerged males and a female were captured at flowers of *Grevillea* sp. and *Thryptomene* sp. 1.2 km away. Fewer more worn adults were present at the same plants on the second visit (21-23 August). Evidently the nesting site had either been abandoned by its population or had failed to produce an adult generation for the season.

Males favoured the *Hakea* flowers over the *Thryptomene* but patrolled and took nectar from both from *c.* 10 am-3 pm. No territorial behaviour was noted in several days of observation. Mating has not been observed for *nicholsoni* and only once did I see an encounter between sexes at Wannoo: a female taking nectar at *Hakea* flowers was approached several times in rapid succession by two flying males but she repelled them each time and they eventually desisted.

Ctenocolletes nigricans Houston

Nest

A solitary nest was found on 16 September 1984 about 100 m from the nesting area of *C. albomarginatus* at East Yuna Nature Reserve. A pollen-laden female entered a simple hole about 9 mm in diameter amongst twigs on largely bare, gently sloping sand. There was no tumulus and the female did not close the entrance. The nest was not excavated.

Adult activity

A flying conjugate pair was observed on 24 August 1984 at the *C. nicholsoni* nesting area south of Wannoo. The pair settled on a shrub stem and the male, mounted above and behind the female, made attempts to engage its genitalia with the female's. When netted, the bees remained *in copula* until placed in a killing jar.

Further observations of mating behaviour were made on 16 September 1984 adjacent to the nesting area of *C. albomarginatus* near East Yuna. Several males were encountered in mid afternoon patrolling and defending areas of bare or sparsely vegetated ground. Males hovered almost stationary within 50 cm of the ground or meandered about for several seconds before suddenly darting off on a rapid foray, then returned to their original position within 5-10 seconds. They darted after any flying insects including other males and butterflies that came near. They also chased small objects flicked over them and a 7 mm diameter plumb-bob swung on the end of a nylon line (the tone of their wing beats rising sharply as they did so). One male, which hovered near the nest mentioned above, darted after the female as she approached her entrance. She fled and he returned to hover as before.

Ctenocolletes smaragdinus (Smith)

Nests

Two burrows about 3 m apart were found on 26-27 October 1985 about 75

km east of Hyden. They were in gently sloping sandy ground sparsely vegetated with stunted heath. The simple round entrance holes amongst litter and wiry grass stems lacked tumuli and were most inconspicuous. They were revealed when the females entered them. One was also entered for several minutes prior to the bee's arrival by a gasteruptiid wasp (*Crassifoenus* sp.). As several of these wasps were observed patrolling the ground nearby (over an area of about ¼ hectare) and occasionally inspected holes, I suspect more nests than the two found occurred there.

The entrance galleries were vertical and plugged with loose sand through which the females burrowed as they entered. Careful excavation failed to reveal an open shaft beneath the first entrance except at a depth of 50-53 cm where the occupant female was turned up. Apparently the shaft above her was compactly soil-filled. There were no brood cells. The second burrow had an entrance gallery about 3 cm deep with a shaft 9 mm in diameter opening off one side near its lower end (Figure 3). The shaft curved around and descended more or less vertically into compacted sand; its lower end curved almost horizontally and ended at a depth of 172 cm and 15 cm from the vertical shaft axis. The burrow was open except for a loose soil barricade in the entry shaft and a plug and barricade in the lower section (the female was recovered below this closure). The walls of the upper section of shaft appeared to be cemented or at least consolidated and of a different colour from the surrounding sand but were not built-in. A short lateral burrow occurred at 52 cm depth.

There were no fresh cells with the second burrow but several old soil-filled cells occurred within a radius of about 25 cm of the shaft at depths of 168-186 cm. Their structure was very similar to that of cells of *ordensis* and *nicholsoni* and they were inclined at an angle of about 45° below horizontal. One such cell had an entire closure and a hole about 4 mm in diameter in the cell ceiling indicated a parasite (? *Crassifoenus*) had emerged there. The closure consisted of a plug with a smooth concave outer surface and a concave mud partition closely applied to it (Figure 8). Maximum internal diameters of cells were 10.5-11.0 mm. Inner surfaces of cells were very smooth, matt, similar in colour to the sand matrix (light yellow) and readily absorbed drops of water. No faecal deposits were noted.

Adult activity

The two females associated with the nests described above entered them without pollen in the early afternoon and did not reappear during the next hour despite suitable conditions for flight. Evidently they were extending their nest burrows and accumulating the loose soil in the shafts. Their wings showed only slight wear indicating that they were young and commencing their first nests.

Occasionally, males flew low over the nesting area but showed no interest in burrows. Instead, they patrolled flowering bushes of *Verticordia picta* scattered

through the heath. Several mating pairs were disturbed from stems of shrubs and others flew conjugately amongst the *Verticordia* flowers foraging.

Ctenocolletes tigris Houston

Two females were observed to enter burrows in bare level sandy ground on 24-28 August 1984 at and near the nesting area of *C. nicholsoni* 13 km south of Wannoo. The burrow entrances were simple holes about 9 or 10 mm wide and lacked tumuli. They were closed with loose sand through which the females burrowed as they entered at a shallow angle to the ground surface (entrance galleries were obviously oblique). The burrows were not excavated.

Males were not observed near the burrows but were abundant about flowers of *Teucrium* on a nearby sand ridge. They patrolled the flowers from morning to evening and several conjugate male/female pairs were encountered. No territorial hovering and darting behaviour was observed.

Discussion

Although our knowledge of the bionomics of *Ctenocolletes* species is far from complete, enough is now known to be able to make some generalisations with reasonable confidence. The species studied demonstrate considerable uniformity of behaviour and nest architecture and the list of ethological characteristics considered to be ancestral for Stenotritidae given by Houston and Thorp (1984) may stand virtually unaltered.

Notwithstanding this, significant interspecific differences occurred in nests in respect of depth, entrance gallery form, inclination of brood cells, presence or absence of concave partitions in cell closures, extent of varnishing in cells, consistency (firmness) of provisions and form of larval faecal deposits.

Nests of *albomarginatus* and *nicholsoni* are remarkable for their depth and surpass the 2.45 m deep nest of *Oxaea flavescens* (Oxaeidae) claimed by Roberts (1973) to be the deepest bee nest on record. Some *Leioproctus* (Colletidae) are known to burrow to depths of 1.8-3.5 m in sand (personal observation and R.W. Thorp, pers. comm.). However, the deepest bee nest ever recorded was one of an anthophorid, *Exomalopsis aureopilosa* which descended to 5.3 m (Zucchi 1973). It was inhabited by 44 females and may have been excavated co-operatively or progressively by more than one generation. While acknowledging that nest burrows of *Ctenocolletes* may be re-used, I believe that individual females burrow to the maximum depths recorded for their species and that nests are not progressively deepened over several generations. Were the latter so, old cells from previous generations would be shallower than new cells but observation has shown they occupy the same horizons. I have no ready explanation of why some species excavate such deep nests but clearly they must gain some survival advantage from doing so. It may be that their brood cells escape the extremes of temperature and humidity occurring nearer the surface and are therefore less susceptible to growths

of pathogenic fungi and micro-organisms. Certainly the soil of the cell horizons at all nesting sites described in this paper was comparatively dry, whereas that nearer the surface was conspicuously damp. Temperatures at a depth of 3 m may be expected to remain within a range of 2°C throughout the year and would approximate the mean annual temperatures at the surface. At Carnarvon this would mean a temperature of *c.* 25°C, at Geraldton 19.5°C and at Perth 18.3°C (R. Belford, pers. comm.).

A notable feature of *Ctenocolletes* (and other stenotritid) nests is the absence of tumuli at burrow entrances. Despite attempts to observe the method of soil disposal, it remains a mystery. I suspect females carry soil well away from their entrances.

Cells are bilaterally symmetrical with the floor flatter than the ceiling. The steep inclination of cells of *albomarginatus* and *nicholsoni* (and possibly also *smaragdinus*) compared with those of *ordensis* may be associated with much softer provisions. The reduced extent of their waterproof lining (confined to the distal end of the cell) may correlate with the more distal position of the provisions. Cell closures of *ordensis* and *smaragdinus,* but not *nicholsoni,* have a concave partition in close juxtaposition to the outer concave surface of the cell plug (no intact closures were found for *albomarginatus*). Gravel particles were consistently present in all access burrow barricades.

Species differences occur in the form of larval faecal deposits: streaks along the cell walls in *ordensis* and hemispherical masses in the distal ends of cells in *nicholsoni.* Both kinds of deposit are also recorded for *Stenotritus* and which is more primitive is now in doubt.

Some species differences in mate-seeking and mating behaviour were evident. While males of all species patrol the forage plants, only those of *albomarginatus* and *nigricans* are known to patrol nesting areas as well. Nesting areas of *ordensis,* *nicholsoni* and *smaragdinus* received no male attention. Territorial behaviour involving hovering and darting is recorded for three species but not in their closest relatives. Thus, it occurs in *centralis* but not *nicholsoni, nigricans* but not *albomarginatus* and *smaragdinus* but not *tigris.*

Rozen (1968) noted unusual sexual dimorphism in two species of Andrenidae and suggested it may be associated with the hovering and darting behaviour of their males. Males of *Meliturgula* and *Melitturga* exhibit (1) enlarged compound eyes which converge dorsally so that the upper part of the face is relatively narrow; (2) clubbed antennal flagella; and (3) hind wings which are broader relative to their length than those of females and which have an enlarged jugal lobe. Similar sexual dimorphism occurs amongst species of *Ctenocolletes* (and also *Stenotritus*) in respect of (1) and (3) above, but no species have clubbed antennal flagella. However, all stenotritid bees of both sexes have the first antennal segment greatly attenuated. The degree to which compound eyes converge and the jugal lobe is enlarged in males varies amongst the species of *Ctenocolletes* and yet does not seem to be correlated with whether males engage in territorial hovering

and darting. Males of *C. smaragdinus* hover and dart although they do not exhibit ocular convergence nor enlargement of the jugal lobe. The reverse is the case with *C. nicholsoni*. Seven of the 10 species of *Ctenocolletes* are now known to exhibit conjugate flight of male/female pairs (identification for two is dubious). Females in such pairs frequently forage for nectar and pollen. Mating has yet to be observed in *centralis, nicholsoni* and *rufescens*.

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A new species of *Sinularia* (Coelenterata: Octocorallia) from Western Australia

Philip Alderslade* and Jody Baxter*

Abstract

A new species of soft coral *Sinularia platysma* (family Alcyoniidae) is described from material collected off Rottnest Island, Western Australia. The unusual encrusting colonies have no lobes and their dish-like aspect easily distinguishes them from previously described species.

Introduction

In 1980 Verseveldt published a revision of the genus *Sinularia* in which he recorded 93 species as being valid. Verseveldt and Tursch (1979), Chupu (1982) and Verseveldt and Benayahu (1983) increased this to 113 species. An examination of all the relevant illustrations easily demonstrates that the diversity of colony morphology within this genus is greater than that of any other soft coral species group. It encompasses such diverse forms as the long, lax, tentacle-like processes of *S. flexibilis* (Quoy and Gaimard), the minute lobules of *S. variabilis* Tixier-Durivault, the funnel-like forms of *S. dura* (Pratt), the hillocks of *S. densa* (Whitelegge), the branches of *S. arborea* Verseveldt and the meandering ridges of *S. muralis* May. Yet the essential nature of the spiculation is more or less constant throughout the group and there is little evidence to suggest the genus should be divided.

The addition of *S. platysma* sp. nov., the subject of this paper, increases the remarkable diversity of the genus even further by adding to it a colonial form completely devoid of natural lobes and presenting an upper aspect reminiscent of a shallow dish, or saucer, of irregular outline.

The new species has many club-shaped sclerites without a central wart and longer than 0.12 mm and therefore falls into Group IV of Verseveldt's 1980 categorisation.

The following abbreviations are used: WAM, Western Australian Museum, Perth; NTM, Northern Territory Museum of Arts and Sciences, Darwin.

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Systematics

Sinularia platysma sp. nov.

Figures 1-8

Holotype

NTM C-1049; collected by K. Harada from Thomson Bay, Rottnest Island, Western Australia, 31°59.7'S, 115°33'E, 10 April 1979, depth 10 m.

Paratypes

WAM 230-86, WAM 231-86, NTM C-1190, NTM C-1193; collected by P. Alderslade from Thomson Bay, Rottnest Island, Western Australia, 31°59.5'S, 115°33'E, 17 March 1980, depth 10 m.

Diagnosis

A small irregularly disc-shaped, encrusting, *Sinularia* the upper aspect of which is flat or slightly dished and devoid of naturally occurring lobes. The margin of the disc is entire and may be raised like the rim of a pie dish. Sclerites of the disc surface: simple clubs and branched forms 0.07 to 0.22 mm long and spindles to 0.35 mm. Sclerites of the basal surface: complexly warted capstans and clubs 0.09 to 0.23 mm long and a few spindles up to 0.40 mm long with high warts. Sclerites of the interior: plump warty spindles up to 5.1 x 1.32 mm and, particularly in the basal zone, a few spindles up to 0.45 mm with high warts. Polyps well armed with crown and points. (For comparisons with other *Sinularia* species see Remarks.)

Description

The spirit-preserved holotype (Figures 6 and 7A) is in two pieces. The pieces combined make up about half of the original encrusting colony and together measure 180 x 115 mm. The colony disc, which is approximately 30 mm thick, is flat, completely devoid of lobes and has the edge raised like the rim of a dish. This erect rim is between 20 and 30 mm high. Where the rim merges into the disc it is 12 to 15 mm thick. It then slowly tapers, being about 8 mm thick halfway up and 2 to 3 mm thick just below its rounded edge.

Polyps occur all over the surface of the disc and the inner surface of the rim. On the flat disc most of the polyps are partially extended and the surface is raised into low calicular mounds. On the inner surface of the rim there are zones of extended polyps, zones of low calicular mounds and zones where the locations of the polyps are difficult to detect. On the disc the polyps are quite evenly spaced. Measured from their centres most autozooids are 1.9 to 2.4 mm apart. On the rim the polyps are noticeably closer, with distances between polyps of 0.9 to 1.2 mm being more common. Some of the extended polyps are up to 1.2 mm long with anthocodia 0.8 to 1.1 mm across.

The polyps are well armed with numerous spindles and sticks. The crown consists of up to about six rows. Immediately above this, small numbers of sclerites are arranged loosely *en chevron* at the base of each tentacle, each group converging distally to a larger group arranged longitudinally (Figure 1A). The
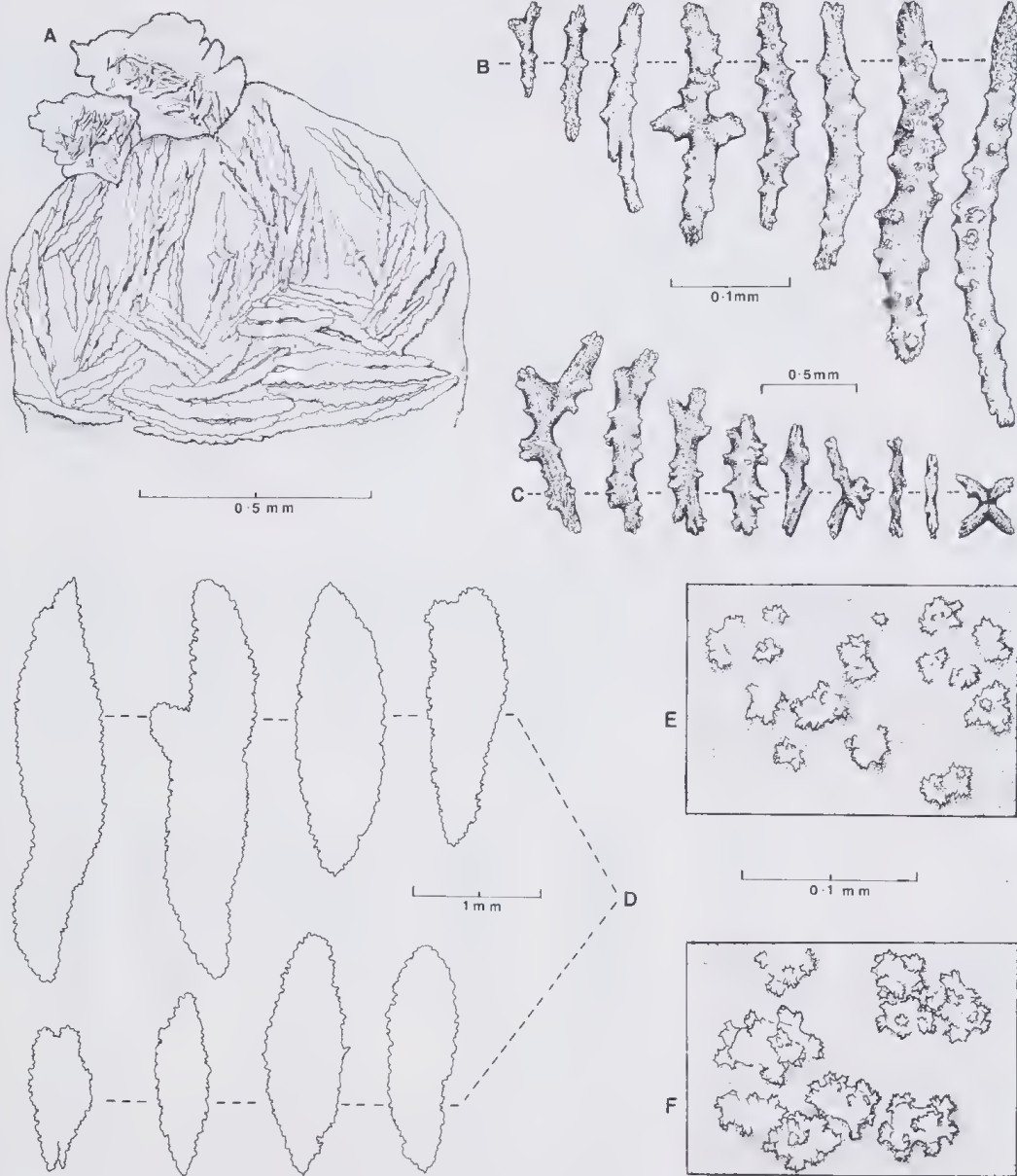
Figure 1   *Sinularia platysma* sp. nov. holotype, NTM C-1049; A, anthocodial armature; B, crown and points sclerites; C, tentacular sclerites; D, interior sclerites; E, warting of sclerites from the interior of the upper part of the colony; F, warting of sclerites from the interior of the basal part of the colony.

anthocodial sclerites (Figure 1B) are mostly 0.08 to 0.36 mm in length and bear conical prominences. The tentacles contain numerous small, slightly flattened, rods and irregularly shaped sclerites, mostly 0.04 to 0.11 mm in length (Figure 1C).

The sclerites in the surface of the disc have extremely varied shapes. Clubs, irregularly branched forms and spindles occur here. The clubs (Figure 2) are from 0.07 to 0.22 mm in length. The heads and handles are mostly ornamented with simple pointed processes but there appears to be little pattern to their construction. The irregularly branched sclerites, and the intermediate shapes between these forms and the clubs, are 0.07 to 0.18 mm in length (Figure 3). The spindles,
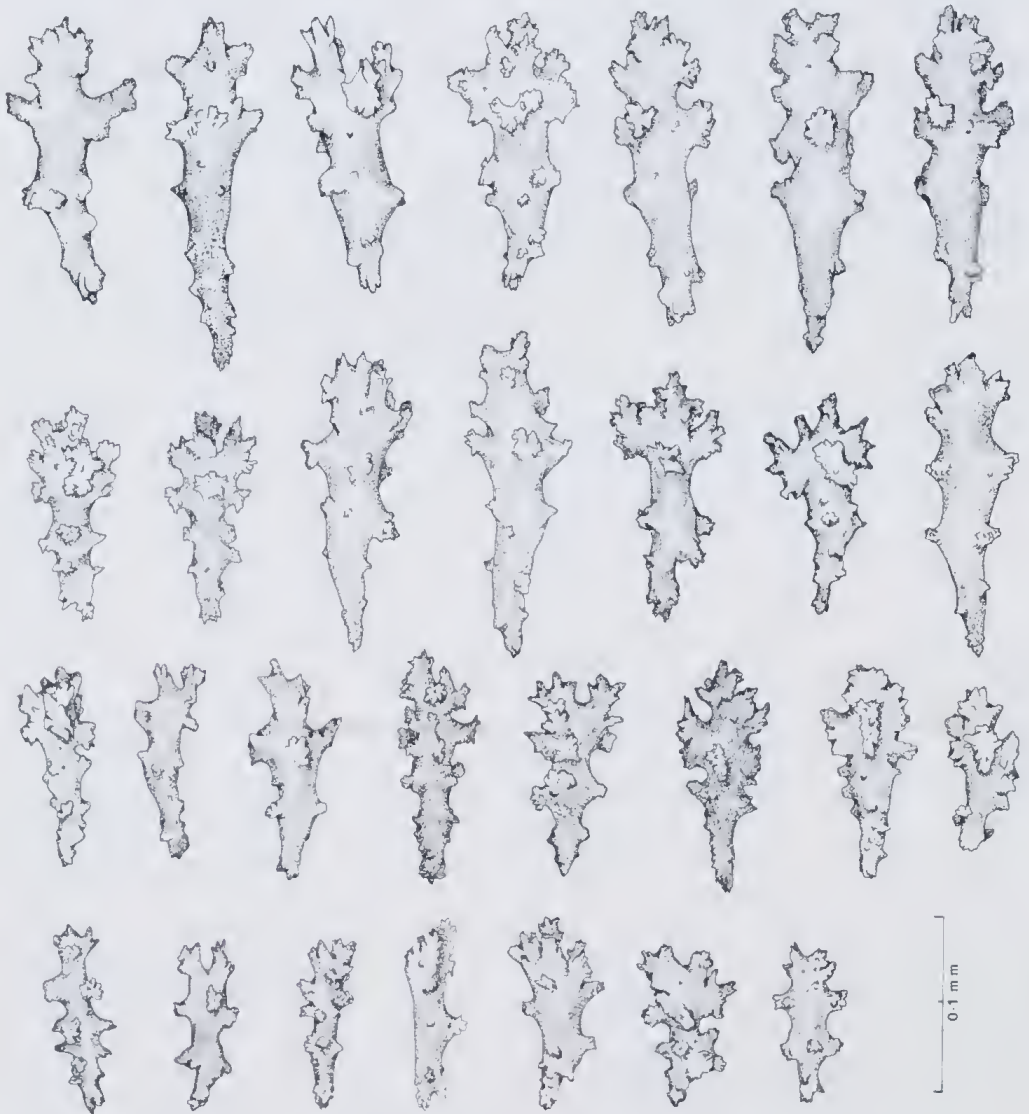
Figure 2   *Sinularia platysma* sp. nov. holotype; sclerites from the surface of the disc.

armed for the most part with simple cone-like prominences, grade into the large interior spindles. The majority of spindles (Figure 3) are less than 0.35 mm long and anything in the sample over about 0.48 mm is heavily warted and probably referable to the interior disc zone.
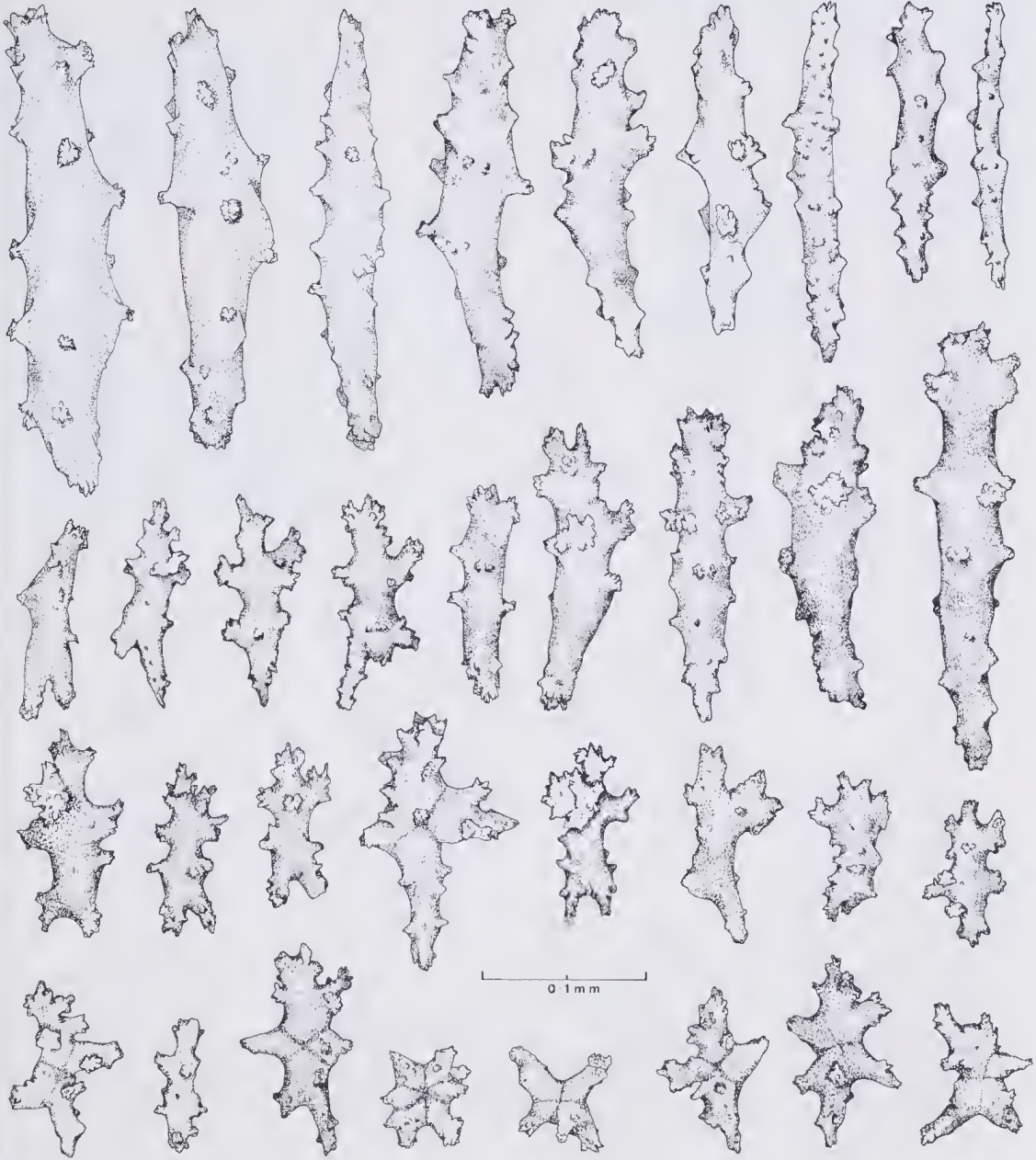
Figure 3   *Sinularia platysma* sp. nov. holotype; sclerites from the surface of the disc.

The sclerites of the surface of the basal part of the colony are quite unlike those of the upper surface of the disc. The majority are eight radiate capstans, 0.09 to 0.23 mm in length, with complex warting, while others are quite irregularly warted and a few approach tuberculate spheroids (Figure 4). A number of the capstans have one whorl of warts reduced producing club-like sclerites 0.15 to 0.23 mm in length, as represented in Figure 5. Also in Figure 5 are several spindles with high warts. A few sclerites of this form may be found in the basal surface samples, but they are more common in the interior of the base where they occur up to 0.45 mm in length distributed amongst the larger warty spindles typical of this genus. These larger coenenchymal sclerites (Figure 1D) are present throughout the interior of the colony. They are packed together in the canal walls, perpendicular to the plane of the colony disc, and there is little distinction
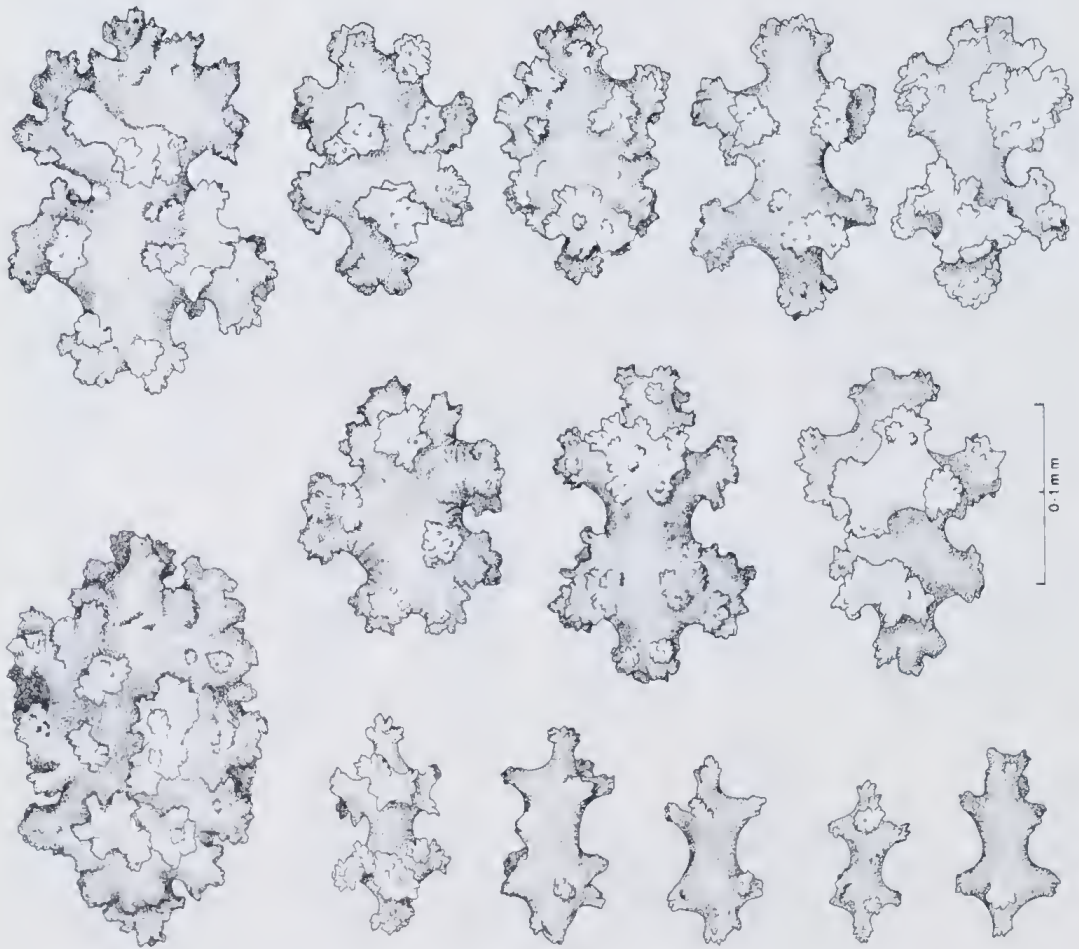
Figure 4   *Sinularia platysma* sp. nov. holotype; sclerites from the surface of the base.

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between those of the upper and lower layers. Many of the spindles are noticeably plump. Some have bifurcated ends and others have developed short branches. Those in Figure 1D are up to 3.2 x 0.7 mm but others to 5.1 x 1.32 mm have been noted. Some of those in the upper regions of the disc have finer warting (Figure 1E) than those from the base (Figure 1F).

In life the colony was blue-grey. In spirit the colony disc is sand coloured with some of the anthocodia being dark brown. The rim is dark brown with sand coloured patches.
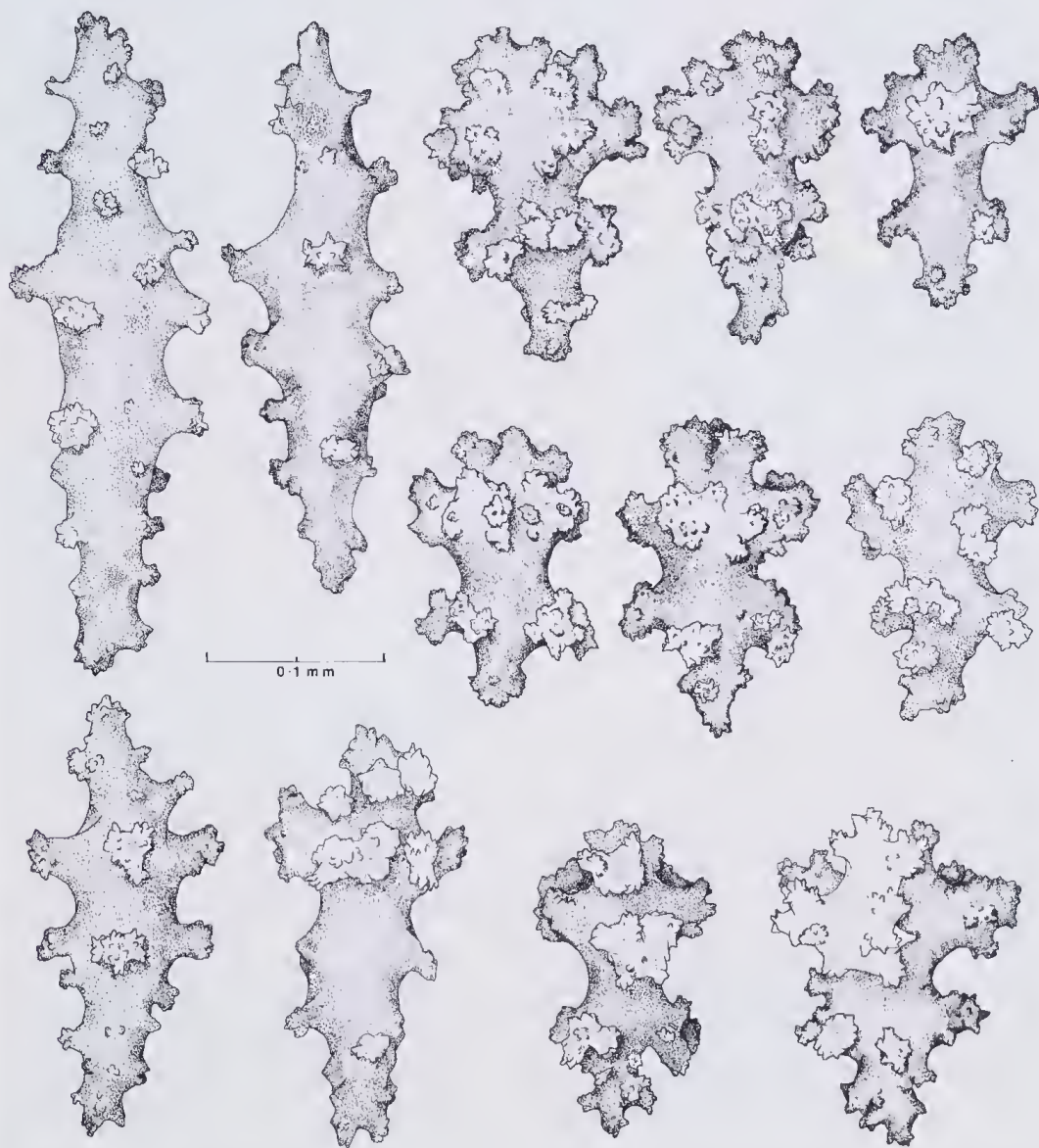
Figure 5   *Sinularia platysma* sp. nov. holotype; sclerites from the surface of the base.

Etymology

From the Greek *Platysma:* flat piece, plate.

Remarks

All specimens of the type series were collected from Rottnest Island and the paratypes (Figures 7B, C and 8A, B) agree in virtually all respects with the major characters of the holotype. There is, however, some variability. Colony WAM 231-86, which is by far the smallest of the series, has a much lower percentage of branched sclerites in the surface of the disc, and of capstans in the surface of the base.

Specimens. NTM C-1193 and WAM 230-86 are whole colonies and opposing edges have tended to curl in towards the centre of the disc during preservation. These colonies do not show the kind of erect rim so prominent in the holotype. If it was possible to uncurl these specimens their upper surface would resemble the concavity of an irregularly shaped saucer. Their appearance may be due to the strong contraction the colonies have undergone, however, this would not account for the similarly shallow concavity of the non-curled specimen WAM 231-86.

Specimen NTM C-1190 is actually two pieces and, like the holotype, is only part of a bigger colony. The larger of the two pieces does have an erect rim. The smaller piece has a cleft ridge on one side which may have resulted from a process of asexual division beginning in this area. Each of the pieces has a large cone-like hillock rising from the disc surface; that on the larger piece rises 35 mm with a base 70 mm across. These mounds appear to have been induced in the animal by the intrusion of an organism up through the base of the colony. Examination of one of the hillocks revealed a hollow central tube-like cavity, about 7 mm across, lined with numerous opaque white coenencymal spindles. The causitive organism was not located. A similar but much smaller hillock is present on specimen WAM 230-86.

The paratypes are all brown in colour, WAM 230-86 and WAM 231-86 being paler than the other colonies, and all have their polyps completely retracted.

Although the thickness of the disc in specimen NTM C-1190 is approximately the same as that of the holotype, in the other three specimens it is only 10 to 15 mm thick.

There are a number of species of *Sinularia* where the centre of the upper face of the capitulum is more or less free of lobes and comparisons should be made with these species. Colonies of *S. dura* (Pratt, 1903) tend to be vase-shaped (see Verseveldt 1974, pl. 2, figs 1b and 1c), however, the inside surface of the concavity is covered with low mounds and ridges, the rim is quite uneven and the colonies are not low and encrusting. Young colonies of *S. fungoides* Thomson and Henderson, 1906, are similar to *S. dura* (see Verseveldt 1980, pl. 22, fig. 4). The colony form of *S. lamellata* Verseveldt and Tursch, 1979 is easily distinguishable and no comment is necessary. *S. facile* Tixier-Durivault, 1970, is somewhat

Figure 6   *Sinularia platysma* sp. nov.; holotype NTM C-1049. Scale line 2 cm.
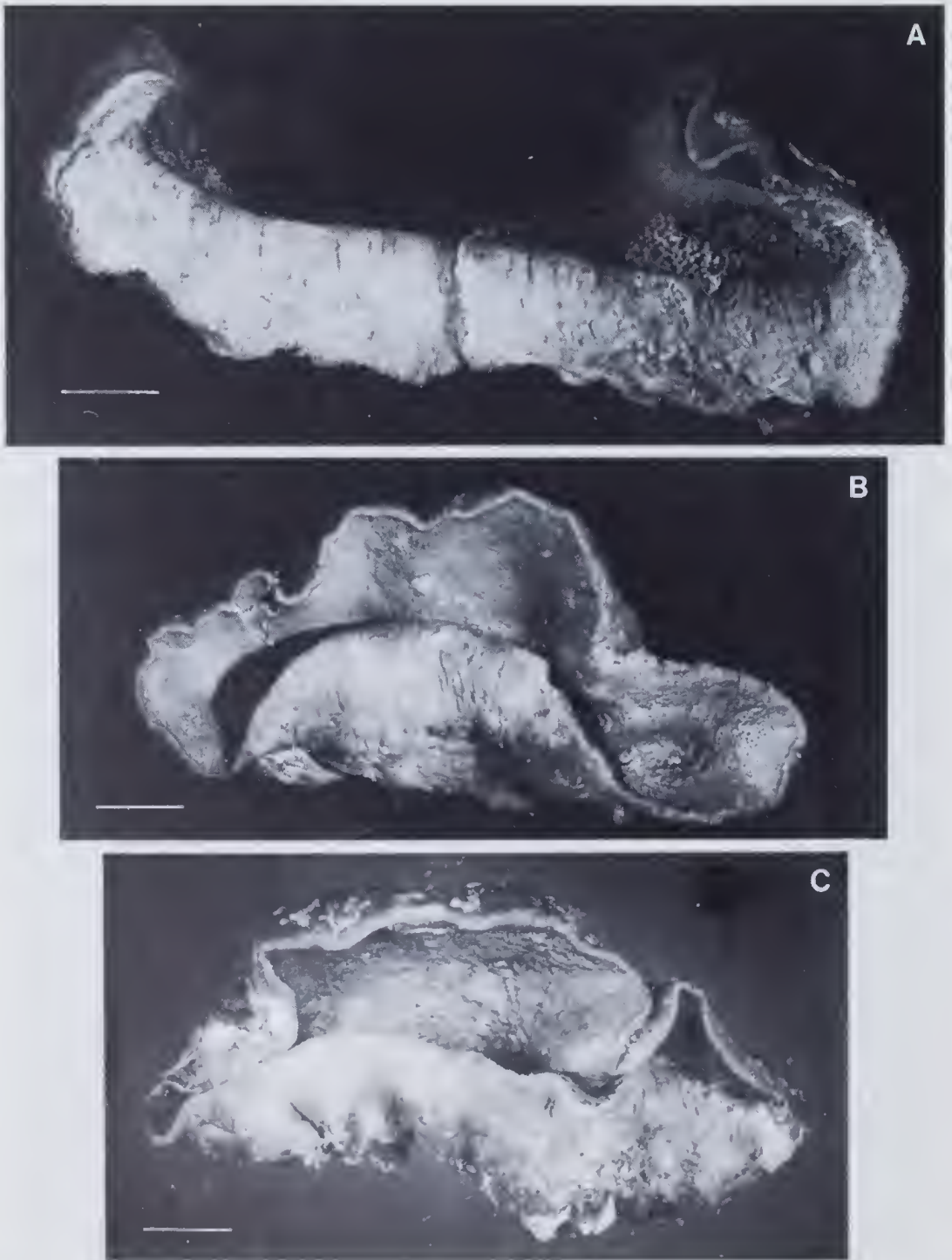
Figure 7   *Sinularia platysma* sp. nov.; A, holotype; B, paratype WAM 230-86; C, paratype NTM C-1193. Scale line 2 cm.
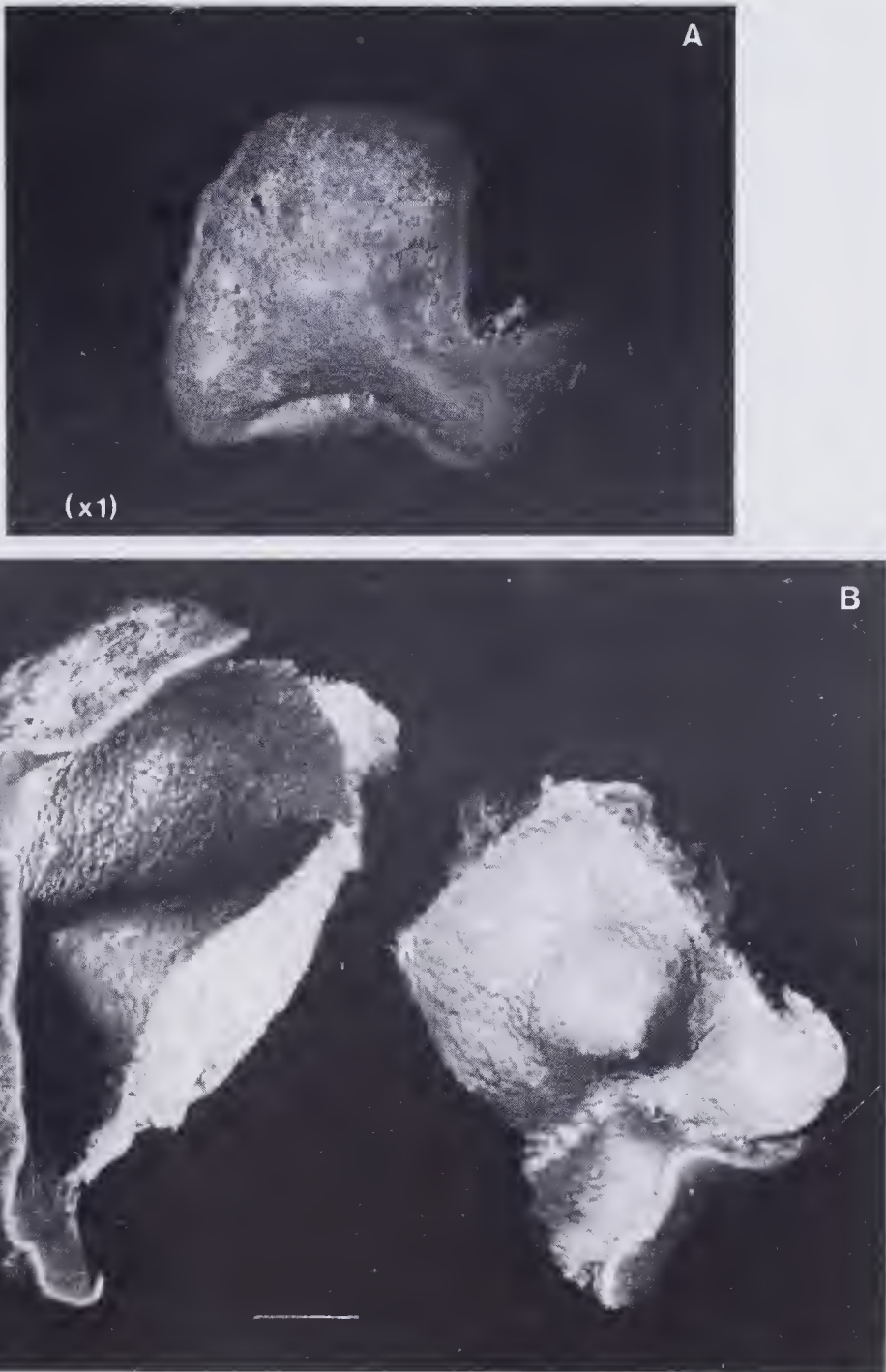
Figure 8   *Sinularia platysma* sp. nov.; A, paratype WAM 231-86, natural size; B, paratype NTM C-1190. Scale line 2 cm.

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dish-like, but the rim is uneven and folded and lobes tend to intrude onto the central space (see Verseveldt 1980, pl. 13, fig. 3). *S. acetabulata* Verseveldt and Tursch, 1979, has a cup-shaped capitulum, the rim of which is deeply divided into lobes and lobules. *S. discrepans* Tixier-Durivault, 1970a, bears some resemblance to the latter species as does *S. barcaformis* Verseveldt and Benayahu, 1983. In *S. barcaformis* the lobed rim is not as strongly divided as in *S. acetabularia*. All of the afore-mentioned species have sclerites which are quite unlike those of *S. platysma*.

In 1977 Verseveldt described *Alcyonium complanatum*, an unusually shaped colony with a concave capitulum, from Rottnest Island. One of us (Alderslade) has personally collected specimens of this species from the type locality of *S. platysma*. It is indeed curious that an unusual colonial form should occur in two different alcyonarians from the same locality. Specimens of *A. complanatum* as large as colony WAM 231-86 have been compared to *S. platysma* and the two taxa found to be quite distinct. *A. complanatum* colonies are relatively soft and compressible due to the paucity of spindle-shaped sclerites in the canal walls. There are no other sclerite forms, such as clubs in the surface layers of the colonies, the interior spindles being visible through the translucent epidermis, and the polyps are quite unarmed.

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The sipunculan fauna (Sipuncula)
of Western Australia

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Abstract

Twenty-three species of sipunculans are here recorded from Western Australia. The record of *Sipunculus norvegicus* is new for Australia and the records of *Golfingia herdmani, Aspidosiphon elegans, Aspidosiphon cumingi, Aspidosiphon jukesi* and *Themiste cymodoceae* are new for Western Australia.

Introduction

The present study is based on about 350 sipunculans in the Western Australian Museum, collected from the coast of Western Australia between Cheyne Bay in the south and Admiralty Bay in the north and from a number of off-shore islands and reefs. All of the coast sampled, therefore, borders the Indian Ocean. Although it contains no new species, the collection, being a large one, provides information about the variability of some species, enables some corrections to be made to a number of earlier identifications and extends the known range of some species, previously thought to be confined to other shores of the continent.

The earliest reports of sipunculans from Western Australia are those of Fischer 1919, 1921 and 1927. Fischer 1919 and 1927 are almost the same report but published in different journals. Fischer's records are listed in Table 1.

Many of the specimens were found intertidally by collectors and some subtidally by divers. A few were washed up after heavy storms. Depths have been given for dredged specimens.

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Table 1   Early records of Western Australian sipunculans.

Species (Fischer's name)	Fischer's record	Locality	Present identity of species
Siphonosoma crassum Spengel	1919	Shark Bay	*Siphonosoma vastum*
Siphonosoma cumanense vitreus (Selenka, de Man and Bülow)	1921	Broome	*Siphonosoma cumanense*
Physcosoma agassizi Keferstein	1919	Shark Bay Fremantle	*Phascolosoma rottnesti*
Physcosoma nigrescens Keferstein	1919 1919 1921	Shark Bay Broome Cape Jaubert	*Phascolosoma nigrescens*
Physcosoma nigritorquartum Sluiter	1919 1921	Shark Bay Cape Jaubert	probably *Phascolosoma rottnesti*
Phascolosoma misakianum Ikeda	1919	Shark Bay	*Apionsoma misakianum*
Phascolosoma pellucidum Keferstein	1919	Fremantle	*Nephasoma* sp. near *schuettei*
Phascolosoma semperi Selenka, de Man and Bülow	1921	Cape Jaubert	*Themiste* sp.
Dendrostomum signifer Selenka, de Man and Bülow	1919	Albany	*Themiste huttoni*
Aspidosiphon hartmeyeri Fischer	1919	Shark Bay	*Aspidosiphon hartmeyeri*

More recent records are contained in Edmonds (1955, 1956 and 1980). Since the last of these papers was written several important changes have been made to the systematics of the phylum, chiefly by Cutler (1979), Cutler and Cutler (1981, 1982, 1983), Cutler, Cutler and Gibbs (1983), Cutler, Cutler and Nishikawa (1984), Cutler and Gibbs (1983) and Gibbs, Cutler and Cutler (1983). Attempts, therefore, have been made in the present paper to bring the nomenclature of the Western Australian fauna in line with the new findings.

Annotated list of sipunculans

Reasonably complete descriptions of all and illustrations of many of the species (excepting *Sipunculus norvegicus*, a new record for Australia) were given in Edmonds (1980). Since some of the species found in Western Australia also

occur in Japan, descriptions given in Cutler, Cutler and Nishikawa (1984) may be useful to Western Australian marine zoologists. The key to genera given in Cutler *et al.* (1984) includes the more recently established genera and consequently is more up-to-date.

Thanks are due to Mrs L. Marsh of the Western Australian Museum, who collected many of the specimens and was responsible for forwarding them for identification.

The following abbreviations are used throughout the paper: AMS = Australian Museum, Sydney; SAM = South Australian Museum, Adelaide; WAM = Western Australian Museum, Perth; NSW = New South Wales; NT = Northern Territory; NZ = New Zealand; Q = Queensland; SA = South Australia; T = Tasmania and V = Victoria.

1. ***Sipunculus indicus*** Peters, 1850
   Sipunculus indicus — Edmonds 1980: 9.

   Distribution
   WA; mouth of Yardie Creek, west side of North West Cape (AMS W 9250) Australia; Coral Sea (AMS 5734). Elsewhere; Indo-Pacific.

   Habitat
   A burrowing species in sand or sandy mud; adult specimens may be very large (400 mm).

2. ***Sipunculus norvegicus*** (Danielssen, 1868)
   Sipunculus norvegicus — Stephen and Edmonds 1972 fig. 3; — Cutler *et al.* 1984: 255.

   Distribution
   WA; Imperieuse Reef, Rowley Shoals, 17°40'S, 118°53'E (SAM E 1716); 16°53'S, 119°53'E at 339-458 m (WAM 52-85); Mermaid Sound, Dampier Archipelago (WAM 42-85, 48-85). This is the first record from Australia. The trunk of the specimen possesses 21-24 longitudinal muscle bands. The species is best known from the colder waters of the North Atlantic but is also reported from India, Japan, Hawaii and the South Pacific.

3. ***Sipunculus robustus*** Keferstein, 1865
   Sipunculus robustus — Edmonds 1980: 9-10, figs 4, 18, 20-22.

   Distribution
   WA; Bremer Bay, 34°23'S, 119°25'E (WAM 30-85); Middleton Beach, Albany, 35°00'S, 119°55'E (WAM 34-85); Woodman Point (WAM 172-76); Safety Bay (WAM 197-76); west of Rottnest I. at 200 m (WAM 125-76); north of Rottnest I. at 137 m (WAM 11-73); north-west of Rottnest I. at 170-174 m (WAM 12-73); Dampier Archipelago (WAM 32-85, 33-85). The specimens from Bremer Bay are excellent. The length of their trunk is up to 180 mm. Australia; Q, V, T, SA, WA. Elsewhere; Indo-Pacific.

Habitat

Burrows in sandy beaches below low tide level. Often washed up after storms.

4. *Xenosiphon mundanus* (Selenka, de Man and Bülow, 1883)
   Xenosiphon mundanus — Edmonds 1980: 12-13, figs 5, 26-27..

   Distribution

   WA; Bremer Bay, 34°23'S, 119°25'E (WAM 322-85, 323-85); Cottesloe Beach (WAM 252-76). Australia; NSW, V, T, SA, WA. Elsewhere; NZ, New Britain, Chile.

   Habitat

   Burrows in sandy beaches or in sand-mud flats.

5. *Siphonosoma cumanense* (Keferstein, 1867)
   Siphonosoma cumanense — Edmonds 1980: 16, fig. 28; — Cutler *et al.* 1984: 258.

   Distribution

   WA; Houtman Abrolhos (WAM 79-85); Cottesloe (WAM 153-76); Kwinana Beach, Cockburn Sound (WAM 196-76); Fisherman's Harbour, Fremantle (WAM 199-76). Australia; Q, NSW, WA. Elsewhere; circumtropical and sub-tropical.

   Habitat

   Burrows in sand and sandy mud.

6. *Siphonosoma vastum* (Selenka, de Man and Bülow, 1883)
   Siphonosoma vastum — Edmonds 1980: 16, fig. 31; — Cutler *et al.* 1984: 261.

   Distribution

   WA; Pt Cloates, 22°43'S, 113°40'E (WAM 4-73); Shark Bay (Fischer 1919), identified as *Siphonosoma crassum* but now considered to be *S. vastum* (Edmonds, 1955). Australia; Q, WA. Elsewhere; Indo-Pacific.

   Habitat

   Burrows in sand and sandy mud.

7. *Golfingia herdmani* (Shipley, 1903)
   Golfingia herdmani — Edmonds 1980: 19, fig. 32, 36-38.

   Distribution

   WA; 79 km west of Cliff Head, 29°28'S, 114°11'E, at 183 m (WAM 70-85). A new record for WA. Australia; SA, WA. Elsewhere; Sri Lanka.

   Habitat

   In sand and debris at base of marine plant growth; also dredged.

8. *Nephasoma (?) schuettei* (Augener, 1903)
   Golfingia schuettei — Edmonds 1980: 25-26, figs 35, 44-45.
   Phascolosoma pellucidum — Fischer 1919.

Distribution

WA; Cockburn Sound (WAM 141-76); Fort Gregory, 28°12'S, 114° 14'E (WAM 15-73); Cockatoo I. 16°06'S, 123°38'E (WAM 149-76). Another specimen from Cockatoo I. (WAM 160-76) previously identified by me as *Golfingia pellucida australiensis* is *Nephasoma schuettei*. Australia; NSW, WA.

Habitat

In sand and sandy mud.

Note

Whether *Nephasoma* is the appropriate genus for these large specimens with a trunk 100-160 mm long is not certain.

9. ***Themiste cymodoceae*** Edmonds, 1956

Themiste cymodoceae — Edmonds 1980: 38-40, figs 58, 63.

Distribution

WA; Leighton Beach (WAM 140-76). A new record for WA. Australia; SA. Elsewhere; no records.

Habitat

In tangled roots of marine angiosperm, *Amphibolis antarctica*.

10. ***Themiste dehamata*** Kesteven, 1903

Themiste dehamata — Edmonds 1980: 34-36, figs 53-57.

Distribution

WA; Bremer Bay (WAM 31-85, 29-85); Cottesloe (SAM E 1248). Australia; NSW, V, SA, T, WA. Elsewhere; no records.

Habitat

In sand and debris among roots of sea grasses.

11. ***Themiste huttoni*** (Benham, 1904)

Themiste huttoni — Edmonds 1980: 36-37, figs 60-64.

Distribution

WA; Trigg I. (WAM 242-76); Garden I. (WAM 179-76); Cockburn Sound (WAM 32-73); Albany (Fischer 1919). Australia; Q, NSW, T, WA. Elsewhere; NZ.

Habitat

In and under rocks.

12. ***Themiste lageniformis*** Baird, 1868

Themiste lageniformis — Edmonds 1980: 41, figs 59, 65-67; — Cutler *et al.* 1984: 283-384.

Distribution

WA; Dampier Archipelago (WAM 171-81); Broome (Hamburg Museum Collection). Australia; Q, NT, WA. Elsewhere; Indo-Pacific.

Habitat
Forms burrows in calcarcous rock; also found under rocks.

13. *Phascolion collare* (Selenke, de Man and Bülow, 1883)
Phascolion collare — Edmonds 1980: 29-30, fig. 52.

Distribution
WA; Rosemary I., Dampier Archipelago (WAM 36-73); Phillip Pt, Dampier Archipelago (AMS W 5497). Australia; WA. Elsewhere; Indonesia, Phillippine Is.

Habitat
Normally in discarded shells of molluscs. The above specimens from solitary corals.

14. *Apionsoma misakianum* (Ikeda, 1904)
Apionsoma misakianum — Cutler *et al.* 1984: 301, figs 10J; 12B.
Golfingia misakiana — Edmonds 1980: 22-23.

Distribution
WA; Mermaid Sound, Dampier Archipelago (WAM 44-85); Mangrove Bay, North West Cape (WAM 138-81, 141-81); Shark Bay (Fischer 1919). Australia; NSW, WA. Elsewhere; Japan, Tanzania.

Habitat
In sand and debris at base of sea plants.

15. *Apionsoma trichocephalum* Sluiter, 1902
Apionsoma trichocephalum — Cutler *et al.* 1984: 301.
Golfingia trichocephala Edmonds 1980: 23-24, figs 34, 40.

Distribution
WA; Mermaid Sound, Dampier Archipelago (WAM 45-85); Rottnest I. (AMS W 10565). Australia; Q, WA. Elsewhere; Indonesia, South and West Africa, West Atlantic, Coral Sea, Tasman Sea.

Habitat
In sand and debris under rocks.

16. *Aspidosiphon cumingi* Baird, 1868
Aspidosiphon cumingi — Stephen and Edmonds 1972: 243; — Edmonds, 1980: 50.

Distribution
WA; Ashmore Reef, 12°15'S, 123°03'E (WAM 136-81). A new record for WA. Australia; Q, WA. Elsewhere; Indo-Pacific.

Habitat
Associated with coral reefs.

17. *Aspidosiphon elegans* (Chamisso and Eysenhardt, 1821)
Aspidosiphon elegans — Edmonds 1980: 47, figs 71-76; — Cutler *et al.* 1984: 304.

Distribution
WA; Kendrew I., 20°28'30"S, 116°32'E (WAM 85-86, 86-85, 275-85).
A new record for WA. Australia; Q, WA. Elsewhere; Indo-Pacific.

Habitat
Associated with coral formations; specimens from WA collected from rock
and amongst oysters.

18. *Aspidosiphon hartmeyeri* Fischer, 1919
Aspidosiphon hartmeyeri — Edmonds 1980: 47, fig. 80.

Distribution
WA; Shark Bay (Fischer, 1919); Rottnest I. (SAM E 1250). Australia;
WA, SA. Elsewhere; Kermadec, West Africa, Cuba.

Habitat
Calcareous rocks.

19. *Aspidosiphon jukesi* Baird, 1873
Aspidosiphon jukesi — Edmonds 1980: 49, fig. 97-99.

Distribution
WA; Houtman Abrolhos I. (WAM 49-85, 51-85). A new record for WA.
Australia; Q, WA. Elsewhere; Indo-Pacific.

Habitat
Lives in solitary corals, especially *Heteropsammia* and *Heterocyathus*.

20. *Phascolosoma arcuatum* (Gray, 1828).
Phascolosoma arcuatum — Edmonds 1980: 58-59, figs 109-111.

Distribution
WA; Port Warrender, Admiralty Gulf, 14°30'S, 125°50'E (WAM 137-
81, 146-81, 96 to 100-85); Derby (WAM 264-76, SAM E 1388,1389).
Australia; Q, NT, WA. Elsewhere; Malaysia, Indonesia, Philippines.

Habitat
Always associated with mangroves.

21. *Phascolosoma nigrescens* Keferstein, 1865
Phascolosoma nigrescens — Edmonds 1980: 59-60, fig. 112; — Cutler *et al.* 1984: 296.

Distribution
WA; Clerke Reef, Rowley Shoals, 17°10'S, 119°20'E (WAM 55-85);
Scott Reef, 14°05'S, 121°51'E (WAM 58-85); 18 km north of Dongara
(WAM 69-85, 71-85); Rottnest I. (WAM 77-85); Kendrew I., Dampier
Archipelago (WAM 87-85, 324-85); Riddell Pt, Broome (WAM 92-85,

94-85); Gantheaume Pt, Broome (WAM 93-85); Montebello I. (WAM 95-85); Cape Jaubert, 18°56'S, 121°33'E (Fischer 1921); Shark Bay (Fischer 1919); Dampier Archipelago (WAM 132-76, 222-76); Port Denison, 29°16'S, 114°55'E (Edmonds 1956); Barrow I. (WAM 246-76); Cape Leveque (WAM 54-85). Australia; Q, NSW, NT, WA. Elsewhere; circum-tropical.

Habitat

In limestone and coral reefs: sometimes under rocks.

22. *Phascolosoma noduliferum* Stimpson, 1855

Phascolosoma noduliferum — Edmonds 1980: 62, figs 114-115.

Distribution

WA; Cape Naturaliste (WAM 62-85); 73 km off Dongara, 29°07.5'S, 114°10'E at 64 m (WAM 72-85); Houtman Abrolhos (WAM 81-85); Great Australian Bight, 35°15'S, 126°22'E at 164 m (WAM 145-76) and 33°19'S, 129°50'E (WAM 110-85); 16 km east of Hopetoun (WAM 225-76). Australia; NSW, V, T, SA, WA. Elsewhere; NZ, Philippines, New Guinea.

Habitat

In littoral collections under rocks; also dredged.

23. *Phascolosoma rottnesti* Edmonds, 1956

Phascolosoma rottnesti — Edmonds 1980: 64-65, figs 116, 124-126.

Distribution

WA; Kendrew I., Dampier Archipelago (WAM 139-76, 49-82, 88-85); near Passage Is, 20°25'S, 115°40'E, at 16 m (WAM 67-85); North West Cape Peninsula (WAM 91-85); Pt Cloates (WAM 16-73); Dorre I., Shark Bay (WAM 63, 65, 66-85); Dirk Hartog I., Shark Bay (WAM 64-85); Horrocks Beach (WAM 166-76); Houtman Abrolhos (WAM 130-76, 186-76, 188-76, 237-76, 241-76, 80-85); Little I., NW of Perth (WAM 84-85); Trigg I. (WAM 177-76); Cottesloe (WAM 68-75); Rottnest I. (WAM 128-76, 158-76, 165-76, 169-76, 176-76, 247-76, 181-76, 47-82, 48-82, 74 to 76-85); Garden I. (WAM 190-76, 234-76); Cockburn Sound (138-76); Cape Peron, 32°16'S, 115°41'E (WAM 180-76); Cape Naturaliste (WAM 239-76); Yallingup Beach (WAM 1990-11995, AMS W 9246); Fremantle Harbour (WAM 69-75, SAM E 1367). Known only from WA.

Habitat

Under rocks or in burrows in calcareous rocks.

Note

Edmonds (1980) considers that this species is very closely related to *Phascolosma scolops* (Selenka, de Man and Bülow, 1883)

Comments on some of the species
named by other authors

1. *Golfingia pellucida* (Keferstein, 1865)
Golfingia pellucida — Cutler 1973: 159-161; — Edmonds 1980: 125.

Fischer (1919) reported this species from Cockburn Sound but gave no details about his specimens. Edmonds (1980) identified two sipunculans from Cockburn Sound as *Nephasoma schuettei*. Whether Fischer's specimens can be referred to *N. schuettei* is not known for sure.

2. *Golfingia semperi* Selenka, de Man and Bülow, 1883
Golfingia semperi — Edmonds 1980: 28.

Fischer's 1921 record occupies only three lines. The species has two retractor muscles. Gibbs, Cutler and Cutler (1983: 300) consider Fischer's specimens from WA to be *Themiste* sp.

3. *Phascolosoma agassizi* Keferstein, 1867

The only WA record is Shark Bay (Fischer 1919). Edmonds (1956) considered the specimen to be *Phascolosoma rottnesti*.

4. *Phascolosoma nigritorquartum* (Sluiter, 1882)

This species was recorded from Shark Bay and Rottnest I. by Fischer (1919, 1921). The present status of the species is not known with certainty (Edmonds 1980: 60); it is closely related to *P. rottnesti* and *P. scolops*.

Conclusions

Of the sipunculan species reported from Western Australia, 10 are Indo-Pacific in their distribution, four are Australian-Malaysian-Philippine, three are southern Australian and one endemic.

Collecting sipunculans usually requires slow and patient work. It involves digging in sand and in mud, turning over rocks, cracking and searching in limestone and coral reefs and in solitary corals, pulling apart the roots of marine angiosperms, examining the encrustations of serpulid worms, the discarded shells of small molluscs and dredging. It is most likely that more species will be found when other areas, especially in the north and north-west of the State, are sampled. So far no species of *Cloeosiphon* or of *Lithacrosiphon*, both inhabitants of coral reefs, have been found.

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Musculista senhousia (Benson, 1842); a mussel recently introduced into the Swan River estuary, Western Australia. (Mollusca: Mytilidae)

S.M. Slack-Smith* and A. Brearley†

Abstract

Introduction of the east Asian bag mussel *Musculista senhousia* to the Swan River estuary in 1982 is reported. A description of its subsequent spread in the estuary and some preliminary comments on its ecology are given.

Introduction

The fauna of the Swan River estuary and adjacent coastal water is well documented and represented in the collections of the Western Australian Museum. The benthic invertebrates of the estuary, particularly the molluscs, were examined by Chalmer *et al.* (1976) and a summary of this work and of previous studies on the fauna of the Swan and other Western Australian estuaries and embayments was compiled by Hodgkin and Majer (1976).

Extension of the geographic range of the mactrid bivalve *Spisula (Notospisula) trigonella* (Lamarck, 1819) into the Swan estuary in about 1964 was documented by Wilson and Kendrick (1968). The nassariid gastropod *Nassarius (Plicarcularia) burchardi* (Dunker, 1849) exhibited a similar extension of range from the southern Australian coast, this having been first recorded in 1965. The east Asian semelid bivalve *Theora (Endopleura) lubrica* Gould, 1861 arrived in Cockburn Sound in about 1971 and in the estuary in about 1973, almost coincidentally with its arrival in California and New Zealand. These last three species still form a significant part of the molluscan biota of the estuary.

The most recent arrival of an exotic molluscan species into the estuary appears to be the bag mussel *Musculista senhousia* (Benson, 1842). Its presence was first recognized when large specimens of about 2.5 cm in length were collected by one of us (A.B.) in 1983 at Chidley Point, Middle Estuary (terminology of Chalmer *et al.* 1976, see Figure 1). Examination of Western Australian Museum records revealed that two very small juveniles had been taken during benthic surveys carried out by the Western Australian Department of Fisheries in February and May, 1982 in Melville Water, Middle Estuary. However these had, at that time,

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Figure 1

INSET A

Geraldton

B

Bunbury

INSET B

Perth

Fremantle

Cockburn
Sound

32°00'

116°50'
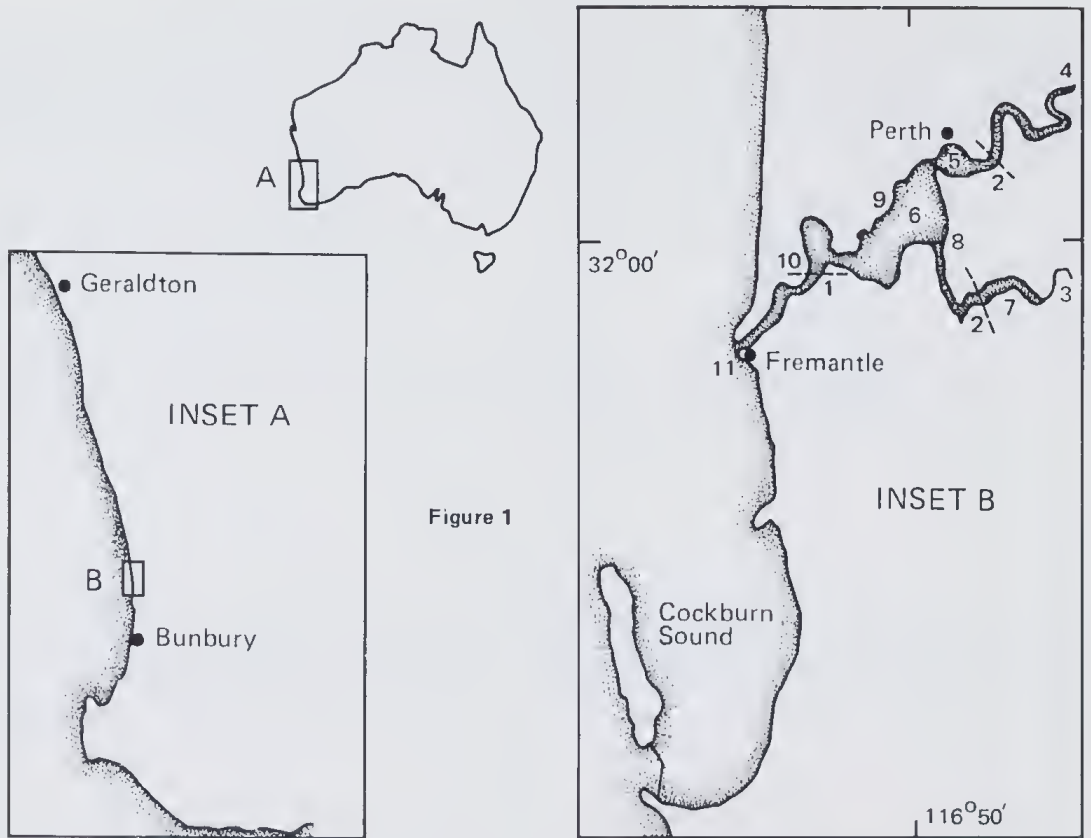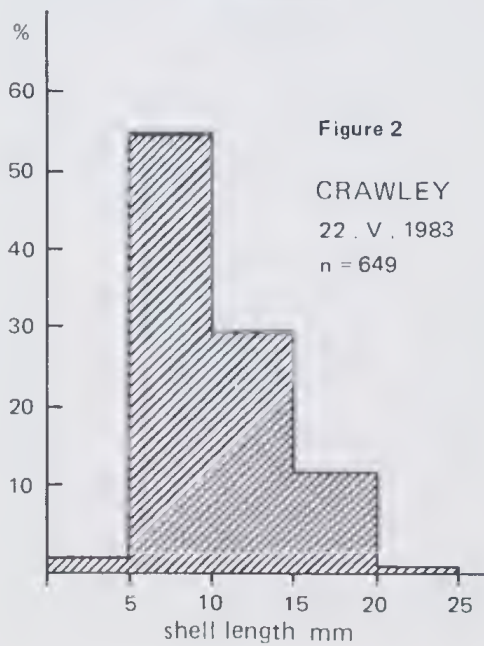
Figure 2

CRAWLEY

22 . V . 1983

n = 649

shell length mm

Figure 3

been identified tentatively as belonging to the endemic marine species *Musculista glaberrima* (Dunker, 1856).

Identification

Musculista senhousia can be distinguished from the other Swan estuary mussels *Xenostrobus securis* (Lamarck, 1819), *X. pulex* (Lamarck, 1819) *Mytilus edulis planulatus* Lamarck, 1819 and *Brachidontes* sp. cf *B. variabilis* Krauss, 1848 by the greenish colour of the outer periostracal layer, by the radiating reddish lines on the posterior area and by the small internal teeth on the dorsal edge just posterior to the ligament of the shell. It can be distinguished from *Musculista glaberrima* by its darker, less glossy, more inflated shell with its curved ventral margin, and by the few, small but definite ribs anterior to the umbones (Figure 3).

Distribution

Musculista senhousia is native to the western Pacific coasts from Siberia and the Kuril Islands (Kuroda, Habe and Oyama 1971) south to Singapore (Chuang 1961 *fide* Morton 1974), with its type locality being Chusan, China. Introduction of this species to the west coast of the United States of America was first reported by Smith (1944). Dr R. Willan (pers. comm.) reports that it has been present in Auckland Harbour, New Zealand since 1980, noting that it was not taken during surveys he conducted in the late 1970's.

Following the recognition of this species in the Swan estuary in early 1983, surveys in mid-1983 revealed that it was abundant as far upstream as Canning Bridge and Perth Water. Sampling in mid-1984 showed that it had spread to Shelley, further upstream on the Canning River. In early 1984 a juvenile specimen was taken just outside the estuary at Bathers' Bay, Fremantle. We have failed to find this species elsewhere in the south of Western Australia.

Ecology

In China and Japan *Musculista senhousia* is found on mud in byssal-thread and mud 'nests' which are fastened together (Kira 1962). Kuroda, Habe and Oyama

◀ Figure 1   Localities mentioned in text. Inset B. (1) Upstream limit of Lower Swan Estuary (2) Upstream limits of Middle Swan Estuary (3) Canning River (4) Swan River (5) Perth Water (6) Melville Water (7) Shelley (8) Canning Bridge (9) Crawley (10) Chidley Point (11) Bathers' Bay.

Figure 2   Size frequency histogram of sample from Crawley, Swan Estuary. 22 May 1983.

Figure 3   *Musculista senhousia* (Benson, 1842) WAM 1416.83. Photograph of exterior of right valve and drawing of interior dorsal margin of left valve showing diagnostic features.

(1971) record this mussel from the intertidal zone to depths of 20 m, while Morton (1974) records its occurrence in large colonies of byssal nests in mud at midtide level, with densities of up to 2500/m². However Hanna (1966) and Morton (1974) recorded it as also attached by byssal threads to piling without forming nests.

In the Swan estuary the habitat of this epifaunal mussel is mainly soft substrates at approximately 0.5 to 4 m below low water level. Here is is abundant, with up to 2,600 individuals/m² forming large dense mats of conjoined byssal bags unlike any other molluscan species in this area. The fine mud upon and within the meshes of this mat is composed of trapped silt and, at least partly, of mucus-bound faeces and pseudofaeces as observed by Morton (1974). The alternative habitat on hard substrates has been observed, again below water level, in Melville Water on boat hulls and at Bathers' Bay on settlement plates.

In the dry season of summer and autumn the estuary is effectively a marine embayment with no river discharge and with salinities close to that of seawater. In winter/spring the rainfall causes river discharge to resume, and salinity to drop markedly (Spencer 1956; Seddon 1972). Though this pattern is constant, the size, timing and duration of these hydrological changes varies from year to year. Molluscs inhabiting the Swan estuary respond variously to the seasonality of the hydrological conditions.

In the late autumn to early winter *Musculista senhousia* exhibits high mortality. This could be due to decreasing salinity as with *Mytilus edulis planulatus* (Wilson and Hodgkin 1967). However this mass mortality in *Musculista senhousia* could be post-reprodutive and unrelated to salinity as in the euryhaline *X. securis* (Wilson 1969) and the marine *Musculista glaberrima* (Wilson and Hodgkin 1967). Morton (1974) reported the disappearance of his study population of *Musculista senhousia* at Tai Tam Bay, Hong Kong in Autumn 1972, when juveniles died before reaching sexual maturity.

A minor cause of mortality in the Swan estuary population is predation by boring carnivorous gastropods, either *N. burchardi* and/or *Bedeva paivae* (Crosse, 1864).

The size frequency distribution of a single sample of 649 individuals of *Musculista senhousia* taken in Crawley Bay in May, 1983 forms a unimodal curve over a large size range (2.8 to 27.5 mm) (Figure 2). The age component of this population is not known. Factors which alone or in combination might have contributed to the size frequency observed in this population could be a lengthy breeding period and a variation in growth rates between individuals.

Discussion

The mode of introduction of *Musculista senhousia* into the Swan estuary is not known. This species was introduced to the west coast of the United States of

America, apparently with shipments of Japanese oysters (Soot-Ryen 1955). Bysally-attached animals could have been transported on the hulls, or more likely in the water intake chambers and ducts of ships entering Fremantle Harbour. Although the duration of the larval life of *Musculista senhousia* is unknown it is also possible that planktonic larvae could have been carried in the ballast water of bulk-cargo vessels. However shipping regulations prohibiting the dumping of ballast water inside the harbour reduce the possibility of introduction by this means.

The persistence of a large population of this species in the estuary since 1982 indicates that it is successfully breeding in the area. Its presence appears to have caused an increase in the biomass of benthic macro-organisms which is particularly significant in some areas of soft substrate in the Middle Estuary.

Acknowledgements

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Description of a new plesiopid fish from south-western Australia, with a discussion of the zoogeography of *Paraplesiops*

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Abstract

Paraplesiops sinclairi sp. nov. is described from six specimens from the Archipelago of the Recherche and Lancelin. It is distinguished from the other members of *Paraplesiops* by the combination of a low lateral line count (29-32) and smooth preopercular margin. The historical events leading to the current distribution of the genus are also discussed.

Introduction

Members of the plesiopid fish genus *Paraplesiops* are cryptic, cave-dwelling species of rocky and coral reefs in temperate and subtropical Australia. A recent revision of the genus (Hoese and Kuiter 1984) recognised four species, *P. bleekeri* (Günther) and *P. poweri* Ogilby from eastern Australia, *P. meleagris* (Peters) from western and southern Australia, and *P. alisonae* from southern Australia. During a recent zoogeographic study of southern Australia's reef-fish fauna, I collected specimens of all four species, in addition to three specimens of a new species from south-western Australia. A search of the collections at the Western Australian Museum produced three additional specimens of the undescribed species. From this total of six specimens, five are from the Archipelago of the Recherche at the western end of the Great Australian Bight, and one is from Lancelin to the north of Perth. The purpose of this paper is to describe the new species, and examine its relationships with the other members of *Paraplesiops*. The zoogeography of the genus is also discussed.

Counts and measurements follow Hoese and Kuiter (1984). The material examined is housed in the Western Australian Museum, Perth (WAM) and the Australian Museum, Sydney (AMS).

Systematics

Paraplesiops sinclairi sp. nov.

Figures 1 and 2; Tables 1 and 2

Holotype

WAM P.28298-008, 108 mm SL, Lucky Bay, east of Esperance, Western Australia (34°00'S, 122°14'E), collected with rotenone at 24 m from coral, J.B. Hutchins et al., 15 April 1984.

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Paratypes

Five specimens from Western Australia, 45-122 mm SL (unless otherwise designated, all at WAM): P.9257-001, 45 mm SL, Lancelin Island, R.J. McKay, March 1958; P.26006-001, 2 specimens, 122 mm SL, Mondrain Island, Archipelago of the Recherche (off Lucky Bay), rotenone at 13 m from coral, J.B. Hutchins, 19 March 1978; P.28298-020, 112 mm SL, collected with holotype; AMS I.25709-001, 119 mm SL, collected with holotype.

Diagnosis

This species is distinguished from all other members of *Paraplesiops* by the combination of a low upper lateral line count (29-32) and a smooth preopercular margin. *P. poweri* has a similar lateral line count but is separable in having a prominently denticulated margin to the preoperculum.

Description

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

Dorsal fin rays XII,10; anal fin rays III,10; pectoral fin rays 18 (17to18); longitudinal scale count 32 (32 to 34); upper lateral line and lower lateral line scale counts 29 (29 to 32) and 12 (11 to 14) respectively; lower gill rakers 11 (11 to 12); vertebrae 10+16=26.

The following measurements are expressed as percentages of SL. Head length 38.0 (35.2-37.7); snout length 7.2 (6.9-8.0); maxilla length 18.5 (17.6-19.3); orbit diameter 10.2 (9.8-12.7); interorbital width 5.9 (4.9-6.3); body depth 37.0 (33.3-36.9); pectoral fin length 29.6 (28.6-32.0); length of longest pelvic fin ray 40.7 (37.0-40.2); length of longest dorsal fin ray 29.6 (29.5-32.8); caudal fin length 34.3 (31.9-36.6).

Head and body moderately compressed; jaws equal anteriorly, maxilla reaching to well behind eye in adults, only slightly behind in juvenile; edge of preoperculum entire; head with small close-set pores on non-scaly surfaces except on maxilla, upper and lower lips and throat. Scales on head cycloid, moderately large in size, those on cheek mostly embedded but usually 1-3 vertical rows exposed, and about two-thirds of operculum with exposed scales; body scales mostly ctenoid, although those above upper lateral line, anterior to dorsal fin, and on breast cycloid. Predorsal scales extend forward to above dorsal extremity of preoperculum, ending well short of eye; 1-3 scale rows along base of dorsal and anal fins. Dentition in upper and lower jaws composed of an outer series of relatively strong conical teeth enclosing a band of smaller teeth, band widest at symphysis of jaws; V-shaped band of small teeth on vomer, and narrow band of similar teeth on each palatine; tongue with a relatively narrow, oblong patch of small teeth aligned longitudinally.

Dorsal spines increasing in length posteriorly, posteriormost noticeably shorter than first soft dorsal ray; spinous dorsal integument moderately incised, swollen

Table 1   Measurement in mm and counts of types of *Paraplesiops sinclairi*

| | Holotype WAM P.28298-008 | Paratypes | | | | |
		WAM P.26006-001	WAM P.26006-001	AMS 1.25709-001	WAM P.28298-020	WAM P.9257
Standard length	108	122	122	119	112	45
Head length	41	46	43	43	42	16
Orbit length	11	13	12	12	12	5.7
Snout length	7.8	9.8	8.5	8.2	8.5	3.2
Maxilla length	20	23	22	23	21	7.9
Suborbital width	2.6	3.5	3.0	2.9	2.8	0.7
Fleshy interorbital width	6.4	7.7	6.9	6.9	6.8	2.2
Body depth at pelvic origin	40	45	43	43	39	15
Pectoral fin length	32	39	35	34	34	14
Pelvic fin length	44	47	46	44	45	18
Caudal fin length	37	44	43	38	41	—
Longest dorsal ray	32	36	37	39	36	—
Pectoral fin count	18	18	18	17	17	18
Longitudinal scale count	32	33	34	32	32	32
Upper lateral line scale count	29	32	32	30	30	31
Lower lateral line scale count	12	14	11	12	13	12
Predorsal scale count	7	7	7	7	6	7
Transverse scale count	12	13	14	14	14	14
Oblique cheek scale rows	2	2	1	3	1	3
Lower gill raker count	11	12	11	11	11	—

at spine tips; fourth or fifth last dorsal and anal rays longest, extending posteriorly to a point level with midlength of caudal fin, or slightly behind; first two soft dorsal and anal rays undivided, others branched; all pectoral fin rays branched, except uppermost and lowermost 1-2 rays simple; all four soft rays of pelvic fin branched, anteriormost deeply forked.

Colour of fresh holotype (from a colour transparency): head blackish brown with numerous iridescent dark blue spots; a black to iridescent blue blotch, roughly circular in shape and somewhat larger than eye, on ventral region of operculum; dark iridescent blue line on suborbital curving posteriorly around margin of eye to end a short distance behind midpoint of eye's posterior border; ventral margin of gill membranes dark iridescent blue; body dark brown with scale centres a paler brown, particularly on lower sides; indications of seven dark cross bars, last on caudal base; dorsal, anal and caudal fins blackish brown with numerous small dark spots on caudal and posterior portions of dorsal and anal fins; swollen tips

of dorsal and anal spines dark iridescent blue, with a similarly coloured line along dorsal and ventral margins of soft dorsal and anal fins respectively; pelvic fin brownish black with several dark iridescent blue streaks; pectoral fin yellow.

Colour of holotype in alcohol: generally similar to fresh coloration, but all blue markings black. The paratypes are similarly coloured, with the exception of the smallest specimen. After many years in preservative, it is now dark brown overall with a few dark spots on the head. The large blackish blotch on the preoperculum is particularly prominent.

Figure 1   *Paraplesiops sinclairi*, holotype, 108 mm SL.

Distribution

Paraplesiops sinclairi is known only from south-western Australia, from the Archipelago of the Recherche (34°08′S, 122°15′E) to Lancelin (31°00′S, 115° 19′E).

Remarks

Paraplesiops sinclairi has been collected with rotenone only from moderate-sized colonies of the coral *Turbinaria* species. Both collection sites in the Archipelago of the Recherche were in water of moderate depth (13-24 m), and isolated from nearby rocky reefs by an open expanse of sandy bottom. Numerous collections made with rotenone from *Turbinaria* colonies in rocky reefs in the same area failed to produce additional specimens. This species is probably more abundant in Western Australian waters than the present small number of specimens seems to indicate, as isolated coral colonies in sandy areas have rarely been sampled.

This species was originally recorded for Western Australia as *Paraplesiops* species (Hutchins and Thompson 1983) on the basis of two specimens collected in

1978 from Mondrain Island in the Archipelago on the Recherche. Although never examined, these specimens were included as non-type material in the original description of *Paraplesiops alisonae* (Hoese and Kuiter 1984) because of a painting in the former paper. However this illustration was based on a colour transparency of a specimen from South Australia (WAM P.27136-005), which is in fact the true *P. alisonae* and not conspecific with the Mondrain Island material. The subsequent collection in 1984 of more specimens of the latter species (herein described as *P. sinclairi*), and the publication of a review of the genus (Hoese and Kuiter 1984), resulted in the discovery of this error. Therefore, *P. alisonae* must now be removed from any faunal lists of Western Australian fishes.

This species is named *sinclairi* in memory of Mr Nick Sinclair who, while a member of the Western Australian Museum's Department of Ichthyology, was involved in the collection of the holotype and two paratypes.

Relationships

A summary of the main differences among the species of *Paraplesiops* is presented in Table 2. This indicates that *P. sinclairi* is most closely related to *P. poweri* (characters 1, 8, 10, 12, 21 and 23), and that *P. meleagris* has more features in common with *P. bleekeri* than with any other member of the genus (characters 1, 4, 7, 12, 21, 22, and 25). *P. alisonae* appears to be the most specialised species due the number of unique features it possesses (characters 1, 2, 3, 5, 6, 11, 12, 13, 14, 15, 17, and 24). When these relationships are compared with the known distribution of *Paraplesiops* (Figure 2), the most obvious feature is the ranges of the two groups of apparent species pairs, *P. poweri* and *P. sinclairi*, and *P. bleekeri* and *P. meleagris*. One species of each pair is found on the east coast of the continent, whereas the other occurs allopatrically on the west coast and at least part of the south coast. The species considered to be the most specialised, *P. alisonae*, occupies the southernmost range. In a recently completed study of the patterns of reef fish distribution in Australia's southern half (Hutchins, in preparation), numerous examples of species pairs with similar distributions to the above were found. Furthermore, some species pairs were joined by a related but more southerly distributed species at or near the southern limits of their distirbutions. Table 3 lists several of these examples. However, phylogenetic analyses of many of the taxa concerned are not presently available, so the apparent close relationships, as indicated in Table 3, must be considered here as only tentative. Nevertheless, the apparent similarity in the patterns of distribution indicate that *Paraplesiops* and the examples mentioned above probably share the same zoogeographic history.

A summary of past events that helpcd shape the present patterns of distribution of southern Australia's shallow water marine fauna was presented by Knox (1980). During the Tertiary, Australia had a climate ranging from tropical to subtropical. Sea temperatures reached a maximum during the mid-Tertiary, and declined during the late Tertiary to reach a minimum in the Quaternary.

Table 2   A comparison of the species of *Paraplesiops*
Data from Hoese and Kuiter 1984 have been incorporated.

No. Character	alisonae	bleekeri	meleagris	poweri	sinclairi
1. Number of undivided soft rays in dorsal and anal fins	4-5	0-1	0-1	1-2	1-2
2. Number of lateral line scales posterior to dorsal fin	1-3	0	0	0	0
3. Scales on bases of dorsal and anal fins	No	Yes	Yes	Yes	Yes
4. Number of predorsal bones	2	3	3	2	2
5. Shape of tooth patch on tongue	large, oval	narrow, oblong	narrow, oblong	narrow, oblong	narrow, oblong
6. Dorsal spine count	11 (rarely 12)	12 (rarely 11)	12 (rarely 11)	12	12
7. Longitudinal scale count	32-39	39-45	37-52	32-38	32-35
8. Upper lateral line count	34-38	34-40	34-43	28-32	29-32
9. Lower lateral line count	12-16	11-14	12-21	9-13	11-14
10. Predorsal scale count	15-20	20-29	10-24	7-12	6-7
11. Lower gill raker count	9-11	13-15	11-15	11-13	11-12
12. Longest dorsal ray (% of SL)	21.7-25.4	39.5-51.9	27.0-56.6	29.3-43.1	29.5-32.8
13. Caudal fin length (% of SL)	23.2-28.4	32.6-40.5	29.2-44.3	35.3-38.9	31.9-36.6
14. Pelvic fin length (% of SL)	26.4-33.8	39.4-48.9	34.2-45.4	38.4-50.6	37.0-40.7
15. Body depth (% of SL)	26.4-32.2	32.6-38.9	34.0-43.3	35.6-44.4	33.3-36.9
16. Preopercular margin	smooth	smooth	smooth	denticulate	smooth
17. Pores on snout	none	few	many	many	many
18. Pores on mandible	few, in clusters	many, in clusters	many	many	many
19. Scales on cheek	mostly exposed	mostly exposed	mostly imbedded	mostly imbedded	mostly imbedded
20. Number of body bars in life	9-10	4-5	8-9	8-9	8-9
21. Blue spots on body	few	many, restricted	many, widespread	none	none
22. Dark posterior band to dorsal, anal and caudal fins of juvenile	no	yes	yes	no	no
23. Large dark spot on operculum ventrally	no	no	occasionally	yes	yes
24. Number of vertebrae	27	26	26	26	26
25. Maximum lengths (mm SL)	115	224	245	129	122

Temperatures then rose progressively to the present level. Species inhabiting the east and west coasts of the continent dispersed northwards with falling sea temperatures and southwards with rising temperatures, whereas species on the south coast were forced to move to one or both the east and west coasts with falling temperatures, and redispersed to the south coast with rising temperatures. Knox drew attention to the fluctuating sea levels and sea temperatures during the Quaternary ice age, and the part these played in the separation of widespread

species into allopatric populations, and eventually into distinct species. Other workers have provided some examples of species pairs in the fish fauna of southern Australia that were presumed to have evolved from ancestral species split into two populations by the emergence of the Bass Strait land bridge (for example, Dartnell 1974; Collette 1974).

It is conceivable that ancestral species of *Paraplesiops* were separated into allopatric populations by events such as described above, eventually achieving reproductive isolation to form closely related species. The separation of the forerunners of *P. bleekeri* and *P. meleagris*, for example, from a common ancestral species widely distributed across southern Australia is easily explained, after noting the present day ranges of these two species (Figure 2), by fluctuations of sea levels and sea temperatures in the Bass Strait area during a period of glacial
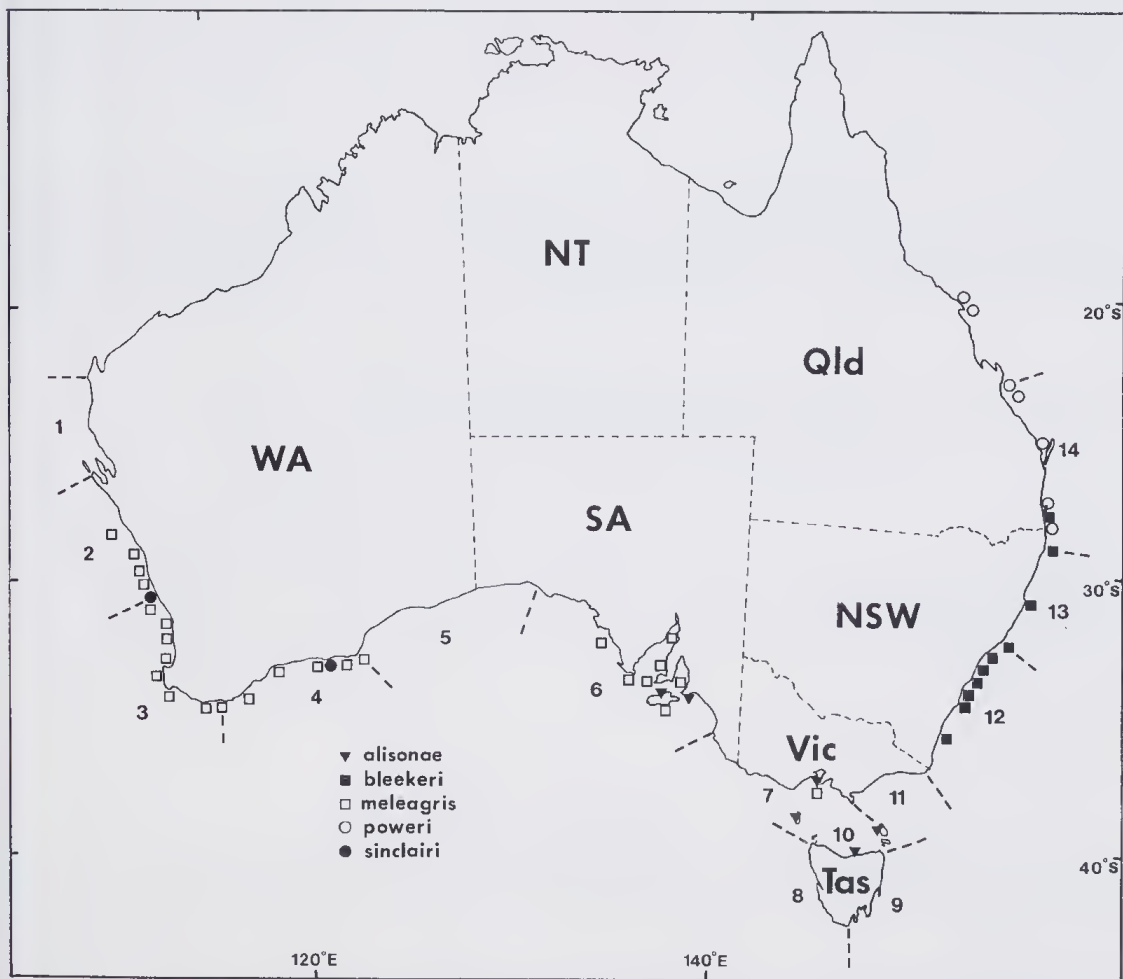
Figure 2   Map of Australia showing recorded localities for the species of *Paraplesiops*. Regions 1-14 (from Hutchins, in preparation) are employed in Table 3.

activity. However, the splitting of the presumed common ancestor of *P. poweri* and *P. sinclairi* is more difficult to explain. These two species are currently widely separated (Figure 2), and any possible explanation involving the geographic isolation of a widespread species into two allopatric populations could just as easily be based on a northern Australian connection as a southern one. Some workers believe that in the late Quaternary, numerous subtropical species were able to extend their ranges into tropical areas when sea temperatures decreased during a period of glacial activity (Randall 1981). Perhaps the common ancestor of *P. poweri* and *P. sinclairi* experienced such a dispersal, ranging across northern Australia only to be separated into an eastern and western population by the subsequent interglacial. These populations have since achieved reproductive isolation but, because they have been isolated only a relatively short period of time, are still very similar morphologically and ecologically. I favour this hypothesis as against one involving a southern connection due to the lack of evidence supporting the presence at any time in the past of large plate corals, the preferred habitat of the above two species, across the southern Australian coastline (Kendrick, pers. comm.).

In contrast to the above discussion on the evolution of species pairs, the history of the most specialised species, *P. alisonae*, appears to have involved a much earlier separation from the main *Paraplesiops* line. The subsequent long period of isolation resulted in the evolution of its many unique characters. Based on its present distribution, *P. alisonae* may have evolved in the Tasmanian/Victorian

Table 3   Distribution of some fish species found in Australia's southern half
Numbers refer to the regions illustrated in Figure 2
Brackets indicate presumed species pairs

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cheilodactylidae														
Cheilodactylus vestitus														
Cheilodactylus gibbosus														
Cheilodactylus nigripes														
Nemadactylus douglasii														
Nemadactylus valenciennesi														
Nemadactylus macropterus														
Labridae														
Achoerodus viridis														
Achoerodus gouldii														
Pseudolabrus guntheri														
Pseudolabrus biserialis														
Pseudolabrus psittaculus														
Gobiesocidae														
Cochleoceps species 1														
Cochleoceps species 2														
Cochleoceps bassensis														

region of southern Australia due to the different environmental conditions that are experienced there in contrast to the rest of Australia (this phenomenon is currently occurring in *P. meleagris*, where the Victorian population differs significantly from the South Australian and Western Australian population - see Hoese and Kuiter 1984).

The present distributions of the species of *Paraplesiops* are mostly dependent on the climatic conditions of the present interglacial (the commencement of the next glacial, for example, would greatly affect these ranges). Another factor is the availability of preferred habitat. The southernmost limits of the coral-dwelling *P. poweri* and *P. sinclairi* are probably determined by the presence or absence of large plate corals (the Solitary Islands off Coff's Harbour on the north coast of New South Wales, and the Archipelago of the Recherche off Western Australia's south coast). The lack of shallow rocky reefs in eastern Victoria between Cape Conran and Wilson's Promontory has probably contributed to this area being at or near the southern limit of *P. bleekeri* and the eastern limits of *P. alisonae* and *P. meleagris*.

Additional Material Examined

(unless otherwise designated, all at WAM)

Paraplesiops alisonae: P.27136-005, paratypes, 3 specimens, 72-107 mm SL, Victor Harbour, South Australia, 28 March 1981; P.27578-001, 2 specimens, 55-100 mm SL, mouth of Tamar River, Tasmania, 20 March 1982.

Paraplesiops bleekeri: P.27099-014, 216 mm SL, Port Hacking, New South Wales, 28 January 1981.

Paraplesiops melagris (all from Western Australia): P.4178, 88 mm SL, Lancelin Island, 21 November 1957; P.25251-012, 140 mm SL, Rottnest Island, 9 April 1975; P.26532-002, 73 mm SL, Geographe Bay, 27 December 1978; P.26614-013, 192 mm SL, Rottnest Island, 6 January 1980; P.26616-012, 74 mm SL, Rottnest Island, 7 June 1980; P.27587-005, 64 mm SL, Long Island, Houtman Abrolhos, 16 April 1982; P.27590-001, 170 mm SL, Dick's Island, Houtman Abrolhos, 17 April 1982; P.27949-007, 44 mm SL, Jurien Bay, 9 April 1983; P.28293-020, 73 mm SL, Lucky Bay, east of Esperance, 12 April 1984.

Paraplesiops poweri (all from Queensland): AMS 1A.874-876, 3 specimens, 84-97 mm SL, Whitsunday Passage, no other data; AMS 1.18258-001, 129 mm SL, Moreton Bay, November 1973; AMS I.19347-002, 100 mm SL, Great Keppel Island, July 1973; P.27065-003, 3 specimens, 31-51 mm SL, Bargara, 3 December 1980.

Acknowledgements

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Breeding in the Australian Yellow-bellied Sheath-tailed Bat, *Saccolaimus flaviventris* (Peters, 1867)(Chiroptera: Emballonuridae).

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Abstract

Saccolaimus flaviventris pregnancies were almost always restricted to the right uterine horn. This horn first increased in diameter in August, and the maximum enlargement was observed in November. The horn regressed rapidly following parturition. Over the species range the parturient season was between December and mid March. Teats and mammary glands were regressed by the end of May. A pregnant female collected in February had a corpus luteum that was deeply embedded in the right ovary and occupied *ca.* 65 percent of the ovary; the contralateral ovary had numerous large atretic secondary and graafian follicles.

In males, there was no significant difference throughout the year in testis size, weight and position or in epididymis weight; nor was there a significant correlation between these parameters and the depth of the throat pouch - which also showed no significant variation in depth.

Introduction

Emballonurids are widely distributed in the tropical and subtropical regions of the world (Nowak and Paradiso 1983). The family has 11 recent genera comprising about 51 species (Honacki *et al.* 1982). In Australia there are only two genera; *Taphozous* and *Saccolaimus*, although some modern authorities do not recognize *Saccolaimus* as distinct from *Taphozous* (Hill and Smith 1984).

Information on reproductive patterns of emballonurids is not particularly extensive compared to that available on other bat families (Rowlands and Weir 1984) and is limited to several New World species of *Saccopteryx, Cormura, Peropteryx* and *Centronycteris* (Arata and Vaughan 1970, Flemming *et al.* 1972, Bradbury and Emmons 1974, La Val and Fitch 1977), *Taphozous longimanus* and *T. melanopogon* in India (Gopalakrishna 1955, Brosset 1962, Khaparde 1976, Mokkapati and Dominic 1976, Lekagul and McNeely 1977, Krishna and Dominic 1982, Swami and Lall 1982, Lall and Biswas 1983, Sapkal and Khamre 1983), *T. nudiventris* in Pakistan (Roberts 1977), *T. mauritianus* in Zaire (Kingdon 1974), the Asian *Saccolaimus saccolaimus* (Medway 1978), *T. georgianus* (Kitchener 1973) and *T. hilli* in Australia (Kitchener 1976). There is no study on the reproduction of Australian *Saccolaimus*, apart from the single observation of

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breeding by Compton and Johnson (1983), who observed that *S. saccolaimus* females collected in mid December in Queensland had advanced pregnancies or attached young.

At least three families of bats have throat or gular pouches and associated glands (Quay 1970). Dobson (1875) recorded that throat glandular structures were characteristic of bats in the genus *Taphozous* and much importance was placed on these structures when Troughton (1925) revised the genus. As in most emballonurids, the gular pouch in *S. flaviventris* occurs only in males and is represented by small folds in the skin of the throat of females (Hall and Richards 1979). Hall and Gordon (1982) report that this pouch is devoid of any glandular secretory material but speculate that it may be used during territorial marking.

In Western Australia, Kitchener (1976) found that in males of *T. georgianus* size of the pouch varied seasonally and that there was a correlation between the depth of the gular pouch and some reproductive parameters. Hall and Gordon (1982) suggested, from a small number of individuals, that the depth of the throat pouch may not vary seasonally. Our large sample size enabled us to investigate this suggestion and to examine correlations with some testis and epididymis parameters.

By reporting on aspects of the reproductive biology of *S. flaviventris,* this paper attempts to increase the knowledge of this little studied bat and of emballonurids in general.

Materials and Methods

This study was based on 54 female and 48 male specimens of *S. flaviventris* from the Queensland, Australian, Victorian, South Australian and Western Australian Museums, CSIRO Wildlife Collection and the Central Australian Wildlife Collection. These specimens (except one) were fixed in 10 percent formalin and preserved in 70 percent ethanol. These specimens were collected over a period of 20 years from widely distributed localities (Figure 1) encompassing a variety of habitats and climates. Specimens from most months of the year are present in the collections, although there are no females from December and only two subadult females from January, and no males from May and December.

Ovaries of the pregnant female collected in February were fixed in Bouin's fluid and preserved in 70 percent ethanol. They were embedded in paraffin and serial sections cut at 6 μm; these were stained and counter stained with Gill's haemotoxylin and eosin, respectively.

The reproductive tract was examined *in situ.* In females, maximum diameters of both uterine horns, length, shape and extent of dark pigmentation of teats and extent of mammary development were recorded. The foetuses of more advanced pregnancies were dissected from their uterine horn to record forearm and crown to rump lengths.
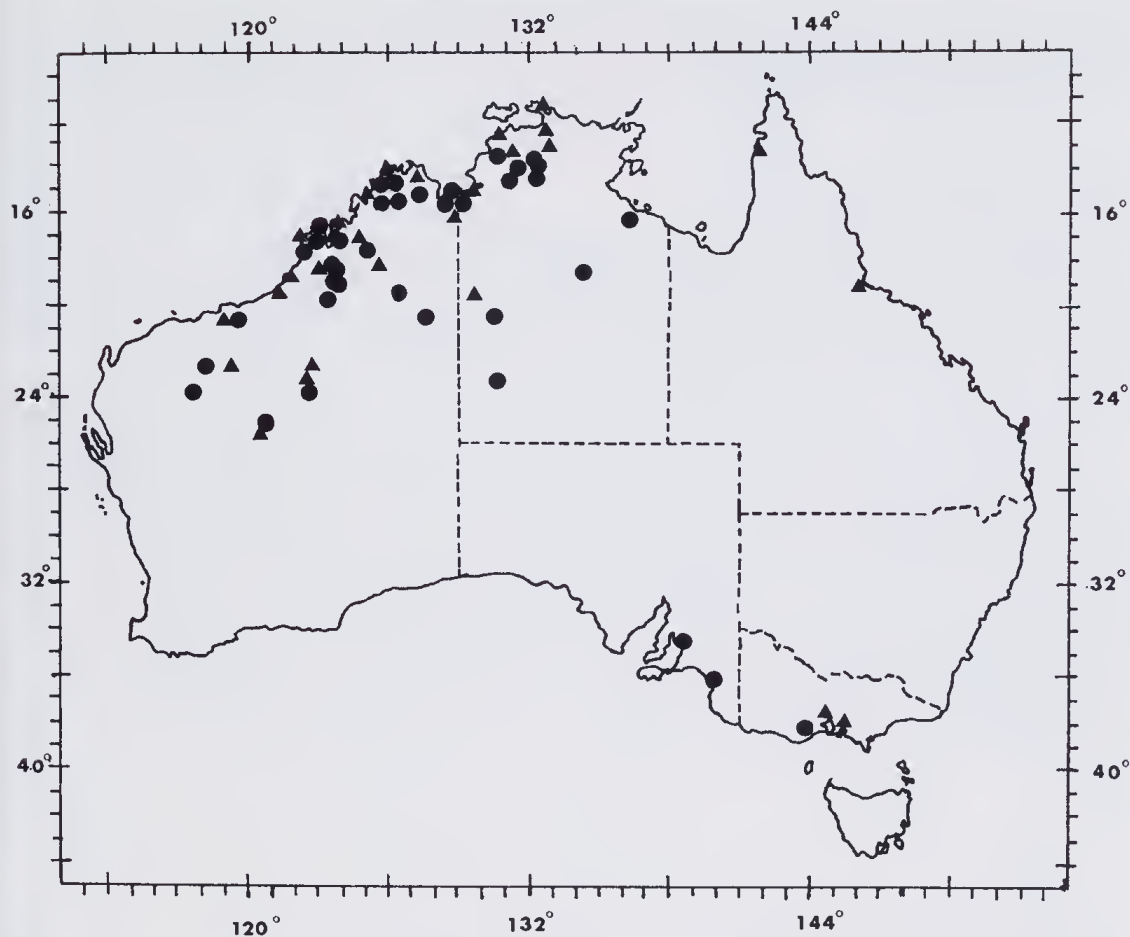
Figure 1   Distribution of *Saccolaimus flaviventris* specimens used in this study. (▲), males; (●), females. Some localities have multiple specimens.

In males, forearm length, position of testes (whether scrotal, base of penis, inguinal or abdominal), testis weight, length and breadth, epididymis weight and the depth of the gular pouch were recorded.

Adult condition was judged by the absence of swelling of the epiphyses in the joints of the digits. Recently parturient and probably lactating females were judged by the presence of an enlarged right uterine horn and/or by enlarged and pigmented teats or enlarged mammary glands.

A one-way analysis of variance was carried out to assess significant seasonal differences in testis length, testis breadth, testis weight, epididymis weight and pouch depth. Correlations between depth of the gular pouch and reproductive parameters were tested by stepwise multiple regression (Nie *et al.* 1975, and Hull and Nie 1981). All statistical analyses were performed through ONE-WAY and REGRESSION subprograms of the Statistical Package for the Social Sciences

(SPSS) (Nie *et al.* 1975 and Hull and Nie 1981) on a Cyber 70 at the Western Australian Regional Computing Centre.

Results

Female Reproduction

Period of birth

All but one of the 16 obviously pregnant females had the foetus in the right uterine horn. The contralateral horn showed little enlargement and ranged in diameter from 0.8 to 3.1 mm. In non-parous females, the size of both uterine horns was almost equal and ranged from 0.8 to 1.4 mm in diameter.

In *S. flaviventris*, embryos were dissected from horns with diameters greater than 7 mm; perceptible swelling in horns of this species was first recorded in August (Figure 2). Diameter of the right uterine horn (d) closely reflects the crown to rump length of the foetus (f): $d=1.0f - 1.6$ ($r=0.95$, df=8 p<.001). The horn appears to increase rapidly in diameter from *ca.* 6 to 16 mm between September and October. Larger foetuses occurred in females collected in November, (foetal forearm lengths 20.3 and 25.9 mm) and mid February (foetal forearm length 10.0 mm). The presence of a foetus in a female collected in mid February that is smaller than those in females from late November indicates a season of births of at least three months duration, extending from approximately

Figure 2   Diameter of right uterine horn (mm) versus month of collection. (●), obviously pregnant; (△), pro-oestrus or recently pregnant; (○), recently parturient — lactating; and [s], southern Australian specimens; [j], juvenile. In some cases more than one specimen with the same sized horns was collected on the same date. The number of such specimens is shown.

early December to mid March. The pregnant female collected in mid February had a large corpus luteum with diameter *ca.* 800 μm deeply embedded and occupying *ca.* 65 percent of the right ovary. The contralateral ovary had numerous large atretic secondary and graafian follicles (up to 210 μm in diameter).

Rapid regression of the right uterine horn followed parturition and left no obvious externally visible implantation scar such that recently parturient or recently lactating females were often detectable only from enlarged, darkly pigmented pubic teats and swollen mammary glands. Females collected at the same localities at the same time showed close synchrony in reproductive condition; we did not detect any obvious geographic trends in reproductive patterns.

Male reproduction

Reproductive cycle

Left and right testes were in the same position in all but three males. In these three males we recorded the position of the testes as that of the most caudally located one. Testes of the subadult male were abdominal.

The caput and cauda epididymis were clearly distinct. The length of the epididymis varied depending on the position of the testis because the cauda epididymis were always located in the scrotal sac. An analysis of variance showed that on a seasonal basis there were no significant differences in testis length ($F_{3,44}$= 0.99), testis breadth ($F_{3,44}$=1.29), testis weight ($F_{3,44}$=0.56), and epididymis weight ($F_{3,44}$=0.05). Similar results were obtained when the analysis was performed by pooling all data or grouping it on a two monthly basis.

Gular pouch

There was no significant seasonal difference in the depth of the gular pouch using data pooled on a seasonal ($F_{3,42}$=1.06), or two monthly basis ($F_{5,42}$=0.70). Pouch depth was not significantly correlated, using stepwise multiple regression analysis, with testis length (r=0.254), testis breadth (r=0.059), testis weight (r=0.245) or epididymal weight (r=0.039)(df=6).

Discussion

From studies cited earlier, the reproductive patterns of emballonurids are quite variable. The Australian *Taphozous* species studied by Kitchener (1973, 1976) give birth to young over a relatively long period. Although Kitchener (1973, 1976) concluded that *T. georgianus* and *T. hilli* (as *T. georgianus*) were monoestrous, there is the possibility that they may give birth to young a second time during this long breeding season. This fact may not be detected in Museum specimens if corpora lutea persist for only a short period following parturition. Females of several Australian bats give birth to young twice a year (i.e. *Myotis adversus* and *Eptesicus pumilus caurinus* (Dwyer 1970, Maddock and McLeod 1976). Our observations on *S. flaviventris* also suggest the possibility of two periods of birth

— one about December and the other during February. Interestingly, these two periods coincide with when the two above mentioned polyoestrous species give birth to young.

There is no indication of an old corpus luteum in either the left or the right ovary of the pregnant *S. flaviventris* female collected in February. This suggests that it is not breeding a second time in the one season. However, examination by histological preparation of a number of female *S.flaviventris* from the late summer months is required before concluding as to the polyoestrous or monoestrous nature of this species.

There was no evidence of seasonal change in testis and epididymal parameters considered in this study. Histological studies show that the extent of spermatogenic activity is directly proportional to both maximum tubular diameter and testicular weight (Racey 1974). If use of testis weight and testicular dimensions are suitable measures of general changes in annual spermatogenic activity, then *S.flaviventris* males appear to be in active reproductive condition throughout the year, This pattern conforms with that of the other Australian male emballonurids studied (Kitchener 1973, 1976).

Australian vespertilionid males, however, show marked seasonal changes in their reproductive cycle. Phillips and Inward (1985) found that the onset of test-ticular enlargement in *Nyctophilus gouldi* coincided with spermatogenesis, which occurred only in summer. Spermatozoa were stored in the epididymides during the hibernating season. Schlawe (1983) found that activity in the primary and secondary reproductive organs in male *Chalinolobus gouldi* was asynchronous. Testicular activity was highest in autumn while accessory organ activity was highest in winter.

S. flaviventris differs from the Indian emballonurid *T. longimanus* which gives birth to young throughout the year, and has both ovaries functional with pregnancies alternating between both the left and the right uterine horns (Gopalakrishna 1955).

This study confirms the findings of Hall and Gordon (1982) by showing that there was no significant seasonal difference in the depth of the gular pouch, nor is this depth correlated with indicators of male reproductive condition such as was exhibited by *T. georgianus* in Western Australia (Kitchener 1976).

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Descriptions of three new pseudochromid fishes of the genus *Pseudoplesiops* from Australia and surrounding regions

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Abstract

Three new pseudochromid fishes are described from the tropical eastern Indian and western Pacific Oceans. *Pseudoplesiops howensis* is described from 22 specimens collected at Lord Howe Island in 1973. It is closely related to *P. knighti,* also described herein, but differs in predorsal scalation and coloration. The latter species is described from 55 specimens, mainly collected on the northern Great Barrier Reef, but it also occurs off north-western Australia, at Manus Islands, and possibly at the Molucca Islands. *Pseudoplesiops multisquamatus,* the third new species, differs from other members of the genus on the basis of its high (usually more than 60) number of scales in a horizontal series. It is described from 44 specimens collected mainly below 30-40 m depth at the Fiji Islands, New Britain, Manus Island, Coral Sea, northern Great Barrier Reef, off north-western Australia, Christmas Island, and the Cocos-Keeling Islands.

Introduction

The marine fish family Pseudochromidae contains about 100 known species, which are mainly confined to the tropical western Pacific and Indian Oceans. They are small fishes (usually under 10 cm standard length) that inhabit caves, crevices, ledges, or rubble habitats. Apart from the outdated work of Fowler (1931) there has been no comprehensive review of the group, although Lubbock (1975, 1976, and 1977) provided regional treatment of the pseudochromid faunas of the Red Sea, and western and central Indian Ocean.

Evidence provided by Springer *et al.* (1977) indicated that *Anisochromis* Smith and *Pseudoplesiops* Bleeker, previously recognised as seperate families (Anisochromidae and Pseudoplesiopidae) should be placed in Pseudochromidae. More recently, Godkin and Winterbottom (1985) provided good evidence for the incorporation of the Congrogadidae within the Pseudochromidae. Other genera recognised by recent authors include *Pseudochromis* Rüppell (with over 50 species), *Labracinus* Bleeker, and *Chlidichthys* Smith.

The present paper describes three new species collected by the author and associates, primarily from Australia and adjacent regions. Although they exhibit some

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features of *Chlidichthys* (i.e., a single tubed lateral-line scale, presence of palatine teeth, and ctenoid scales in two species), the three are provisionally placed in *Pseudoplesiops* on the advice of A. Gill, who is engaged in revisionary studies of the family. The discovery of new species during the past decade necessitates a revision of generic lines within the family. According to Edwards and Randall (1982) it is doubtful if *Chlidichthys* as traditionally defined can be maintained as distinct from *Pseudoplesiops*.

The format of the new species descriptions is based on those of Lubbock (1975, 1976, and 1977) with certain modifications. Type specimens were deposited at the following institutions (abbreviations are used in the subsequent text): Academy of Natural Sciences, Philadelphia (ANSP); Australian Museum, Sydney (AMS); Bernice P. Bishop Museum, Honolulu (BPBM); Queensland Museum, Brisbane (QM); Royal Ontario Museum, Toronto (ROM); United States National Museum of Natural History, Washington, D.C. (USNM); and Western Australian Museum, Perth (WAM).

Systematics

Pseudoplesiops howensis sp. nov.

Figures 1 and 2; Tables 1 and 2

Holotype

AMS I.17358-018, 30.5 mm SL, Lord Howe Island, Australia (31°32'S, 159°04'E), 20-25 m, G. Allen *et al.*, rotenone, 5 February 1973.

Paratypes (all from Lord Howe Island)

AMS I.17422-010, 31.6 mm SL, Australian Museum party, rotenone, February 1973; AMS I.17357-013, 3 specimens, 24.2-26.4 mm SL, off Phillip Point, 20-25 m, G. Allen *et al.*, rotenone, 5-16 February 1973; AMS I.17358-008, 2 specimens, 28.7-30.2 mm SL, collected with holotype; AMS I.17362-027, 31.5 mm SL, 18-25 m, G. Allen *et al.*, rotenone, 18-25 February 1973; BPBM 14925, 8 specimens, 28.0-32 mm SL, collected with holotype; BPBM 14944, 4 specimens, 28.0-30.0 mm SL, Phillip Rock, 30 m, J. Randall *et al.*, rotenone, 26 February 1973; WAM P.28622-001, 2 specimens, 26.5-28.8 mm SL, collected with AMS I.17357-013.

Diagnosis

A species of pseudochromid fish differing from other members of the family by the following combination of characters: dorsal rays usually 1,23; anal rays I,14; pectoral rays 16 or 17; pelvic rays I,4; branched caudal rays 14 (rarely 13); vertical scale rows 33 to 38; a single tubed lateral-line scale. It is closely allied to *P. knighti*, described herein, but differs in having the predorsal scales extending forward to the rear margin of the preopercle (scales and well forward of this point in *P. knighti*; compare Figs 2 and 4). In addition, the dorsal and anal fins tend to be dusky brown in *P. howensis* and pale (yellow in life) in *P. knighti*.
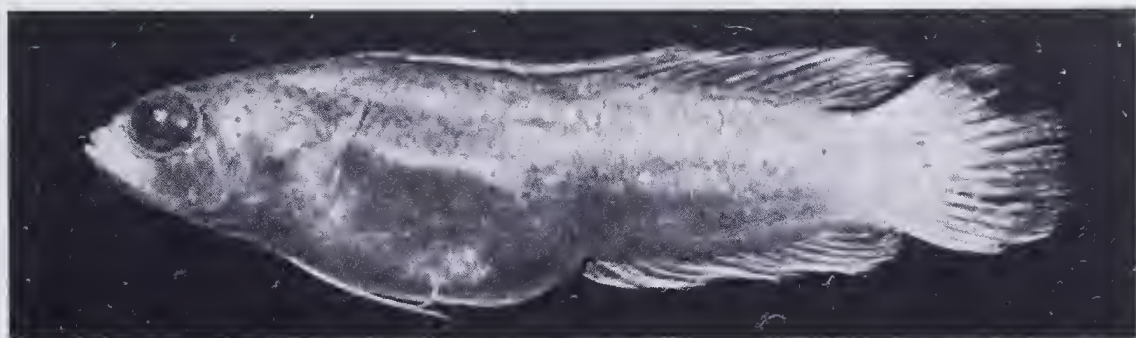
Figure 1   *Pseudoplesiops howensis*, holotype, 30.5 mm SL, Lord Howe Island.
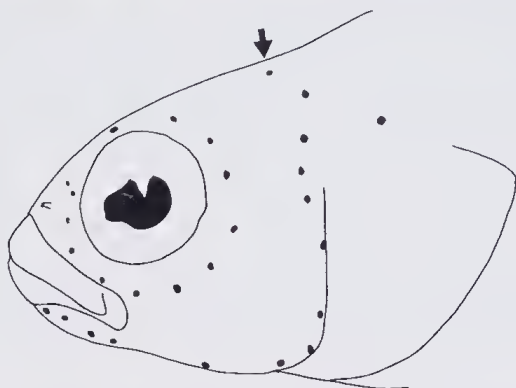
Figure 2   Camera lucida drawing of head of *Pseudoplesiops howensis* showing sensory pores of head. Arrow denotes extent of predorsal scalation.

Description

Dorsal fin rays I,23 (single paratype with I,24); anal fin rays I,14; pectoral fin rays 17 (16 or 17); pelvic fin rays I,4; segmented caudal fin rays 14 (13 or 14), with four or five small supplementary rays above and below. Vertical scale rows from origin of lateral line to base of caudal fin 35 (33 to 38); a single tubular lateral line scale above upper limit of operculum; transverse scale series, counted forwards and upwards from anal fin origin 14 (12 to 14); predorsal scales 9(9 to 11); 3(2 or 3) rows of scales on preoperculum; 8(8 or 9) sensory pores in the post- and sub-orbital series, starting on the vertical above eye centre and extending down the hind margin of the eye to the upper edge of the maxilla (the first pore adjacent to the maxilla is included in the count); median interorbital pore absent. Gill rakers on first arch 4 + 8 = 12 (3 or 4 + 7 to 11 = 10 to 15).

Greatest body depth 3.6 (3.6 to 4.0), head length 3.4 (3.2 to 3.4), length of dorsal fin base 1.7 (1.6 to 1.7), length of anal fin base 3.0 (2.9 to 3.3), all in standard length. Snout length 6.1 (5.3 to 6.4), eye diameter 3.4 (3.2 to 3.9), predorsal distance 0.9 (0.9 to 1.0), least depth of caudal peduncle 2.1 (1.9 to 2.1),

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pectoral fin length 1.3 to 1.6 in paratypes (damaged in holotype), pelvic fin length 1.2 (0.9 to 1.2), all in head length.

Table 1   Fin-ray and gill raker counts for new species of *Pseudoplesiops*.
Dorsal and anal counts include both spinous (unsegmented) and soft (segmented) elements.

Species	Dorsal rays					Anal rays			Pectoral rays			Total gill rakers on first arch									
	24	25	26	27	28	15	16	17	16	17	18	10	11	12	13	14	15	16	17	18	19
P. howensis	21	1				22			9	13		1	7	9	3	1	1				
P. knighti			26			24	2		22	4				3	13	8	2				
P. multisquamatus			3	20	2		8	17		18	10						3	2	10	8	2

Table 2   Morphometric proportions (as percentage of standard length) for selected type specimens of *Pseudoplesiops howensis*.

Character	Holotype	Paratypes				
	AMS I.17358-018	AMS I.17422-010	AMS I.17358.008	AMS P.28622-001	AMS I.17357-013	AMS I.17357-013
Standard length (mm)	30.5	31.6	30.2	28.8	25.5	24.2
Body depth	27.9	25.0	26.5	26.0	24.7	26.4
Head length	29.8	28.5	29.8	31.3	31.0	30.2
Snout length	4.9	4.7	4.6	5.9	5.9	5.4
Eye diameter	8.9	8.9	7.6	9.0	9.4	8.7
Predorsal distance	32.1	31.0	29.8	33.0	32.2	31.4
Caudal peduncle depth	14.4	13.6	14.9	14.9	15.3	15.7
Pectoral fin length	*	20.3	21.2	21.5	23.5	23.6
Pelvic fin length	24.9	27.8	28.1	*	32.9	34.3
Dorsal fin base length	57.7	62.0	59.9	62.8	63.5	62.0
Anal fin base length	33.8	34.2	33.1	34.7	34.1	34.7

*denotes damaged or missing

Small, elongate, reef fish; head and body moderately compressed. Jaws nearly equal anteriorly, reaching posteriorly to below pupil; cleft of mouth oblique. Eye with pear-shaped pupil. Scales on head and anteriormost part of body cycloid, remainder ctenoid; predorsal scales extending to about level of rear margin of preopercle; snout, preorbital, interorbital and frontal portion of nape, chin and maxilla naked; scales irregular and large on operculum. Upper part of operculum, edge of preoperculum, orbital and supraorbital region of head, lower jaw and snout bearing sensory canals (Fig 2); preopercular and opercular edges entire.

Upper jaw with 1-2 lateral series of subconical teeth on posterior part of jaw; at symphysis several series of teeth, those of the anterior series caniniform and en-

larged, the teeth behind these small and setiform; anteriorly 5 or 6 enlarged curved canines. Lower jaw dentition similar, but with single lateral series on posterior part of jaw; 6 enlarged canines anteriorly. Vomer with an irregular, chevron-shaped series of fine teeth; palatines with similar teeth. Tongue tip rounded, its upper surface finely papillate.

Dorsal fin with single feeble spine, little differentiated from soft rays; last 5(5 to 7) rays of dorsal fin branched; last 5 (3 to 5) rays of anal fin branched. Pectoral fins rounded, principal rays branched. Pelvic fins inserted below pectoral fins, pointed, soft rays unbranched, second soft ray longest; pelvic fin tips extending nearly to anus (except damaged in some specimens). Caudal fin rounded, with basal scaly sheath.

Colour in alcohol: overall brown, tan on breast, belly, and lower part of head; dorsal and anal fins slightly dusky; pectoral and pelvic fins pale tan.

Colour when fresh: overall medium brown, including dorsal and anal fins; breast, belly, and lower part of head tan; pelvic, pectoral, and outer part of caudal fins tan to translucent; margins of dorsal and anal fins and tip of pelvic fins narrowly blue.

Remarks

This species inhabits reef crevices in the lagoon at Lord Howe Island in 5-10 m depth, and also occurs outside the lagoon to at least 30 m. Two specimens (AMS 1.15485-002 and 1.19338-020), from Heron and One Tree Islands in the Capricorn Group on the southern Great Barrier Reef are provisionally identified as *P. howensis*. They seem to agree in most respects with material from Lord Howe Island, although it would be desirable to examine additional specimens to confirm the identification.

It was reported from Lord Howe Island as *Pseudoplesiops* sp. by Allen *et al.* (1976). They mentioned the presence of a fleshy keel in the intermandibular space. Although this feature is apparent in several of the type specimens it is nevertheless poorly developed, and easily overlooked. The only member of the genus possessing a well developed intermandibular keel is *P. revellei* Schultz, a widespread species in the tropical Indo-Pacific region.

The species in named *howensis* in reference to the type locality.

Pseudoplesiops knighti sp. nov.
Figures 3 and 4; Tables 1 and 3

Holotype
WAM P.28534-001, 29.2mm SL, Number 8 Ribbon Reef, Great Barrier Reef, Queensland, Australia (14°58'S, 145°44'E), north end, 25-40 m, G. Allen, rotenone, 13 November 1985.

Paratypes
Great Barrier Reef, Queensland: AMS I.18739-063, 7 specimens, 13.0-17.5 mm SL, Lizard Island (14°42'S, 124°32'E), 3-10m, AMS party, rotenone, 21 November 1975; AMS I.18740-

070, 2 specimens, 23.9-28.4 mm SL, Yonge Reef (14°35′S, 145°37′E), 8-10 m, AMS party, rotenone, 8 November 1975; AMS I.19454-034, 26.0 mm SL, Yonge Reef, 1-18 m, AMS party, rotenone, 11 November 1985; AMS I.19472-119, 11 specimens, 12.0-26.5 mm SL, Yonge Reef, 7-15 m, AMS party, rotenone, 23 November 1975; AMS I.19472-126, 26.5 mm SL, Yonge Reef, 7-15 m, AMS party, rotenone, 23 November 1975; AMS I.20775-008, 2 specimens, 19.1-29.3 mm SL, Raine Island (11°35′S, 144°01′E), 0-20 m, AMS party, rotenone, 11 February 1979; AMS I.22640-002, 31.0 mm SL, Escape Reef (15°49′S, 145°50′E), 15-17 m, W. Starck, rotenone, 9 November 1980; BPBM 30930, 2 specimens, 22.8-24.7 mm SL, collected with holotype; QM I.22340, 2 specimens, 26.1-26.6 mm SL, outer reef 20 km west of Lizard Island (14°54′S, 145°40′E), 15 m, G. Allen, rotenone, 4 November 1985; ROM 40459, 2 specimens, 25.0-28.5 mm SL, Escape Reef, T. Ayling *et al.*, rotenone, 1 November 1981; ROM 40479, 2 specimens, 23.6-24.7 mm SL, Escape Reef, J. Paxton *et al.*, rotenone, 7 November 1981; USNM 278457, 23.4 mm SL, same data as QM paratypes; WAM P.25322-004, 24.6 mm SL, Pixie Reef (16°33′S, 145°52′E), 12 m, G. Allen, rotenone, 3 July 1972; WAM P.28531-004, 3 specimens, 15.5-26.8 mm SL, same data as QM paratypes; WAM P.28533-013, 3 specimens, 26.0-30.0 mm SL, south end of Number 9 Ribbon Reef (15°00′S 145°42′E), 15 m, G. Allen, rotenone, 11 November 1985; WAM P.28534-002, 3 specimens, 26.8-27.7 mm SL, north end of Number 8 Ribbon Reef (14°58′S, 145°44′E), 25-40 m, G. Allen, rotenone, 13 November 1985; WAM P.28535-015, 2 specimens, 29.0-31.5 mm SL, south end of Number 10 Ribbon Reef (14°56′S, 145°41′E), 4-5 m, G. Allen, rotenone, 14 November 1985. **North-west shelf of Australia:** AMS I.21316-018, 24.3 mm SL, Scott Reef (14°10′S, 121°55′E), 7-10 m, F. Talbot, rotenone, 20 September 1979. **Papua New Guinea:** WAM P.27826-067, 5 specimens, 23.0-25.0 mm SL, Manus Island (2°04′S, 147°25′E), 35-41 m, G. Allen and R. Knight, rotenone, 6 October 1982. **Solomon Islands:** ROM 45993, 2 specimens, 15.5-27.0 mm SL, 12 km west of Honiara, Guadalcanal (9°26′S, 160°03′E), shipwreck in 20-22 m, P. Nichols and D. Evans, rotenone, 24 April 1982.

Diagnosis

A species of pseudochromid fish differing from other members of the family by the following combination of characters: dorsal rays I,23; anal rays usually I,14; pectoral rays 17 or 18; pelvic rays I,4; branched caudal rays 13 (rarely 14); vertical scale rows 32 to 35; a single tubed lateral-line scale. It is closely allied to *P. howensis*, described herein, but differs in having a larger eye (2.5-3.0 in head length v. 3.2-3.9) and in the extent of the predorsal scalation, which reach to the rear part of the interorbital region (scales end well behind this point in *P. howensis*; compare Figs 2 and 4). It is also similar in appearance to *P. annae* (Weber) of the Indo-Australian Archipelago but different in fin ray counts (*annae:* dorsal rays I,25-27; anal rays I,16 or 17; pelvic rays I,3) and predorsal scalation (not reaching interorbital). In addition, *P. annae* appears to be more restricted to deep water (23-113 m). It is also similar to *P. inornatus* (Lubbock) from the central Indian Ocean (Sri Lanka, Maldives, Chagos) but differs in fin ray counts (*inornatus:* dorsal rays II,21 or 22; anal rays III,13; pectoral rays 19 or 20) predorsal scalation (only to level of preopercultum), and a larger maximum standard length (45.5 mm v. 31.5 mm).

Description

Dorsal fin rays I,23; anal fin rays I,14 (2 paratypes with II,14); pectoral fin rays 17 (17 or 18); pelvic fin rays I,4; principal caudal fin rays 13 (one paratype
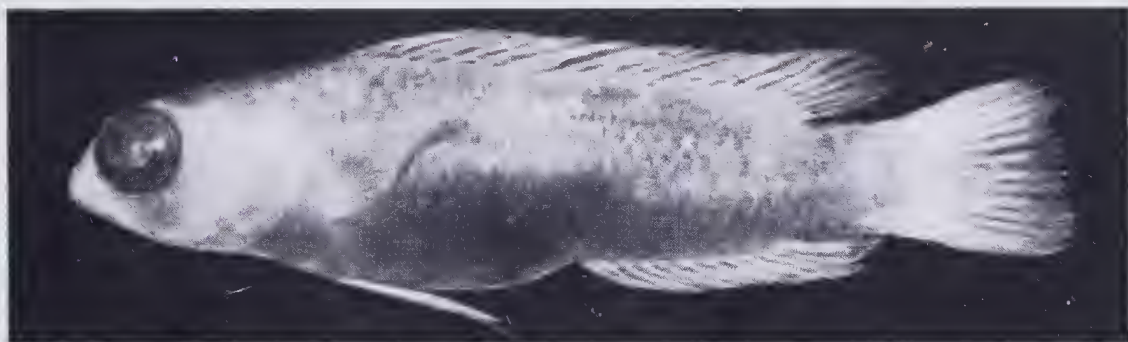
Figure 3   *Pseudoplesiops knighti*, holotype, 29.2 mm SL, Great Barrier Reef, Queensland.
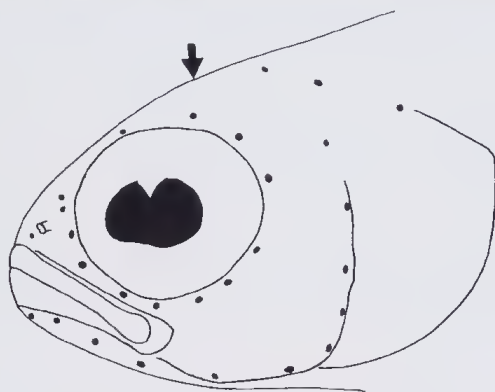
Figure 4   Camera lucida drawing of head of *Pseudoplesiops knighti* showing sensory pores of head. Arrow denotes extent of predorsal scalation.

Table 3   Morphometric proportions (as percentage of standard length) for selected type specimens of *Pseudoplesiops knighti*.

Character	Holotype WAM P.28534-001	Paratypes AMS I.18740-070	WAM P.27826-067	WAM P.27826-067	WAM P.27826-067	WAM P.27826-067
Standard length (mm)	29.2	28.5	26.5	24.9	23.7	22.9
Body depth	26.0	25.6	27.9	29.7	29.5	28.8
Head length	30.8	33.3	30.6	31.3	32.5	32.3
Snout length	5.1	5.3	5.7	5.6	5.1	6.1
Eye diameter	12.3	11.9	12.5	12.4	12.7	12.7
Predorsal distance	35.6	35.8	36.6	34.5	36.3	36.7
Caudal peduncle depth	13.4	14.4	15.1	16.1	15.2	17.0
Pectoral fin length	20.5	20.7	22.6	22.5	21.5	21.0
Pelvic fin length	27.4	26.7	27.2	30.5	27.0	29.3
Dorsal fin base length	56.2	54.7	58.9	59.0	57.8	59.4
Anal fin base length	25.7	26.7	26.4	25.7	24.9	28.4

with 14), with 5 or 6 small supplementary rays above and below vertical scale rows from origin of lateral line to base of caudal fin 34 (32 to 35); a single tubular lateral line scale above upper limit of operculum; transverse scale series, counted forwards and upwards from anal fin origin 12 (11 or 12); predorsal scales 10(9 to 10), 3 (2 or 3) rows of scales on preoperculum; 8 sensory pores in the post- and sub-orbital series, starting on the vertical above eye centre and extending down the hind margin of the eye to the upper edge of the maxilla (the first pore adjacent to the maxilla is included in the count); median interorbital pore absent. Gill rakers on first arch 4 + 10 = 14 (3 to 5 + 9 or 10 = 12 to 15).

Greatest body depth 3.8 (3.4 to 3.9), head length 3.2 (3.0 to 3.3), length of dorsal fin base 1.8 (1.7 to 1.8), length of anal fin base 3.9 (3.5 to 4.0), all in standard length. Snout length 6.0 (5.3 to 6.4), eye diameter 2.5 (2.5 to 3.0), predorsal distance 0.9 (0.8 to 0.9), least depth of caudal peduncle 2.3 (1.9 to 2.3), pectoral fin length 1.5 (1.4 to 1.7), pelvic fin length 1.1 (1.0 to 1.6), all in head length.

Small, elongate, reef fish; head and body moderately compressed. Jaws nearly equal anteriorly, reaching posteriorly to below pupil; cleft of mouth oblique. Eye with pear-shaped pupil. Scales on head and anterior part of body cycloid, remainder ctenoid; predorsal scales extending to rear of interorbital; snout, preorbital, most of interorbital area, chin and maxilla naked; 3 transverse scale series on preoperculum; scales irregular and large on operculum. Upper part of operculum, edge of preoperculum, orbital and supraorbital region of head, lower jaw and snout bearing sensory canals (Fig 4); opercular and preopercular edges entire.

Upper jaw with 1-2 lateral series of subconical teeth on posterior part of jaw, at symphysis several series of teeth, those of the anterior series caniniform and enlarged, the remaining teeth behind small setiform; anteriorly 6-8 enlarged curved canines. Lower jaw dentition similar, row of enlarged canines anteriorly. Vomer with irregular, chevron-shaped series of fine teeth; palatines with similar teeth. Tongue tip rounded or truncate, its upper surface finely papillate.

Dorsal fin with single feeble spine, little differentiated from soft rays; last 7 (4 to 8) rays of dorsal fin branched; last 7(4 to 7) rays of anal fin branched. Pectoral fins rounded, principal rays branched. Pelvic fins inserted below pectoral fins, pointed, soft rays unbranched, second soft ray longest; pelvic fin tips extending to anus or nearly so. Caudal fin slightly rounded, with basal scaly sheath.

Colour in alcohol: overall medium brown to tan with pale tan to whitish fins.

Colour when fresh: varies from bright yellow, including fins, to overall brown, lighter on breast, belly and lower half of head; caudal fin of brown variety yellow, other fins translucent to pale yellow; iris orange, perimeter of eye often narrowly blue or purple.

Remarks

This species inhabits coral rubble and reef crevices, usually at depths ranging from about 10 to 30 m, although specimens from as shallow as 4 m and as deep as 41 m are know.

Most specimens have been collected from the northern Great Barrier Reef of Australia between Pixie Reef (16°33'S) and Yonge Reef (14°35'S). It is also known from Manus Island in the Bismark Archipelago, the Solomon Islands, and from Scott Reef, near the edge of the north-western continental shelf of Western Australia. A specimen (WAM P. 25235-0220, 25 mm SL) from Ambon, Molucca Islands is provisionally identified as *P. knighti,* agreeing in most respects with the type material except it has a lower dorsal fin-ray count (I,21).

The species is named *knighti* in honour of Mr Ronald Knight Sr of Manus, Papua New Guinea for his generous hospitality during a collecting visit to the island in 1982.

Pseudoplesiops multisquamatus sp. nov.

Figures 5 and 6; Tables 1 and 4

Holotype

WAM P. 27470-002, 41.8 mm SL, Escape Reef (15°50'S, 145°50'E), Great Barrier Reef, Queensland, Australia, outside of northern passage, 40 m, G. Allen and W. Starck, rotenone, 3 November 1981.

Paratypes

Fiji Islands: ROM 50734, 4 specimens, 23.8-48.7 mm SL, Astrolabe Reef (18°42'S, 178° 30'E), outer reef, 20-23 m, A. Emery, R. Winterbottom *et al.*, rotenone, 21 March 1983. **Papua New Guinea:** USNM 278458, 2 specimens, 31.0-37.0 mm SL, Rabaul, New Britain (4°08'S, 152°10'E), off Japanese submarine base, 23-30 m, G. Allen, rotenone, 8 October 1983; WAM P.28172-007, 4 specimens, 24.0-42.0 mm SL, same data as USNM specimens; WAM P.28170-010, 3 specimens, 32.7-39.5 mm SL, Rabaul, New Britain, near Bai Village, 25-34 m, G. Allen, rotenone, 7 October 1983; WAM P.28174-028, 38.6 mm SL, Rabaul, New Britain, east side of harbour entrance, 25-30 m, G. Allen, rotenone, 9 October 1983; WAM P.27826-041, 3 specimens, 30.8-38.4 mm SL, Manus Island, Los Negros Islet (2°04'S, 147°25'E), 3 km east of Momote Aerodrome, 35-41 m, G. Allen and R. Knight Jr, rotenone, 6 October 1982. **Coral Sea:** WAM P.28541-030, 3 specimens, 15.8-37.0 mm SL, Holmes Reef (16°31'S, 147°50'E), south-western corner of Eastern Reef in lagoon, 12-14 m, G. Allen, rotenone, 20 November 1985. **Great Barrier Reef:** AMS I.20775-007, 4 specimens, 30.9-35.7 mm SL, Raine Island (11°36'S, 144°01'E), off western tip, 0-20 m, AMS party, rotenone, 11 February 1979; AMS I.22627-012, 33.0 mm SL, Escape Reef (15°49'S, 145°50'E), north reef on outer slope, 52-60 m, G. Allen, A. Ayling, and D. Blake, rotenone, 4 November 1981; BPBM 30929, 2 specimens, 25.7-32.0 mm SL, Escape Reef, outer slope, 58-60 m, G. Allen and W. Starck, rotenone, 5 November 1981; WAM P.27476-001, 38.8 mm SL, same data as BPBM specimens. **Western Australia:** WAM P.27659-025, 31.7 mm SL, Clerke Reef (17°16'S, 119°22'E), Rowley Shoals, outer reef east of Bedwell Islet, 32 m, G. Allen, rotenone, 22 July 1982. **Christmas Island (10° 27'S, 105°40'E):** WAM P.26082-019, 47.4 mm SL, off Ethel Beach, 30-40 m, G. Allen and R. Steene, rotenone, 19 May 1978; WAM P.26087-012, 2 specimens, 35.6-43.1 mm SL, same data as preceding paratypes except 40-45 m, 22 May 1978; WAM P.26097-010, 37.6 mm SL, off West White Beach, 30-40 m, G. Allen and R. Steene, rotenone, 26 May 1978; WAM P.26099-011, 2 specimens, 23.8-38.8 mm SL, Flying Fish Cove, off cantilevers, 25-35 m, G. Allen and R. Steene, rotenone, 27 May 1978; WAM P.26116-010, 23.9 mm SL, 1 km south-east of North West Point, 35-45 m, G. Allen and R. Steene, rotenone, 7 June 1978; WAM P.26121-003, 29.2 mm SL, 2 km south-east of North West Point, 40-50 m, G. Allen and M. Kitney, rotenone, 10

June 1978. Cocos-Keeling Islands: ANSP 137860, 3 specimens, 35.3-45.0 mm SL, Turk Reef (12°06'S, 96°50'E), drop-off in 51-58 m, W. Smith-Vaniz *et al.*, rotenone, 25 March 1974; ANSP 137861, 3 specimens, 35.9-37.6 mm SL, same locality as preceding paratypes, 67-73 m, W. Smith-Vaniz and P. Colin, rotenone, 26 March 1974.

Diagnosis

A species of pseudochromid fish differing from other members of the family by the following combination of characters: dorsal rays II,24 to 26; anal rays I,15 or 16; pectoral rays 17 or 18; pelvic rays I,4; branched caudal rays 15 (rarely 14); vertical scale rows 57 to 68 (usually more than 60); a single tubed lateral-line scale; all scales cycloid. It appears to have no close relatives and is particularly unique among pseudoplesiopines in relation to the combination of its very small scales and presence of only a single tubed lateral-line scale. It is further distinguished by the presence of a median interorbital pore and in having most dorsal fin rays branched.

Description

Dorsal fin rays II,25 (24 to 26); anal fin rays II,15 (15 or 16); pectoral fin rays 18 (17 or 18); pelvic fin rays I,4; principal caudal fin rays 15 (rarely 14), with 4 to 7 small supplementary rays above and below. Vertical scale rows from origin of lateral line to base of caudal fin about 67 (57 to 68, usually more than 60); a single tubular lateral line scale above upper limit of operculum; transverse scale series, counted forwards and upwards from the second anal spine 22 (19 to 22); predorsal scales 15 (12 to 16); 6 (5 to 7) rows of scales on preoperculum; 10 (9 to 13) sensory pores in the post- and sub-orbital series, starting on the vertical above eye centre and extending down the hind margin of the eye to the upper edge of the maxilla (the first pore adjacent to the maxilla is included in the count); median interorbital pore present. Gill rakers on first arch 4 + 13 = 17 (4 to 6 + 11 to 14 = 15 to 19).

Greatest body depth 4.3 (3.6 to 4.4), head length 3.3 (2.9 to 3.3), length of dorsal fin base 1.7 (1.5 to 1.7), length of anal fin base 3.4 (2.5 to 3.4), all in standard length. Snout length 5.1 (4.1 to 5.0), eye diameter 3.0 (2.8 to 3.3), predorsal distance 1.0 (0.9 to 1.1), least depth of caudal peduncle 2.4 (2.2 to 2.6), pectoral fin length 1.5 (1.3 to 1.7), pelvic fin length 1.5 (1.4 to 1.6), all in head length.

Small, elongate, reef fish; head and body moderately compressed. Jaws nearly equal anteriorly, reaching posteriorly to below middle part of pupil; cleft of mouth oblique. Eye with pear-shaped pupil. Scales on head and body cycloid, predorsal scales extending to slightly anterior of level of rear margin of preoperculum; snout, preorbital, interorbital and frontal portion of nape, chin and maxilla naked; scales irregular and large on operculum. Upper part of operculum, edge of preoperculum, orbital and supraorbital region of head, lower jaw and snout bearing sensory canals (Fig 6); opercular edges entire, inconspicuously serrated dorsally; edge of preoperculum entire.
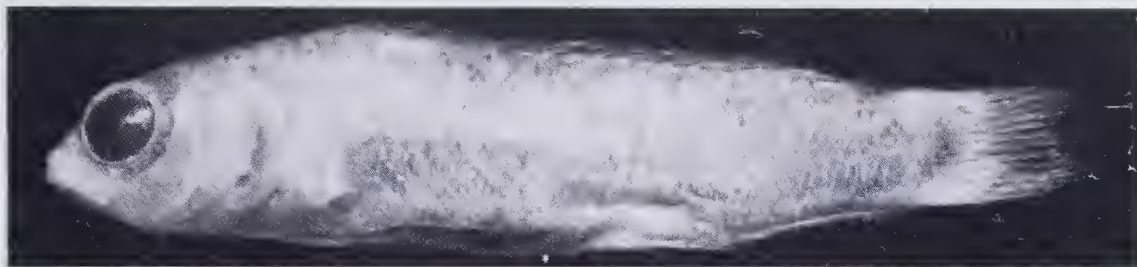
Figure 5   *Pseudoplesiops multisquamatus*, holotype, 41.8 mm SL, Great Barrier Reef, Queensland.
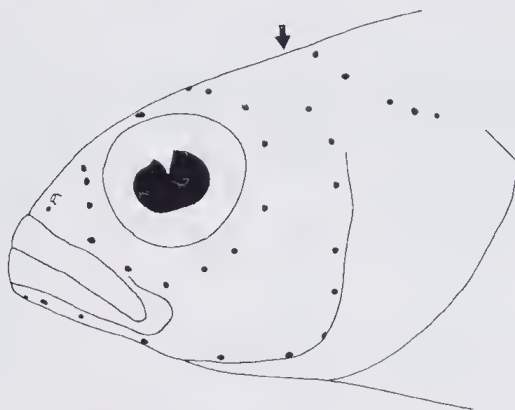
Figure 6   Camera lucida drawing of head of *Pseudoplesiops multisquamatus* showing sensory pores of head. Arrow denotes extent of predorsal scalation.

Table 4   Morphometric proportions (as percentage of standard length) for selected type specimens of *Pseudoplesiops multisquamatus*.

Character	Holotype WAM P.27470-002	Paratypes WAM P.26082-019	WAM P.26087-012	WAM P.26097-010	WAM P.27476-001	WAM P.26121-003
Standard length (mm)	41.8	47.4	43.1	37.6	31.7	29.2
Body depth	23.2	23.2	27.6	26.6	23.3	25.3
Head length	30.6	31.6	33.4	32.7	30.9	34.2
Snout length	6.0	6.5	7.0	8.0	6.3	6.8
Eye diameter	10.3	10.5	10.7	10.6	9.8	11.3
Predorsal distance	32.1	32.5	34.3	33.5	32.8	31.8
Caudal peduncle depth	12.9	12.7	13.5	14.1	12.0	13.0
Pectoral fin length	20.8	23.6	21.1	21.8	18.9	20.0
Pelvic fin length	20.3	23.0	23.2	21.3	20.0	21.6
Dorsal fin base length	58.6	60.3	63.1	63.6	65.6	67.1
Anal fin base length	30.0	31.4	33.9	34.0	30.6	39.7

Upper jaw with 2-3 lateral series of fine, subconical teeth on posterior part of jaw, the outer series enlarged; at symphisis 4 to 6 series of teeth, those of the outer series caniniform and irregular in size, the remainder small and setiform;

anteriorly 4 to 8 enlarged curved canines, outer canines largest. Lower jaw dentition similar, with 1 or 2 lateral series on posterior part of jaw; 4 to 8 enlarged canines anteriorly. Vomer with 2 or 3 rows of fine teeth, about 3 rows of fine teeth on palatines. Tongue tip pointed, its upper surface finely papillate.

Dorsal fin with two feeble spines anteriorly, little differentiated from soft rays; branching of segmented dorsal and anal rays variable, but usually with anterior 3 to 10 rays unbranched. Pectoral fins rounded, principal rays branched. Pelvic fins inserted below pectoral fins, pointed, soft rays unbranched, second soft ray longest; extent of pelvic fin tips variable, from about half the distance between pelvic fin base and anus to nearly reaching anus; caudal fin slightly rounded, with basal scaly sheath.

Colour in alcohol: overall tan to brown, head and breast region often lighter (light tan to whitish); dorsal, anal, and caudal fins dusky grey, frequently with darkish grey patch at base of caudal fin; pelvic and pectoral fins translucent.

Colour when fresh: overall red, reddish-brown, or pink, usually with yellow suffusion on head; breast, belly and lower part of head lighter (frequently pink); dorsal fin translucent to reddish or yellow (juveniles), sometimes with narrow fuscia margin; other fins mainly translucent or whitish except caudal fin yellow.

Remarks

This species inhabits reef crevices and rubble, usually on outer reef slopes, at depths ranging from about 12 to at least 60 m. Most specimens have been collected below 25-30 m. The stomach contents of several paratypes indicate a diet of small crustaceans.

The known range extends from the Fiji Islands westward to Cocos-Keeling Atoll in the eastern Indian Ocean and also includes New Guinea, the Coral Sea, northern Western Australia, and Christmas Island. It is most likely widespread over a large area of the tropical Indo-Pacific region, but has remained largely unsampled because of its small size and relatively deep habitat.

It was previously reported from Christmas Island by Allen and Steene (1979) as *Chlidichthys* sp. 2. They also reported a *Chlidichthys* sp. 3 on the basis of two specimens, 23.4-38.6 mm SL, that differed from sp. 2 (i.e. *P. multisquamatus*) mainly on the basis of a more slender body shape and shorter pelvic fins. The status of these specimens (WAM P.26116-009) remains questionable, but they are possibly conspecific with *multisquamatus*. The larger specimen is a mature female with ripe ova.

The species is named *multisquamatus* (Latin: "many scales") in reference to this diagnostic feature.

Acknowledgements

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A new species of pomacentrid fish with notes on other damselfishes of the Kermadec Islands

Gerald R. Allen*

Abstract

A new species of pomacentrid, *Parma kermadecensis*, is described from four specimens collected during 1984 and 1985 at the Kermadec Islands. It is closely related to *P. polylepis* from south-eastern Australia, Lord Howe Island, Norfolk Island, and New Caledonia. The two species differ, however with regards to both juvenile and adult coloration, and head morphology. A key to the species of *Parma* is included and notes are provided on four pomacentrids that occur at the Kermadic Islands: *Chromis dispilus, Chrysiptera rapanui, Parma alboscapularis,* and *Stegastes fasciolatus.*

Introduction

Damselfishes (Pomacentridae) are among the most speciose and conspicuous of all fish groups associated with tropical and subtropical reefs. Although most of the estimated 300 species are confined to warm seas, several genera including *Parma* of the south-western Pacific and southern Australia, are inhabitants of temperate latitudes. The present paper describes a new member of this genus that was recently procured on separate expeditions to the Kermadec Islands by M. Kingsford (March, 1984) and M. Francis (October, 1985). The Kermadec Islands, lying some 900 km north-east of North Island, New Zealand are of special interest to biologists because of their remoteness, mixture of temperate and tropical faunal elements, and the scarcity of collections from there. A detailed report of the fish fauna is currently being prepared by M. Francis, R. Grace, and C. Paulin.

The methods of counting and measuring are the same as those described by Allen (1972) except the length of the dorsal and anal spines are measured proximally at the base of the spine rather than the point where the spine emerges from the scaly sheath. Caudal cavity is the horizontal distance between the longest and shortest caudal rays. The last dorsal and anal rays are split near their bases giving the appearance of two rays, but were counted as a single element.

The counts and proportions which appear in parentheses in the description of *Parma kermadecensis* represent the adult paratype if differing from the holotype. Morphometric proportions for both adult and juvenile types are expressed as percentage of the standard length (abbreviated SL) in Table 1. Type specimens

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are deposited at the National Museum of New Zealand, Wellington (NMNZ), New Zealand Oceanographic Institute, Wellington (NZOI); and Western Australian Museum, Perth (WAM).

The genus *Parma* was comprehensively reviewed by Allen and Hoese (1978), who provided a key to the eight known species. An additional species, *P. bicolor* from Western Australia was later (1979) described by Allen and Larson. An updated version of Allen and Hoese's key that incorporates *P. bicolor* and *P. kermadecensis* is presented below.

Table 1   Morphometric proportions of type specimens of *Parma kermadecensis* (in thousandths of the standard length)

Character	Holotype	Paratypes		
	NMNZ P.17849	WAM P28425-002	WAM P28425-002	NZOI P967
Standard length (mm)	201.3	201.7	44.7	198.7
Greatest depth of body	528	537	485	552
Greatest width of body	230	223	183	249
Head length	308	308	349	326
Snout length	122	126	101	120
Diameter of bony orbit	68	64	136	78
Width of bony interorbital	113	120	82	124
Least depth of caudal peduncle	160	169	159	172
Length of caudal peduncle	111	104	116	133
Snout to origin of dorsal fin	410	423	447	425
Snout to origin of anal fin	727	719	685	680
Snout to origin of pelvic fin	442	413	443	441
Length of dorsal fin base	638	657	597	659
Length of anal fin base	208	227	201	237
Length of pectoral fin	265	300	295	317
Length of pelvic fin	266	311	329	298
Length of pelvic spine	152	171	213	192
Length of 1st dorsal spine	88	81	116	78
Length of 2nd dorsal spine	122	124	181	124
Length of longest dorsal spine	156	186	201	176
Length of longest dorsal ray	248	262	260	293
Length of 1st anal spine	62	74	78	66
Length of 2nd anal spine	158	169	224	172
Length of longest anal ray	199	229	257	229
Length of caudal fin	308	331	313	284
Caudal concavity	140	187	107	132

Systematics

Key to the species of *Parma*

1a   Inferior limb of preopercle naked, vertical scale rows from upper edge of gill opening to base of caudal fin 30 to 38; tubed lateral-line scales 21 to 28 2

1b   Inferior limb of preopercle scaled; vertical scale rows from upper edge of gill opening to base of caudal fin 36 to 46; tubed lateral-line scales 25 to 35 6

2a   Preopercle largely naked, scales covering about half
     total area, arranged in 3-4 transverse rows below sub-
     orbital; snout profile convex; predorsal scales extend-
     ing to about anterior margin of eye; preorbital naked;
     tubed lateral-line scales 18 to 22 3

2b   Preopercle mostly scaled, scales covering more than
     half total area, arranged in 6-7 transverse rows; snout
     profile concave or more or less straight; predorsal
     scales extending to level of posterior nostrils; pre-
     orbital scaled on posterior section; tubed lateral-line
     scales 22 to 28 4

3a   Tubed lateral-line scales 18 to 20; most of body pale
     (yellow in life) with head and anterodorsal part of body
     dark (blue in life) (south-western Australia) ...... *bicolor* Allen and Larson

3b   Tubed lateral-line scales 21 to 22; colour not as in 3a,
     most of head and body mottled brown, lighter ventrally
     (Victoria; Tasmania; South Australia; Western Australia.. *victoriae* (Günther)

4a   Lower margin of preorbital only slightly produced,
     not forming triangular projection; scale rows between
     lateral-line and first dorsal spine 5 to 6; upper corner of
     operculum frequently with white patch (New South
     Wales).. *microlepis* Günther

4b   Lower margin of preorbital distinctly triangular; scale
     rows between lateral-line and first dorsal spine 4; upper
     corner of operculum without white patch 5

5a   Lower margin of preorbital with notch in front of
     triangular projection; soft dorsal rays usually 19 or
     19½; surface of preorbital smooth without bony ridges;
     whitish bar on middle of sides absent (Queensland;
     New South Wales) .... *oligolepis* Whitley

5b   Lower margin of preorbital without notch in front of
     triangular projection; soft dorsal rays usually 17½;
     surface of preorbital with bony ridges, at least in adults;
     whitish bar on middle of sides (New South Wales)..*unifasciatus* (Steindachner)

6a   Lower margin of preorbital and suborbital disconti-
     nuous, separated by patch of scales and skin (not
     apparent without magnification in specimen less than
     about 90 mm SL); adults with poor to well developed
     bony knobs above anterior corner of eye; juveniles with
     alternating dark and light bands across head and body 7

6b   Lower margin of preorbital and suborbital continuous, not separated by patch of scales; specimens of all sizes without bony knobs above eye; specimens of all sizes without alternating dark and light bands across head and body 8

7a   Bony knobs well developed above anterior corner of eye and at mid-interorbital in specimens more than about 100 mm SL, becoming more noticeable with increased size; ground colour of adults dark, dusky brown; juveniles less than about 100 mm SL with pale bar at rear of head and two pale bars across middle of side, pale band on caudal peduncle absent, ocellus present at base of last dorsal spines (New South Wales; S Queensland; Lord Howe Island; Norfolk Island; New Caledonia) .... *polylepis* Günther

7b   Bony knobs only slightly developed above anterior corner of eye at any size, absent from mid-interorbital; ground colour of adults medium to light brown (whitish in life); juveniles less than about 100 mm SL with pale (yellow in life) bar at rear of head and three pale (yellow in life) bars across body, including caudal peduncle, ocellus at base of last dorsal spines absent .... *kermadecensis* sp. nov.

8a   Tubed lateral-line scales usually 32 to 35; occipital slightly arched; snout profile distinctly concave; predorsal scales extending to about anterior margin of eye; vertical scale rows from upper edge of gill opening to base of caudal fin 43 to 46; head and body usually light brown in preservative, frequently with pair of faint dusky bars on sides (Western Australia) ...... *occidentalis* Allen and Hoese

8b   Tubed lateral-line scales 25 to 32; occipital not arched, confluent with contour of head profile; snout profile convex; predorsal scales extending to level of nostrils; vertical scale rows from upper edge of gill opening to base of caudal fin 36 to 41; head and body entirely dark brown in perspective 9

9a   Surface of preorbital with bony tubercles or ridges, at least in adults; pectoral rays usually 22, occasionally 21 (Lord Howe Island; New Zealand; Kermadec Islands) .... *alboscapularis* Allen and Hoese

9b   Surface of preorbital without bony tubercles; pectoral rays usually 21, occasionally 20 (Western Australia) .... *mccullochi* Whitley

Parma kermadecensis sp. nov.

Figures 1-4; Table 1

Holotype

NMNZ P17849, 201.3 mm SL, collected with handspear at Te Konui Point Boat Cove, Raoul Island, Kermadec Islands (approximately 29°17'S, 177°53'W) in 20 metres by M. Francis on 20 October 1985.

Paratypes

NZOI P967, 198.7 mm SL, Herald Islets, north-eastern Raoul Island, Kermadec Islands (29°14'S, 177°51'W), 0-5 m, spear, R.S. Singleton, 11 June 1980 and WAM P28425-002, 2 specimens, 44.7-201.7 mm SL, collected at type locality with handspear by M. Kingsford on 21 March 1984.

Diagnosis

A species of the pomacentrid genus *Parma* characterised by a combination of features that include a scaly inferior preopercular limb, 25 to 30 lateral line scales, irregular ridges and bony tubercles on surface of preorbital, bony knobs only moderately developed in front of eye and lacking in the mid-interorbital region. It is closely allied to *P. polylepis* Günther from south-eastern Australia, Lord Howe Island, Norfolk Island, and New Caledonia. Both species have similar distinctively banded juvenile colour patterns, however, *P. kermadecensis* possesses an extra pale band on the caudal peduncle and furthermore it lacks an ocellus at the base of the posteriormost dorsal spines. *Parma polylepis* adults differ by having well developed bony knobs in front of the eye and in the mid-interorbital region.

Description

Dorsal rays XIII, 18; anal rays II, 14; pectoral rays 21 (22); pelvic rays I, 5; branched caudal rays 13; gill rakers on first arch 7 + 12 (6 or 7 + 11 to 14), total 16 to 21; tubed lateral-line scales 25 (25 to 30); vertical scale rows from upper edge of gill opening to base of caudal fin 36 (34 to 36); horizontal scale rows from base of dorsal fin to terminal lateral-line scale (exclusive of dorsal base sheath scales) 3 or 4; from lateral-line to anal fin origin 18 (15 to 18); teeth elongate and narrow with rounded to nearly flat tips, about 50 to 60 in a single row in each jaw of adults.

Body ovate, laterally compressed, the greatest depth 1.9 (1.8 to 1.9) in the standard length, greatest width 2.3 (2.2 to 2.4) in depth. Head profile rounded, the head length contained 3.2 (3.1 to 3.2) times in the standard length; snout 2.5 (2.4 to 2.7), eye 4.5 (4.2 to 4.8); interorbital 2.7 (2.6), least depth of caudal peduncle 1.9 (1.8 to 1.9), length of caudal peduncle 2.8 (2.5 to 3.0), of pectoral fin 1.2 (1.0), of pelvic fin 1.2 (1.0 to 1.1), caudal concavity 2.2 (1.6 to 2.5) all in head length.

Pair of small nasal openings on each side of snout, the posterior nares inconspicuous; mouth oblique, terminally located; lateral-line gently arched (3 to 5
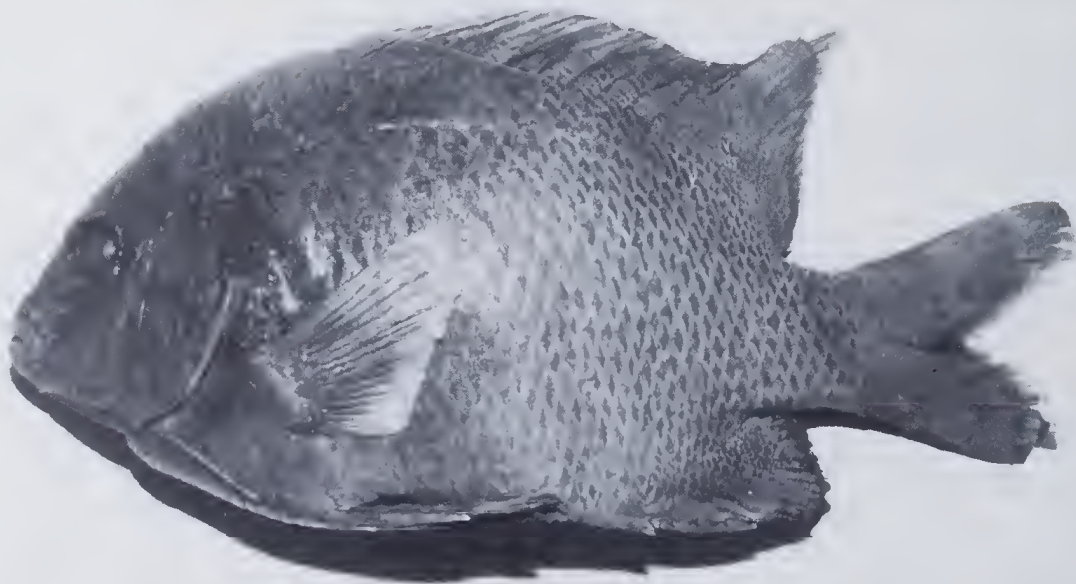
Figure 1   *Parma kermadecensis*, holotype, 201.3 mm SL, Te Konui Point Boat Cove, Raoul Island, Kermadec Islands.

Figure 2   *Parma kermadecensis*, underwater photograph of mature adult, Meyer Island, Kermadec Islands (photograph by J. Voot).

Gerald R. Allen

Figure 3   Juvenile colour pattern of *Parma kermadecensis* (drawing by R. Swainston).
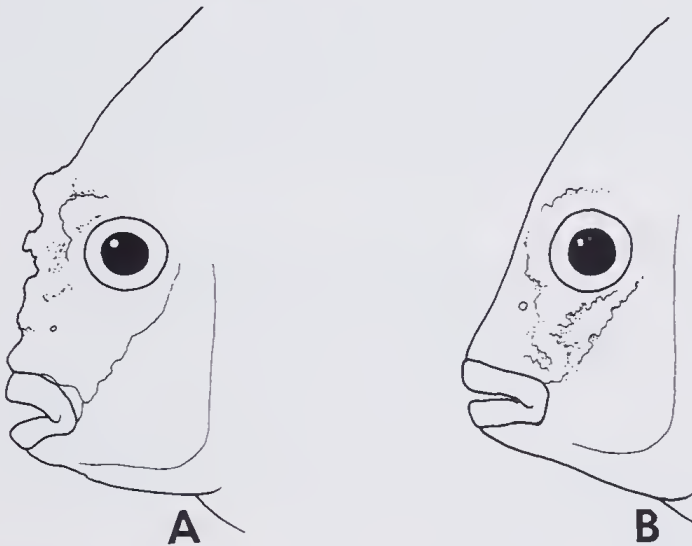
Figure 4   Head profiles of *Parma* species: (A) *P. polylepis*, adult; (B) *P. kermadecensis*, adult
(drawings by R. Swainston).

scale rows beneath dorsal fin), terminating below anterior section of soft dorsal
fin; preorbital extremely rugose without scales; suborbital with a few scales
posteriorly; snout, lips, chin, and isthmus naked; remainder of head and body
scaled; scales finely ctenoid; predorsal scales extending to about mid-interorbital
(front of eye on juvenile); preopercle scale rows about 6-7 with additional row of
scales (may be embedded) on inferior limb; small sheath scales covering basal
two-thirds of membranous portion of spinous dorsal fin and most of soft dorsal,

anal, pectoral, and caudal fins; margin of preorbital and suborbital jagged due to bony ridges and tubercles; margin of preopercle weakly crenulate; margin of opercle smooth except large flattened spine at angle and one or more lesser projections on upper edge.

Origin of dorsal fin at level of third tubed lateral-line scale; spines of dorsal fin gradually increasing in length to about sixth or seventh spine; remaining spines gradually decreasing in length; length of first dorsal spine 3.5 (3.8 to 4.2), of seventh dorsal spine 2.0 (1.7 to 1.9), of longest soft dorsal ray 1.2 (1.1 to 1.2), of first anal spine 5.0 (4.1 to 4.9), of second anal spine 1.9 (1.8 to 1.9), of longest soft anal ray 1.6 (1.3 to 1.4), of caudal fin 1.0 (0.9 to 1.1), all in the head length; caudal fin forked with rounded lobes; pectoral fins pointed.

Colour of holotype in alcohol: head and body medium brown, slightly yellowish on breast, abdomen, and lower part of head; fins brownish except outer edge of pectorals pale tan. The adult paratypes are similarly coloured except the yellow hue is absent.

Colour of juvenile paratype in alcohol: head and side of body with alternating pale grey and dark brown bars as indicated in Figure 3; several narrow dark brown bars radiating from eye, one across side of snout, another below middle of eye to rear part of chin, and a third across upper edge of preopercle; one or two brown spots, about half size of pupil, on middle of opercle; dorsal and anal fins with continuation of light and dark bands of body; caudal fin pale greyish with some dusky brown at base and along dorsal and ventral margins; pelvic fins dark brown; pectoral fins mainly translucent.

Colour of live adults (from underwater Ektachrome transparencies by M. Francis and J. Voot): most of body and fins very pale bluish-grey, the scale centres lighter, giving an overall impression of a nearly white fish; head brownish blue, particularly on nape, interorbital, and snout, giving a "masked appearance". One photographed adult had the entire head and breast region suffused with yellowish brown. Field notes taken by J. Voot in May 1983 indicate that some adults have a distinct, broad pale greenish bar just behind the head extending from the nape to the pectoral region. He further stated that the eyes are dark blue and the lips are very pale orange-yellow. Also there are small streaks of yellow between the eye and rear edge of the preopercle.

Colour of live juveniles (from underwater Ektachrome transparencies by M. Francis): head and body with striking pattern of alternating yellow and black alternating bars as indicated in Figure 3; chin and lips yellow; caudal fin translucent or dusky with yellow V-shaped area and dark brown bar at base extending out along dorsal and ventral margins; dorsal, anal, and pelvic fins narrowly edged with bright blue; anteriormost part of pelivic fin dark brown, remainder of fin paler dusky brown; bars radiating from eye as described for preserved material except blue rather than brown; also small scattered blue spots on head, particularly on interorbital, nape, and opercle; similar blue spots near dorsal and ventral edge of caudal peduncle, just behind base of last dorsal and anal rays.

Remarks

According to field notes of M. Francis and M. Kingsford the species is relatively common throughout the Kermadec Islands. A number of pairs and solitary juveniles were observed on each dive between about 3 and 20 m. Adults appeared to be strongly territorial and were associated with cracks and crevices of the reef.

As mentioned in the diagnosis *P. kermadecensis* is most closely related to *P. polylepis* differing most notably with regards to colour pattern of both juvenile and adults, and also in the development of bony knobs in the orbital region and forehead. The latter feature is strongly developed in *P. polylepis* and poorly developed in *P. kermadecensis* (see Figure 4). The two species further differ from other *Parma* in having the lower margin of the preorbital and suborbital discontinuous, being seperated by a patch of scales. Although this feature is clearly evident in the juvenile paratype of *P. kermadecensis* it is difficult to detect in the holotype and adult paratypes.

The species is named *kermadecensis* in reference to the type locality, the only place it has been collected. The Kermadec Islands represent the easternmost record for the genus *Parma*.

Notes on other pomacentrids of the Kermadec Islands

Five species of pomacentrids, including *Parma kermadencis,* were noted by M. Francis and M. Kingsford during 1984 and 1985.

Chromis dispilus Phillips

Ayling and Cox (1982) reported that this species is common off rocky coasts between North Cape and East Cape along the northeastern coast of New Zealand. It occurs down to depths of about 60 m. Kermadec specimens are deposited at NMNZ. A colour illustration was provided by Doak (1978) of a New Zealand fish.

Chrysiptera rapanui Greenfield and Hensley

This species was previously known only from Easter Island (Greenfield and Hensley, 1970). Although specimens from the Kermadec Islands are essentially identical to those from Easter Island with regards to meristic and morphometric data, there are pronounced colour differences. Fish from both areas are basically blackish or very dark brown posteriorly and mainly pale on the anterior part of the body; also the caudal fin, adjacent peduncle, and posteriormost rays of the dorsal, anal, and pelvic fins are pale. The colour differences between the two populations are primarily related to the pale areas. Live individuals from Easter Island are mainly bluish anteriorly with the pale parts of the fins whitish. In addition, much of the anterodorsal portion of the head and body is blackish and there is a large blackish spot covering the pectoral fin base. These observations are based on Ektachrome transparencies taken underwater by the author and the colour illustration of a freshly dead specimen in Allen (1975). Underwater photographs of Kermadec specimens, taken by M. Francis, indicate that the anterior half of the

body is yellow-orange and the pale fin parts are similarly coloured. There is only a small brownish spot at the uppermost portion of the pectoral fin base. Intraspecific colour variation related to geography is not uncommon in pomacentrids. It is found in a number of species from the Indo-west Pacific region including *Acanthochromis polycantha* (Bleeker), *Amblyglyphidodon leucogaster* (Bleeker), *Chrysiptera rex* (Snyder), *C. rollandi* (Whitley), *C. unimaculata* (Cuvier), *Paraglyphidodon nigroris* (Cuvier), *Pomacentrus philippinus* (Evermann and Seale), *Stegastes fasciolatus* (Ogilby), and *S. insularis* (Allen and Emery). The last mentioned species has two colour variants related to widely seperated insular populations (Christmas Island, Indian Ocean and Marcus Island [Minami-Tori Shima] in the western Pacific and thus resembles the situtation of *Chrysiptera rapanui*. The distribution of both these fishes probably represent relics of former widespread species. I have examined 17 specimens of *C. rapanui* (NMNZ P.17755, P.17778, P.17863), 26-41 mm SL, from Raoul Island and Meyer Island.

Parma alboscapularis Allen and Hoese

This species is common at a number of localities along the north-east coast of the North Island of New Zealand (Ayling and Cox, 1982). It occurs throughout the Kermadec Islands and is also known from Lord Howe Island (Allen and Hoese, 1975). Colour illustrations were provided by Allen (1975) and Doak (1978). I have examined five juvenile specimens (NMNZ P.13356), 22-78 mm SL from Raoul Island.

Stegastes fasciolatus (Ogilby)

This species is one of the most widely distributed members of the family, occurring from East Africa to Easter Island and the Hawaiian Islands. It is found throughout the Kermadec Islands. However, it is primarily an inhabitant of tropical coral reefs. Illustrations of regional colour variants were provided by Allen and Emery (1985). I have examined four specimens (WAM P.28425-003, 106-135 mm SL from Raoul Island.

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The Genus *Phyllodactylus* (Lacertilia: Gekkonidae) in Western Australia

*G.M. Storr

Abstract

In Western Australia *Phyllodactylus* is represented by only one species, *P. marmoratus* Gray, which is divisible into two subspecies: the nominate in the lower west, south-west and south, and *P. m. alexanderi* subsp. nov. in the far south-east (and far western South Australia). The type locality of *P. marmoratus* is restricted to the Houtman Abrolhos, Western Australia.

Introduction

In 1976 M. King and R. Rofe described three chromosome races in the southern Australian gecko *Phyllodactylus marmoratus*, one of which (2n=34) was confined to Western Australia. After examining much more western material M. and D. King (1977) reported the presence in Western Australia of two more chromosome races. One of them (2n=32) was restricted to a small area south of Pemberton in the deep south-west; the other was the east Australian race 2n=36, which extended into the south-east of Western Australia as far west as Israelite Bay. The race 2n=34 was found to occur from Yanchep in the north to Cape LeGrand in the east.

In order to check King and King's belief that these chromosome races probably represented distinct species, I examined specimens of *Phyllodactylus marmoratus* from Western Australia and western South Australia. The following characters were studied: snout-vent length, relative length of tail, rostral shape, rostral contact with nostril, number of internasals, postnasals, upper labials (excluding the undifferentiated small scales lining the rictus), postmentals and subdigital lamellae (excluding the 1-5 series of small scales immediately preceding the pads), shape of mental and postmentals, and dorsal coloration.

Specimens from the range of the 2n=32 race, including those used by King and King, could not be distinguished morphologically from neighbouring specimens of the 2n=34 race and so are included in the nominate subspecies. However, the boundary between the races 2n=34 and 2n=36 (a north-south line immediately west of Israelite Bay) coincides with small but abrupt changes in coloration and scalation; I have therefore separated the westernmost segment of King and King's 2n=36 race as a new subspecies.

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As Dixon (1964:110) pointed out, the genus *Phyllodactylus* (type species: *P. pulcher* of Barbados) is almost certainly polyphyletic. Perhaps *Euleptes* or *Paraoedura* (the only generic names based on Old World species) is applicable to *marmoratus;* but this will remain unknown until the phylogeny of the Old World species is deduced.

This study is based on 1103 specimens in the Western Australian Museum (register numbers without prefix) and 84 from western South Australia (numbers prefixed with SAM R) kindly loaned by the South Australian Museum.

Systematics

Phyllodactylus marmoratus marmoratus (Gray)

Figures 1 and 2

Diplodactylus marmoratus Gray (1845:149)

Diagnosis

A small to moderately large subspecies of *Phyllodactylus marmoratus* with dorsal pattern typically consisting of thick, blackish, deeply undulate or zigzagging transverse lines, each followed by a pale spot or blotch.

Description

Snout-vent length (mm): 19-68 (N 897, mean 42.9). Length of tail (% SVL): 86-140 (N 293, mean 115.3).

Rostral more than twice as wide as high, usually hexagonal with apex short to moderately long and flat (occasionally rounded or with one or two notches); rarely a short crease descending from an apical notch. Nostril surrounded by first labial, rostral (except in the 22% of specimens with anterior supranasal contacting first labial), anterior supranasal, posterior supranasal, and 1 (N 764), 2 (62) or 3 (1) postnasals. Posterior supranasal much smaller than anterior supranasal and about as large as undivided postnasal. Internasals 0 (N 2), 1 (192), 2 (500), 3 (127) or 4 (1). Upper labials 6 (N 1), 7 (37), 8 (241), 9 (381), 10 (142) or 11 (12). Mental trapezoid, usually much wider than deep. Postmentals 1 (N 2), 2 (452), 3 (196) or 4 (17); usually (93%) not much longer than wide. Lamellae under fourth toe 7 (N 39), 8 (251), 9 (280), 10 (111), 11 (20) or 12 (3).

Upper surface brownish grey. Back with thick, black or blackish brown, deeply undulate or zigzagging, transverse lines shaped like a series of Us or Ws, each line immediately followed by a small to large, subcircular, amoeboid or rounded oblong, greyish white or pale grey blotch; median Us on back sometimes coalescing to form a series of ellipses or a reticulum; pale spots sometimes absent, small or barely discernible. Pattern on tail similar to that on back except for straighter transverse lines and for continuous or broken, whitish median streak (orange-brown in life).

Figure 1   A *Phyllodactylus marmoratus marmoratus* from the Houtman Abrolhos, photographed by R.E. Johnstone.

Figure 2   A *Phyllodactylus marmoratus marmoratus* from near Walpole, photographed by D. Mead-Hunter.

Distribution

Lower west coast and south coast of Western Australia north to Green Head (with an isolated population much further north in Edel Land) and east to the Thomas River, inland to Mt Lesueur, Moora, Julimar Forest, Mundaring, Dale, Kulin, Lake Grace South, Frank Hann National Park, Peak Charles, Jyndabinbin Rocks, Fraser Range, Heinsman Rock and Junana Rock. Also numerous islands from North Island (Houtman Abrolhos) south and east to Daw Island (Archipelago of the Recherche). See map, Figure 3.

Figure 3   Map of southern Western Australia and western South Australia showing location of specimens of *Phyllodactylus marmoratus marmoratus* (spots) and *P. m. alexanderi* (circles).

Geographic variation

The population on the Houtman Abrolhos is one of the more distinctive. These lizards are smaller (maximum SVL 52 mm) than elsewhere and have fewer upper labials (6-10, N 91, mode 8, mean 8.3 *v.* 7-11, 723, 9, 8.8), fewer postmentals (11.8% with more than 2, *v.* 33.6%) and fewer subdigital lamellae (7-11, N 71, mode 8, mean 8.2; *v.* 7-12, 633, 9, 8.9). This population did not necessarily acquire its differences in isolation, for the now-extinct population of the opposite mainland may have had similar characteristics. At any rate the Abrolhos lizards are connected by clines to another distinctive population, that of the deep south-west.

Specimens from the deep south-west (including those with 2n=32 chromosomes) are characterised by large size, strong colour pattern (here the pale blotches are

largest, whitest and most rectangular [Figure 2]), high number of internasals (41% with more than 2, *v.* 13.2% elsewhere) and high number of postnasals (53.5% with more than one, *v.* 3.3% elsewhere. Eastwards the geckos are more like those of the west coast (Figure 1).

Another fairly distinctive population is that of the southern wheat belt. Here the dorsal pattern is finer than elsewhere and the pale markings are reduced, both conditions foreshadowing those in the next subspecies.

Remarks

Gray based this species on four specimens collected by John Gilbert in the Houtman Abrolhos and on one labelled 'Australia'. I hereby restrict the type locality to the Houtman Abrolhos, Western Australia.

As mentioned earlier, specimens with 2n=32 chromosomes and others collected from the same or nearby localities could not be distinguished morphologically from neighbouring specimens with 2n=34 chromosomes.

Material

North-West Division (WA)

False Entrance Well, Carrarang (69846).

South-West Division (WA)

North I. (13684, 15336-9, 47821-2); Pelican I. (15346-55); West Wallabi I. (15340-5, 29494); Tattler I. (15357-60); Turnstone I. (25831-2); Rat I. (30459-60, 41238-40, 41523, 41534, 41540-1, 41543-5, 93704); Little Rat I. (37513); Morley I. (37539, 41528-32); Wooded I. (37540-5, 41518-9); Shark I. (37505-6); Basile I. (27172); Pelsaert I. (27144-60, 52023, 58915-8); Gun I. and islets S of it (27189, 30455-8, 30469-70, 40232); Murray I. (30454); islet off Green Head (15361-3); 5 km W Padbury (49094); Cockleshell Gully (48432); Mt Lesueur (11166); Sandland I. (15364-77, 58909-10); Hill River ford (12876); 16 km SE Jurien (46592); Whittell I. (93719); Green Is (15378-401, 19153, 58896, 93720); Yewadabby Spring (15402-3); Woolka Woolka (15404-6); Dandaragan (25991); 5 km W Moora (12875); Koojan (40658); Wedge I. (93721); Julimar Forest (47792, 85195); Yanchep (12880, 59947-50); Neerabup National Park (59355, 59391-2); Burns Beach (83115); Wanneroo (78476); Mussel Pool (51525-6); Tuart Hill (93722); Dianella (36323); Maylands (24687-8); Mt Lawley (28952); Wembley Downs (24886, 73458); Reabold Hill (39641-2); Subiaco (3312); Leederville (3328); Perth (7540); Mundaring Weir (16530); Kalamunda (14183) and 9 km E (14667, 19238, 19749, 19924, 19980, 20593, 20598); Victoria Park (78235); Crawley (15409-12); Dalkeith (19680); Cottesloe (15407-8); South Perth (2973, 25979); Como (3761); Lesmurdie (15413-4); Riverton (54255); Applecross (4210, 21848); Alfred Cove (75553); Rottnest I. (2554, 2855, 3273-82, 3754-6, 12762-3, 14242, 15415-7, 15419-22, 17128, 51756); Green I. (58901-2); Willagee (54409); Kelmscott (51424); Forrestdale (4390, 93731); Carnac I. (11996-7, 15423-31); Garden I. (3314, 28473-4, 35029-34, 54381, 87989-91); Brookton Hwy 54 km

ESE Kelmscott (58276, 58284-5); Rockingham (47353-6); Bird I. (15432-6, 58905); Seal I. (15437-40); Shag I. (7885, 15441, 58904); Penguin I. (7886, 15442-56); first island S of Penguin I. (58906); Jarrahdale (78062) and 13 km E (87924); Yunderup (37753); Kulin (4218); Boddington (4939); Waroona (41242); Yalgorup National Park (73585); Narrogin (25964-5, 43926); 3 km SW Nalyerin Lake (76285); 22 km N Collie (82783-5) and 25 km W (49256); Brunswick Junction (26460); Bunbury (4606, 5348); Dongolocking Reserves (49601-8, 49765-6); south end Lake Grace Reserve (43824); Chinocup Reserve (41077-83); Lake Magenta Reserve (39911-3, 39926, 43983, 45304, 45321, 47332-3); Ravensthorpe (10518-9, 30816) and 8 km N (54292) and 27 km W (44830-2, 44839) and 15 km ESE (67417-8); Cape Naturaliste (29897-8, 54261, 54268); Meelup (49661-4); Point Picquet (67398-400); Dunsborough (15457-60, 40830); Yallingup (48296-7); Busselton (26841) and 15 km NE (67407); 17 km SW Boyup Brook (22273) and 12 km SW (31119-21); Katanning (40981); Ongerup (2512-3, 2516, 2518-9, 15511) and 10 km SE (42618-21); Jerramungup (15512-3) and 40 km NNE (83182); Kybulup Pool (89461-3); Gordon Inlet (86978-82, 86991-2, 89483); Hopetoun (6421, 55939); East Mt Barren (15554); Fitzgerald River (39000); upper Twertup Creek (36976-83); Twertup (85468); middle Fitzgerald River (36791-801, 36857, 36859-62, 36870-2, 36908-10, 36943-50, 36954-8); Mid Mt Barren (36895-6); Dempster Inlet (36805, 36807-8); Fitzgerald Inlet (36923-5, 55932-3, 56061-3) and SW (36930-2); Fitzgerald National Park (89282); Mt Bland (47731); Boondadup River (37186, 37201, 37214-5); Quaalup (59041-2, 59044-5); 25 km N Bremer Bay (36185-6, 47730); Bremer Bay (47730); Pallinup River (269, 271, 27414-6); Bluff Knoll (51774); Red Gum Pass (54260, 67487); Stirling Range (15510); near Tambellup (1345, 2267, 2328); between upper reaches of Perup and Tone Rivers (42549-52); 13 km S Heartlea (64906); Perup River (15508); Newbicup (443); Bridgetown (7259); Margaret River (47753-4); Witchcliffe (58749); Forest Grove (5904); Boranup (13877, 19832, 93702-3); Hamelin I. (15461-79); outer island, Cosy Corner (21294); Deepdene (12777-8); Augusta (6200-1, 39127); and 8 km N (37800, 37803-4); Cape Leeuwin (273-4, 12782, 15485-6, 26660-4, 54259, 54265, 54297-8); St Alouarn I. (15487-91, 83993); Gingilup Swamp (80747); Manjimup (5605); near Pemberton (8496); 10 km W Rocky Gully (15509); 70 km NW Walpole (54273, 54308, 54322-3, 54327); Yeagerup (47864, 47923); Meerup (47886); Muirillup Rock (54330); Granite Peak (54258, 54262); Little Chudalup (49707); Mt Chudalup (15492-506, 49714, 54252-3, 54257, 54304, 54326); 35 km NW Walpole (54307, 54325); Broke Inlet (47799, 47968-72, 68161-3); Chatham I. (49832-7); Walpole (51437, 51449, 51452-3, 51465); Nornalup (6897); Valley of the Giants (19842-4, 26042-4); Kent River (44665-8); 45 km S Rocky Gully (46259); Denmark (17658, 19841, 54263) and 16 km N (43828, 43839) and 15 km NE (71027-8); Mt Barker Lookout (54272); Mt Barker (54254) and 22 km E (54271); Devils Slide, Porongorup Range (54264, 54331); Cheyne Bay (47734-5); Cape Riche (15553, 47733); Bald I. (15518-51, 19952-61, 19962-4, 19975, 40812-4, 40817, 53095, 53176, 53196-

204, 53223-4); Cheyne Beach (15516-7, 36007, 36034); Waychinicup River (15514-5, 61388); Mt Manypeaks (17869-71, 54345); Manypeaks (81284); Two Peoples Bay (36367, 44981-2); Chorkerup (5903); Pelican I., Wilson Inlet (19835-40, 37899-901); Albany (10945, 11054, 24088, 25836, 54296, 54324); Breaksea I. (52168-72); West Cape Howe (21830-1, 73176); Torbay Head (51789); Eclipse I. (6796-8, 11276, 45770, 49668-75).

Eucla Division (WA)

13 km E Fraser Range (30750); 8 km N Jyndabinbin Rocks (58053) and 35 km E (62452); Clear Streak Well (58044) and 8 km NNE (58006); Frank Hann National Park (78395); Peak Charles National Park (78407-9); 10 km NNW Heinsman Rock (59726-7); Junana Rock (22524); 37 km N Esperance (15559); 10 km N Linkletter's Place (85025-6); Dalyup River (15555-8); Stokes Inlet (82995); Esperance (11367, 15560-2, 25842-9) and 23 km E (15563-4); mouth of Thomas River (36269); Duke of Orleans Bay (42476-8); Frenchmans Peak (67742-3); Mt LeGrand (22526-8, 41999); Cape LeGrand (42000); Figure of Eight I. (10118); Thomas I. (10233); Sandy Hook I. (10123-4); Remark I. (8683); Corbett I. (53150); Wilson I. (53143-4); Termination I. (10126); Mondrain I. (15566-7, 35108, 53118, 53120, 54421, 68195-7, 68227); North Twin Peak I. (53074-85); South Twin Peak I. (53132-5); Middle I. (47659); Salisbury I. (76330, 763367-7, 76342, 76348-51, 76355); Daw I. (76361, 93630).

Phyllodactylus marmoratus alexanderi subsp. nov.

Figure 4

Holotype

R281 in Western Australian Museum, collected by W.B. Alexander in 1914 at Eucla, Western Australia, in 31°43'S, 128°53'E.

Paratypes

For details of 240 specimens from Western Australia and South Australia see under Material.

Diagnosis

Differing from *P. m. marmoratus* in its dorsal pattern typically consisting of fine, blackish, shallowly zigzagging or undulate transverse lines; lines on back not foll-owed by a pale spot or blotch. For differences in scalation see under Remarks.

Description

Snout-vent length (mm): 19-61 (N 241, mean 41.6). Length of tail (% SVL): 98-141 (N 89, mean 113.2).

Rostral usually more than twice as wide as high, usually pentagonal with upper sides curving up to a rounded apex (occasionally hexagonal with apex short and flat or with one, rarely two, notches); very rarely a short crease descending from an apical notch. Nostril surrounded by first labial, rostral (except in the 5% of specimens with anterior supranasal contacting first labial), anterior supranasal, posterior supranasal and postnasal (invariably single). Posterior supranasal usually

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much smaller than anterior supranasal and usually slightly larger than postnasal. Internasals 0 (N 15), 1 (155), 2 (55) or 3 (14). Upper labials 7 (N 15), 8 (88), 9 (102), 10 (29) or 11 (3). Mental trapezoid, wider than deep. Postmentals 1 (N 3), 2 (88), 3 (90) or 4 (1), commonly (60%) much longer than wide. Lamellae under fourth toe 7 (N 6), 8 (30), 9 (72), 10 (53), 11 (33) or 12 (4).

Upper surface brownish grey or greyish brown. Back with fine, blackish, shallowly zigzagging or undulate, transverse lines, not followed by a pale spot or blotch (at most and rarely a transverse series of white dots); dorsal lines sometimes broken up into numerous scattered short dashes or (especially on neck and foreback) modified into a median series of ellipses. Dark transverse lines on tail straight or chevron-shaped, immediately followed by a whitish triangular spot or longitudinal streak (orange-brown in life).

Figure 4   A *Phyllodactylus marmoratus alexanderi* from Eucla, photographed by G. Harold.

Distribution
The Nullarbor Plain and adjacent coasts of south-eastern Western Australia and far western South Australia, west to Balladonia HS and Israelite Bay, north at least to the Trans Australian Railway, and east to Cook and Head of Bight. See map, Figure 3.

Remarks
The differences between this and the nominate subspecies are less significant than the abruptness of the change, which parallels the equally abrupt change in

habitat — *P. m. marmoratus* on the precambrian shield and *P. m. alexanderi* in the Eucla Basin.

Apart from coloration, *P. m. alexanderi* differs from neighbouring *P. m. marmoratus,* i.e. those of the Eucla Division, in several scale characters. The rostral is much more frequently (60% *v.* 27%) pentagonal with a gable-like apex and is much more frequently (70% *v.* 10%) in wide contact with the nostril. A much higher proportion of specimens have fewer than two internasals (71% *v.* 23%) and have the postmentals long and narrow (60% *v.* 10%). There are more subdigital lamellae (7-12, N 198, mode 9, mean 9.4 *v.* 7-10, 63, 8, 8.3).

On Eyre Peninsula, judging from 71 specimens from the Nuyts Archipelago, Smoky Bay, Port Neill, Tumby Bay and Reevesby Island, coloration is mostly as in *P. m. alexanderi* but some aspects of scalation are considerably different. The rostral is usually hexagonal with a short flat apex and is usually excluded from the nostril. Only 15% of specimens have fewer than two internasals, and only 12% have the postmentals much longer than wide. Because these scale differences are as trenchant as those separating *P. m. alexanderi* and *P. m. marmoratus,* the Eyre Peninsula population cannot be included in *alexanderi.*

Derivation of name

After William Backhouse Alexander (1885-1965), Keeper of Biology in the Western Australian Museum from 1915 to 1919.

Material

Eucla Division (WA)

Israelite Bay (31111-2, 54256, 54269, 67211-2); Balladonia HS (53356-61) and 70 km ENE (31897-9); 11 km E Kilidwerinia Granite Rock (91318, 91339, 91341, 91343, 91348); Mullendunya Tank (45354); Toolinna Rockhole (45344-6, 45645, 66801-33, 83963-4) and 3 km SW (66687-714) and 11 km WSW (66777) and 27 km N (93738) and 7 km N (93737, 93739-40) and 7 km NE (66987) and 6 km E (93736); Toolinna Cove (66780-1); 42 km WSW Caiguna (24670-1, 31895) and 14 km W (54314); Baxter Memorial (51807); Twilight Cove (44979); Cocklebiddy (54315, 67240) and 11 km W (54329) and 10 km SSE (66968-9) and 14 km SSE (66783) and 25 km ESE (34449-50); 6 km ENE Moondadong Rockhole (91345); 4 km SW Graham Tank (91956-7) and 10 km SSW (91317); Eyre (67314); Nurina (37664); Lynch Cave (28707); 8 km S Loongana (29443-54, 34494-50); 40 km N Madura (36168) and 33 km N (29424-9); Madura Cave (25472); Madura Pass (24650-1, 29468-9); 15 km NNW Middini Beach (91314-5, 91340, 91342, 91344) and 10 km NNW (91316); 91 km W Mundrabilla (54266); 12 km NW Mundrabilla HS (36472); 8 km SW Yuwanyadi Rockhole (91346) and 19 km S (91347); 23 km S Reid (37672-3) and 65 km SSE (37665); Eucla (24603-6, 31875, 54270, 66480, 66482-7, 66627-8, 66630-1) and 4 km S (66612, 66612, 66862-71); Wilson Bluff (37047; SAM R117513 A-B, 25635-6).

South Australia

Warbla Cave (SAM R15981 A-B, 25632, 26264); 17 km E Western Australian border (SAM R23042-8) and 30 km E (SAM R15789); Koomooloobooka Cave (25405-15); 11 km W Koonalda (SAM R29218-24); Koonalda Cliffs (SAM R 15980); 12 km SE Cook (31872); Knowles Cave (SAM R26402); Nullarbor HS (SAM R4983 A-B) and 52 km N (36163) and 29 km N (SAM R25665, 25669-70) and 7 km NW (SAM 25657); White Wells Cave (SAM R25620); Head of Bight (SAM R5831).

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Description of a new subspecies of *Pseudomys* (Rodentia: Muridae) from Northern Territory

*D.J. Kitchener and W.F. Humphreys

Abstract

Pseudomys laborifex calabyi subsp. nov. is described from six specimens collected in 1973 from near the Uranium Development Project (UDP) Falls, Northern Territory. On skull and dentary characters it is generally larger but most similar in form to *Pseudomys laborifex laborifex* Kitchener and Humphreys, 1986. On external characters it is readily distinguished, using either univariate or discriminant function analysis, from *P.l. laborifex* and from other tropical and subtropical small (< 20 gm) *Pseudomys* with which it could be confused.

Introduction

Kitchener and Humphreys (1986) drew attention to the unsettled taxonomic situation regarding *Pseudomys* and described the new species, *Pseudomys laborifex*. This species is uncommon in the Western Australian Museum collection but widely distributed in the Kimberley, from the moist northwest to the more arid Ord River Region.

In January and July 1973 Dr John Calaby and Mr Tony Wolfe collected six specimens of *Pseudomys* from near UDP Falls, Northern Territory, which Dr Calaby considered to be a unique form (pers. comm.). Our examination of these specimens supports this view.

We are unable to compare directly measurements of externals of the UDP Falls form with other specimens because only scientific skins are available of the new form. We consider that a comparison of external measurements based on scientific skins to be unsatisfactory because different preparation methods alter the overall size and relative dimensions of such skins. However the field measurements of the new form, recorded by Dr Calaby just after their death, were compared with our measurements of formalin fixed and cthanol preserved specimens. Again such measurements will differ but they are a much better basis for comparison.

We consider the UDP Falls form to be most similar to *P. laborifex,* although easily distinguishable from that form on external measurements — certainly at least to the extent of warranting subspecific distinction using Mayr's 'seventy-five percent rule' (Mayr 1969). When additional specimens become available of this new form it may well be seen to warrant the status of a species. As no specimens of this new form have appeared in the last 14 years wc have proceeded herein to recognise it as a subspecies of *P. laborifex.*

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Methods

Measurements

Twenty-one skull (including dentary and teeth) and six external characters (listed in Table 1) were recorded from six adult *P. laborifex calabyi* (4 ♂, 2 ♀). The measurements, in millimetres, were recorded as shown in Kitchener (1985: Figure 1). Measurements of the holotype of *P. laborifex calabyi* are presented in Table 1. Terminology for vibrissae and other external characters follows Wood Jones (1923). Hair counts on the tail were taken as the number of hairs round the circumference of the tail at a point 1 cm from the anus. Measurements for *P. l. laborifex* (Kimberley, Western Australia), *P. chapmani* (Pilbara District, Western Australia), *P. hermannsburgensis* (central Northern Territory), *P. delicatulus* (Kimberley and Pilbara districts, Western Australia), *P. johnsoni* (central Northern Territory) and the type specimens examined are those presented in Kitchener (1985) and Kitchener and Humphreys (1986). Registration numbers of specimens are of the Australian National Wildlife Collection, CSIRO, Canberra.

Ageing

All specimens were regarded as adult after consideration of ossification of cranial sutures and tooth wear.

Univariate analysis

Means and standard deviations were obtained for all adult skull and external body characters. For each species all characters were examined for sexual dimorphism using t-test for unequal sample size. *A posteriori* multiple comparisons were conducted using analysis of variance and the GT2 follow up procedure at $\alpha = 0.05$ (Sokal and Rohlf 1981).

Multivariate analysis

Cranial and external characters were examined separately using multiple discriminant analysis (Davies 1971) and the centroids tested for significance using Hotellings' T^2 (Sneath & Sokal 1973). Five individuals from the comparative forms and three variables (body weight, nasal length, and coronoid-angle length) were dropped from the analysis due to missing data. Dendrograms were drawn from WPGMA cluster analysis of the range scaled data (Sneath and Sokal 1973) using euclidian distance.

Systematics

Pseudomys laborifex calabyi subsp. nov.
Tables 1, 2; Figures 1 - 3

Holotype

Australian National Wildlife Collection registration number CM7895, adult male, dry scientific skin, skull and dentaries separate.

Type locality

3 km SE Uranium Development Project (UDP) Falls, Northern Territory, 13°27′S, 132°26′E, altitude *c.* 100 m, collected on 14 July 1973 by J. Calaby and T.O. Wolfe.

Paratypes

(all dry scientific skins with skull and dentary seperate, all collected by J. Calaby and T.O. Wolfe.) UDP Falls (13°26′S, 132°25′E): CM7633, adult male, collected on 20 January 1973; CM7907, adult male, collected on 15 July 1973. 3 km SE UDP Falls (13°27′S, 132°26′E): CM 7875, adult female, collected on 13 July 1973; CM7880, adult female, collected on 13 July 1973; CM7898, adult male, collected on 14 July 1973.

Diagnosis (mean and range values)

Field measurements of *P.l. calabyi* tail, body and pes lengths are followed in brackets by measurements from scientific skins.

Pseudomys laborifex calabyi differs from *P. l. laborifex* in having its tail to vent length relatively shorter than snout to vent length 0.92 (0.88) [0.90 (0.80) - 0.95 (0.91)] v. 1.19 (1.05-1.35); snout to vent length much greater 85.2 (82.9) [82 (78.4) - 90 (87.4)] v. 64.5 (56.4-71.1); pes generally longer 17.8 (17.5) [16.7 (16.6) - 18.6 (18.3)] v. 16.6 (16.1-17.8); body weight generally heavier 16.4 (15.3-19.2) v. 11.8 (8.3-17.0); tail generally with more hairs/scale row 44.0 (35-51) v. 37.5 (31-41); generally larger in all skull and dentary measurements: greatest skull length 24.3 (22.9-25.1) v. 22.9 (22.2-23.5), $M^{1\text{-}3}$ length 4.4 (4.2-4.5) v. 4.1 (3.8-4.3) and $M_{1\text{-}3}$ length 3.8 (3.7-3.9) v. 3.6 (3.4-3.9).

Pseudomys laborifex calabyi differs from other small *Pseudomys* as outlined in the diagnoses of *P. laborifex laborifex* (Kitchener & Humphreys 1986: 422-425) except for the following additional details.

It differs from *P. hermannsburgensis* in having tail to vent length relatively shorter than snout to vent length v. 1.15 (1.07-1.31); anterior palatal foramen shorter relative to palatal length 0.32 (0.30-0.35) v. 0.37 (0.34-0.41); braincase narrower relative to greatest skull length 0.45 (0.45-0.46) v. 0.48 (0.47-0.50).

It differs from *P. delicatulus* in having tail to vent length relatively shorter than snout to vent length v. 1.22 (0.99-1.39); snout to vent length much greater v. 55.1 (50.2-61.7); tail with more hairs/scale row v. 33.9 (30-38); braincase narrower relative to greatest skull length v. 0.49 (0.45-0.50).

It differs from *P. chapmani* in having tail to vent length relatively shorter than snout to vent length v. 1.33 (1.07-1.43); snout to vent length longer v. 60.5 (52.2-67.7); braincase width narrower relative to greatest skull length v. 0.48 (0.45-0.50); bulla shorter v. 5.8 (5.5-6.0).

It differs from *P. johnsoni* in having tail to vent length relatively shorter than snout to vent length v. 1.20 (1.06-1.38); tail with more hairs/scale row v. 36.8 (30-44).

Description

As for *Pseudomys laborifex laborifex* (Kitchener and Humphreys 1986) except for the following details:

Table 1   Skull, dentary and external body measurements of the *Pseudomys laborifex calabyi* types. External measurements given (apart from hairs/scale row) are field measurements taken by J. Calaby and our measurements from scientific skins (in brackets).

| Catalogue Number	CM7895 Holotype	CM7633	CM7898	CM7907	CM7875	CM7880
Sex	♂	♂	♂	♂	♀	♀
Character						
Skull						
greatest length	24.1	24.9	24.4	24.6	25.1	22.9
nasal length	8.9	9.7	8.7	9.3	9.5	8.5
nasal width	2.4	2.5	2.4	2.2	2.2	2.3
interorbital width	3.5	3.4	3.7	3.4	3.3	3.4
zygomatic width	11.7	12.1	11.6	11.7	11.3	11.0
mastoid width	9.0	9.2	9.1	9.0	8.9	8.6
braincase width	10.6	11.0	10.7	10.8	10.5	10.3
braincase depth	7.4	7.5	7.7	7.3	7.3	7.3
interparietal width	7.3	7.1	7.3	6.9	6.4	7.9
palatal length	13.0	13.4	12.9	12.9	13.2	11.9
ant. palatal foramen length	4.3	4.2	4.3	4.5	4.0	3.7
basicranial length	20.5	21.2	20.3	20.7	20.8	19.1
bulla length	4.9	4.8	4.9	4.8	5.0	4.7
bulla width	10.7	10.8	10.8	10.5	10.4	10.4
M^{1-3} length	4.2	4.4	4.2	4.5	4.4	4.4
M^1 length	2.3	2.5	2.3	2.5	2.5	2.6
M^1 width	1.2	1.2	1.2	1.3	1.2	1.2
M^3 length	0.8	1.0	1.0	0.9	0.9	0.9
Dentary						
M_{1-3} length	3.7	3.9	3.8	3.8	3.8	3.8
coronoid-angle length	5.2	5.3	NA	5.3	5.1	5.3
condyle-incisor length	15.2	15.8	15.3	15.1	15.5	14.6
Externals						
snout-vent length	82 (87.4)	90 (85.9)	82 (84.3)	87 (78.4)	86 (82.0)	84 (79.4)
tail-vent length	78 (70.1)	82 (78.1)	77 (74.5)	78 (71.7)	81 (73.1)	76 (NA)
pes length	18.3 (18.0)	18.6 (18.3)	18.4 (17.7)	18.0 (17.2)	17.0 (17.4)	16.7 (16.6)
ear length	12.7 (9.4)	13.8 (11.4)	13.7 (8.8)	13.3 (9.6)	13.2 (9.5)	13.1 (8.9)
weight	17.0	19.2	15.8	15.3	15.5	15.4
hairs/scale row	47	43	41	35	47	51

Table 2   Discriminant function scores for the variables used for both skull and external characters of five species of *Pseudomys (laborifex laborifex, laborifex calabyi, hermannsburgensis, delicatulus, chapmani and johnsoni)*. Canonical variate values for an individual specimen are calculated by the summation of the products of each character value with its function score.

SKULL CHARACTERS	VECTORS				
	I	II	III	IV	V
greatest skull length	-.262	-.010	-.097	-.010	-.176
nasal width	-.173	-.028	-.062	-.281	-.014
interorbital width	-.173	-.011	-.026	-.094	-.124
zygomatic width	-.061	-.065	-.146	-.037	-.116
mastoid width	-.165	-.025	-.145	-.111	-.032
braincase width	-.049	-.309	-.207	-.026	-.007
braincase depth	.320	.151	.055	.069	-.069
interparietal width	-.032	.160	.144	.054	.012
palatal length	.545	.155	.059	-.006	.440
ant. palatal foramen length	-.201	.296	.130	-.193	-.072
basicranial length	.053	-.058	.124	.014	-.034
bulla length	-.008	-.009	.017	-.027	.035
bulla width	.108	-.237	.067	.035	.062
upper molar row length	.066	-.184	-.217	-.079	-.128
M^1 length	.236	.133	-.413	-.202	-.297
M^1 width	.467	.559	.755	.691	.769
M^3 length	.033	.548	-.044	.555	.064
lower molar row length	.315	.039	.187	-.126	-.156
condyle-incisor length	.034	.026	-.097	.022	-.043
χ^2	133.2	115.8	87.3	56.8	37.5
df	23	21	19	17	15
% variation explained	44	30	16	7	4

EXTERNAL CHARACTERS	I	II	III
snout-vent length	.228	-.071	-.037
tail-vent length	-.112	-.080	.101
pes length	.907	.085	-.837
ear length	.262	.990	.532
hair/scale row	.208	-.008	.050
χ^2	106.9	62.1	17.4
df	9	7	5
% variation explained	70	24	4

Skull and dentary (Figure 1)

Blunt projection of occipital intrudes approximately three quarters length of dorsal edge of postsquamosal sinus; anterior palatal foramen short, extending posteriorly to a point level with or just anterior to a line joining anterior edge of M^1 alveoli, although extends just posterior to this line in CM7907; mesopterygoid fossa with parallel sides for most of its length and slightly widened posteriorly.
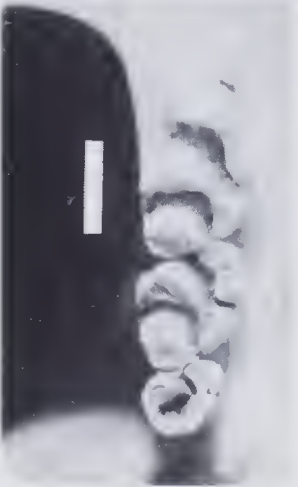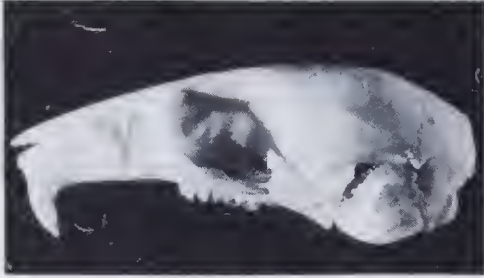
Dentition (Figures 1 and 2)

M^1 occlusal surface oval in outline differing slightly from *P. l. laborifex* (Figure 2; but see Corbet 1986).

External morphology (Figure 3)

Small 16.4 (15.3-19.2) gm; tail length from field measurements 92 (90-95) percent of total body length; ear and pes lengths, from field measurements, moderate 13.3 (12.7-13.8) and 17.8 (16.7-18.6) respectively.

Pelage and skin colour

Described following Ridgeway's (1912) colour standards (capitalised).

Hairs on shoulder, back and flanks average 6 mm long, base of hairs Neutral Gray, distal 2 mm Tawny Olive, lightly tipped with Sepia. Hairs on forehead, rosttrum and sides of face shorter (3.0-3.5 mm) with distal one-third Tawny Olive, tipped with Sepia. Ears lightly furred with 1.0-1.5 mm long hairs, these Warm Sepia on outer surface and Light Ochraceous Salmon tipped with white on inner surface. Guard hairs on dorsum numerous, up to 11 mm long, Black - on flanks less numerous, slightly shorter (10 mm), Black. Hairs on ventral surface of body, throat, chin, sides of mouth, manus and pes White - which contrasts sharply with Cinnamon Buff of lateral surfaces; ventral hair 5 mm long, basal half Light Neutral Gray. Guard hairs on venter and abdomen less numerous, up to 8.5 mm long, White. Hairs on tail 1.2 mm long, averaging 44 hairs/scale row; on dorsal surface of tail hairs Bister, on ventral surface White. No terminal tuft on tail. On each side up to 36 mystacial vibrissae, posteriorly these are up to 26.5 mm long, mostly Sepia, on edge of lips shorter (6 mm) and White. One genal vibrissa 10 mm long, Sepia; one long (16.5 mm) and one or two shorter (10 mm) supraorbital vibrassae; two short (7 mm) White interramal vibrissae. Skin of pes and manus Pinkish Buff. Skin of ear Hair Brown. Ventral skin of tail Pale Smoke Gray, dorsal skin Buffy Olive.

Etymology

Named after Dr John Calaby for his discovery of this subspecies and for his contribution to Australian mammalogy.

Distribution and habitat

Known only from the vicinity of UDP Falls, Northern Territory. It is separated from *Pseudomys l. laborifex* by approximately 560 km. (Figure 4).

The habitat of the holotype and paratypes is as follows (J. Calaby pers. comm.):

◀ Figure 1   Skull, dentary and occlusal view of RHS upper molar row of *Pseudomys laborifex calabyi* holotype. Molar row and ventral aspect of the skull as stereopairs. Scale lines: upper molar row, 1 mm; skull and dentary, 10 mm.
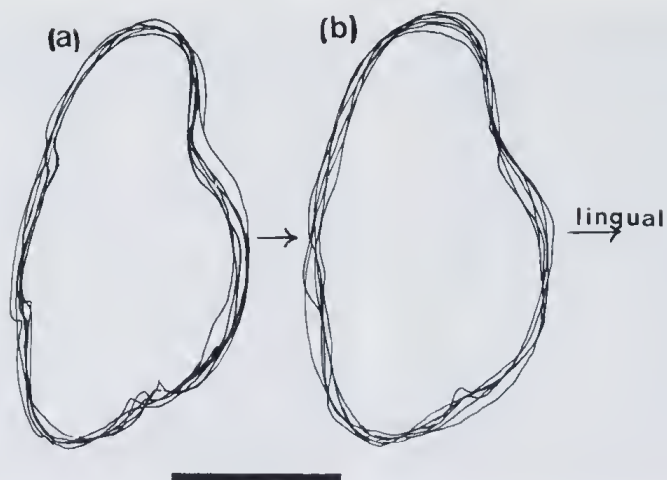
Figure 2   Outline of M^1 occlusal surface of six specimens showing approximately similar tooth wear of (a) *Pseudomys laborifex calabyi* and (b) *P.l. laborifex*. Scale line, 1 mm.

Figure 3   *Pseudomys laborifex calabyi* holotype: scientific skin. Scale line 2 cm.
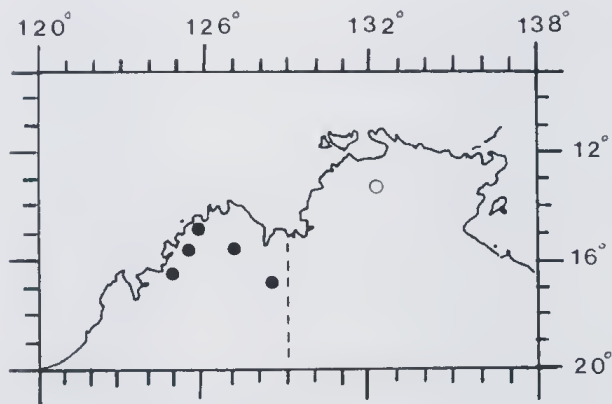

Figure 4   Locality records of *Pseudomys laborifex calabyi* (○) and *P.l. laborifex* (●).

CM7895 (holotype), CM(7875, 7880, 7898).

From edge of small 'swamp' at base of escarpment, or small watercourse flowing from 'swamp'. Swamp and watercourse dry in July 1973 at time of capture of these specimens but sandy-clay soil damp. Vegetation in depression and along watercourse predominantly large tussocks of a tall broad-bladed perennial grass, and other grasses. These were green in July. Vegetation surrounding and at edge of swamp was a tall open eucalypt forest grading to woodland on sandy or sandy loam soil. There were occasional *Pandanus* sp., *Erythrophleum* sp. and flowering *Grevillea* sp., tall shrubs and a ground stratum of moderately dense, long, dry annual grass with a few shrubs.

There were burrows in the sandy soil near the 'swamp' edge but these appeared to be those of *Rattus tunneyi* and *"Pseudomys gracilicaudatus"*. *Pseudomys delicatulus* was trapped on the lighter soils in woodland.

CM7633 (January 1973), CM7907 (July 1973)

At UDP Falls at bottom of slope at base of escarpment. Sparse eucalypt woodland on moderately hard stony soil. Some larger boulders on slope. Understorey of moderately sparse short grass with some ephemeral herbs and vines. CM7633 caught in live trap on bare area at base of a very large mound nest of *Nasutitermes triodiae*. CM7907 caught on similar substrate within 200 m of trapsite of CM7633. These above habitats very close to a sparse eucalypt woodland on friable sandy soil covered with tall annual grass (dried out in July) and with sparse shrubs. *Pseudomys delicatulus* and other murids common in the latter habitat.

These habitats are similar to some of those occupied by *Pseudomys laborifex laborifex* (Kitchener and Humphreys 1986).

Morphometric Analyses: Results and Discussion

Univariate analysis.

The sample size is too small to test for sexual dimorphism. Eighteen of the 24 characters differed ($p < .05$) between *P. l. laborifex* and *P. l. calabyi;* those not differing are:

interparietal width, anterior palatal foramen length, M^1 width, M^3 length and condyle-incisor length. Multiple comparision tests on the six data sets show: *P. l. calabyi* differs from *P. l. laborifex* on snout to vent length, pes length, greatest skull length, basicranial length, M^1 length; and from *P. johnsoni* on snout to vent length and M^1 length.

Multiple discriminant analysis:

This analysis extracted five significant vectors for skull and dentary characters and three for external characters. The discriminant function statistics are given in Table 2. While *P. l. calabyi* could be separated on skull characters from *P. hermannsburgensis*, *P. delicatulus*, *P. chapmani* and *P. johnsoni*, it could not be separated graphically from *P. l. laborifex* (Figures 5a, b and 6a). On the more dubious

external characters it is well separated from adjacent groups (Figure 6b). Examination of the three species overlapping on their skull and dentary characters using Hotellings' T² shows that *P. l. laborifex* differs significantly from *P. johnsoni* (P=0.009), but not from *P. l. calabyi* (P=0.177); too few data are available to test the difference between *P. johnsoni* and *P. l. calabyi*.

Phenetic analysis

This analysis on skull and dentary characters places *P. l. calabyi* closest to *P. johnsoni*, with *P. l. laborifex* closely grouped. On external characters *P. l. calabyi* is widely separated from all other species (Figure 7). The grouping on skull and dentary characters requires comment as we consider *P. l. calabyi* closest to *P. l. laborifex*. The phenetic grouping is the most robust obtained and the apparent anomaly results from the distribution of the data; the phenetic analysis is based
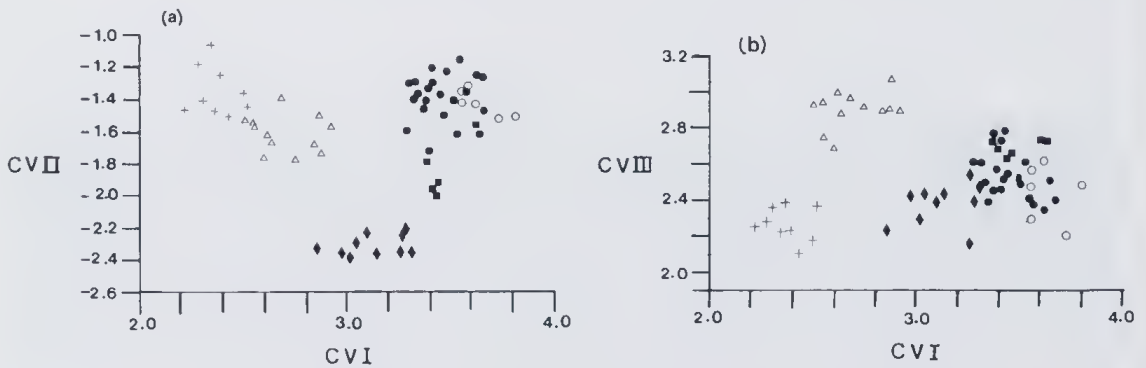
Figure 5   Discriminant function plots for combined male and female adult *Pseudomys* of (a) skull characters, vectors I and II and (b) skull characters, vectors I and III: *P. laborifex calabyi* (○), *P. laborifex laborifex* (●), *P. chapmani* (◆), *P. hermannsburgensis* (△), *P. delicatulus* (+) and *P. johnsoni* (■).

Figure 6   Discriminant function plot of (a) cranial characters of *P.l. laborifex* and *P.l. calabyi* on vectors I and III. (b) external characters of the four closest groups (see Figure 5) plotted on vectors I and II. *P.l. calabyi* (○), *P.l. laborifex* (●), *P. hermannsburgensis* (△) and *P. johnsoni* (■).

on considerably less information than is the graphical analysis which shows clear separation between *P. johnsoni* and both *P. l. laborifex* and *P. l. calabyi* (Figure 5a).
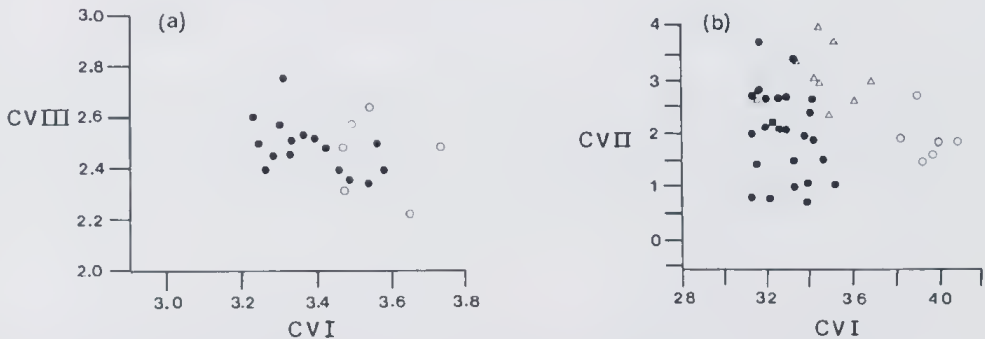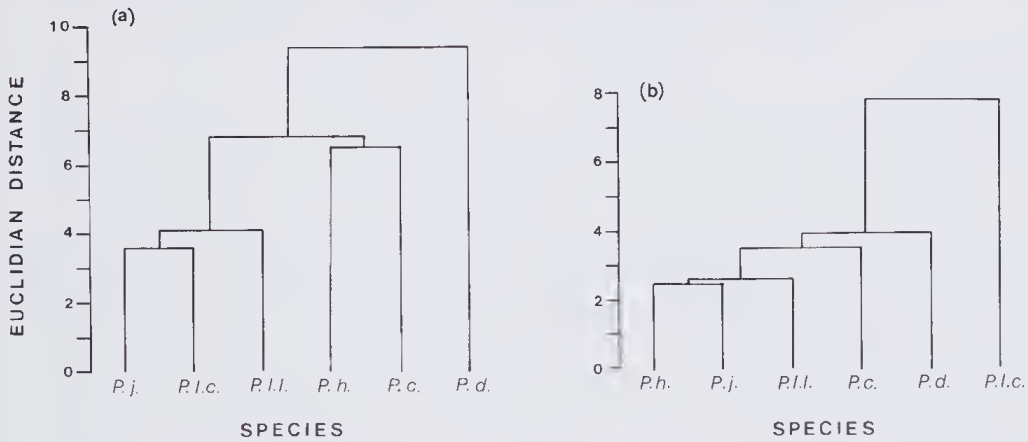

Figure 7   Dendrogram of the phenetic relationships for (a) skull characters and (b) external characters of combined male and female adult: *Pseudomys laborifex calabyi (P.l.c.), P.l. laborifex (P.l.l.), P. hermannsburgensis (P.h.), P. delicatulus (P.d.), P. chapmani (P.c.) and P. johnsoni (P.j.).*

Acknowledgements

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A redescription of the lungfish *Eoctenodus* Hills 1929, with reassessment of other Australian records of the genus *Dipterus* Sedgwick & Murchison 1828.

J.A. Long*

Abstract

Eoctenodus microsoma Hills 1929 (= *Dipterus microsoma* Hills, 1931) from the Frasnian Blue Range Formation, near Taggerty, Victoria, is found to be a valid genus, differing from *Dipterus*, and other dipnoans, by the shape of the parasphenoid and toothplates. The upper jaw toothplates and entopterygoids, parasphenoid, cleithrum, anocleithrum and scales of *Eoctenodus* are described. *Eoctenodus* may represent the earliest member of the Ctenodontidae. *Dipterus* cf. *D. digitatus.* from the Late Devonian Gneudna Formation, Western Australia (Seddon, 1969), is assigned to *Chirodipterus australis* Miles 1977; and *Dipterus* sp. from the Late Devonian of Gingham Gap, New South Wales (Hills, 1936) is thought to be congeneric with a dipnoan of similar age from the Hunter Siltstone, New South Wales. This form differs from *Dipterus* in the shape of the parasphenoid. The genus *Dipterus* appears to be restricted to the Middle-Upper Devonian of Europe, North America and the USSR (Laurasia).

Introduction

Although Hills (1929) recognised a new dipnoan, *Eoctenodus microsoma*, in the Late Devonian fish remains from the Blue Range Formation, near Taggerty, he later (Hills 1931) altered the generic status of this species after a study trip to Britain in which D.M.S. Watson pointed out similarities between the Australian form and the British genus *Dipterus* Sedgwick and Murchison 1828. Studies of the head of *Dipterus* by Westoll (1949) and White (1965) showed the structure of the palate and, in particular, the shape of the parasphenoid which differs from that in the Taggerty dipnoan. These works, together with new discoveries of Upper Devonian dipnoans from Victoria at Mt Howitt, have prompted a re-examination of Hill's original material of *Eoctenodus*. The aim of this paper is to redescribe *Eoctenodus* and clarify the generic status of the other Australian Devonian dipnoans which have been referred to the genus *Dipterus*.

Australia has a particularly good record of fossil dipnoans from the Devonian, including superb specimens of Early Devonian dipnorhynchids from Taemas, New South Wales (Thomson and Campbell 1971, Campbell and Barwick, 1983, 1984, 1985), and good representation in both marine and terrestrial facies of the Late Devonian. The best preserved fossil lungfish material comes from the Frasnian

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Gogo Formation, Western Australia, where four local species are known (Miles 1977), all belonging to genera known from the Northern Hemisphere *(Griphognathus, Chirodipterus* and *Holodipterus). Soederberghia,* also known from the Northern Hemisphere, was recorded from the Cloughnan Shale, New South Wales, by Campbell and Bell (1982). Well preserved dipnoans from Mt Howitt, Victoria, are currently under study by the author. These comprise two new genera which have resemblances to *Scaumenacia* and *Fleurantia* in overall morphology and cranial bone patterns.

The Taggerty fauna was the first Late Devonian fish assemblage described from Australia, and from the nature of its fauna, Hills (1929, 1931) was able to deduce the age of the Cerberean Cauldron complex. The fauna includes *Bothriolepis gippslandiensis* Hills (1929), an indeterminate phyllolepid, scales of the osteolepiform *Marsdenichthys longioccipitus* (personal observation) and the dipnoan *Eoctenodus microsoma.* The placoderm plates are found in an orange silty-sandstone whereas the dipnoan remains and the osteolepiform scales occur in a laminated dark blue-grey shale which outcrops a short distance across strike from the placoderm-bearing sandstone. New collections from this site were made during 1981-1983 by Dr Anne Warren (Latrobe University) and the author, enabling redescription of *Bothriolepis gippslandiensis* (Long 1983; Long and Werdelin, 1986). Williams *et al.* (1982) discussed the age of the Cerberean succession, giving a minimum date of 367+−2 million years for the early Frasnian Blue Range Formation. Long (1982*b*) commented on the depositional environment of the Taggerty fish beds.

Specimens were studied by latex casting of the natural moulds as all traces of the original bone were weathered away. Nearly all of the Taggerty material comprised isolated bones and scales, except for two specimens which contained closely associated skeletal elements (MUGD 772, cleithrum and anoclcithrum; MUGD 775, toothplate and suboperculum). The Taggerty material is housed in the Geology Department, Melbourne University (MUGD), although some specimens (prefix NMV) are in the Museum of Victoria. The specimens of *Chirodipterus australis* from the Gneudna Formation are housed in the Geology Museum, University of Western Australia (UWA). Terminology used in this work follows that of Miles (1977) for cranial bones and toothplates, and Jarvik (1980) for the shoulder girdle.

Systematics

Subclass Osteichthyes
Infraclass Dipnoi
Family Ctenodontidae Woodward 1891

Remarks

Although the skull roof of *Eoctenodus* is unknown apart from a single imperfect B-bone (Hills 1929, Fig. 2-2) the close resemblance to *Ctenodus* in the shape of

the parasphenoid, toothplates and cleithrum (Watson and Gill 1923) are here considered as indicative of close affinity between *Eoctenodus* and the Ctenodontidae. I agree with Miles (1977) in referring *Sagenodus, Straitonia* (Thomson 1965) and closely related forms to a separate family, Sagenodontidae, but accept that this family has close affinity to the Ctenodontidae as exemplified by the similar morphology of the parasphenoid and dentition (Miles 1977, page 157).

Eoctenodus Hills 1929

Type species
  Eoctenodus microsoma Hills 1929.

Amended diagnosis

A ctenodontid having a parasphenoid one third as broad as long, and being of almost uniform breadth for the anterior two thirds of its length, and with anterolateral margins forming an angle of approximately 60 degrees. Upper jaw toothplates more ovoid than triangular, with up to 10 subparallel, relatively straight tooth ridges of separated cusps which coalesce towards the centre of radiation of the tooth plate, and separated by relatively deep clefts. Cleithrum with a very narrow waist between the ventral and dorsal division of the external lamina, and having a very large branchial lamina. Scales, thin, subrectangular and cycloid with an ornament of fine wavy ridges which are not closely packed but sparsely distributed.

Remarks

The above diagnosis distinguishes *Eoctenodus* from *Dipterus* and other Devonian dipnoans principally by the shape of the parasphenoid and toothplates (Figure 3-A), and from *Ctenodus* (Figure 3-C) and other ctenodontids by the relative shape of the parasphenoid, apical angle of the parasphenoid, and number of tooth-rows on the toothplates.

Eoctenodus microsoma Hills, 1929, p. 193

Figures 1-7

1931 .... *Dipterus microsoma* Hills, p. 222.
1958 .... *Dipterus microsoma* Hills, p. 89.
1966 .... *Dipterus* Lehman, pp. 249, 289.
1976 .... *Dipterus microsoma* Marsden, pp. 87, 122.
1977 .... *Dipterus* Kemp, p. 253.
1977 .... *Dipterus microsoma* Kemp, p. 256.
1982 .... *Dipterus* Long, p. 63, Fig. 5-H.
1983 .... *Dipterus (Eoctenodus)*, Long, p. 298.
1984 .... *Dipterus microsoma*, Long & Turner, p. 241.

Holotype

MUGD 775 (fig. 1-C), left upper toothplate and entopterygoid (figured Hills, 1929, pl. 18, fig. 7).

Other material

MUGD 773a, b (782), parasphenoid; MUGD 772, (counterpart 781) Cleithrum and part of anocleithrum; MUGD 770, very small toothplate; MUGD 784, moderate sized toothplate. In addition Hills lists other elements (e.g. a B-bone, Hills 1929, fig. 2-2) which were not found with the borrowed MUGD collection in the Bureau of Mineral Resources from which this study was based. Scale number P 186565 is housed in the Museum of Victoria.

Diagnosis

As for genus.

Description

Eoctenodus was a moderate-sized Devonian dipnoan having an estimated skull length around 6 cm, based on proportions of the toothplates compared with those of *Dipterus valenciennesi.*

The parasphenoid (Figures 1-A, E; 2; 3-B) is almost completely preserved from natural moulds of both dorsal and ventral surfaces, missing only the posterior tip of the stalk. It is a rather thin bone of almost uniform thickness, being slightly thicker at the anterior end. It comprises a large anterior division (corpus, Miles 1977) which occupies two-thirds of the estimated total length of the bone, and a very narrow occipital stalk (st). The anterior angle, contained by the straight anterolateral margins of the corpus (Miles, 1977 page 153), is close to 60 degrees, being quite distinct from both *Dipterus* (70-72 degrees, as measured from figures in White 1965) and *Ctenodus* (ca 105 degrees, Watson and Gill 1923, fig. 25). The dorsal surface (Figure 2-A) has thickened anterolateral margins for the overlap surfaces of the entopterygoids (ov. pt) which anteriorly meet two pairs of parallel grooves which are separated medially by a central ridge. The grooves are presumably for the palatine nerves and arteries (gr. pal). The probable course of arteries in close contact with the parasphenoid is shown in Figure 2-C, showing a pattern not far from that known in *Dipnorhynchus sussmilchi* (Campbell and Barwick 1982) or *Chirodipterus* (Save-Soderbergh 1952). The hypophysial fossa (hyp) is a large keyhole shaped depression which does not appear to penetrate through to the ventral surface of the bone, similar to the condition in *Chirodipterus* (Campbell and Barwick 1982). This condition is a feature of advanced dipnoans in which the palate is well known, as only a few primitive forms retain a bucco-hypophysial opening on the ventral side of the parasphenoid (e.g. *Dipnorhynchus, Speonesydrion and Dipterus*). Inside the hypophysial fossa appear to be irregular tubules, possibly a vascular plexus as occurs in the hypophyseos of *Dipnorhynchus* (Campbell and Barwick 1982, fig. 16) and in most fishes, e.g. *Amia* (Bjerring 1977). The stalk is seen running anteriorly as a raised thickening on the dorsal surface of the bone, terminating just posterior to the hypophysial fossa. The stalk broadens slightly as it leaves the corpus posteriorly, becoming thinner distally.

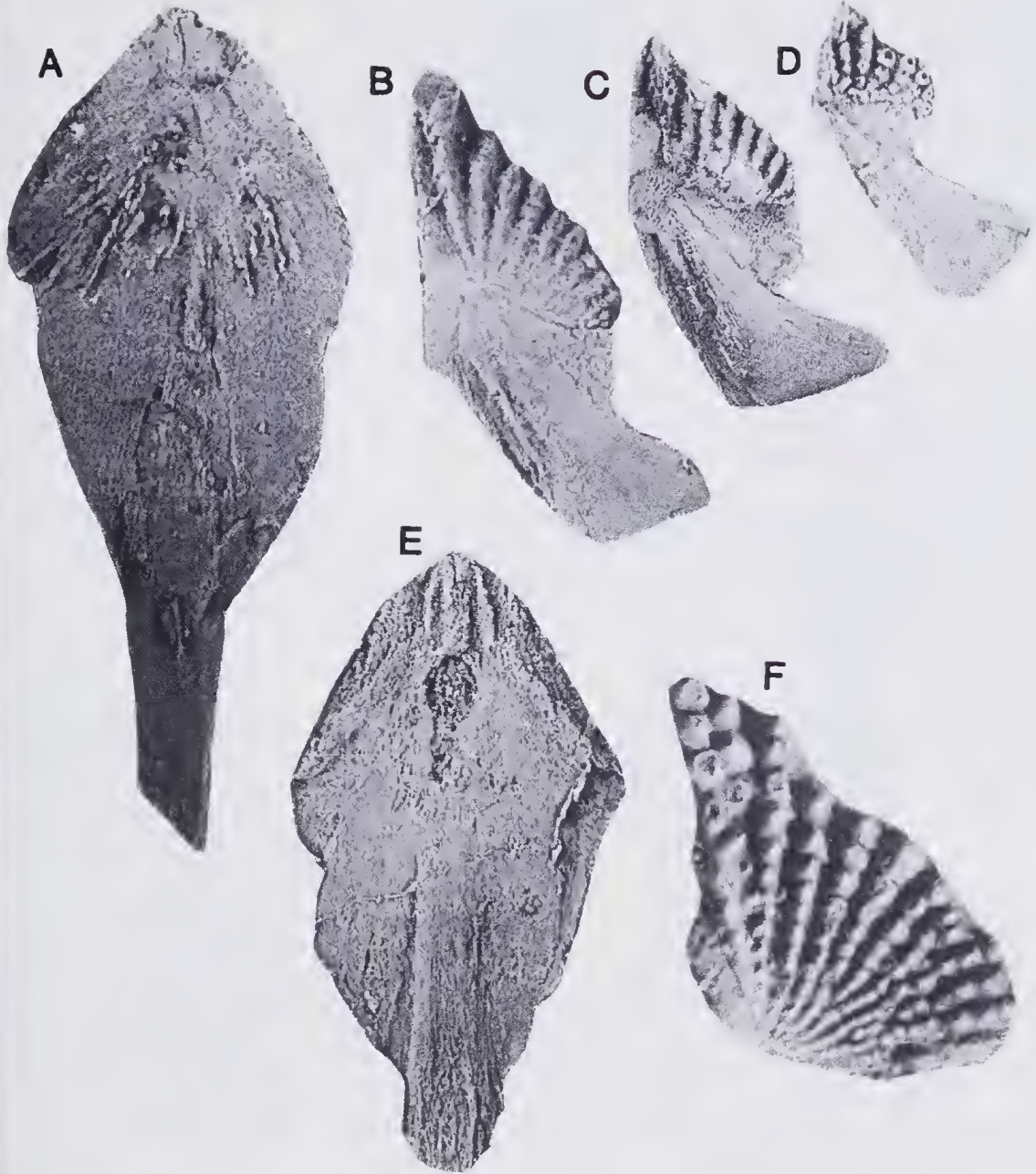Figure 1   A-E, *Eoctenodus microsoma* Hills. A, E, parasphenoid in ventral (A) and dorsal (E) views, MUGD 773, X3.5. B-D, left pterygoids and entopterygoids in various stages of growth, youngest to the right. B, MUGD 775, X2.5. C, MUGD 784, X2. D, MUGD 770, X4. F, left pterygoid toothplate of *Dipterus valencienessi* Sedgewick and Murchison, British Museum (Nat. Hist.) P 34549, X3.5, photograph courtesy Dr Moya Smith.
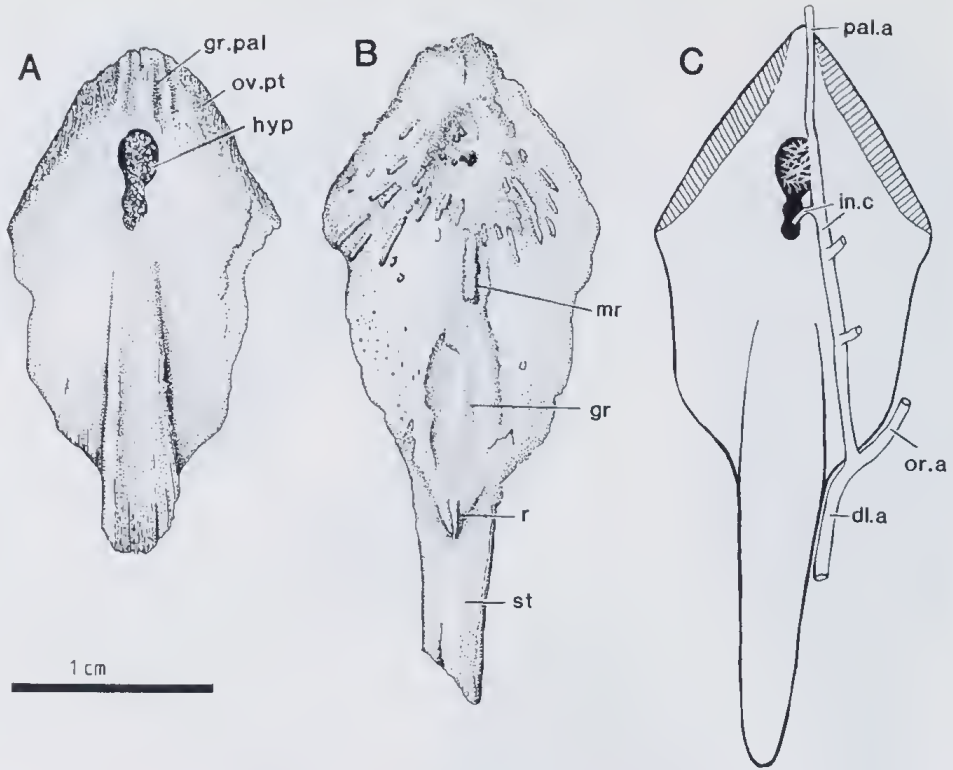
Figure 2   *Eoctenodus microsoma* Hills. Parasphenoid in (A) dorsal view and (B) ventral view. C, attempted restoration of complete parasphenoid shape, dorsal view, showing possible course of arteries. dla, dorsolateral aorta; gr, median groove; gr.pal, groove for palatine artery and nerve; hyp, hypophysial fossa; in. c, internal carotid artery; mr, median ridge; or.a, orbital artery; ov.pt, overlap surface for pterygoid; pal.a, palatine artery; r, posterior ridge on parasphenoid; st, stalk of parasphenoid.

The ventral surface of the parasphenoid is rather flat and featureless. The anterior region of the corpus has some irregularly disposed thin ridges of bone running radially out from the depressed area adjacent to the hypophysial fossa. In the midline there is a short median ridge (mr) which separates paired shallow grooves which broaden posteriorly (gr). At the posterior end of the corpus there is another short median ridge where the corpus is slightly elevated above the stalk. Figure 2-C shows an attempted restoration of the shape of the parasphenoid and possible vascular supply to the region.

The parasphenoid of certain primitive dipnoans *(Chirodipterus* and dipnorhynchids, Campbell and Barwick 1982) is small, being about 30% of the length and breadth of the braincase, with a weakly developed anterior division. In *Dipterus* the parasphenoid is much larger, being approximately half the length and breadth of the braincase, with a well developed anterior end and a posterior stalk which extends almost as far posteriorly as the braincase (White 1965). In other fresh-

water dipnoans from the Late Devonian onwards this trend has continued (e.g. *Gnathorhiza,* Carlson 1968; *Megapleuron,* Schultze 1977) and the parasphenoid in living dipnoans is typically very large relative to the braincase (e.g. *Neoceratodus* Figure 3-G). Although the relative size of the parasphenoid to braincase is not known for *Eoctenodus,* the relative sizes of the corpus to upper jaw toothplates is similar for *Dipterus, Eoctenodus* and *Ctenodus* (Figure 3 A-C), indicating that the parasphenoid of *Eoctenodus* can be assumed to have been relatively large, with a much longer posterior stalk in relation to braincase length compared to *Dipterus.* The development of the long occipital stalk on the parasphenoid of
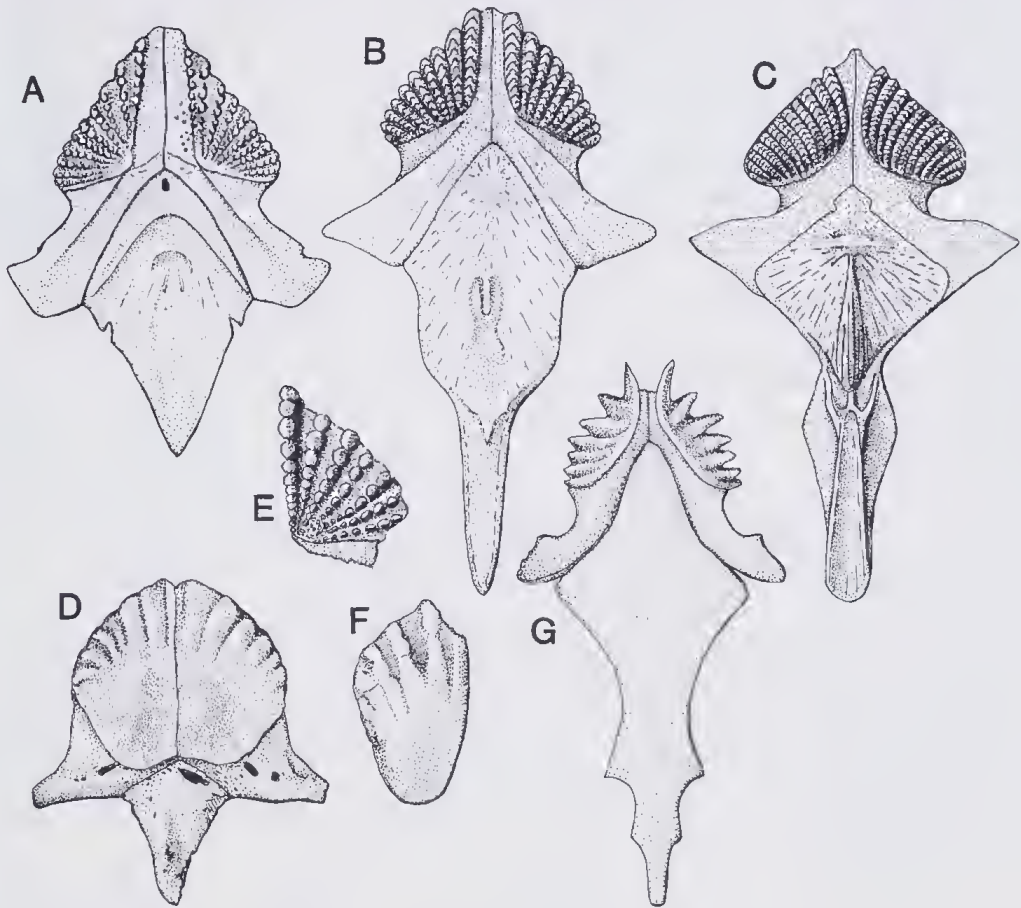
Figure 3   Comparison of upper jaw dentitions of certain Palaeozoic and Recent dipnoans, not to scale. A, *Dipterus valencienessi,* after White (1965). B, *Eoctenodus microsoma* Hills, attempted restoration of palate. C, *Ctenodus cristatus,* after Watson & Gill (1923). D, *Chirodipterus australis* Miles (after Campbell & Barwick, 1982). E, '*Dipterus*' sp., Hervey Range, after Hills (1936). F, right pterygoid toothplate of *Chirodipterus australis* from the Gneudna Fm, Western Australia (U.W.A. 62148). G, *Neoceratodus forsteri,* palate after Jarvik (1980).

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Eoctenodus seems to represent an intermediate condition between that of *Dipterus* and *Ctenodus*, and is here taken to represent an incipient stage towards the ctenodontid line of evolution. The enlargement of the parasphenoid in dipnoans is a specialised condition which may relate to the invasion of freshwater habitats and the development of air gulping (Prof. K. Campbell, pers comm.).

The upper jaw toothplates are known from three examples in different stages of growth, showing only the oral surfaces. The largest (holotype, Figure 1-B) has a toothplate 16 mm long whereas the smallest (Figure 1-D) is almost complete yet the toothplate is only 4 mm in length. The major changes observable with this growth sequence are, firstly, in the ratio of toothplate (pterygoid) size compared with pterygoid size (Table 1), showing a significant increase in the growth of the pterygoid toothplate relative to the pterygoid. Secondly there is an increase in number of tooth rows and cusps in each row, although this is well known for dipnoans (e.g. Schultze 1977, *Megapleuron*). The angles between the first tooth row and all other tooth rows (as measured according to Kemp and Molnar, 1981 fig. 1) also differs considerably with growth (Table 2), a feature noted for *Neoceratodus* by Kemp (1977).

Table 1   Changes in upper jaw toothplate: entopterygoid relative sizes with growth.

	A.	B.	C.
MUGD 770	app. 4 mm	app. 9 mm	44
MUGD 784	13 mm	24 mm	54
MUGD 775	17 mm	29 mm	59

A, maximum linear dimension of the upper jaw toothplate.
B, maximum linear dimension of the entopterygoid bone.
C, index A/B x 100.

Table 2   Changes in angle between tooth ridges relative to growth.

	MUGD 775	MUGD 784	MUGD 770
Angle between tooth			
ridge 1-2	14°	8°	6°
1-3	25°	10°	12°
1-4	31°	15°	17°
1-5	40°	17°	25°
1-6	50°	21°	39°
1-7	57°	26°	-
1-8	62°	-	
1-9	66°		
1-10	69°		
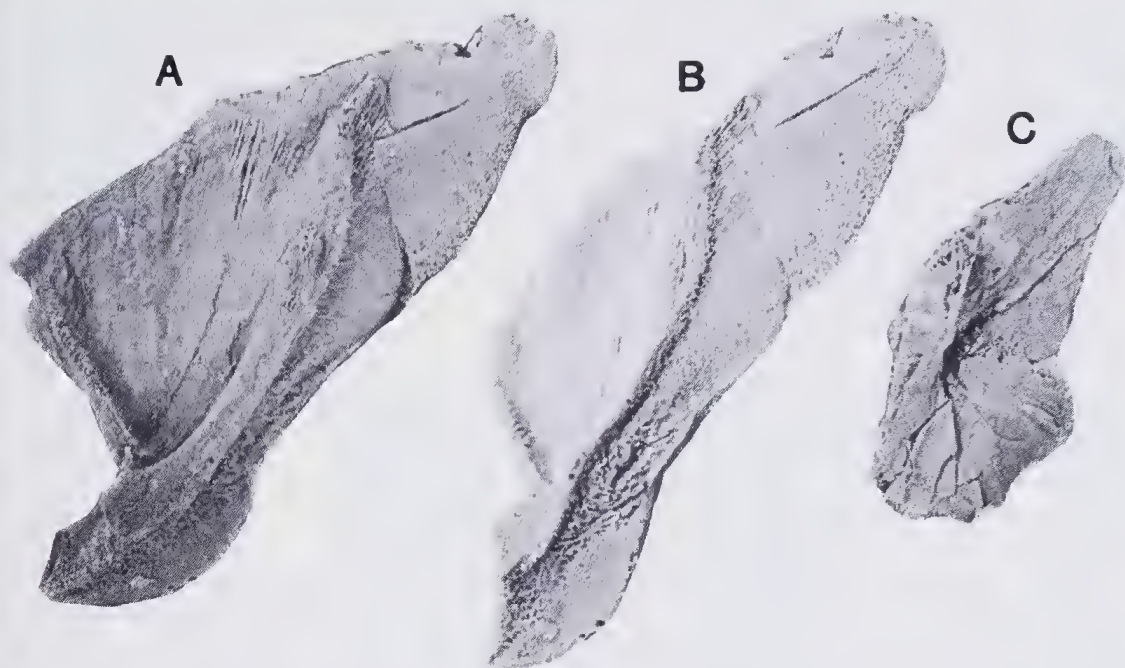
Figure 4   *Eoctenodus microsoma* Hills. Shoulder girdle bones. A, B, cleithrum in (A) antero-lateral and (B) lateral veiws. MUGD 781, X3. C, anocleithrum associated with MUGD 781, in mesial view, X3.
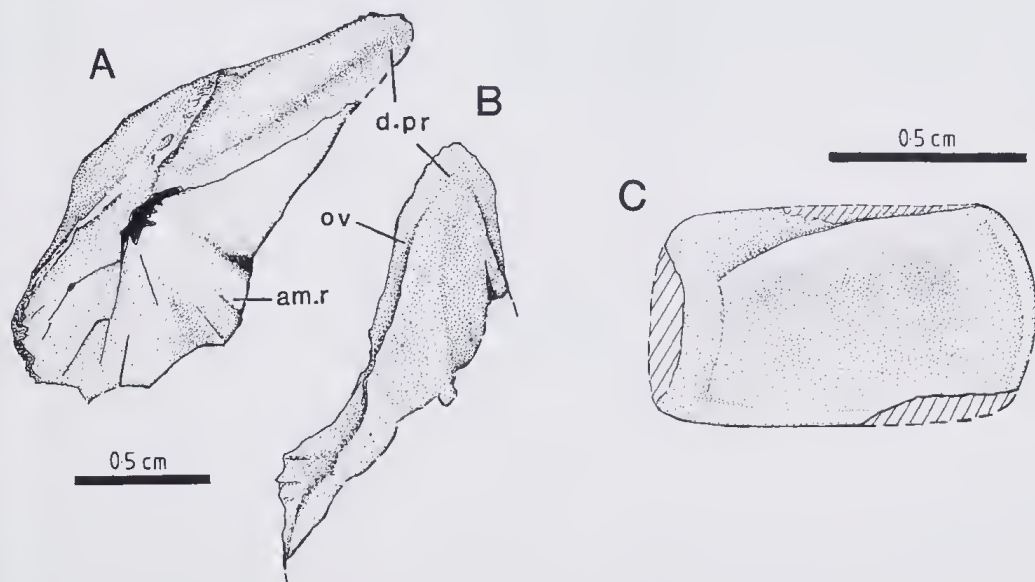
Figure 5   *Eoctenodus microsoma* Hills. A, B, anocleithrum, MUGD 781, in mesial (A) and lateral (B) views. C, possible subopercular bone in mesial view, associated with MUGD 775. am. r, anterior median ridge; d. pr, dorsal process; ov, overlap or ligamentous attachment area.

The following description of the upper jaw toothplate and entopterygoid is based on the presumed adult condition exemplified by the holotype. The toothplate is more ovoid in form than triangular, but is rather narrow relative to the longest (anterolateral) axis. The first tooth row ridge is the longest, extending noticeably further than the second ridge, and diverging from this ridge slightly more than do the remaining ridges. Cusps closer to the centre of radiation of the tooth ridges coalesce to form tooth ridges with an almost continual edge, although the lateral edges of the toothplate show distinctly separate higher cusps with apices directed laterally, similar to the figured condition in *Delatitia* (Long and Campbell 1985, fig. 4-E). The posterior half of each tooth ridge is weakly depressed relative to the rest of the tooth ridges, possibly due to wear. There are 10 distinct tooth ridges, numbering up to about 10 cusps on the first two ridges, although there is some damage to the anterior of the first tooth ridge on the holotype. On the smaller toothplates the cusps are more conical with deeper clefts between the tooth ridges (Figure 1-C, D). The oral face of the entopterygoid has a smooth surface which is gently concave, becoming thicker as a ridge develops along the posteromesial edge that has a roughened margin for contact with parasphenoid. The posterior wing of the entopterygoid splays out into a rounded lateral process, as seen on MUGD 775 (Figure 1-C). The anterior region of the entopterygoid narrows towards the base of the toothplate where an anteromesial ridge develops, ending just posterior to the posterior limit of the first tooth row. The shape of the entopterygoid indicates that the quadrates were widely spaced from the parasphenoid as in *Ctenodus* (Watson and Gill 1923).

The cleithrum in general is poorly known for Devonian dipnoans (e.g. Denison 1968, Schultze 1969), and although recent restorations have been given of this bone for *Scaumenacia* (Jarvik 1980, vol. 1, fig. 335) and for *Chirodipterus* in mesial view (Janvier 1980, fig. 12, Long 1985a, fig. 11), there is not a good description of this bone available for any Devonian lungfish. The cleithrum of *Eoctenodus* (Figures 4-A, B; 5) is well preserved in lateral view with partial preservation of the internal or mesial surface. Overall the cleithrum was mostly subdermal with only a narrow lateral lamina being exposed externally (Figure 4-B). It is characterised by having a narrow external lateral lamina (lat. 1) which is strongly waisted ventrally, and by the extensive flat branchial lamina (br. 1). The lateral lamina in *Eoctenodus* is quite narrow, being broadest at the dorsal margin which is relatively straight. The ventral division of the lateral lamina is well rounded, separated from the dorsally broadening upper half by a constricted waist. The anterior edge of this external lateral lamina bears a strong thickening (th) which is broadest anterior to the rounded ventral region of the cleithrum, where it forms a short anteriorly directed mesial process (m.pr) for interlocking with the clavicle. Immediately medial to this process is a concave smooth area for overlap with the clavicle (ov. Clav). The branchial lamina extends forward from the lateral lamina at an acute angle, meeting this lamina along a smooth contact ridge which develops into a deep pit (p) at the ventral edge. The anterior margin of the branchial lamina

is also thickened into an anterior ridge (an. r) which bears a small notch (n). The lateral surface of the branchial lamina is smooth with a thickened low ridge running almost vertically back towards the ventral pit. The dorsal (or anterodorsal) margin of the branchial lamina shows a slight angle (a) where it meets this ridge. The mesial surface of the cleithrum is not well preserved as it is obscured by superimposition of the anocleithrum and lacks the anterior and ventral edges. All that is shown by the cast is a smooth surface with a weak thickening parallel to the posterior margin.
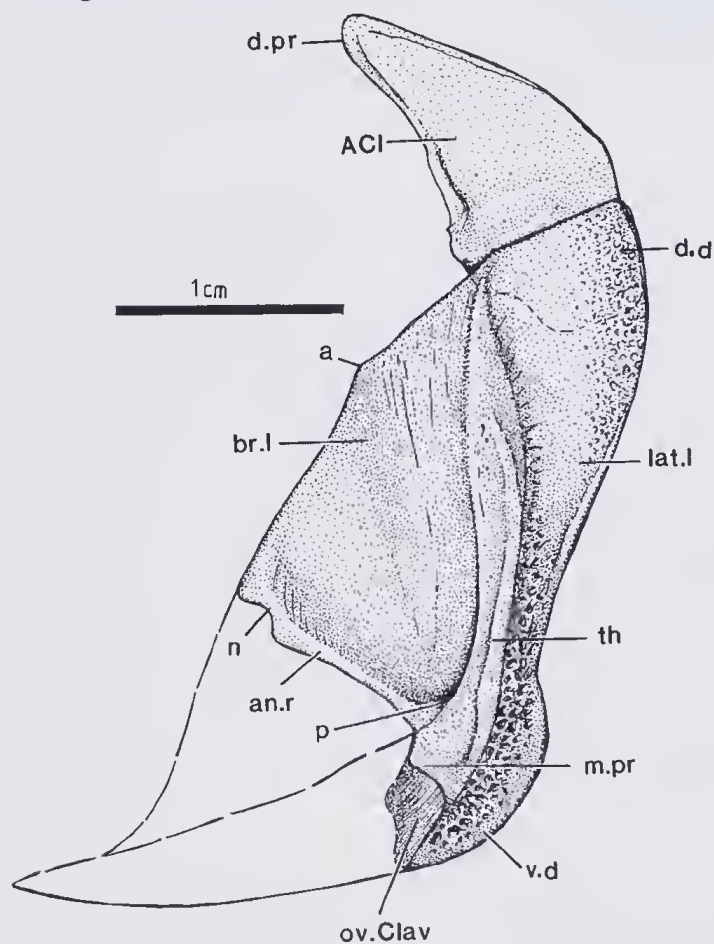
Figure 6   *Eoctenodus microsoma* Hills. Attempted reconstruction of the shoulder girdle. a, anterior angle of branchial lamina; ACl, anocleithrum; an. r, anterior ridge of branchial lamina; br. l, branchial lamina of cleithrum; d.d, dorsal division of cleithrum; d. pr, dorsal process of anocleithrum; lat. l, lateral lamina of cleithrum; m. pr, median process of ventromesial surface of cleithrum; n, notch on the anterior apex of the branchial lamina; ov. Clav, overlap surface for clavicle; p, mesial pit where branchial lamina meets lateral lamina; th, lateral thickening of cleithrum; v.d, ventral division of external (lateral) lamina of cleithrum.
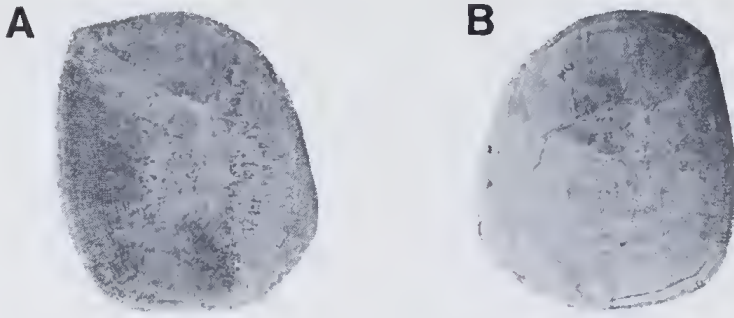
Figure 7   *Eoctenodus microsoma* Hills. Scale, NMV P 186565 in A, external and B, basal view. X2.

The mesial surface of the anocleithrum (Figures 4-C; restored in Figure 5) is found resting inside the cleithrum. The close association of these two bones indicates that in life they were probably held together by ligaments, as most of the material from Taggerty consists of detached, isolated bones. It is identified as an anocleithrum by its large size relative to the cleithrum, close association with the cleithrum, and by having a well developed anterior median ridge (am. r) and long tapering dorsal process (d. pr). In these respects it corresponds with that of other Devonian Dipnoi (*Scaumenacia*, Jarvik 1980, vol. 1, fig. 335; *Chirodipterus australis*, *Griphognathus whitei* — A.N.U. specimens). It is a rather flat, irregularly-shaped bone, approximately twice as long as broad, and was situated mesial to the cleithrum, probably buried in the dermis (subdermal) as appears to be the case in all the known dipnoans. A small part of the lateral surface of the anocleithrum is preserved, showing some fine pitting close to the centre of the bone, and well developed overlap ridges along both anterior and posterior margins (Figure 5). The fine pitting on the lateral surface does not indicate that the bone was necessarily part of the externally exposed shoulder girdle, instead it probably functioned as a roughened attachment area for skin or ligaments. In *Chirodipterus australis* the anterodorsal tip of the anocleithrum articulates to the rear of the braincase (Prof. K. Campbell, pers. comm.), where it was probably joined by ligaments in life. The long dorsal process of the anocleithrum of *Eoctenodus* and *Scaumenacia* indicates that this may have been a specialised condition for dipnoans as in other osteichthyans which possess an anocleithrum it serves merely as a surface to accomodate movements between the dorsal and ventral divisions of the pectoral girdle (Andrews and Westoll 1979*a*, *b*; Andrews 1972; Long 1985*a*, 1985*b*).

There is a small bone preserved in mesial view on the same rock as the holotype upper jaw. It is rectangular in shape, having a breadth/length index of 65 with a well rounded posterior margin, and a broad overlap surface at the anterior of the bone which narrows posteriorly along the dorsal margin terminating at the presumed posterodorsal corner. This bone (Figure 5-C) corresponds both in size

(assuming it is associated with the holotype upper jaw which gives an estimated head size of 6 cm), shape and overlap margins to being either a subopercular or branchiostegal ray (cf. Campbell and Barwick 1984, fig. 27-C). There are no indications of ligamentous attachment areas as occur inside the opercular bones (Campbell and Barwick 1984). The mesial surface is smooth with a shallow depression running parallel to its long axis in the centre of the bone.

The scales of *Eoctenodus* have been described and figured by Hills (1929, plate 18, figs. 3, 5, 6). In addition to Hills' description it may be added that the ornamentation comprises very fine wavy ridges which are sparsely distributed over the externally exposed portion of the scale, which comprises about one-third of the scale length (Figure 7). In this respect they differ noticeably from scales of the *Scaumenacia* type (Jarvik 1950, fig. 33) which have a higher density of ornamental ridges.

Relationships of *Eoctenodus*

The presence of a long, narrow occipital stalk on the parasphenoid, similar form of the toothplates and tooth ridges, and cleithrum with very broad branchial lamina indicate that *Eoctenodus* is probably closely related to *Ctenodus* and other ctenodontids. The presence of a similar type of parasphenoid, dentition and cleithrum in *Sagenodus,* which shows more derived features of the skull roof pattern than for *Ctenodus* (Miles 1977), would suggest placement of *Eoctenodus* close to the base of the group containing ctenodontids and sagenodontids. Its exact relationship remains indeterminate due to the paucity of present material. The Frasnian occurrence of *Eoctenodus* would make it the oldest known member of the ctenodontid-sagenodontid group, which are otherwise restricted to the Carboniferous and Permian periods. *Delatitia (Ctenodus breviceps* Woodward 1906), from the Lower Carboniferous of Victoria, is the only other member of this group which has been described from Australia (Long and Campbell 1985). As this genus and *Eoctenodus* are both primitive relative to other ctenodontids it is possible that the ctenodontid group may have originated in the East Gondwana region.

Comments on other Australian records of the genus *Dipterus*

As *Eoctenodus* has now been shown to be a valid genus the presence of *Dipterus* in the Australian Devonian remains to be shown. Two other reported occurrences of *Dipterus* are from the Late Devonian (Frasnian) Gneudna Formation, Western Australia (*Dipterus* cf. *D. digitatus,* Seddon 1969) and from the Famennian Hervey Group, NSW (*Dipterus* sp. Hills 1936).

The two upper jaw toothplates from the Gneudna Formation which were figured by Seddon (1969, plate 2) have been re-examined. The largest and better

preserved of the two specimens is shown in Figure 3-F. Both Miles (1977, page 292) and Dring (1980, unpublished Ph.D thesis, Geology Department, University of Western Australia) have remarked on the similarity of these specimens to the dentition of *Chirodipterus australis,* which occurs in the Gogo Formation, of similar age to the Gneudna Formation. The chirodipterid type of dental plate is generally distinguished from those of other Devonian dipnoans in lacking well formed rows of discrete cusps, as in dipterid or ctenodontid tooth-plates, instead showing bulbous, well-rounded ridges or swellings at the anterior end of the plate which merge into the smooth depressed area comprising the posterior half of the tooth-plate. The histology of the chirodipterid dental plate is also distinctive (Dr Moya Smith, pers. comm.). In their shape, development and number of grooves present, and approximate relative size of tooth-ridges the Gneudna dipnoan dental-plates can be assigned to *Chirodopterus australis* with reasonable confidence. *Chirodipterus paddyensis* Miles, also from the Gogo Formation, can be distinguished from *C. australis* by the deeper grooves and higher, sharper tooth-ridges (Miles 1977), and *C. wildungensis* Gross differs from both of these species in possessing well formed tubercular cusps along the tooth rows (Save-Soderburgh 1952). Other chirodipterid-type toothplates, such as those reported from the Middle Devonian of Iran by Blieck *et al.* (1980, plate 1-18, 19) differ from *Chirodipterus australis* by their narrower form and more pustulose, shorter tooth rows.

Dipterus sp. was reported by Hills (1936) from Gingham Gap, in the Hervey Range, NSW on the basis of a single left upper jaw toothplate (Figure 3-E). In having discrete round cusps set in rows which are well separated, and radiate out to form almost a right angle from the first to last rows this specimen does appear to be close to *Dipterus* in as far as dentition may allow such comparisons. A radiating pattern of numerous separate cusps forming the tooth ridges also occurs in *Rhinodipterus,* (Ørvig 1961), and *Scaumenacia* (Westoll 1949). However, other dipnoan toothplates which are identical to the Gingham Gap specimen in their shape, arrangement of cusps and angular radiation of tooth ridges are common in the Famennian Hunter Siltstone, near Grenfell, New South Wales. This fauna is of similar age and geographic location to the Gingham Gap fauna, and it would not be unlikely that the dipnoan toothplates from these two locations could be congeners or even conspecific. The resemblance to *Dipterus* in toothplate morphology is, however, offset by the shape of the parasphenoid in the Hunter Siltstone dipnoan. Two specimens of the parasphenoid (Australian Museum F 56323, F 56155) from the Hunter Siltstone occur with the *Dipterus*-type of toothplate, and as there is no evidence suggesting that more than one form is present in the fauna it can be assumed that the parasphenoids belong to the same species which possessed the toothplates. The parasphenoids have no similarities to that of *Dipterus* as they have a square-shaped corpus and a very long occipital stalk (ratio of corpus length to overall length being between 30-37%), thus being closer in form to the parasphenoid of *Ctenodus.* A further distinction from *Dipterus* is in the apical angle of the parasphenoid which is close to 90 degrees in

the Hunter Siltstone dipnoan (approximately 70 degrees in *Dipterus*). If the Hunter Siltstone dipnoan and the Gingham Gap dipnoan are congeners then they do not belong to the genus *Dipterus,* but are more apomorphic than this genus in the development of the parasphenoid. In conclusion the presence of *Dipterus* in Australia cannot be confidently demonstrated.

The genus *Dipterus* is known from complete material only from the Middle Devonian of Britain (Forster-Cooper 1937, Westoll 1949), and from partial skulls and toothplates from Germany and Baltic Russia (Gross 1934, 1951, 1964), from inland Russia (Obruchev 1940) and dubiously from North America (see discussion in Denison 1951; Denison 1968). The reported *Dipterus* toothplate from Alaska (Perkins 1971) appears to be similar to the chirodipterid dental plate type and needs further investigation. Reed (1985) recognised the difficulties in determining isolated dipnoan toothplates to genera and preferred to assign material from the Late Devonian of Nevada into indeterminate taxa at the *Dipterus* grade of organisation. A single worn, damaged toothplate of *Dipterus* was reported from the Late Devonian of Iran (Janvier and Martin 1978) but does not reliably indicate the presence of *Dipterus* from a Gondwana country when considering the nature of the Hunter Siltstone dipnoan which has *Dipterus*-type dentition with an advanced parasphenoid. The genus *Dipterus* occurs in Laurasian countries during the Middle and possibly Late Devonian, but is not yet proven to occur in Australia or any part of the East Gondwana Province (*sensu* Young 1981) during these times.

Acknowledgements

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SHORT COMMUNICATIONS

A note on the occurrence of *Bolbosoma capitatum* (Linstow, 1880) (Acanthocephala) from a false killer whale stranded on the coast of Western Australia

S.J. Edmonds*

About 50 specimens of an acanthocephalan, *Bolbosoma capitatum* (Linstow), were found firmly embedded in a section of the gut wall of one of the false killer whales, *Pseudorca crassidens* Owen, stranded in late July, 1986 at Augusta, Western Australia. The section of gut to which the parasites were attached was sent for examination from the Veterinary Clinic of the Department of Agriculture, Western Australia. The infestation must have been a heavy one. Linstow (1880:49) cited *Pseudorca crassidens* as the type host of the acanthocephalan. It is most likely that a crustacean is the first intermediate host of the parasite and a fish the second.

The specimens are long and wormlike. Length of trunk, female 20-90 mm, male 30-35; maximum width 2-3 mm. An anterior 'fastening complex' is set on a long neck and consists of (1) most anteriorly an introvert, (2) a median truncated, conical structure and (3) posteriorly a larger globular to subglobular, heavily armed region. The introvert is 0.5-0.6 mm long, 0.2-0.45 wide, armed with 15-17 rows of 6-8 hooks/row. The conical section consists of an anterior spined part about 0.5-0.6 mm long and an unarmed part about 0.4-0.5 mm long. The globular structure is 1.1-2.0 mm long and 2.6-3.1 mm wide and is heavily armed with strong spines. The whole 'complex' constitutes a very effective adhesive organ. When it penetrates below the submucosal layers of the gut it expands to become a swollen bulb with sharp, backwardly directed spines. Embryonated eggs are 0.130-0.140 mm long, 0.030-0.038 wide and possess polar prolongations of the middle membrane. The specimens differ from *Bolbosoma hamiltoni* Baylis, 1929 from the fin whale, *Balaenoptera physalus,* in the number of rows of introvert hooks.

The only other report of *B. capitatum* from Australia is that of Edmonds (1957) who reported it from some specimens of *Globiocephala melaena* Traill stranded at Prime Beach, St Vincent Gulf, South Australia in 1944. In a more recent publication Ling & Aitken (1981) considered these whales to have been *P. crassidens* and not *G. melaena*. Specimens of the parasite have been deposited in the Western Australian Museum (WAM 405-86) and the Australian Helminthological Collection (AHC 16307), South Australian Museum, Adelaide.

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The rediscovery, after 56 years, of the Heath Rat
Pseudomys shortridgei (Thomas, 1907)(Rodentia: Muridae)
in Western Australia

Alexander Baynes[1], Andrew Chapman[2]
and Antony J. Lynam[3]

The Heath Rat *Pseudomys shortridgei* (Thomas, 1907), was described from a single individual obtained by G. Shortridge in 1906 in the course of the Balston Expeditions (Shortridge 1936). The specimen was collected at "Woyaline Wells", which later became the gazetted townsite of Woyerling (32°31'S, 117°24'E). The only other specimens taken as fresh material in Western Australia were two received by the Western Australian Museum (M1389, M1406) in April and June 1931 from Joyce Savage, who lived near Buniche in the south-eastern wheat belt. The first had been caught by the family cats, presumably near the homestead on her parents' property, Roe Location 1182 at 32°52'S, 118°48'E, which is immediately south of the current Harris Nature Reserve (No. 32549). In 1961 *P. shortridgei* was discovered living in western Victoria (e.g. Seebeck 1976).

Material from surface cave deposits shows that immediately before European colonization, *P. shortridgei* had an extensive distribution (Figure 1) through the west coastal heaths and the mallees of south-western Australia, reaching to the extremities of the South-west Botanical Province of Beard (1980) (Butler and Merrilees 1971; Archer and Baynes 1973; Baynes 1982, in press). Until recently it seemed that *P. shortridgei* had disappeared from its entire Western Australian range, and it was generally regarded as extinct in the state (e.g. Cockburn 1983).

Its rediscovery comprises a typical combination of coincidence and serendipity (see Ride 1970, Chap. 2).

The first indication that *P. shortridgei* might have persisted until relatively recently, came in the form of remains of three individuals in a small owl pellet deposit found in 1984 in a dead tree by K. Bradby, south-west of Ravensthorpe and north of the Fitzgerald River National Park (Figure 1). The associated fauna was restricted to extant species. There was no indication of the precise age of the material, but it appeared unlikely to be more than a few decades old.

The next, much stronger lead arose out of the fauna survey of Fitzgerald River National Park being carried out by Chapman. In January 1987 he sent bones from

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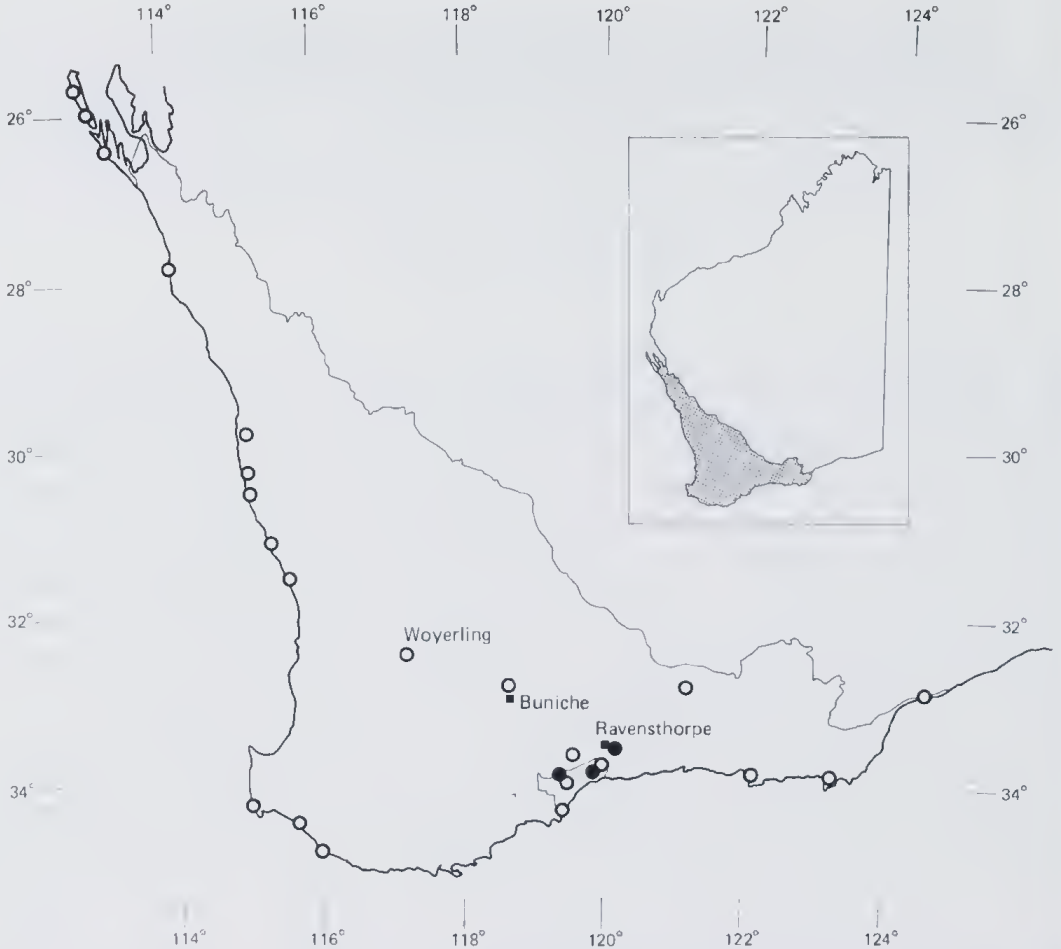
Figure 1   South-western Australia, showing the boundaries of the South-west Botanical
             Province of Beard (1980) and Fitzgerald River National Park, with former (open
             circle) and present day (closed circle) locality records of *Pseudomys shortridgei*.

some apparently fresh owl pellets from the western part of the Park to Baynes for
identification. The bones are translucent white, consistent with being fresh, and
include remains of a single subadult *P. shortridgei*. This discovery led to a decision
to seek funding to search for a living population in the following financial year.

On Friday 13 February 1987, Chapman telephoned Baynes to ask if he was
willing to identify owl pellet specimens generated by the proposed search. Later
the same day, Baynes was looking through the WA Museum collection of *Rattus
fuscipes* specimens in spirit for a totally unconnected reason. He wanted a well
preserved specimen with an evenly scaled tail to use in redrawing the final illus-
tration for the last of a set of keys to the mammals of Australia. Examining a
specimen through the side of its glass container he noticed that the individual
tail scales were more clearly visible than those on the *R. fuscipes* he had been

drawing. It then became apparent that the tail on this rat was more densely covered in hairs, and darker on the dorsal surface than the ventral; both characteristic of *Pseudomys* rather than *Rattus*. The bottle contained another *P. shortridgei* and one *R. fuscipes*. The specimens had been collected by Chapman in 1983 in the Ravensthorpe Range!

The rediscovery was undoubtedly delayed by the great similarity in external appearance of *P. shortridgei* to Western Australian individuals of *R. fuscipes*. Indeed, Joyce Savage's specimens were originally registered as *R. fuscipes* by L. Glauert, Curator of the WA Museum in 1931. Shortridge (1936) himself also noted a similarity. The Ravensthorpe Range specimens were among a series of 13 individuals retained by Chapman from among the many animals he trapped in the course of a survey of the Range (Chapman 1984), and which he identified as *R. fuscipes*. They were received at the WA Museum in 1984 and duly registered as *R. fuscipes*. Examination of the rest of the series revealed one more *P. shortridgei*. The registration numbers are M24951, M24959 and M24971. The skull was removed from M24971 to confirm the identification.

On 14 February 1987 Lynam joined Chapman in the Fitzgerald River National Park in order to live-trap Dibblers *(Parantechinus apicalis),* as part of a study of geographic variation in that species. They set out grids of Elliott traps and pit traps in mallee heath. Alerted by Baynes' discovery in the WA Museum, they carefully checked the tails of the *"Rattus fuscipes"* that entered the traps. On 18 February Lynam caught a *P. shortridgei* in an Elliott trap. The same trap had contained a *R. fuscipes* the morning before and contained another the following day. This *P. shortridgei* was retained and has been accessed into the WA Museum collection (M26644). On 19 February Chapman pit trapped another *P. shortridgei* about 300 m away.

The Ravensthorpe Range *P. shortridgei* originated, respectively, from Chapman's traplines 7, 8 and 9, 10-12 km east of Ravensthorpe townsite. The habitats at these sites (Chapman 1984) were: Shrub Mallee over Banksia scrub over mixed Low Scrub A on gravelly fine sandy loam; mixed Low Scrub B over *Lepidosperma* Open Low Grass on fine sandy loam; and Shrub Mallee over mixed scrub over *Lepidosperma* Open Low Grass on clay loam. The habitat at both sites in the Fitzgerald River National Park is Very Open Shrub Mallee over Open Low Scrub B over Dwarf Scrub C over Dwarf Scrub D over Open Low Sedges on light brownish grey, loamy fine sand.

Pseudomys shortridgei in Victoria occurs in recently burnt heath, reaching maximum numbers when productivity is at a maximum and then disappearing (Cockburn 1983). In marked contrast, the mallee heath in which the Ravensthorpe Range specimens were trapped has not been burnt for at least 40 years, and the Fitzgerald River National Park habitat for at least 30 years (cf. fire age map in Muir 1985).

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CONTENTS

museum

RECORDS of the Western Australian Museum

Volume 13, Parts 3 & 4. 1987

A new species of *Adinolepis* Neboiss from Western Australia (Cupedidae : Coleoptera)

Arturs Neboiss*

Abstract

Adinolepis apodema sp. nov. is described from a specimen collected at Gleneagle near Perth, Western Australia. This is the first record of the family Cupedidae from Western Australia.

Introduction

In the reclassification of the genus *Cupes sensu lato* Neboiss (1984) placed four of the Australian species in a new genus *Adinolepis*. While the fifth Australian species, *varians* Lea, was referred to another new genus *Distocupes*. All these species have been restricted to the eastern part of the continent, and the capture of *Adinolepis eumana* (Neboiss) near Adelaide was the furthest western record.

Shortly after publication of this paper (Neboiss 1984) two additional specimens were received for identification. One of them from Davies Creek road via Mareeba North Queensland, captured in Malaise trap in rainforest belongs to *Adinolepis scalena* Neboiss, while the other from Western Australia represents an undescribed species of the genus *Adinolepis* closely resembling *A. mathesonae* (Neboiss). This is the first record of the family Cupedidae from Western Australia, extending the distribution for more than 2000 km westward.

Systematics

Adinolepis apodema sp. nov.

Figures 1 and 2

Holotype

In WAM (87/886), ♀, Canning River, 4 km E of Gleneagle, Western Australia by Hanich on 6 January 1981.

Diagnosis

The colour pattern of the elevated interval 3 distinguishes this species from *A. mathesonae* (Neboiss) (Figure 3).

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Description

Female. Length 7.8 mm, maximum width 2 mm; head densely covered with pale sandy brown scales, irregularly intermixed with individual dark brown scales; a pair of conical tubercles close behind the bases of antennae, there are no elevations above eyes (Figure 1). Eyes proportionally similar in size to those in *A. mathesonae*. Scales present on all antennal segments.

Pronotum generally pale sandy brown with sprinkling of dark scales, barely wider than long; lateral margins gently curved; anterior angles indistinct.

Elytra dorsally flattened; suture moderately raised on the entire length; uniformly covered with dark brown scales; interval 3 evenly elevated, most of it covered with dark brown scales except for a short pale section just posteriorly of middle and at junction of interval 3 and 5; interval 5 with two short pale sections; interval 7 with pale scales at the humeral end, a long section posterad of middle, and a short one a little further distad (Figure 2).

The specimen was captured at night with black-light trap.

Male unknown.
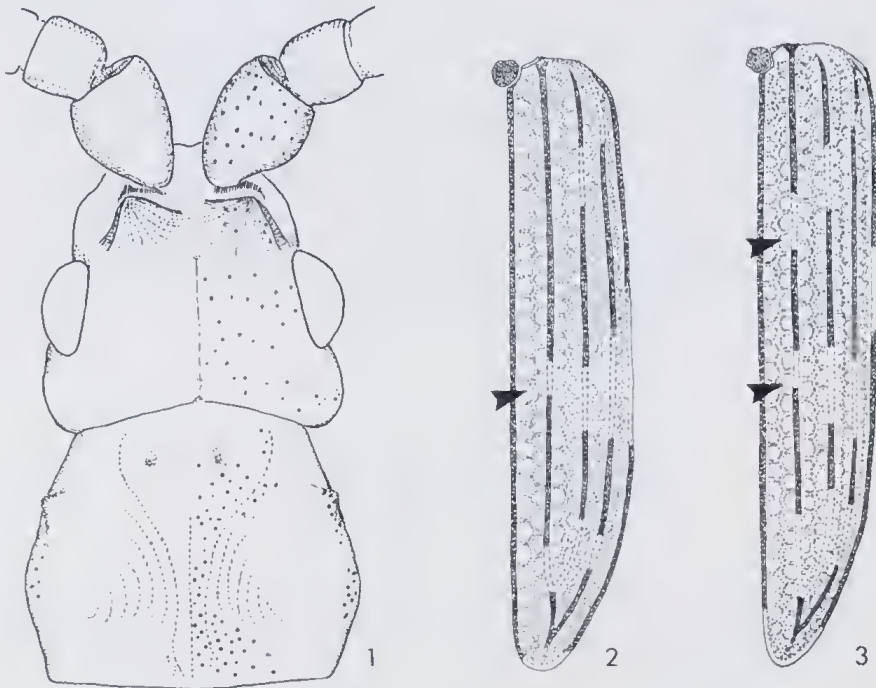
Figure 1   *Adinolepis apodema* sp. nov. holotype, outline of head and pronotum in dorsal view (density of dark scales on right side).

Figure 2   *A. apodema* sp. nov. holotype, dorsal aspect of right elytron showing arrangement of dark and pale scales on elevated interval 3.

Figure 3   *A. mathesonae* (Neboiss) paratype, dorsal aspect of right elytron showing arrangement of dark and pale scales on elevated interval 3.

A key to the species was given by Neboiss (1984). *A. apodema* may be included in this key by amending couplet 3 and adding a new couplet as follows:

3 Humeral end of elevated interval 3 covered with dark brown scales 4
- Humeral end of elevated interval 3 covered with pale brownish scales. . . . . . .
. . . . *youanga* (Neboiss)

4 Elevated interval 3 with two moderately long sections of pale scales on disc, and at the junction of intervals 3 and 5. . . . .*mathesonae* (Neboiss)
- Elevated interval 3 with only one short section of pale scales just beyond middle and and at the junction of intervals 3 and 5. . . . . *apodema* sp.n.

Acknowledgements

Reference

Neboiss, A. (1984) — Reclassification of *Cupes* Fabricius (s. lat.), with descriptions of new genera and species (Cupedidae : Coleoptera). *Systematic Entomology* 9: 443-477.

Morphology of a remarkably well preserved australite found near Ravensthorpe, Western Australia

W.H. Cleverly*

Abstract

An australite (Australian tektite) found near Ravensthorpe, Western Australia, is unweathered except for a complex pattern of lines etched on the posterior surface of flight. Other australites from the area show various degrees of weathering and abrasion. A double rim and obtuse ridges on the anterior surface are minor by-products of the loss of the stress shell which have survived because of the insignificant degree of weathering. The surface flaking of the two retained areas of stress shell could be artificial. Enclosure within clayey soil may have minimised water circulation and restricted weathering.

Introduction

In June 1985 Mr A.C. Anderton took an australite (Australian tektite) which he had found on his property near Ravensthorpe to the Albany Branch of the Western Australian Museum for identification and report. Subsequently he donated it to the Western Australian Museum (registration number G13 655). It is remarkable for the almost complete absence of weathering and hence the survival of minor features which have not been reported previously on an australite.

Mr Anderton found the specimen while clearing stones from cultivated ground near the north-east corner of Oldfield Location 850, 11 km west of Ravensthorpe, at c.- 119°56′E, 33°35′S. It was at the edge of a stone pile on a low ridge of soil turned up by the plough and thus exposed to rain wash.

Description

Australite G13 655 is a round "indicator" in the sense of Fenner (1935, Fig. 1, 1940, p. 316), i.e. a round core from which the aerothermal stress shell has been incompletely discarded. The dimensions are (40.5-42.2) mm diameter x 33.4 mm thick, weight 73.87 g, specific gravity 2.431. Morphological details are described below in sequence from the posterior surface of flight to the anterior surface.

The posterior surface of flight, a remnant of the surface of the primary body, is shiny but with some deep scratches. A test cut in the edge made by the finder with a grinding wheel resulted in a minor loss ~ 0.05 g. Close inspection in oblique

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light shows the presence of three dark clear areas with circumferential bands, and outside them, a matte surface. One of the round clear areas is 10.3 mm diameter and near the edge of the posterior surface (the rim): the other, *c.* 16.4 mm diameter, is truncated by the rim (Figure 1A) and has a less regular, poorly defined feature with etched centres and complex structure tangential to it. A poorly defined, ovoid feature ajoins and is truncated by the rim. It has a clear central area about 10 mm long (incomplete) and up to 4 mm wide. All of these structures appear to be flow swirls at a very early stage of delineation by etching.

Microscopic examination reveals complex patterns of very finely etched lines surrounding the clear areas and responsible for the matte appearance. The types of pattern (Figure 2) tend to progress outward from the central clear area through parallel lines to braided lines, braided cells, cells, and complex patterns of cells in sheaves or other arrangements, but with some reversals and omissions. There are generally 20-50 lines per millimetre of width. At the opposed ends of a diameter of the smaller round clear area, the following were observed outward using the type letters of Figure 2, width in millimetres and estimated number of lines or cells per millimetre in brackets.

(i) A 10.31 mm, B a single line, A 0.05 mm, B 0.69 mm (25), C 1.03 mm (50), B 0.92 mm (40), E 1 mm plus (20).

(ii) A 10.31 mm, B 0.88 mm (40), C 1.17 mm (50), D 1.68 mm (50), E 2 mm plus (35).

For the ends of a diameter of the larger clear round area, the following were observed outward:-

(i) A 16.37 mm, B a single line, A 0.15 mm B 0.06 mm (80), D 0.91 mm (30), E 0.87 mm (30), F 2 mm plus.

(ii) A 16.37 mm, B two lines, A 0.16 mm, B 0.14 mm (57), C 0.90 mm (40), E 3.6 mm plus (25).

The above figures are approximate, partly because the observations are of an unprepared and strongly curved surface, partly because boundaries between types may be transitional as shown somewhat diagrammatically in Figure 2. It may be seen by comparing the ends of a traverse line that there are considerable differences arising from the lensing out of pattern types. The traverses should not be regarded as necessarily typical. Two additional traverses outward from the larger round clear area gave results which are yet further variations on the general theme.

The rim of the australite is sharp and regular but missing along two diametrically opposed lengths of 17 mm and 35 mm respectively where there are extensive areas of conchoidal flaking (Figures 1B and 1C). Close inspection shows that the rim is double, a second gently convex ridge being present on an average 1 mm beneath the overhang (i.e. to the anterior) of the main rim, somewhat in the mannner of a double chin (Figures 1D and 1E).
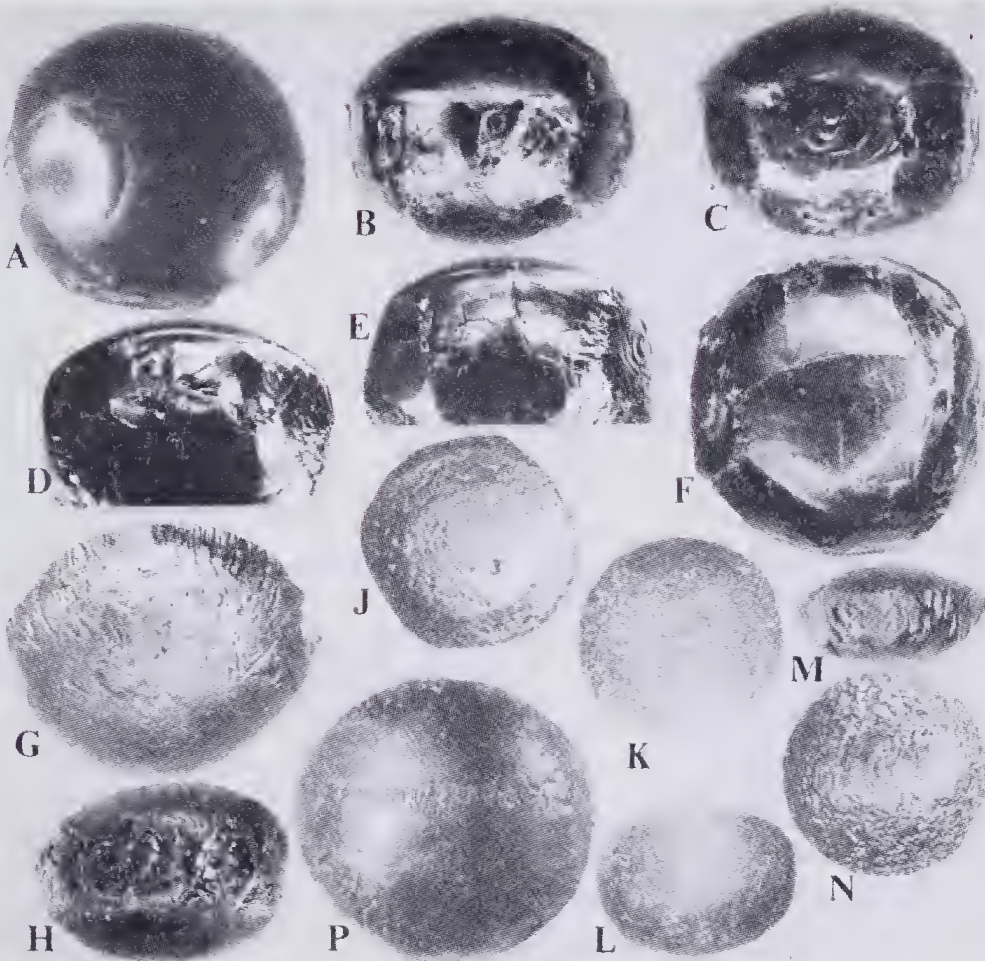
Figure 1   Australites from Western Australia, natural size unless otherwise stated. In elevational views, direction of flight is towards bottom of page. A-F. Round indicator G13 655 from west of Ravensthorpe. A. Oblique view of posterior surface, highlighted to show the circumferential bands of the two round smooth areas. B. Elevation with flake scars centre and left and the wider of the two flaked areas at extreme right. C. Elevation with narrower conchoidally flaked area central and showing point of percussion. D. Posterior half of australite viewed obliquely upward towards the double rim. E. Another view upward toward the double rim with an obtuse ridge sub-dividing the field of view. F. Anterior surface with narrow and wide flaked plateaus to left and right and obtuse ridges elsewhere. G. Obliquely upward view of anterior surface and equatorial zone of broad oval core from west of Ravensthorpe. H. Side veiw of round core from west of Ravensthorpe. J. Anterior surface of button core from west of Ravensthorpe showing two flow ridges (one near the edge and incomplete). x 2. K. and L. Posterior surface and elevation of severely abraded round core from west of Ravensthorpe. M. Elevation of round core from west of Ravensthorpe. N. Posterior surface of round core from Mount Madden showing group of flow swirls in deeply bubble pitted surround. P. Anterior surface of round core G13 654 from Gnowellen.
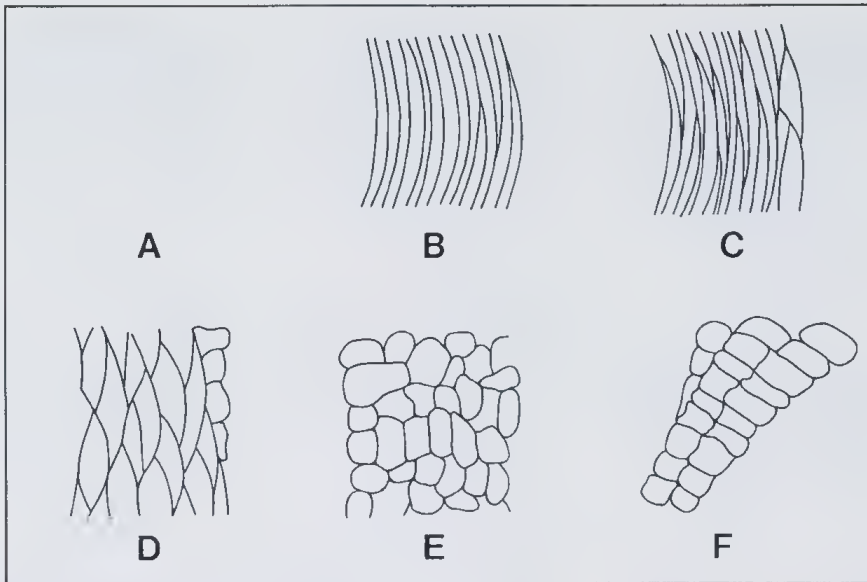
Figure 2   Types of etched pattern on the posterior surface of the australite G13 655 from west of Ravensthorpe. A. Clear. B. Lined. C. Braided. D. Braided cellular. E. Cellular. F. Complex cellular.

The equatorial zone is 13-14 mm wide. Where undamaged, it shows some so-called "flake" scars (Baker 1940) separated by low obtuse ridges. The two conchoidally flaked areas mentioned above are also centred on this zone and extend beyond it to affect in the one direction the rim and posterior surface and in the other the anterior surface (Figures 1B and 1C). In spite of their flake losses, these two areas stand up as low plateaus ~ 1 mm above the adjacent equatorial zone (Figure 1F). There are centres of percussion upon each (Figure 1C).

The obtuse ridges between the "flake" scars of the equatorial zone extend out over the anterior surface created by loss of the stress shell and are the dominant feature there, sub-dividing the surface into several blocks (Figure 1F). Sprays of fine lines such as occur on australite artefacts are related to the rim and to these low ridges. Similar fine lines are also abundantly present on the two conchoidally flaked areas.

A traversing vernier microscope was used to determine the form of the posterior surface of the australite along two profiles through the posterior pole approximately 90° apart. Both profiles are closely arcs of circles. The first has radius of curvature 24.9-25.1 mm and the second 24.6-25.0 mm. The mean of these ranges is 24.9 mm and the primary body has been calculated as a sphere of that radius. The primary sphere had volume nearly 65 cm^3 and mass c. 157 g, on the assumption that it had the same specific gravity as the remnant australite. In forming the indicator, the primary body lost rather more than half of its volume (or mass) and one-third of its thickness. These losses are within usual ranges.

The site of find

The site of find is close to the concealed boundary between gneiss and a complex unit of metamorphosed sediments and igneous rocks (Sofoulis 1958). Most boulders on the stone pile appear to be of acid gneiss but some could be arenaceous metasediment. The soil contains a full range of sizes from coarse angular quartz of centimetre size down to silt and clay. It appears to have formed *in situ*. The silt and clay fraction is evidently prominent because water from earlier rain and the light rain falling at the time of inspection was lying on the surface of the ground. The soil at the site of find had been treated with superphosphate and cropped several times but a sample could be taken for chemical testing from about 2 m distant beneath the shallow stone pile, thus reducing the chance of contamination by fertilizer.

Other australites from the same general area

It is pertinent to investigate whether the state of preservation of the australite G13 655 is unique or usual amongst australites of the district.

The only australite known to the writer from the Ravensthorpe area prior to Mr Anderton's find is a rather weathered, plano-convex form in the E.S. Simpson collection held by the Western Australian Museum. However, enquiries at properties neighbouring Location 850 yielded several additional specimens for inspection and comparison with G13 655.

A large broad oval core from the gravel pit 11 km west-south-west of Location 850 shows considerable chemical weathering in the etching of schlieren on the posterior surface and abundant development of U-grooves (Figure 1G).

Three australites from Location 65 to the immediate south of Location 850 comprise: a round core with "irregular base" (Chapman 1964; p. 851 and Fig. 11) and severely ctched "flake" scars (Figure 1H); a somewhat weathered button core, on the anterior surface of which two flow ridges are still discernible (Figure 1J); a round core which is severely abraded, showing occasional round percussion scars and innumerable lunate remnants of such scars, having evidently travelled a considerable distance down the Phillips River (Figure 1K and L).

A round core from the bank of Annabel Creek 7 km east-north-east of Location 850 has the "black enamel" appearance resulting from rapid chemical dissolution of glass. Chemical attack has accentuated schlieren on the posterior surface, developed U-grooves and modified the "flake" scars (Figure 1M).

No australites were available from immediately north of Location 850 but two were examined from the Mount Madden area about 30 km north-north-west. They are a round core with a group of three flow swirls accentuated by etching of the deeply bubble-pitted posterior surface (Figure 1N) and a specimen which has lost flakes, been worn smooth and since further modified by chemical action.

Thus eight australites from points around Location 850 show variously an imperfection of form, mild to severe degrees of chemical etching, mild abrasion, and in one instance, severe abrasion; none shows the perfection of form and high degree of preservation of G13 655.

Discussion and conclusions

The australite shows rare and possibly unique features — the double rim, the obtuse rim, the obtuse ridges, the etched patterns of the posterior surface and the flaked remnants of stress shell. It is conceivable that the minor features were once present on many australites and that they are remarkable here only because they have survived.

The second small rim and the obtuse ridges are on surface created by loss of the acrothermal "strained zone" (Baker 1963) or "stress shell" (Chapman 1964). The following mechanism is proposed to account for the loss of the stress shell and the creation of a rim (or rims), the so-called "flake" scars of the equatorial zone and the obtuse ridges on the anterior surface. The heated and expanded anterior shell exerted pressure on the protected and relatively cold posterior shell during ablation flight. Frontal air pressure assisted the compression. The anterior shell tended to override the posterior surface on a shear which steepened towards free surface in the manner of a thrust fault. The pressure thus established a sheared weakness which was utilised by the subsequent tensile forces of contraction to detach the stress shell in that vicinity and form the rim. The smoothly curved underside and regular nature of many rims is in keeping with a pattern of failure initiated by compression. Tension in rapidly cooling and brittle glass would be expected to result in ragged and irregular fractures. It is a matter of further conjecture whether the site of the shear would migrate posteriorly as ablation stripping continued from the anterior surface to result in two or even a series of shears: in that manner there might arise a double rim as on the Ravensthorpe australite.

The even size and spacing of the "flake" scars (Baker 1940) on many cores points to an origin related to the thermal history of the symmetrical form as a whole in steady flight orientation. It is suggested that a mechanism similar to rim formation operated where the expanded anterior shell had its greatest circumference, causing it to ride up at regular circumferential intervals now marked by the obtuse ridges of the equatorial zone. Subsequent to being heated and expanded, the stress shell shrank through a petaloid form, each "petal" detaching from the rim fracture and from its neighbours to curve up somewhat in the manner of drying and shrinking mud flakes, leaving a concave surface, the so-called "flake" scar, and an obtuse ridge between the up-curved "petals". Small remnants of a "petal" persist occasionally within the scar and are separated from the main body by an incomplete concave fracture. The size of the australite and the range

of heating would dictate the number of ridges and "petals" necessary to detach the stress shell with minimal expenditure of work. If flaking of the kind envisaged by Baker (1940) were possible once it would surely have been possible again, yet overlapping scars have never been reported. Further, it would be necessary for all "flakes" to be lost simultaneously or at least in some symmetrical manner if stable flight orientation were to be maintained while the balance of "flakes" were lost.

Detachment of the remainder of the stress shell may have been less systematic. On the well preserved Ravensthorpe specimen the obtuse ridges of the equatorial zone extend out over the anterior surface sub-dividing it into a number of areas from which individual plates of stress shell were detached in mud-flake style as the cooling surface contracted before the hotter interior. Sprays of fine lines related to these low ridges and to the rim such as are present on australite artefacts indicate that the ridges are sites of fracture and parting of the stress shell.

The only other examples of obtuse ridges known to the writer are on two specimens from Finke, NT (SA Museum T. 1375), but a distinctly different feature with the same pattern is often developed on anterior surfaces by weathering. The pattern consists of rows of short transverse U-grooves like a minute ladder (Figure 1P). Several rows with various degrees of development and orientation may be present. These rows of transverse grooves on cores lacking obtuse ridges may mark former plate boundaries with various degrees of residual strain in the glass underlying the stress shell. The grooves would thus be analogous to those developed elsewhere on surface created by loss of stress shell — those normal to the rim in equatorial zones, as a "beard" around remnants of stress shell (Cleverly 1979) or as longer meandrine grooves on anterior surfaces (Chapman 1964 Fig. 6).

Retention of parts of the stress shell on australites as large as G13 655 is not usual but occurs occasionally even on specimens of twice the size (Cleverly 1979). The centres of percussion present on each remnant of stress shell and their opposed relationship suggest the possibility that the australite was struck severely on some anvil but Mr Anderton knows of no such incident. Another possibility is that it became firmly clamped by its most upstanding parts in a piece of machinery during clearing of the land or on one of the several later occasions when the land was ploughed and cropped.

The etched patterns are confined to the posterior (primary) surface. The etching was presumably done by soil water, and as with most other types of minor surface sculpture, reflects "built-in" weaknesses such as residual strains or variations in chemical composition arising from earlier events. The relationship here is to primary events because the etch pattern conforms to the boundaries of various round and ovoid features, two of which are truncated by the rim and must therefore have pre-dated secondary events. The only known features of posterior surfaces having centimetre dimensions are flow swirls, and bubble craters. Those present are evidently flow swirls, but seen at a very early stage of delineation. Baker (1972) has described flow swirls on the posterior surface of a large australite

from Victoria as "just detectable", but that is because etched schlieren have been partially removed by abrasion until barely visible. The Victorian specimen is very badly weathered and abraded relative to the Ravensthorpe australite.

The up-welling of melt during the brief and violent primary period of australite genesis is generally held responsible for the clear pools central to flow swirls, but would hardly appear adequate to provide complex surrounding patterns of tens of linear compositional bands per millimetre suited ultimately to differential etching. Nor are the bubble pits of posterior surfaces (Figure 1N) likely to have any relationship to the cellular patterns. They are generally one or two orders of size larger than the etched cells.

The etch pattern tends to change outward from purely circumferential through increasing degrees of obliquity to the cellular with random orientation of individual lines or with complex clustering of cells. It is suggested that this pattern arose from tension in a surface skin of glass, the tension becoming decreasingly radial and increasingly random outward from the flow swirls and having its origin in the drag by down-turn of the liquid currents. The etched lines would then have close analogy with the macroscopic V-grooves of australites, which look like tension cracks and occupy the expected locations of tension cracks, but are produced by preferential solution of glass which has residual strain, thus allowing the crack to gape open and the surface to spread. At greater distance from an individual swirl, the surface would come under the conflicting influence of other swirls, resulting in complex patterns. The thin layer of glass susceptible to etching in this way has probably been removed long since by weathering from the surface of most australites.

Considerations of specific gravity make it unlikely that G13 655 differs significantly in its chemistry from other australites found in the general area in spite of considerable differences in their states of weathering. Nor is there any major difference in the form or relationship to the primary body. Thus the remarkably well preserved condition of G13 655 is not likely to have resulted from any property of its own but from those of its environment since arrival on the earth's surface.

It is suggested that the australite G13 655 fell onto and was embedded in a soil through which water circulation was minimal and that it remained there until brought up during clearing of the land or preparation of the soil for cropping some time during the last 15 years. Etching by soil water prior to disinterment produced the complex patterns of the posterior surface, possibly guided by the in-built "memory" of some primary event. Weathering has been insufficient to eliminate the double rim or the low obtuse ridges of the anterior surface. Some artificial damage has occurred.

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Brooding of juveniles and observations on dispersal of young in the spider crab *Paranaxia serpulifera* (Guérin)(Decapoda, Brachyura, Majidae) from Western Australia

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Abstract

Aspects of the eggs, brooding behaviour and juvenile dispersal of *Paranaxia serpulifera* (Guérin) are described. Observed females carried in excess of 1000 large eggs, the highest recorded fecundity for a direct developing marine brachyuran. Most juveniles leaving the brood chamber dispersed over the posterior carapace and pereiopods of the mother. Juveniles unattached to the mother and on an exposed substrate formed dense aggregations but dispersed when shelter was provided. Juveniles displayed decorating behaviour.

Introduction

Direct (epimorphic) development is uncommon in the Decapoda and very rare in the Brachyura (Williamson 1982). The terms 'abbreviated development' and 'direct development' have been accorded a variety of meanings in the scientific literature (Rabalais and Gore 1985) and are here employed as defined by Gore (1985: 21). The freshwater potamoid crabs and at least one freshwater member of the Hymenosomatidae display direct development and several species of terrestrial Grapsidae have very abbreviated development (Rabalais and Gore 1985), but there are few recorded marine examples. Table 1 summarises aspects of fecundity and hatching in known and possible examples of direct development in marine crabs. All of these species occur in Australian or New Zealand waters. In addition, Kurata (1970) noted direct development in an unidentified species of *Pinnotheres* (Pinnotheridae). Marine Brachyura with very abbreviated, or 'advanced', development as defined by Gore (1985: 23) are not included in the table (see Rabalais and Gore 1985: 82-85).

Of the family Majidae, only *Paranaxia serpulifera* (Guérin) has been recorded as having direct development (Rathbun 1914). This moderately large crab occurs from south-western Australia near Perth northward and eastward to northern Queensland, in depths ranging from the intertidal to approximately 30 m. Rathbun (1914) described and illustrated two stages of juvenile taken from the brood

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Table 1   Egg number, size and hatching stage in marine Brachyura with direct development; c.w. = carapace width, c.l. = carapace length.

Family	Species	Size of mature female (mm)	Number of eggs or young	(e)/(y)	Egg size (mm)	Hatching stage	Reference
Dromiidae	*Petalomera lateralis* (Gray)	14.0-17.0 c.w.	± 20	(y)	1.14 x 1.00	Juvenile	Montgomery (1922), Hale (1925)
	Cryptodromia octodentata Haswell	→85.0 c.w.	530	(y)	± 2.00	Juvenile	Hale (1925), Hale (1927)
	*Epipedodromia thompsoni (Fulton and Grant)	11.0 c.w.	20	(e)	> 1.00	?	Hale (1925)
	*Dromidia australis (Rathbun)	40.0 c.l.	?		± 2.00	?	Hale (1927)
Xanthidae	*Pilumnus novaezealandiae* Filhol	19.0-22.5 c.w.	67-96	(e)	1.50 x 1.40- 1.75 x 1.65	Megalopa	Wear (1967), Wear and Fielder (1985)
	Pilumnus lumpinus Bennett	12.0-22.5 c.w.	53-257	(e)	1.25 x 1.10- 1.45 x 1.35	Late zoea	Wear (1967), Wear and Fielder (1985)
	Pilumnus vestitus Haswell	→18.0 c.w., 12.5 c.l.	→ 100	(e)	1.50 x 1.10	Megalopa	Hale (1931)
Hymenosomatidae	*Elamenopsis bovis* (Barnard)	5.5 c.w.	30	(e)	?	Juvenile	Barnard (1950), Lucas (1980)
	*Hallicarcinus afecundus Lucas	5.4 c.w.	24	(e)	0.70	?	Lucas (1980)
Majidae	*Paranaxia serpulifera* (Guérin)	59.0 c.w., 92.0 c.l. 1250-1690 -85.0 c.w.,129.0 c.l. 162-176		(e) (y)	2.40 - 2.90 ($\bar{x}$ = 2.70)	?	Rathbun (1914), Present sudy

* Suspected direct development

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chamber between abdomen and thorax of a female from the Monte Bello Islands, north-western Australia.

In January 1986, two females of *P. serpulifera* with juveniles held in their brood chambers were netted in Cockburn Sound, 10 km south of Perth. This is only the second recorded observation of brooding in this species and the first in waters in the south of its range. In March 1986, I collected two ovigerous females from Shark Bay, 650 km north-north-west of Perth.

Sizes of specimens are indicated by carapace length (c.l.) and carapace width (c.w.) excluding lateral spines.

Observations of eggs

The ovigerous females (c.l. 115.8 mm and 107.9 mm, c.w. 76.6 mm and 72.8 mm) carried in the brood chambers *ca.* 1690 and 1250 subspherical eggs respectively (estimated by volumetric displacement). Comparison of species in Table 1 indicates that *P. serpulifera* is highly fecund for a direct developing crab and that the eggs are the largest recorded for marine brachyurans with direct development.

Eggs were attached to long, sparse oosetae on the endopods of pleopods. In life, eggs were burgundy with the embryos paler with distinct dark eyes. Embryos possessed a large yolk reserve. Pereiopods were distinctly segmented and the first pair were clearly chelate. The telson was weakly bilobed and the abdomen quite short and narrow. In these features, embryos resemble the zoea/megalopa transition stage of *Pilumnus novaezealandiae* (Wear 1967).

Observations of young

The smaller female with young (c.l. 107.8 mm, c.w. 71.5 mm) was recently dead when examined and carried 176 juveniles of a single size class in the brood chamber (Figure 1). Carapace lengths ranged from 6.1 mm to 6.6 mm, averaging 6.3 ± 0.11 (S.D.) mm. This compares with Rathbun's (1914) record of 162 juveniles of two size classes, averaging 3.5 mm and 5.7 mm c.l. respectively, on a female of c.l. 92 mm and c.w. 59 mm. As observed by Rathbun, the young were definitely juveniles ('in the adult state'). It is not known if they hatched as megalopas or late zoeas as in xanthids (Table 1) or if all larval stages were passed in the egg. Rathbun's observations indicated that at least one moult after eclosion occurs in the brood chamber. The juveniles described here correspond to the larger and presumably older of the size classes recorded by Rathbun.

The larger female (c.l. 129.0 mm, c.w. 85.0 mm) was maintained alive with young in a 45 cm long, 30 litre aquarium. Since it was intended to keep disturbance of the mother and young to a minimum, an accurate count of the juveniles was not attempted. Subsequent removal of the young as they died yielded 117 specimens, but this is certainly an underestimate of numbers due to

loss through cannibalism. Juveniles ranged from 6.0 mm to 6.7 mm c.l., averaging 6.3 ± 0.20 (S.D.) mm.

The large difference between numbers of apparently fertile eggs and brooded juveniles on similarly sized females implies a loss of many eggs prior to hatching, a very high mortality of recently hatched juveniles or sequential eclosion, perhaps with juveniles feeding on the remaining unhatched eggs or younger juveniles.

The juveniles appeared to be in the process of leaving the brood chamber of the female when the specimens were acquired. Numerous juveniles were still present on the female's pleopods but many were on her carapace and pereiopods and others were loose in the bucket in which they were transported. It is possible that

Figure 1   Ventrolateral view of female *P. serpulifera* showing juveniles in brood chamber. Scale = 10 mm.
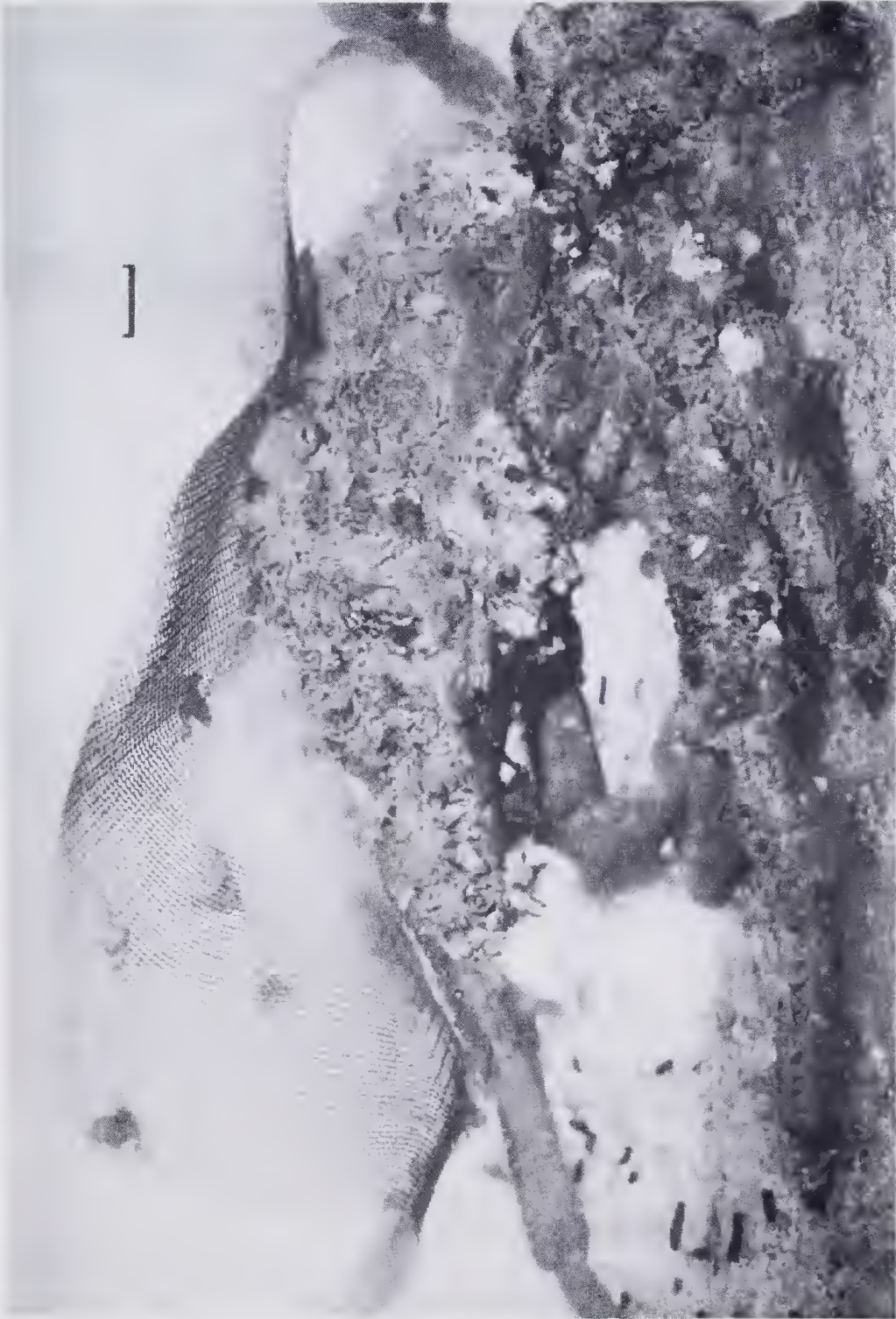
Figure 2   Female *P. serpulifera* with attached flyscreen, juveniles dispersed over female's carapace and pereiopods and screen. Scale = 10 mm.

the exit from the brood chamber may have been premature due to the stress of capture. When introduced to the aquarium those juveniles separated from the female clumped together in associations of two to 20 or more individuals. Over a period of hours the clumps merged into one, comprising more than 100 juveniles. When touched by a second pereiopod of the female (it was not evident if this was a deliberate or accidental contact), the large clump attached to the leg. By the following day, most of the juveniles in this aggregation had dispersed over the female's back and legs (Figure 2). Those juveniles unattached to the female formed several smaller clumps on the floor of the aquarium.

During this period, the female appeared to continually preen the growth of epizoic algal turf, sponges, barnacles and hydroids with her chelipeds. When a chela encountered a juvenile it was grasped lightly, the cheliped extended away from the mother and the juvenile dropped to the aquarium floor. After two days in the aquarium, most of the young still attached to the female were on her back or proximal segments of rear pereiopods where her chelipeds could not reach.

Juveniles on the female did not display the obvious aggregating behaviour shown by juveniles on the aquarium floor. A small sheet of plastic flyscreen was introduced to the aquarium as an artificial substrate and young which moved onto and under this sheet dispersed from each other (Figure 2). The clumping behaviour of the young may be a protective mechanism when on an exposed substrate without shelter. The female attached the flyscreen to her carapace, apparently as a substitute for algae.

While on the female, juveniles fed upon either epizoic organisms or detritus caught in the epizoic growths. Only days after the animals were received, the juveniles displayed both carnivorous habits and decorating behaviour. The female was fed on pieces of crab meat *(Portunus pelagicus)* and fish, and small remnants of the meat were voraciously consumed by the young. Over a period of several days, the number of juveniles declined. Mortality was probably due in part to the aquarium environment but cannibalism cannot be discounted. Dead juveniles did not remain long intact. Siblings removed legs of the dead specimens and decorated their carapace with the appendages, especially on the rostrum and anterior carapace where attachment hooks are most numerous. In some instances the entire corpse of a juvenile was worn by a sibling.

The female was not observed to consume juveniles, either alive or dead, but the decline in numbers of the young over several days without leaving traces probably could not be ascribed only to dismemberment and decoration by other juveniles. All juveniles had died and been removed or had disappeared, presumably eaten, after 20 days of confinement. There was no evidence of juvenile growth in this period.

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Three new legless lizards (Pygopodidae)
from Western Australia

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Abstract

The new taxa are *Delma butleri, Delma haroldi* and *Aclys concinna major. D. butleri* is widespread in southern Australia but was previously confused with *D. nasuta*, which is redescribed. *D. haroldi* occurs in the northern arid zone of Western Australia and is readily distinguished from its congeners by coloration; it alone has narrow pale bands across the head and neck but no broad dark bands. *A. c. major* is an addition to the considerable number of reptiles endemic to the Shark Bay region.

Introduction

In his monograph of the Pygopodidae, Kluge (1974: 110) observed that southern specimens of *Delma 'nasuta'* differed from northern specimens, but he believed that the two forms were connected by clines. Recent collections, notably by the Western Australian Museum's Department of Biogeography and Ecology, the Western Australian Wildlife Centre, and amateur herpetologists financed by grants from Mr and Mrs W.H. Butler to the Museum, have demonstrated sympatry between *D. nasuta* and the southern form, herein described as a new species.

Among the numerous specimens of *'Delma borea'* in the Western Australian Museum were ten that differed from true *borea* markedly and consistently in coloration. They too are described as a new species.

Kluge had only two specimens when he described the genus *Aclys* and its single species. Since then the Western Australian Museum has received another 89 specimens, which permits an evaluation of individual and geographic variation in *A. concinna.* Precisely as in *Pletholax,* the other pygopodid genus endemic to south-western Australia, *A. concinna* proved divisible into northern and southern subspecies separated by *c.* 350 km of well-collected country, from which the species is almost certainly absent.

Kluge departed considerably from the standard nomenclature of lizard head scales. In this paper (and in a forthcoming book on the gekkonid and pygopodid lizards of Western Australia) I return to a more traditional usage and call the scales immediately above and behind the nostril supranasal(s) and postnasal respectively, and I count as loreals all the small scales between the postnasal and ring of ocular scales.

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This paper is based on material in the Western Australian Museum. Except for holotypes the R suffix is omitted from register number of specimens.

Systematics

Delma butleri sp. nov.

Figure 1

Holotype
R76742 in Western Australian Museum, collected by G. Harold and C. Winton on 22 May 1982 at 5 km SE Gnaraloo, WA, in 23°52'S 113°32'E.

Paratypes
The 97 specimens listed under Materal examined.

Diagnosis
A small *Delma* without dark or pale bands across top of head and neck. Distinguishable from *D. nasuta* by fewer and differently patterned loreals, shorter and darker snout, dark brown upper labials variably marked with white (rather than brownish white, narrowly edged above with dark brown), dorsals dark brown finely edged with blackish (rather than pale brown, spotted dark brown) and ventrals and subcaudals never dark-edged. Distinguishable from *D. grayii*

Figure 1   Holotype of *Delma butleri,* photographed in life by G. Harold.

by finely dark-edged dorsals and little or no development of ventrolateral vertical barring behind ear.

Description

Snout-vent length (mm): 36-91 (N 98, mean 69.7). Tail (% SVL): 245-345 (N 34, mean 300.6). Two pairs of supranasals, posterior occasionally much the larger. Loreals 3-9 (N 98, mean 6.0). Upper labials 6 with fourth under eye (N 83) or 7 with fifth (3). Midbody scale rows 15 (N 2), 16 (57), 17 (13) or 18 (11).

Upper surface brown tinged olive, all scales finely dark-edged. Lores, lips, temples and side of neck variably marked with pale brown, dark brown and white, the white taking form of spots, blotches, or vertical streaks up from white under surface; lores, lips etc. sometimes dark brown and almost entirely without pattern. Lower surface yellow, white, greyish white or brownish white.

Distribution

Arid and semiarid zones of central and southern Western Australia from Lake MacLeod, the Hamersley Range and Ethel Creek south to Dirk Hartog I., Northampton, East Yuna Nature Reserve, Youanmi, Mt Jackson, Boorabbin, 40 km SE Coolgardie, 30 km NW Heartbreak Ridge and Charlina Rock, and east to Lake Carnegie, White Cliffs and Zanthus; also northern South Australia. Mainly found in spinifex (*Triodia* and *Plectrachne* spp.) on sandy and loamy soils. See map, Figure 2.

Geographic variation

From north-west to south-east there is a slight reduction (90-79 mm) in maximum snout-vent length and in strength of colour pattern on side of head and neck, and ventral coloration changes from yellow to whitish. For differences between the strongly-patterned north-western populations and weakly-patterned south-eastern populations, compare the photograph of the holotype with the South Australian specimen of *'nasuta'* in Kluge (1974: 111, Fig. 71).

Derivation of name

After naturalist W.H. (Harry) Butler, who was first to collect this species for the Western Australian Museum (on 30 December 1961 at Queen Victoria Spring).

Material examined

North-West Division (WA)

Marandoo (94585); 16 km N Ethel Creek HS (28359); 3 km SE Gnaraloo (76645); Dirk Hartog I. (45850, 57087-8, 57093-4); 25 km SSE Denham (54556).

Eastern Division (WA)

9 km SW Mt Lockeridge (64727); 33 km W Carnegie (21073); 22 km SE Mt Keith (62822) and 29 km SE (78553) and 30 km SSE (78548); 7 km WNW Point Salvation (85605-6); 9 km SSE Banjawarn (74784) and 12 km SSE (69288); 17 km NE Youanmi (86658); 27 km NE White Cliffs (53291) and 15 km E (85305); Ivor Rocks (53255-6); 39 km ENE Laverton

(85600-1, 85603-4); Mt Windarra (70876-7); 35 km SSE Dandaraga (67974); 24 km ENE Yuinmery (74677, 74679) and 8-9 km ENE (69080, 69104, 69108, 74658); Blue Hill (64794, 64813-4); 3 km NE Comet Vale (72669, 72728); Queen Victoria Spring (18531) and 53 km NNE (94077); near Mt Manning Range (64754-5, 78680, 78688-9); 75 km N Kalgoorlie (53277); 15 km NE Bungalbin Hill (67188); 16 km SSW Mt Jackson (76121); Yowie Rockhole (70893) and 6 km ENE (73212, 73228-9); 4 km E Zanthus (91510); near Buningonia Spring (65531, 65539, 65569-70, 65590, 65654, 72503, 72537, 74557, 74591, 74597); near Boorabbin (72248, 72255-6, 72285-6, 72291); 32 km S Woolgangie (71775); 30 km NW Heartbreak Ridge (65463, 65484).

South-West Division (WA)

44 km NE Yuna (57541) and 40 km NE (57522); Northampton (47709); East Yuna Nature Reserve (48184-8, 48261, 48270, 75559).

Eucla Division (WA)

Newman Rock (53459-60); 4 km E Boingaring Rocks (57959, 58072); 17 km N Charlina Rock (59854-5).

South Australia

56 km NW Mt Lindsay (44362); 43 km NE Maralinga (36649).

Delma nasuta Kluge

Delma nasuta Kluge (1974: 109-113). Pollock Hills, WA.

Diagnosis

A moderately large *Delma* without dark or pale bands across top of head and neck. Distinguishable from *D. butleri* by more numerous and differently patterned loreals, longer and paler snout, pale brown upper labials narrowly edged above with dark brown, dorsals pale brown spotted with dark brown, and ventrals and subcaudals often dark-edged.

Description

Snout-vent length (mm): 46-112 (N 157, mean 85.4). Tail (% SVL): 251-412 (N 36, mean 328.4). Two pairs of supranasals, posterior usually much the larger. Loreals 4-23 (N 155, mean 11.8). Upper labials 5 with third under eye (N 3), 6 with fourth (119), 7 with fourth (1), 7 with fifth (25) or 8 with sixth (1). Midbody scale rows 15 (N 1), 16 (60), 17 (24), 18 (48) or 20 (1).

Upper surface pale brown, palest on snout and darkest on crown; dorsals and supracaudals with a dark brown apical spot, sometimes a basal spot and rarely a median bar. Loreals usually bicoloured, i.e. each scale anteriorly and inferiorly pale brown or brownish white, and posteriorly and superiorly dark brown. Upper labials pale brown or brownish white, edged above with dark brown. Lower surface white, the ventrals and subcaudals anteriorly edged or not with pale or dark brown.

Distribution

Arid and semiarid zones of northern and central Western Australia from southern Kimberley south to Shark Bay (Edel Land and Peron Peninsula), Erlistoun, Point

Salvation and the Cavenagh Range, including Hermite and Barrow Is; also arid and semiarid interior of Northern Territory north to the upper Victoria River drainage (Spring Creek), far western interior of Queensland and extreme north of South Australia. Inhabiting spinifex (*Triodia* spp.) on sandy, clayey and stony soils. See map, Figure 2.

● *Delma nasuta*
○ *Delma butleri*
◐ both species
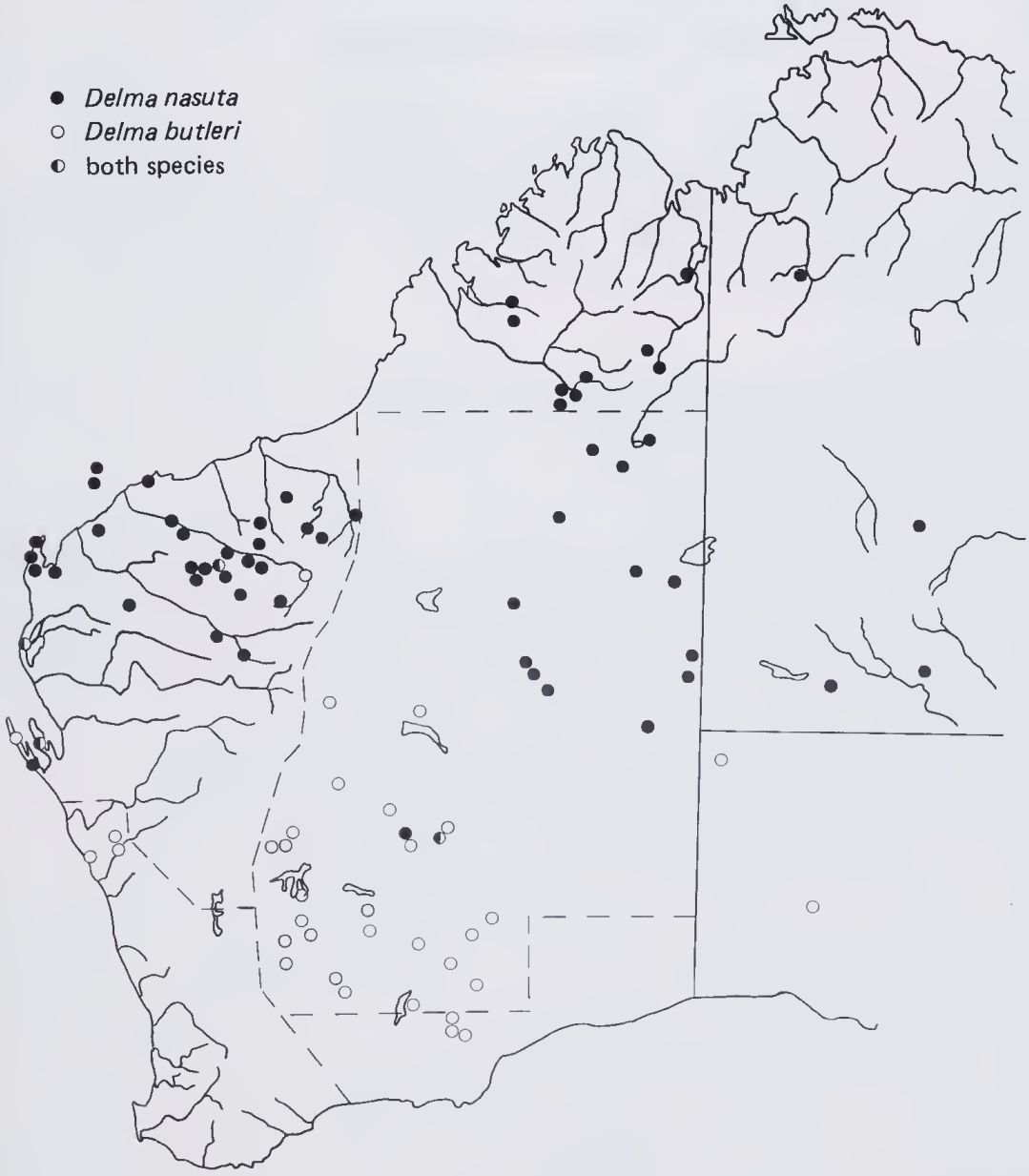
Figure 2   Map of western half of Australia, showing location of specimens of *Delma butleri* and *Delma nasuta*.

Geographic variation

In the far north (Kimberley Division and Victoria River drainage) the ventrals and often the subcaudals are immaculate. Southwards there is a steady increase in the frequency of specimens with dark-edged ventrals and/or subcaudals, so that within the range of *D. butleri* almost all specimens are thus marked.

Remarks

For photographs of the head of a *Delma nasuta* see Kluge (1974: 112, Fig. 72).

Material examined

Kimberley Division (WA)

11 km NNW Mt Evelyn (70953); 11 km WSW Lissadell (70411); 3 km E Yammera Gap (56436) and 12 km ESE (57318); 6 km S Mt Percy (70034, 70637); Halls Creek (26638, 83567-8, 87117-20) and 8 km NE (87121-2) and 43 km SE (23060); 25 km E Bohemia Downs (23049); 3 km W Christmas Creek HS (25590); Bull Flat Bore (51264-5); Wattle Creek Spring (51284); 58 km SSW Christmas Creek HS (45984).

North-West Division (WA)

Hermite I. (37405); Barrow I. (27611-2, 28453, 28655, 47853, 48563-615, 56709-10); 20 km W Karratha (75118); Myaree Pool (61576-7); Marble Bar (67604, 67610); Woodstock (14782, 27610); Millstream (20110); Mt Ulric Gorge (20112); Asbestos Gorge (20111); Woodie Woodie (63147); Nullagine (64700); 4 km N Palm Springs (63131); 5 km ENE Kurrana Well (73953-4); Cattle Pool (61600); 8 km NW Cane River HS (80598) and 5 km WNW (96541); Chichester Range (31484); Noreena Downs (37018); Yardie Creek Station (13195); 9 km N Yardie Creek watercourse (61042-4); 40 km NE Ningaloo (21773); 3 km E Giralia (61425); Dales Gorge (14806-7); Marandoo (54380, 59709, 60494); Tom Price (42996) and 18 km SSW (76565) and 22 km W (73741); 18 km NW Juna Downs (69780-1) and 9 km W (81296); 24 km SW Marillana (70752) and 22 km SW (70750) and 22 km W (73741) and 18 km SSW (76565); 31 km SE Mt Meharry (63626, 64829); Mt Newman (26547); 21 km NW Ullawarra (25261) 5 km SE Gnaraloo (76743); 28 km NW Mt Vernon HS (25230); Nichol Spring (22806); 25 km S Denham (54555, 54694); False Entrance Well (74950).

Eastern Division (WA)

Balgo Hill (63276); Bungabiddy Well (64055); Godfrey Tank (63410); Bishop Range (69896 -8); Well 39 (64160, 64210); Tobin Lake (63465); 80 km S Telfer (94766); Pollock Hills (40178 holotype); Dover Hills (45240); 48 km W Windy Corner (45277); Walter James Range (45241), 57 km E Giles (20770) and 37 km SE (20751); Charlies Knob (53601-2); 33 km W Browne Range (21043); near Young Range (78127); near Baker Range (78123); Cavenagh Range (20735); 7 km WNW Point Salvation (85607); Erlistoun (70832); Ivor Rocks (53253-4).

Northern Territory

Spring Creek, 58 km N Wave Hill (60234-6); 10 km SW Barrow Creek (24353-4); Maryvale (55348, 55398); Angas Downs (20816).

Delma haroldi sp. nov.

Figure 3

Holotype

R85094 in Western Australian Museum, collected by G. Harold and C. Winton on 11 August 1983 at 11 km NNW Uaroo, WA, in 22°41'S, 115°20'E.

Paratypes

Kimberley Division (WA)
   146 km E McLarty Hills (46043).

North-West Division (WA)
   Wallal (45811); 2 km SW Barradale (51722); Marandoo (64715); 14 km SW The Governer (63632); Ophthalmia Range (73630).

Eastern Division (WA)
   Balgo Mission (64703); Twin Heads (63427); 45 km N Windy Corner (45243).

Diagnosis

A small *Delma* with two pairs of supranasals, fourth upper labial below eye, usually 16 midbody scale rows, and with very narrow pale bands on head and neck but no dark bands. Most like faintly patterned examples of *D. borea* but distinguishable by pale bands on head and neck being wavy (rather than straight), by additional pale band(s) on side of head between postocular and auricular bands, and by dark spot at apex of anterior dorsals.

Description

Snout-vent length (mm): 48-75 (N 10, mean 62.4). Length of tail (% of SVL): 314-369 (N 4, mean 347). Two pairs of supranasals, anterior in contact with each other (N 8) or separated (2). Loreals 5-7 (N 10, mean 5.4). Fourth upper labial under eye (N 9) or fifth (1). Midbody scale rows 16 (N 9) or 18 (1).

Figure 3   A paratype of *Delma haroldi* from Marandoo, photographed in life by G. Harold.

Figure 4   Map of Western Australia, showing location of specimens of *Delma haroldi*, *Aclys concinna major* and *Aclys concinna concinna*.

Top of head and neck dark brown, occasionally mottled with pale brown. On back of head and on neck a narrow, brownish white or pale brown band, each becoming whiter and broader as it descends to lower surface, the anterior forking at ear aperture; 3 or 4 additional pale bands on side of head, one passing over loreals, one over postoculars and one (occasionally 2) over temple. Remaining upper surfaces pale brown, each scale edged with dark brown, margin thickest at apex of anterior dorsals. Labials marked with dark brown and white. Sides of body and tail paler than dorsum except for dark apical spot on each scale; side of forebody marked with narrow white or brownish white vertical bands, the first occasionally joining its opposite number, the rest decreasing in height backwards; these bands (like those on side of head) irregularly edged with dark brown. Lower surface white.

Distribution

Northern arid zone of Western Australia between latitudes 19°25' and 23°15'S. See map, Figure 4.

Derivation of name

After naturalist Gregory Harold, co-collector of the holotype.

Aclys concinna concinna Kluge

Aclys concinna Kluge (1974: 46-48). Sorrento, WA.

Diagnosis

A relatively small (total length 177-496 mm, N 42) and pale subspecies with dorsal pattern consisting mainly of three blackish lines or series of spots; venter white or pale grey, occasionally with pale brown spots.

Description

Snout-vent length (mm): 37-101 (mean 69.5, N 87). Length of tail (% SVL): 302-450 (mean 377, N 42). Two pairs of supranasals, the anterior narrowly to widely separated from each other (N 81), in point contact (2) or forming a short or moderately long suture (N 2). Anterior frontal slightly to much larger than posterior (N 70), its apex cut off in two specimens to form a small azygous scale. Supraoculars 2, anterior larger (N 86). Supraciliaries 2 (N 2, when second and third fused) or 3 (84), second largest. Postnasal occasionally separated from anterior supranasal. On both sides of one specimen supraloreal horizontally divided towards apex. Loreals 1 (N 1), 2 (1), 3 (41), 4 (37), 5 (3) or 7 (1). Upper labials 6 with fourth largest and subocular (N 4), 7 with fourth (60), 8 with fourth (1), 8 with fifth (4) or 9 with fifth (1); last smallest except on few occasions when fused to penultimate. Midbody scale rows 18 (3), 19 (11), 20 (39), 21 (4) or 22 (3).

Upper surface brownish grey, head darkest and brownest along contact with white labial stripe; occasionally a darker, broad, median stripe on back c. 4 scales wide, contrasting with narrow pale laterodorsal stripe (thus approaching condition in next subspecies), overlaying but not concealing 3 blackish brown, longitudinal lines or series of spots on back (less distinct on tail). Sides of body and tail pale brownish grey with one or more longitudinal series of darker spots, less distinct than those on dorsum. Lips, chin and throat white. Rest of under surface white or very pale grey, breast and abdomen occasionally and undertail always spotted pale brown (one spot per scale). See photograph in Kluge (1974: 47, Fig. 17).

Distribution

Lower west coast of Western Australia between lat. 29°50' and 31°50'S, inland to Badgingarra and Cataby. See map, Figure 4.

Material examined

South-West Division (WA)

5 km E Coolimba (72983), 5 km E Leeman (85015); near Mt Peron (48809, 49123, 59644, 61295-6, 64718-21); near Coomallo Hill (41156); Badgingarra (64722) and 30 km WSW (60018-20, 60026-7) and 22 km S (60021-3, 60512); Badgingarra Nat. Park (68408-42, 68846, 68848-69, 68472-9, 68711-2); Cataby (51729); Yanchep Nat. Park (59132); Sorrento (17312, holotype).

Aclys concinna major subsp. nov.

Figure 5

Holotype

R66192 in Western Australian Museum, collected by T.M.S. Hanlon and G. Harold on 29 August 1979 at 2 km N Tamala, WA, in 26°40'S, 113°43'E.

Paratypes

North-West Division (WA)

7 km NE Tamala (96898, 97010).

Diagnosis

A relatively large (total length 538-542 mm, N 2) and dark subspecies of *A. concinna* with dorsal pattern consisting of a broad, blackish, longitudinal stripe; venter white, spotted with dark brown.

Description

Snout-vent length (mm): 100-112 (N 3). Length of tail (% SVL): 398-438 (N 2). Two pairs of supranasals, anterior separated. Anterior frontal larger than posterior. Supraoculars 2, anterior larger or subequal. Supraciliaries 2 or 3. Postnasal and supraloreal present. Loreals 3-5. Upper labials 7 with fourth subocular (N 2) or 8 with fifth (1), last smallest. Midbody scale rows 20.

Head dark brownish grey. Broad, blackish brown, median stripe on back 3-4 scales wide, becoming narrower and paler posteriorly. Narrow laterodorsal

stripe pale brownish grey. Lateral scales brownish grey, edged brownish white. Chin and throat white. Breast and abdomen white, each scale with a dark greyish brown or blackish brown triangular spot. Subcaudals greyish brown, edged greyish white.

Figure 5   Holotype of *Aclys concinna major*, photographed in life by G. Harold.

Distribution

Known from only one locality near mid-west coast of Western Australia. See map, Figure 4.

Remarks

This is one of several lizards endemic to the Shark Bay region. Others include the pygopodids *Aprasia haroldi* and *Pletholax gracilis edelensis*, the agamid *Tympanocryptis butleri* and the skinks *Ctenotus youngsoni*, *Egernia stokesii aethiops*, *Lerista varia* and *Menetia amaura*.

Reference

Kluge, A.G. (1974). A taxonomic revision of the lizard family Pygopodidae. *Misc. Publs Mus. Zool. Univ. Mich.*, No. 147.

Catalogue of type specimens of worms (Phyla: Platyhelminthes, Nematoda and Annelida) in the Western Australian Museum, Perth.

Gary J. Morgan*

Abstract

Information is presented pertaining to 176 registered type specimen lots of 103 species or subspecies of worms held in the Western Australian Museum collection. A further 28 specimen lots of 15 species or subspecies are of uncertain or invalid type status. Original authors and subsequent emendations are indicated. Four type lots could not be located.

Introduction

At the time of writing, the Western Australian Museum (WAM) does not possess a Department responsible solely for worms. Worms are presently lodged with the Department of Carcinology. A catalogue of WAM crustacean type specimens has been prepared by Jones, D. (1986) and this paper provides similar information for the type specimens of worms (Phyla Platyhelminthes, Nematoda and Annelida) in the WAM collection.

The format is similar to that of Jones, D. (1986). Phyla and classes are arranged in taxonomic sequence based upon Barnes (1974). While polychaete orders are used by some authors (e.g. Fauchald, 1977), family sequence is used for convenience in this paper, based upon Day (1967) and Hutchings and Murray (1984). Oligochaete orders and families are based on Brinkhurst and Jamieson (1972). Genera are ordered alphabetically within families and species alphabetically within genera.

Species are listed by their original published name. Discrepancies between labelled or registered information and that cited in publications are indicated in Remarks, as are changes to nomenclature subsequent to original description and, where determinable, locality of other type material. Designation of holotype, syntypes and paratypes follows Jones, D. (1986) and the International Code of Zoological Nomenclature, Article 73 and Recommendation 73D. Where originally designated, allotypes are also listed. Unpublished manuscript names are not included in the catalogue.

Where information pertaining to type material has been published in a language other than English, the data have been translated into English, though not necessarily verbatim. Latitudes and longitudes of collection sites are rarely cited by

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original authors and have been included where sites can be accurately placed. Unless otherwise stated, type material is stored in 75% (v/v) ethanol in glass jars.

Several specimen lots, especially oligochaetes described by Jackson (1931), have been labelled and registered as 'probably type material'. These lots are listed under the heading of 'Uncertain type status'.

Inglis (1971) described seven new species of enoplid nematodes and stated that holotypes and some paratypes were lodged in the WAM collection. These specimens could not be located nor are they registered. Inglis (1971) recorded lodgement of other paratypes with the British Museum (Natural History), but neither those specimens nor the purported WAM material are with that institution. The fate of these types is unknown.

The following institutional abbreviations are employed in the text: AM, Australian Museum, Sydney; BMNH, British Museum (Natural History), London; HZM, Zoologisches Institut and Zoologisches Museum, University of Hamburg; USNM, United States National Museum, Smithsonian Institution, Washington D.C.; WAM, Western Australian Museum, Perth.

List of type specimens

Phylum Platyhelminthes
Class Turbellaria
Order Seriata
Family Planariidae

Planaria böhmigi Weiss, 1909: 407. Syntype, 1 WAM 7158. Locality: Gooseberry Hill, WA, 31°59'S, 116°04'E. 31.v.1905.
Remarks: Not in genus *Planaria* sens. str. (see Hyman, 1951) but synonymy could not be traced.

Planaria hoernesi Weiss, 1909: 405. Syntypes, 4 WAM 7180. Locality: Boyanup, WA, 33°29'S, 115°44'E. From freshwater. 1.viii.1905.
Remarks: As for *Planaria böhmigi*.

Planaria pinguis Weiss, 1909: 408. Syntypes, 4 WAM 7181. Locality: Jarrahdale, WA, 32°20'S, 116°04'E. From small fast flowing stream. 20.ix.1905.
Remarks: As for *Planaria böhmigi*.

Order Neorhabdocoela
Family Typhloplanidae

Mesostoma michaelseni Weiss, 1909: 404. Syntypes, 3 WAM 7186. Locality: Boorabbin, WA, 31°12'S, 120°19'E. From rainwater channel off granite. 3.vii.1905.

Phylum Nematoda
Class Adenophorea
Order Chromadorida
Family Chromadoridae

Euchromadora eileenae Inglis, 1969: 193, Figs 31-37, 94-95. Holotype, WAM
4-70. Locality: Sarge Bay, Cape Leeuwin, WA, 34°22'S, 115°08'E. From weed
and silt of exposed beach, 0.6 m. 1967. Paratypes, several WAM 5-70. Locality:
Radar Reef, Strickland Bay, Rottnest Island, WA, 32°00'S, 115°30'E. From
weed on coral of reef, 0.6-1.0 m. 17.iii.1967.
Remarks: Type locality cited by Inglis (1969) as that of paratypes.

Graphonema georgei Inglis, 1969: 195, Figs 80-84, 96, 99. Holotype, WAM 6-70.
Locality: Goode Beach, Albany, WA, 35°05'S, 117°56'E. From weed and sand
in algal holdfasts on exposed rocks. 1.xi.1966.

Hypodontolaimus slacksmithi Inglis, 1969: 197, Figs 56-59, 102-109. Holotype,
WAM 3-70. Locality: Shark Bay, midway between Dirk Hartog Island and
Denham, WA, 25°50'S, 113°20'E. From weed and sand, trawled from 12 m.

Parapinnanema wilsoni Inglis, 1969: 194, Figs 51-55, 66-72, 73-75, 97-98.
Holotype, WAM 17-70. Paratypes, several WAM 18-70. Locality: Sarge Bay,
Cape Leeuwin, WA, 34°22'S, 115°08'E. From weed and sand, exposed beach,
0.6 m. 31.x.1966. Paratypes, several WAM 23-70. Locality: Bunker Bay, Cape
Naturaliste, WA, 33°32'S, 115°02'E. From finger-like green algae, in rock
pools. 29.x.1966.

Order Dioctophymatida
Family Dioctowittidae

Dioctowittus denisoniae Jones, 1978*b*: 141, Figs 1-10. Holotype, ♂ WAM 23-79.
Allotype, ♀ WAM 24-79. Locality: King Edward River, Kimberley District,
WA, 15°33'S, 126°09'E. From peritoneal cavity of snake *Denisonia punctata*
(WAM R53725). 1976.

Class Secernentea
Order Oxyurida
Family Oxyuridae

Parathelandros carinae Inglis, 1968*b*: 176, Figs 11, 12, 16, 20, 29, 32. Holotype,
WAM 14-70. Paratypes, many WAM 1-83. Locality: 29 mile peg from Perth, on
Northam Road. From rectum of *Helioporus inornatus*. 1966-1967.
Remarks: Type locality cited by Inglis (1968*b*) as Bakers Hill, Northam. Type
host cited as *Helioporus albopunctatus; H. inornatus* not cited as a host of
Parathelandros carinae. Paratypes also in BMNH.

Parathelandros johnstoni Inglis, 1968*b*: 175, Figs 21, 22, 30. Holotype, WAM 15-70. Paratypes, *ca.* 30 WAM 2-83. Locality: Sheepwash Creek, 25 km north-east of Denmark on Mt Barker Road, WA, 34°45'S, 117°30'E. From rectum of *Helioporus eyrei.* 1966-1967.
Remarks: Type locality cited by Inglis (1968*b*) as Bibra Lake, WA.

Parathelandros maini Inglis, 1968*b*: 176, Figs 10, 14, 24-26. Holotype, WAM 16-70. Paratypes, *ca.* 10 WAM 3-83. Locality: Near Garratt Road Bridge, Bayswater, Perth, WA. 31°56'S, 115°55'E. From rectum of *Hyla moorei.* 23.v.1966.
Remarks: Type locality cited by Inglis (1968*b*) as swamp in Hardy Road, Cloverdale, WA.

Order Spirurida
Family Diplotriaenidae

Hastospiculum drysdaliae Jones, 1980: 429, Figs 4-10. Holotype, ♂ WAM 26-79. Allotype, ♀ WAM 27-79. Paratypes, 2 ♀♀ WAM 28-79. Locality: North Twin Peaks Island, Recherche Archipelago, WA. 37°59'S, 122°50'E. From peritoneum of posterior end of stomach of snake *Drysdalia coronata* (WAM R53092). 9.v.1976.
Remarks: Type locality mistakenly cited (Jones, 1980) as 33°97'S, 122°85'E.

Family Physalopteridae

Abbreviata aechmespiculum Jones, 1978*a*, Figs 7-11. Holotype, ♂ WAM 29-77. Paratype, 1 immature WAM 29-77. Locality: Near Canning Dam, WA 32°10'S, 116°08'E. From stomach of *Acanthophis antarcticus* (WAM R25080). 7.v. 1965.

Abbreviata anomala Jones, 1986: 694, Figs 15-22. Holotype, ♂ WAM 182-85. Allotype, ♀ WAM 183-85. Paratypes, 5 ♂♂, 6 ♀♀ WAM 184-85. Locality: 3 km west of Boorabbin, WA, 31°12'S, 120°18'E. From stomach of *Pogona minor minor* (WAM R21705). 2.xi.1963.

Abbreviata barrowi Jones, 1978*a*: 791, Figs 1-6. Holotype, ♂ WAM 6-77. Allotype, ♀ WAM 7-77. Paratypes, *ca.* 40 WAM 5-77, *ca.* 60 WAM 8-77, *ca.* 60 WAM 9-77. Locality: Barrow Island, WA, 20°50'S, 115°25'E. From stomach of *Pseudechis australis* (WAM R28696). i.1967. Paratypes, *ca.* 40 WAM 4-77. Locality: Turec Creek, WA. From *Pseudechis australis* (WAM R22735). x.1963. Paratypes, 40 (+120 larvae) WAM 10-77. Locality: Kumarina, WA, 24°42'S, 119°38'E. From *Pseudechis australis* (WAM R25151). 8.iii.1965. Paratypes, 50 (+35 larvae) WAM 11-77. Locality: Kumarina, WA. From *Pseudechis australis* (WAM R22731). iii.1964. Paratypes, *ca.* 100 WAM 12-77. Locality: Albion Downs

Station, WA, 27°17'S, 120°23'E. From *Pseudechis australis* (WAM R30981). xii.1967. Paratype, ♀ WAM 13-77. Locality: Point Coulomb, north of Broome, WA, 17°22'S, 122°09'E. From stomach of *Pseudonaja nuchalis* (WAM R40275). 1971.

Remarks: *Abbreviata occidentalis* in same host as WAM 5-77, 6-77, 7-77, 8-77 and 9-77. *Abbreviata* sp. in same host as WAM 13-77. Host of WAM 10-77 cited by Jones (1978a) as WAM R25191.

Abbreviata kumarinae Jones, 1978a: 796, Figs 17, 18. Holotype, ♂ WAM 28-77. Locality: Kumarina, WA, 24°42'S, 119°38'E. From stomach of *Pseudechis australis* (WAM R25151). 8.iii.1965.

Remarks: *Abbreviata barrowi* WAM 10-77 in same host.

Abbreviata levicauda Jones, 1983: 286, Figs 1-7. Holotype, ♂ WAM 84-79. Allotype, ♀ WAM 85-79. Paratypes, 17 ♂♂ WAM 86-79, 23 ♀♀ WAM 87-79. Locality: 70 km south-south-west of Balladonia, WA, 33°10'S, 123°45'E. From stomach of *Varanus rosenbergi* (WAM R60375). 28.ii.1978.

Remarks: Holotype could not be located.

Abbreviata occidentalis Jones, 1978a: 794, Figs 12-16. Holotype, ♂ WAM 14-77. Allotype, ♀ WAM 15-77. Paratypes, 40 WAM 16-77. Location: Barrow Island, WA, 20°50'S, 115°25'E. From stomach of *Pseudechis australis* (WAM R28696). i.1967. Paratypes, 2 ♂♂, 3 ♀♀ WAM 17-77. Location: Esperance, WA, 33°51'S, 121°54'E. From *Notechis scutatus* (WAM R12338). 19.xii.1956. Paratypes, 15 WAM 18-77. Location: Mundaring, WA, 31°54'S, 116°10'E. From *Notechis scutatus* (WAM R19499). 1963. Paratypes, 2 ♀♀ WAM 19-77. Location: York, WA, 31°53'S, 116°46'E. From *Pseudechis australis* (WAM R22900). ix.1964. Paratypes, *ca.* 150, WAM 20-77. Locality: Mt Lawley, Perth, WA, 31°55'S, 115°50'E. From *Pseudechis australis* (WAM R2111). 1927. Paratypes, 75 WAM 21-77. Locality: Unknown. From *Pseudechis australis* (WAM R576).

Remarks: Species synonymised with *A. antarctica* (Linstow, 1899) by Jones (1983). Host of WAM 17-77 and 18-77 cited by Jones (1978a) as *Notechis ater*. *Abbreviata barrowi* in same host as WAM 14-77, 15-77 and 16-77.

Abbreviata perenticola Jones, 1985a: 380, Figs 1-9. Holotype, ♂ WAM 115-84. Allotype, ♀ WAM 116-84. Paratypes, 127 (+ 28 larvae) WAM 116-84. Locality: West face of Kennedy Range, WA, 24°31'S, 114°58'E. From gastrointestinal tract of *Varanus giganteus* (WAM R81668). 7.xi.1982.

Abbreviata pilbarensis Jones, 1986: 691, Figs 6-14. Holotype, ♂ WAM 111-85. Allotype, ♀ WAM 112-85. Paratypes, 12 ♂♂, 29 ♀♀ WAM 113-85. Locality: Mallina Station, 110 km south of Port Hedland, WA, 20°51'S, 118°02'E. From stomach of *Pogona minor mitchelli*. 7.xi.1982.

Abbreviata tumidocapitis Jones, 1983: 288, Figs 8-15. Holotype, ♂ WAM 34-80. Allotype, ♀ WAM 35-80. Paratypes, 5 ♂♂, 6 ♀♀, 5 larvae WAM 36-80. Locality:

10 km east of Yamarna Homestead, WA, 27°95'S, 123°90'E. From stomach of *Varanus gouldii* (WAM R53584). 21.iii.1976. Paratypes ?, 3 ♂♂, 3 ♀♀ WAM 37-80. Locality: 4 km north of Jyndabinbin Rock Hole, WA. 32°26'S, 122°04'E. From stomach of *Varanus gouldii* (WAM R62225). 31.x.1978. Paratypes ?, 1 ♂, 1♀, WAM 38-80. Locality: 70 km south-south-west of Balladonia, WA, 33°10'S, 123°45'E. From stomach of *Varanus rosenbergi* (WAM R60375). Remarks: WAM 37-80 and 38-80 labelled and registered as paratypes but not cited as such by Jones (1983). *Abbreviata levicauda* in same host as WAM 38-80. All specimens labelled *Abbreviata tumidoesophagus*.

Kreisiella chrysocampa Jones, 1985*b*: 1231, Figs 1-9. Holotype, ♂ WAM 62-84. Allotype, ♀ WAM 63-84. Locality: 100 km northeast of Laverton, WA, 28°12'S, 123°36'E. From stomach of *Egernia inornata* (WAM R3827). 8.iii.1979. Paratypes, numerous WAM 65-84 to 76-84. Locality: Ibid. From 12 *E. inornata*. Remarks: Holotype incorrectly printed in Jones (1985*b*) as ♀, WAM 62-64. Type species of genus.

Kreisiella lesueurii Jones, 1986: 697, Figs 23-31. Holotype, ♂ WAM 192-85. Allotype, ♀ WAM 193-85. Paratypes, 2 ♂♂, 6 ♀♀ WAM 194-85. Locality: Mt Lesueur, WA, 30°10'S, 115°12'E. From gastrointestinal tract of *Pogona minor minor* (WAM R48439). 2.xi.1973.

Physalopteroides filicauda Jones, 1985*b*: 1234, Figs 10-19. Holotype, ♂ WAM 77-84. Allotype, ♀ WAM 78-84. Paratypes, 6 ♂♂, 23 ♀♀, 3 larvae WAM 79-84. Locality: 100 km northeast of Laverton, WA, 28°12'S, 123°36'E. From stomach of *Nephrurus laevissimus* (WAM R3794). 6.iii.1979.

Order Strongylida
Family Amidostomatidae

Mackerrastrongylus mawsonae Inglis, 1968*a*: 341, Figs 31, 32, 36-38, 39-43. Holotype, WAM 10-70. Paratypes, 12 WAM 11-70. Locality: Shepherd Road, Glen Forest, WA, 31°55'S, 116°06'E. From caecum of *Isoodon obesulus*. 10.viii.1967.
Remarks: Paratypes also in BMNH.

Mackerrastrongylus waringi Inglis, 1968*a*: 339, Figs 22, 25-30, 33-35. Holotype, WAM 8-70. Paratypes, several WAM 9-70. Locality: Ginn Road, Mundaring Forest Reserve, WA, 31°57'S, 116°10'E. From intestine of *Dasyurus geoffroyi*. 10.v.1966.
Remarks: *Mackerrastrongylus mawsonae* present in same host. Paratypes also in BMNH.

Nicollina cathiae Inglis, 1968*a*: 338, Figs 18-21, 23, 24. Holotype, WAM 12-70. Paratypes, 34 WAM 13-70. Locality: Base of Mt Grungin, near Mundaring, WA,

31°54'S, 116°10'E. From small intestine, first 140 mm after stomach, of *Dasyurus geoffroyi*. 10.v.1966.
Remarks: Paratypes also in BMNH.

Nicollina ridei Inglis, 1968*a*: 337, Figs 14-17. Holotype, WAM 19-70. Paratypes, ? WAM 20-70. Locality: Walter Road, Morley Park, Perth, WA, 31°53'S, 115° 54'E. From small intestine, first 250 mm posterior of stomach, of *Tachyglossus aculeatus*. 10.viii.1966.
Remarks: Specimens could not be located. Not in BMNH.

Phylum Annelida
Class Polychaeta
Family Polynoidae

Lepidonotus brunneus Day, 1975: 181, Fig. 2 g-k. Holotype, WAM 42-72. Locality: Woodman Point groyne, Cockburn Sound, WA, 32°08'S, 115°43'E. From *Caulerpa*, 0-1.0 m. 13.ii.1972.
Remarks: Unique type.

Lepidonotus jolli Day, 1975: 173, Fig. 1 a-f. Holotype, WAM 129-74. Locality: North Point, Rottnest Island, WA, 32°00'S, 115°31'E. From seaweed on limestone reef platform, 0.5 m. 7.vii.1971. Paratypes, 22 WAM 79-72. Locality: Rottnest Island, Cottesloe and Cockburn Sound, WA. 1971-72.
Remarks: Paratypes also at University of Cape Town and USNM.

Family Chrysopetalidae

Bhawania multisetosa Hartmann-Schröder, 1981: 20, Figs 2-6. Paratype, 1 WAM 1-81. Locality: Near Chinaman Rock, Kalbarri, WA, 27°45'S, 114°08'E. From algae on rock platform. 16.x.1975.
Remarks: Specimen incomplete. Holotype and 3 paratypes in HZM.

Family Phyllodocidae

Eulalia microphylloides Hartmann-Schröder, 1979: 81, Text figs 19-22. Paratypes, 3 WAM 2-79. Locality: Gantheaume Point, Broome, WA, 17°58'S, 122°14'E. From lower littoral, on rock platform near lighthouse. 24.ix.1975.
Remarks: Holotype and 27 paratypes in HZM.

Phyllodoce australis Day, 1975: 187, Fig. 3 a-c. Holotype, WAM 78-72. Locality: North Point, Rottnest Island, WA, 32°00'S, 115°30'E. From seaweed on limestone reef platform, 0.3-0.6 m. 30.vi.1971. Paratypes, 6 WAM 130-74. Locality: Unknown. 11.ix.1974.

Remarks: Type locality cited by Day (1975) as Cottesloe, Perth. Paratype number cited as 3.

Family Pilargidae

Sigambra pettiboneae Hartmann-Schröder, 1979: 84, Text figs 37-42. Paratype, 1 WAM 3-79. Locality: In front of Mangrove Motel, Broome, WA, 17°58′S, 122°14′E. From mangrove swamp, upshore flat with sand and plant detritus. 24.ix.1975.
Remarks: Holotype and 4 paratypes in HZM.

Family Syllidae

Brania longisetosa Hartmann-Schröder, 1979: 102, Text figs 136-137. Paratypes, 2 WAM 8-79. Locality: In front of Highway Motel, Port Hedland, WA, 20°19′S, 118°34′E. From fossil reef platform, in sand and detritus. 30.ix.1975.
Remarks: Hartmann-Schröder (1979) cited 1 paratype in WAM 8-79. Collection date cited as 27.ix.1975. Holotype and 3 paratypes in HZM.

Brania opisthodentata Hartmann-Schröder, 1979: 101, Text figs 134-135. Paratype, 1 WAM 9-79. Locality: East end of Port Hedland, WA, near mouth of Pretty Pool. 20°19′S, 118°34′E. From sandflat with coarse sand and shell grit, middle littoral. 28.ix.1975.
Remarks: Holotype and 2 paratypes in HZM.

Exogone heterosetoides Hartmann-Schröder, 1979: 110, Text figs 171-174. Paratype, 1 WAM 12-79. Locality: Broome, WA, 500 m from *Avecennia* mangroves. 17°58′S, 122°14′E. From fine sand flat with plant detritus. 8.ix.1975.
Remarks: Hartmann-Schröder (1979) cited 2 paratypes in WAM 12-79. Holotype and 5 paratypes in HZM.

Exogone spinisetosa Hartmann-Schröder, 1981: 39, Figs 77-79. Paratypes, 2 WAM 8-81. Locality: Cape Burney, near mouth of Greenough River, south of Geraldton, WA, 28°52′S, 114°38′E. From algae on rock platform. 18.x.1975.
Remarks: Holotype and 7 paratypes in HZM, 2 paratypes in AM.

Odontoautolytus annulatus Hartmann-Schröder, 1979: 112, Text figs 178-182. Paratype, 1 WAM 13-79. Locality: East end of Port Hedland, WA, near mouth of Pretty Pool. 20°19′S, 118°34′E. From sandflat with coarse sand and shell grit, middle littoral. 28.ix.1975.
Remarks: Holotype and 2 paratypes in HZM.

Odontosyllis globulocirrata Hartmann-Schröder, 1981: 31, Figs 49-51. Paratypes, 2 WAM 3-81. Locality: Cervantes, WA, 30°30'S, 115°05'E. From *Posidonia* and fine sand. 24.x.1975.
Remarks: Holotype and 9 paratypes in HZM.

Odontosyllis langerhansiaesetosa Hartmann-Schröder, 1979: 94, Text figs 91-96. Paratypes, 2 WAM 5-79. Locality: In front of Mangrove Motel, Broome, WA, 17°58'S, 122°14'E. From mangrove swamp, in sand and detritus. 24.ix.1975.
Remarks: Holotype and 6 paratypes in HZM.

Opisthodonta curticirris Hartmann-Schröder, 1983: 130, Figs 11-14. Paratype, 1 WAM 5-83. Locality: Dunsborough, Geographe Bay, WA, 33°37'S, 115°08'E. From intertidal flat of fine sand with diatomaceous layer, protected by sandbar. 9.xi.1975.
Remarks: Holotype and 3 paratypes in HZM, 1 paratype in AM.

Pionosyllis augeneri Hartmann-Schröder, 1979: 98, Text figs 119-125. Paratypes, 3 WAM 6-79. Locality: In front of Mangrove Motel, Broome, WA, 17°58'S, 122°14'E. From mangrove swamp, in sand and detritus. 24.ix.1975.
Remarks: Holotype and 10 paratypes in HZM.

Pionosyllis samsonensis Hartmann-Schröder, 1980: 52, Figs 39-43. Paratype, 1 WAM 94-79. Locality: Point Samson, WA, 20°38'S, 117°10'E. From intertidal platform in fossil reef, coarse sand with shell grit and algae. 1.x.1975.
Remarks: Holotype and 3 paratypes in HZM.

Sphaerosyllis erinaceus serratosetosa Hartmann-Schröder, 1982: 70, Text figs 57-59. Paratypes, 2 WAM 1-82. Locality: Cervantes, WA, 30°30'S, 115°05'E. From beach of fine sand and *Posidonia,* lower littoral. 24.x.1975.
Remarks: Holotype and 8 paratypes in HZM, 2 paratypes in AM.

Sphaerosyllis papillosissima Hartmann-Schröder, 1979: 108, Text figs 159-162. Paratype, 1 WAM 11-79. Locality: Derby, WA, 17°18'S, 123°38'E. From mud flat with some fine sand and plant detritus at base of harbour, lower littoral. 20.ix.1975.
Remarks: Holotype and 4 paratypes in HZM.

Sphaerosyllis sexpapillata Hartmann-Schröder, 1979: 105, Text figs 144-147. Paratypes, 2 WAM 10-79. Locality: Gantheaume Point, Broome, WA, 17°58'S, 122°14'E. From rock pools, with fine sand and detritus. 9.ix.1975.
Remarks: Holotype and 9 paratypes in HZM.

Syllides articulosus pumilus Hartmann-Schröder, 1983: 131, Figs 16-17. Paratypes, 2 WAM 4-83. Locality: Dunsborough, Geographe Bay, WA, 33°37'S, 115°07'E. From littoral *Posidonia* and *Halophila.* 9.xi.1975.
Remarks: Holotype and 28 paratypes in HZM, 2 paratypes in AM.

Syllides articulosus spinosus Hartmann-Schröder, 1979: 99, Text figs 126-128. Paratype, 1 WAM 7-79. Locality: East end of Port Hedland, WA, near mouth of Pretty Pool. 20°19'S, 118°34'E. From sandflat with coarse sand and shell grit, middle littoral. 28.ix.1975.
Remarks: Holotype and 2 paratypes in HZM.

Typosyllis albanyensis Hartmann-Schröder, 1984: 16, Figs 16-19. Paratype, 1 WAM 6-84. Locality: Goode Beach, Frenchman Bay, near Albany, WA, 35°05'S, 117°56'E. From coralline and encrusting algae with sand and detritus, on rock, littoral. 21.xi.1975.
Remarks: Holotype and 3 paratypes in HZM.

Typosyllis broomensis Hartmann-Schröder, 1979: 88, Text figs 50-56. Paratype, 1 WAM 4-79. Locality: Broome, WA, 500 m from mangroves. 17°58'S, 122° 14'E. From tidal flat of fine sand and plant detritus. 8.ix.1975.
Remarks: Holotype and 2 paratypes in HZM.

Typosyllis busseltonensis Hartmann-Schröder, 1982: 62, Text figs 31-35. Paratypes, 2 WAM 4-82. Locality: Eagle Bay, Cape Naturaliste, WA, 33°35'S, 115°06'E. From algae and sand on rock platform, littoral. 7.xi.1975.
Remarks: Holotype and 4 paratypes in HZM, 2 paratypes in AM.

Typosyllis erikae Hartmann-Schröder, 1981: 27, Figs 28-31. Paratypes, 5 WAM 7-81. Locality: Horrocks Beach, north of Geraldton, WA, 28°22'S, 114°25'E. From encrusting algae, seaweed and sand on fossil reef. 17.x.1975.
Remarks: Including chaetosyllis stage. Holotype and 27 paratypes in HZM, 5 paratypes in AM.

Typosyllis gerhardi Hartmann-Schröder, 1980: 51, Figs 33-38. Paratypes, 3 WAM 93-79. Locality: Near Vlaming Head lighthouse, North West Cape, WA, 21°48'S, 114°07'E. From algae and crusts on reef, littoral. 9.x.1975.
Remarks: Holotype and 6 paratypes in HZM, 2 paratypes in AM.

Typosyllis guildertonensis Hartmann-Schröder, 1982: 61, Text figs 26-30. Paratypes, 3 WAM 2-82. Locality: Near groyne, Guilderton, WA, 31°21'S, 115° 30'E. From brown and coralline algae on rocks, littoral. 26.x.1975.
Remarks: Holotype and 47 paratypes in HZM, 3 paratypes in AM.

Typosyllis lincolnensis Hartmann-Schröder, 1985a: 67, Figs 7-10. Paratypes, 2 WAM 7-85. Locality: Sleaford Bay, 20 km south of Port Lincoln, SA, 34° 53'S, 135°45'E. From algae on limestone platform, littoral. 3.xii.1975.
Remarks: Holotype and 8 paratypes in HZM, 2 paratypes in AM.

Typosyllis macrodentata Hartmann-Schröder, 1982: 60, Text figs 22-25. Paratype, 1 WAM 3-82. Locality: Near groyne, Guilderton, WA, 31°21'S, 115°30'E.

From brown and coralline algae on rocks, littoral. 26.x.1975.
Remarks: Holotype and 7 paratypes in HZM, 1 paratype in AM.

Family Nereididae

Ceratonereis perkinsi Hartmann-Schröder, 1985*b*: 43, Figs 24-35. Paratypes, 3 WAM 8-85. Locality: Near lighthouse, Gantheaume Point, Broome, WA, 17°59'S, 122°11'E. From coralline algae on rock platform. 9.ix.1975.
Remarks: Holotype and 25 paratypes in HZM, 3 paratypes in AM.

Family Glyceridae

Glycera derbyensis Hartmann-Schröder, 1979: 123, Text figs 248-250. Paratype, 1 WAM 14-79. Locality: Near Derby jetty, WA, 17°18'S, 123°38'E. From stone debris, upper littoral. 20.ix.1975.
Remarks: Holotype and 3 paratypes in HZM.

Family Eunicidae

Marphysa sessilobranchiata Hartmann-Schröder, 1984: 32, Figs 34-39. Paratypes, 2 WAM 7-84. Locality: Little Grove near Pelican Point, Princess Royal Harbour, Albany, WA, 35°05'S, 117°54'E. From fine sand with broken mussel shell, littoral. 22.xi.1975.
Remarks: Holotype and 14 paratypes in HZM, 2 paratypes in AM.

Family Lumbrineridae

Lumbrineris orensanzi Hartmann-Schröder, 1980: 64, Figs 64-69. Paratypes, 2 WAM 95-79. Locality: Near Vlaming Head lighthouse, North West Cape, WA, 21°48'S, 114°07'E. From algae and crusts on reef, littoral. 9.x.1975.
Remarks: Holotype and 4 paratypes in HZM, 2 paratypes in AM.

Family Orbiniidae

Orbinia felix australis Hartmann-Schröder, 1984: 33. Paratype, 1 WAM 8-84. Locality: Little Grove near Pelican Point, Princess Royal Harbour, Albany, WA. 35°05'S, 117°54'E. From fine sand with broken mussel shell, littoral. 22.xi.1975.
Remarks: Hartmann-Schröder (1984) cited 2 paratypes as lodged with WAM. Holotype and 22 paratypes in HZM, 2 paratypes in AM.

Protoariciella australiensis Hartmann-Schröder, 1981: 48, Figs 106-114. Paratype, 1 WAM 2-81. Locality: Drummonds Cove, Geraldton, WA, 28°45'S, 114°36'E.

From fine sand, amongst seagrass. 22.x.1975.
Remarks: Holotype and 4 paratypes in HZM.

Family Spionidae

Microspio occipitalis Hartmann-Schröder, 1983: 143, Figs 42-49. Paratype, 1 WAM 7-83. Locality: Peaceful Bay, Walpole, WA, 35°58'S, 116°43'E. From algae on rocks, littoral. 17.xi.1975.
Remarks: Holotype and 10 paratypes in HZM, 1 paratype in AM.

Scolelepis denmarkensis Hartmann-Schröder, 1983: 145, Figs 51-57. Paratype, 1 WAM 6-83. Locality: South end of Ocean Beach, Denmark, WA, 34°58'S, 117°21'E. From sand, littoral. 18.xi.1975.
Remarks: Hartmann-Schröder (1983) cited habitat as brown algae on rock substrate. Holotype and 4 paratypes in HZM, 1 paratype in AM.

Family Magelonidae

Magelona jonesi Hartmann-Schröder, 1980: 71, Figs 112-118. Paratype, 1 WAM 96-79. Locality: Exmouth Gulf, 24 km south of town, WA, 21°55'S, 114°09'E. From fine sand flat on reef, littoral. 10.x.1975.
Remarks: Holotype and 3 paratypes in HZM.

Family Capitellidae

Notomastus broomensis Hartmann-Schröder, 1979: 141, Text figs 326-330, Pl. 1 Fig. 6. Paratypes, 3 WAM 16-79. Locality: Willie Creek, Broome, WA, 17°58'S, 122°14'E. From estuary with mangroves, fine sand and detritus, with strong reducing layer below. 12.ix1975.
Remarks: Holotype and numerous paratypes in HZM.

Notomastus hedlandica Hartmann-Schröder, 1979: 141, Text figs 324-325. Paratype, 1 WAM 15-79. Locality: Pretty Pool, Port Hedland, WA, 20°19'S, 18°34'E. From mangrove flat, firm mud with sand and plant detritus. 26.ix.1975.
Remarks: Holotype and 3 paratypes in HZM.

Family Ampharetidae

Neosabellides australiensis Hartmann-Schröder, 1981: 56, Figs 165-170. Paratypes, 2 WAM 6-81. Locality: Cervantes, WA, 30°30'S, 115°05'E. From sandy beach with *Posidonia*. 24.x.1975.
Remarks: Holotype and 5 paratypes in HZM, 1 paratype in AM.

Family Terebellidae

Nicolea minima Hartmann-Schröder, 1984: 44, Fig 53. Paratypes, 3 WAM 9-84. Locality: Goode Beach, Frenchman Bay, Albany, WA, 35°05'S, 117°56'E. From coralline and encrusting algae on rocks with sand and detritus, littoral. 21.xi.1975.
Remarks: Holotype and 15 paratypes in HZM, 3 paratypes in AM. Species recently synonymised with *Nicolea amnis* Hutchings and Murray, 1984 by Hutchings and Glasby (in press).

Family Sabellidae

Fabriciola australiensis Hartmann-Schröder, 1981: 60, Figs 138-145. Paratype, 1 WAM 4-81. Locality: Horrocks Beach, north of Geraldton, WA, 28°22'S, 114°25'E. From encrusting algae, seaweed and sand on fossil reef. 17.x.1975.
Remarks: Holotype and 5 paratypes in HZM.

Oriopsis busseltonensis Hartmann-Schröder, 1982: 93, Text figs 95-100. Paratype, 1 WAM 5-82. Locality: Yallingup, near Cape Naturaliste, WA, 33°38'S, 115° 02'E. From algae and crusts on rock platform, littoral. 7.xi.1975.
Remarks: Holotype and 4 paratypes in HZM.

Class Oligochaeta
Order Haplotaxida
Family Haplotaxidae

Pelodrilus darlingensis Michaelsen, 1907: 134. Syntypes, 6 WAM 4405. Locality: Collie, WA, 33°22'S, 116°09'E. From marshy soil at edge of creek.

Family Enchytraeidae

Fridericia cylindrica Springett 1971: 17, Fig. 3. Holotype, WAM 7-69. Locality: Beedelup Falls (Brook) near Pemberton, WA, 34°25'S, 115°51'E. 27.viii.1969. Paratypes, 10 WAM 8-69. Locality: Ibid. 3.ix.1969.

Fridericia giniata Springett, 1971: 17, Figs 1,2. Holotype, WAM 5-69. Paratypes, 8 WAM 6-69. Locality: CSIRO Experimental Orchard, 27 mile peg on Albany Highway, WA. 3.ix.1969.
Remarks: Springett (1971) cited type locality as Bedfordale, WA, 32°12'S, 116°08'E.

Fridericia holmesa Springett, 1971: 19, Figs 4, 5. Holotype, WAM 9-69. Locality: Beedelup Falls (Brook) near Pemberton, WA, 34°25'S, 115°51'E. 23.vii.1969. Paratypes, 2 WAM 10-69. Locality: Ibid. 3.ix.1969.

Remarks: Springett (1971) incorrectly cited registration numbers as WAM 7-69 and 8-69 (= numbers for *F. cylindrica*).

Family Tubificidae

Clitellio abjornseni Michaelsen, 1907: 124. Syntype, 1 WAM 4407 (slide). Locality: Princess Royal Harbour, Albany, WA, 35°02'S, 117°53'E. 14-20.viii.1905. Remarks: Mounted on slide by C. Erseus, 1979.

Family Megascolecidae

Austrohoplochaetella kendricki Jamieson, 1971*a*: Figs 5a, 6f, 7i. Holotype, WAM 37-70. Paratypes, 2 WAM 37-70. Locality: Cape Range, Wapet No. 4 deep well, WA, 22°15'S, 113°55'E. From bone earth with leaf mould, in cave 30 m deep. 15.v.1965.
Remarks: Label bears name *Austrotravoscolides kendricki.* Holotype clitellate. Jamieson (1971*a*) cited 1 paratype.

Eodrilus cornigravei Michaelsen, 1907: 144, Pl. 1 Figs 3-6. Syntype, 1 WAM 4403. Locality: Cannington, WA, 32°02'S, 115°55'E. From marshy soil. 28.vi.1905.
Remarks: Genus *Eodrilus* synonymised with *Diplotrema* by Jamieson (1970, 1971*a*).

Graliophilus georgei Jamieson, 1971*a*: 476, Figs 1a, 7a. Holotype, WAM 30-70. Paratype, 1 WAM 31-70. Locality: Old entrance of Mammoth Cave, south of Margaret River, WA, 34°03'S, 115°01'E. From mud in bank of freshwater stream. 31.i.1961.
Remarks: Labels bear name *Plutellus georgei.* Jamieson (1971*a*) cited several paratypes and registration number WAM 30-70 for holotype and paratypes.

Graliophilus secundus Jamieson, 1971*a*: 478, Figs 1b, 6a, 7b. Holotype, WAM 33-70. Locality: Culvert on road to Thompsons Bridge (probably Warren River), WA, 34°30'S, 116°02'E. 24.xi.1938.
Remarks: Label bears name *Plutellus secundus.* Unique type.

Megascolex albanyensis Michaelsen, 1907: 221, Text fig. 32. Syntype, 1 WAM 4391. Locality: Albany, WA, 35°02'S, 117°53'E. From ash mulch of grasstrees. 13-22.viii.1905.

Megascolex bistichus Michaelsen, 1907: 216, Text fig. 28. Syntype, 1 WAM 4436. Locality: Donnybrook, WA, 33°34'S, 115°49'E. From under stones in rather dry soil in forest. 28-29.vii.1905.

Megascolex colliensis Michaelsen, 1907: 219, Pl. 2 Fig. 53, Text fig. 31. Syntype, 1 WAM 4435. Locality: Collie, WA, 33°22'S, 116°09'E. On roots of grasses in damp soil. 26.viii.1905.

Megascolex galei Michaelsen, 1907: 223, Pl. 2 Fig. 55, Text fig. 33. Syntype, 1 WAM 4392. Locality: Collie, near Collie River, WA, 33°22'S, 116°09'E. Under fallen branches in dry soil in forest. 26.viii.1905.

Megascolex monostichus Michaelsen, 1907: 217, Text fig. 29. Syntype, 1 WAM 4221. Locality: Harvey, WA, 33°05'S, 115°54'E. From damp, humus-rich soil under fallen branches and amongst grass roots, near creek. 27.vii.1905.

Megascolex whistleri Michaelsen, 1907: 212, Pl. 2 Fig. 50, Text fig. 26. Syntype, 1 WAM 4437. Locality: Boyanup, WA, 33°29'S, 115°44'E.

Notoscolex hortensis Michaelsen, 1907: 199, Pl. 2 Figs 41, 42, Text fig. 19. Syntypes, 11 WAM 4401. Locality: Lion Mill (=? Lionel Mill, 21°41'S, 120°06'E), WA. From under fallen branches and bark in forest. 27.viii.1905.

Notoscolex modestus Michaelsen, 1907: 203, Pl. 2 Figs 46, 47, Text fig. 21. Syntype, 1 WAM 4400. Locality: York, WA, 31°53'S, 116°46'E. 11.viii.1905.

Notoscolex suctorius Michaelsen, 1907: 207, Pl. 2 Fig 56, Text fig. 23. Syntype, 1 WAM 4399. Locality: Bridgetown, WA, 33°58'S, 116°08'E. From forest. 30.vii.1905.

Plutellus blackwoodianus Michaelsen, 1907: 179, Pl. 1 Figs 21, 22, Text fig. 8. Syntype, 1 WAM 4427. Locality: Bridgetown, WA, 33°58'S, 116°08'E. From under stones in forest. 30-31.vii.1905.
Remarks: Transferred to genus *Graliophilus* by Jamieson (1971a).

Plutellus levis Michaelsen, 1907: 173, Pl. 1 Figs 15, 16, Text fig. 5. Syntype, 1 WAM 4430. Locality: Cannington, WA, 32°02'S, 115°55'E. Under stones in marshy soil near pond. 28.vi.1905.
Remarks: Collection date cited by Michaelsen (1907) as 28.v.1905. Transferred to genus *Graliophilus* by Jamieson (1971a).

Plutellus mendilai Michaelsen, 1907: 177, Pl. 1 Figs 19, 20, Text fig. 7. Syntype, 1 WAM 4428. Locality: Bed of Greenough River, Eradu, WA, 28°42'S, 115°02'E. From under stones, dry river bed. 13.vii.1905.
Remarks: Transferred to genus *Graliophilus* by Jamieson (1971a).

Plutellus murrayensis Michaelsen, 1907: 175, Pl. 1 Figs 17, 18, Text fig. 6. Syntype, 1 WAM 4426. Locality: Jarrahdale, WA, 32°20'S, 116°04'E. 19-20.ix.1905.
Remarks: Transferred to genus *Graliophilus* by Jamieson (1971a).

Plutellus strelitzi Michaelsen, 1907: 168, Pl. 1 Figs 11, 12, Text fig. 3. Syntype, 1 WAM 4429. Locality: Lion Mill (=? Lionel Mill, 21°41'S, 120°06'E), WA. From under rocks in dry sand-gravel road. 9.viii.1905.
Remarks: Transferred to genus *Graliophilus* by Jamieson (1971a).

Plutellus termitophilus Michaelsen, 1907: 164, Pl. 1 Figs 9, 10, Text fig. 1. Syntype, 1 WAM 4431. Locality: Lunenberg (=? Lunenburgh River, 33°15'S, 115°56'E), WA. From firm dry earth at base of termite nest. 22.ix.1905.
Remarks: Transferred to genus *Graliophilus* by Jamieson (1971a).

Plutellus woodwardi Michaelsen, 1907: 171, Pl. 1 Figs 13, 14, Text fig. 4. Syntype, 1 WAM 4425. Locality: Collie, WA, 33°22'S, 116°09'E. From marshy soil under branches and amongst grass roots. 26.viii.1905.
Remarks: Transferred to genus *Graliophilus* by Jamieson (1971a).

Pseudonotoscolex pallinupensis Jamieson, 1971a: 497, Figs 5b, 6g, 7j. Holotype, WAM 35-70. Paratype, 1 WAM 36-70. Locality: Pallinup River, WA, 34°29'S, 118°54'E. v.1914.
Remarks: Jamieson (1971a) cited holotype and paratype as WAM 3570. Specimens were part of WAM 8960. Monotypic genus.

Woodwardia affinus Michaelsen, 1907: 191, Pl. 2 Figs 31-33, Text fig. 15. Syntypes, 2 WAM 4432. Locality: Jarrahdale, WA, 32°20'S, 116°04'E. From under stones. 19-20.ix.1905.
Remarks: *Woodwardia* a junior homonyms ands replaced by *Woodwardiella* Stephenson, 1925 (see also Stephenson, 1930 and Jamieson, 1971b).

Woodwardia callichaeta Michaelsen, 1907: 189, Pl. 2 Figs 29, 30. Syntype, 1 WAM 4433. Locality: Jarrahdale, WA, 32°20'S, 116°04'E. From under stones. 19-20.ix.1905.
Remarks: See *Woodwardia affinus*.

Woodwardiella acanthodriloides Jamieson, 1971a: 488, Figs 2a, 4b, 6e, 7g. Holotype, WAM 34-70. Paratype, 1 WAM 34-70. Locality: Frankland River, WA, 34°24'S, 117°01'E. 23.xi.1939.
Remarks: Holotype pinned.

Class Hirudinea
Order Gnathobdellida
Family Richardsonianidae

Habeobdella stagni Richardson, 1971: 49, Fig. 1a-g. Holotype, WAM 49-69. Paratype, 1 WAM 49-69. Locality: South end of Herdsman Lake, Perth, WA, 31°44'S, 115°47'E. From mud. 5.ii.1965.

Remarks: Jaws of holotype on slide. Length of holotype 43.0 mm. Collection date cited by Richardson (1971) as 5 Nov 1965.

Uncertain Type Status

Phylum Annelida
Class Polychaeta
Family Nereididae

Quadricirra bansei Hartmann-Schröder, 1979: 121, Text figs 227-237. Paratype(s), 3 WAM 20-79. Locality: Gantheaume Point, Broome, WA, 17°58'S, 122°14'E. From algae and sand on rocks, lower littoral. 24.ix.1975.
Remarks: Specimens could not be found in WAM collection. Paratypes not cited by Hartmann-Schröder (1979) as lodged in WAM. Holotype and 3 paratypes in HZM. Transferred to genus *Micronereis* by Paxton (1983).

Class Oligochaeta
Order Haplotaxida
Family Megascolecidae

Kerria nichollsi Jackson, 1931: 121, Pl. 16 Figs 5, 8, 9, 11. Syntypes ?, many WAM 8-61, 3 WAM 9-61, WAM 26-61 (12 slides). Locality: South Perth, near Swan River, WA, 31°59'S, 115°52'E. From vegetable garden, swampy ground. 1926.
Remarks: WAM 8-61 and 9-61 labelled as probable type material. Slides WAM 26-61 lack type designation but registered as probable type material.

Megascolex affinis Nicholls and Jackson, 1926: 145, Pl. 18 Figs 3-5. Holotype ?, WAM 88-86 (slide). Locality: South-west Australia.
Remarks: 1 slide of spermatheca and spermiducal gland. Slide lacks type designation but since only one type specimen was described by Nicholls and Jackson (1926) it represents probable holotype material.

Megascolex albidus Jackson, 1931: 118, Pl. 15 Fig. 2, Text fig. 12. Syntypes ?, 2 WAM 21-61. Locality: Condinup, WA, 33°45'S, 122°32'E. 8.ix.1925.
Remarks: Labelled as probable type material.

Megascolex longicystis Nicholls and Jackson, 1926: 142, Pl. 18 Figs 1, 2. Syntype(s) ?, WAM 31-61 (2 slides). Locality: Armadale, WA, 32°10'S, 116°00'E.
Remarks: 2 slides, possibly of same specimen, lacking type designation but registered as probable type material.

Megascolex swarbricki Nicholls and Jackson, 1926: 143, Pl. 18 Figs 6-10. Syntype(s)?, WAM 30-61 (7 slides). Locality: Near Nornalup, WA, 35°00'S, 116°49'E. From valleys of Deep and Frankland Rivers.
Remarks: 7 slides, specimen number indeterminate, lacking type designation but registered as probable type material.

Megascolex syndetoporus Jackson, 1931: 117, Pl. 15 Fig. 1, Text figs 10, 11. Syntype(s)?, WAM 27-61 (7 slides). Locality: Pemberton, WA, 34°26'S, 116°02'E.
Remarks: 7 slides, specimen number indeterminate, lacking type designation but registered as probable type material.

Notoscolex leios Jackson, 1931: 108, Pl. 15 Figs 3, 5. Holotype ?, WAM 20-61, WAM 23-61 (slide). Locality: Murchison, WA, 27°38'S, 114°55'E.
Remarks: WAM 20-61 labelled as probable type material. Slide WAM 23-61 without type designation but registered as probable type material. Jackson (1931) described a single type specimen, therefore both WAM 20-61 and 23-61 probably holotypic.

Plutellus candidus Jackson, 1931: 90, Pl. 15 Figs 9, 12,13, Text fig. 6. Holotype ?, WAM 15-61, WAM 24-61 (slide). Locality: Roleystone, WA, 32°07'S, 116°04'E. 1927.
Remarks: WAM 15-61 labelled as probable type material. Slide WAM 24-61 without type designation but registered as probable type material. Jackson (1931) described a single type specimen, therefore both WAM 15-61 and 24-61 probably holotypic. Transferred to genus *Graliophilus* by Jamieson (1971*a*).

Plutellus dalgarangae Jackson, 1931: 90. Syntype ?, 1 WAM 16-61. Locality: Dalgaranga Station, north-east of Yalgoo, WA, 27°45'S, 117°01'E. From under rocks. 1925.
Remarks: Labelled as probable type material. Transferred to genus *Graliophilus* by Jamieson (1971*a*).

Plutellus varicystis Jackson, 1931: 92, Pl. 15 Fig. 4, Text figs 7, 8. Syntypes ?, 5 WAM 17-61, WAM 22-61 (slide). Locality: Porongorups, WA, 34°41'S, 117°54'E. 1926. Syntypes ?, many WAM 18-61. Locality: Faulkners (property), Porongorups. 29.v.1927.
Remarks: WAM 17-61 and 18-61 labelled as probable type material. One specimen of WAM 18-61 separately labelled as lectotype, by persons unknown. Slide WAM 22-61 without type designation but registered as probable type material. Transferred to genus *Graliophilus* by Jamieson (1971*a*).

Pontodrilus albanyensis cygni Jackson, 1931: 94, Pl. 14 Figs 2, 3, 4, 9. Syntypes ?, 31 WAM 12-61, 2 WAM 13-61. Locality: Swan River bank, Claremont, Perth, WA, 31°59'S, 115°47'E. v.1927. Syntypes ?, many WAM 14-61. Locality:

Nornalup, WA, 35°00'S, 116°49'E. Syntypes ?, WAM 28-61 (6 slides). Locality: Claremont and Nornalup, WA.

Remarks: WAM 12-61, 13-61 and 14-61 labelled as probable type material. 6 slides WAM 28-61 without type designation but registered as probable type material. *Pontodrilus albanyensis* regarded by Jamieson (1971a) as synonym of *P. litoralis* (Grube).

Woodwardiella magna Jackson, 1931: 103, Pl. 15 Figs 7, 10, Text fig. 9. Syntype ?, 1 WAM 19-61, WAM 25-61 (slide). Locality: Lesmurdie, WA, 32°00'S, 116°00'E. 1927.

Remarks: WAM 19-61 and 25-61 labelled as *Woodwardia magna* . WAM 19-61 labelled as probable type material. Slide WAM 25-61 without type designation but registered as probable type material.

Family Lumbricidae

Eiseniella intermedius Jackson, 1931: 123, Pl. 16 Figs 4, 6, 7, Text fig. 16. Syntypes ?, many WAM 10-61, 3 WAM 11-61, WAM 29-61 (14 slides). Locality: Lake Monger, Perth, WA, 31°55'S, 115°49'E. From freshwater along margin of lake. 1927.

Remarks: WAM 10-61 and 11-61 labelled as probable type material. Slides WAM 29-61 without type designation but registered as probable type material.

Invalid types

Phylum Nematoda
Class Secernentea
Order Oxyurida
Family Cosmocercidae

Maxvachonia brygooi Mawson, 1972: 102, Figs 7-10. Allotype and paratypes in Jones, 1986: 690, Figs 1-5. Allotype, ♂ WAM 225-85. Paratypes, 2 ♂♂ WAM 226-85. Locality: 5 km west of Mt Percy, WA, 17°37'S, 124°55'E. From rectum of *Pogona minor mitchelli* (WAM R70655). 19.v.1980. Paratype, ♂ WAM 228-85. Locality: Martins Well, WA, 16°34'S, 122°51'E. From rectum of *Pogona minor mitchelli* (WAM R58532). 28.v.1977.

Remarks: Mawson (1972) established the species *M. brygooi* without indication of a holotype nor adequate species description. No indication is given of which specimen(s) is (are) illustrated though several females are cited. Under Articles 72 and 73 of the International Code of Zoological Nomenclature the specimens must be regarded as syntypes. These are lodged in the South Australian Museum.

Jones (1986) described males of the species, designating an 'allotype' and 'paratypes'. (The allotype WAM 225-85 bears label of 'holotype'.) This move was invalid under the Code since paratypes (including allotype) can only be designated in the original species description. Under Article 74 of the Code, a lectotype could be designated subsequently from the syntypic series but not from additional material. The allotype and paratypes designated by Jones (1986) therefore have no type status.

Acknowledgements

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A new and aberrant species of *Paguristes*
(Anomura: Diogenidae) from northern Australia

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Abstract

A new diogenid hermit crab, *Paguristes monoporus*, is described from shallow waters of the Northern Territory, Australia. The species is unique in the genus, and in the family Diogenidae, in that males lack a gonopore on the left side. Additionally, the left first pleopod of males is very much reduced and the left second pleopod is absent.

Introduction

Hermit crabs, particularly the family Diogenidae, are common and diverse in tropical inshore waters of the Indo-Pacific region (e.g. Alcock 1905; Ball and Haig 1972; Khan and Natarajan 1984). Recent collection of material from Port Essington (11°15'S, 132°07'E), 200 kms north-east of Darwin, Northern Territory, Australia yielded specimens of an undescribed species of hermit crab. The species agrees with the genus *Paguristes* Dana, 1851 in most characters but displays some sexual characteristics unique to the genus and to the family Diogenidae.

All material was collected by the author from Port Essington. Measurements of specimens are cited for shield length (SL) and for the holotype, carapace length (CL). Northern Territory Museum registration numbers are prefixed by NTM, Western Australian Museum numbers by WAM.

Systematics

Paguristes monoporus sp. nov.

Figures 1-3

Holotype

♂, SL 4.1 mm, CL 7.1 mm, Orontes Reef, west end, (11°04'S, 132°04'E), Port Essington, 11-12 m, in *Cronia avellana* (Reeve, 1846) shell, 10 August 1986, NTM Cr004345.

Paratypes

♂, SL 3.8 mm, 2 ♀♀, 3.1 mm and 2.9 mm, type locality, WAM 2240-86; 4 ♂♂, SL 3.4 mm-2.9 mm, 2 ♀♀, SL 3.0 mm and 3.0 mm, Orontes Reef, west end, 14-17 m, in *Cronia avellana* shells, 9 August 1986, WAM 2241-86; 3 ♂♂, SL 3.8 mm, 3.1 mm, 2.9 mm, 3 ♀♀, SL 3.9 mm, 3.5 mm, 3.3 mm, Orontes Reef, west end, 12 m, in *Cronia avellana* and *Peristernia incarnata* (Deshayes, 1830) shells, 13 August 1986, WAM 2242-86; ♂, SL 3.5 mm, 2 ♀♀, SL 3.6 mm (ovig)

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and 3.0 mm, Coral Bay, (11°11'S, 132°03'E), sand and coral, 4-6 m, in *Cronia avellana* shells, 11 August 1986, WAM 2243-86; 2 ♂♂, SL 3.4 mm and 3.3 mm, ♀, SL 3.4 mm, Coral Bay near headland, 4 m, in *Cerithium* sp. shells, 12-13 August 1986, NTM Cr004346; ♀, SL 3.7 mm, Coral Bay, on small island, sand and rocks, littoral, 12 August 1986, WAM 2244-86.

Diagnosis

Distinguishable from all other *Paguristes* species in that males possess gonopore on coxa of pereiopod 5 on right side only; pleopods 1 and 2 modified as copulatory appendages on right side; pleopod 1 very much reduced and pleopod 2 absent on left side. Females with gonopore on coxa of pereiopod 3 on left side only; pleopods 1 paired; abdominal brood pouch absent.

Description

Shield (Figure 1a) longer than broad. Anterior margin between rostrum and lateral projections concave; rostrum broadly triangular, similarly produced or slightly exceeding lateral projections, with terminal spinule; lateral projections usually with terminal spinule. Dorsal surface of shield lightly sculptured, lateral margins with some scattered spines and spinules. Plumose setae scattered on dorsal surface of shield, denser laterally.

Ocular peduncles long, roughly cylindrical and slightly longer than width of anterior margin of shield; peduncles gradually inflated proximally; corneas only slightly inflated; peduncles almost naked, some long setae proximodorsally. Ocular acicles distally slender, simple; mesial margins slightly convex, lateral margins right angular; acicles heavily setose with plumose setae and separated basally by slightly more than half width of one acicle.

Antennular peduncles (Figure 2a) similar length to or slightly longer than ocular peduncles. Ultimate and penultimate segments unarmed, proximal segment with 2 distolateral and 1 distomesial spines. Peduncular setation sparse.

Antennal peduncle (Figure 2b) reaching to distal half or third of ocular peduncles. Fifth (ultimate) segment unarmed; fourth segment with dorsolateral spine; third with distoventral spine; second with 2 or 3 distolateral spines and 1 distomesial spine; first segment unarmed. Antennal acicle almost reaching distal end of ultimate peduncular segment; acicle terminating in bifid spine, lateral margin with 2-3 spines, mesial margin with 1 spine (sometimes absent). Peduncle quite heavily setose. Antennal flagella much shorter than thorax; articles each with about 10 simple setae.

Mouthparts illustrated in Figure 2c-h. Maxillule with proximal endite subquadrate; endopodite with external lobe very strongly produced, one-half length of endopodite. Maxilla with endopodite slightly inflated basally. First maxilliped with endopodite shorter than basal segment of exopodite. Second maxilliped with basis-ischium fusion apparently incomplete. Third maxilliped with basis-ischium fusion apparently incomplete; ischium with crista dentata well developed, no accessory tooth, spine at dorsodistal and ventrodistal margins; merus usually with 3 spines on ventral margin.
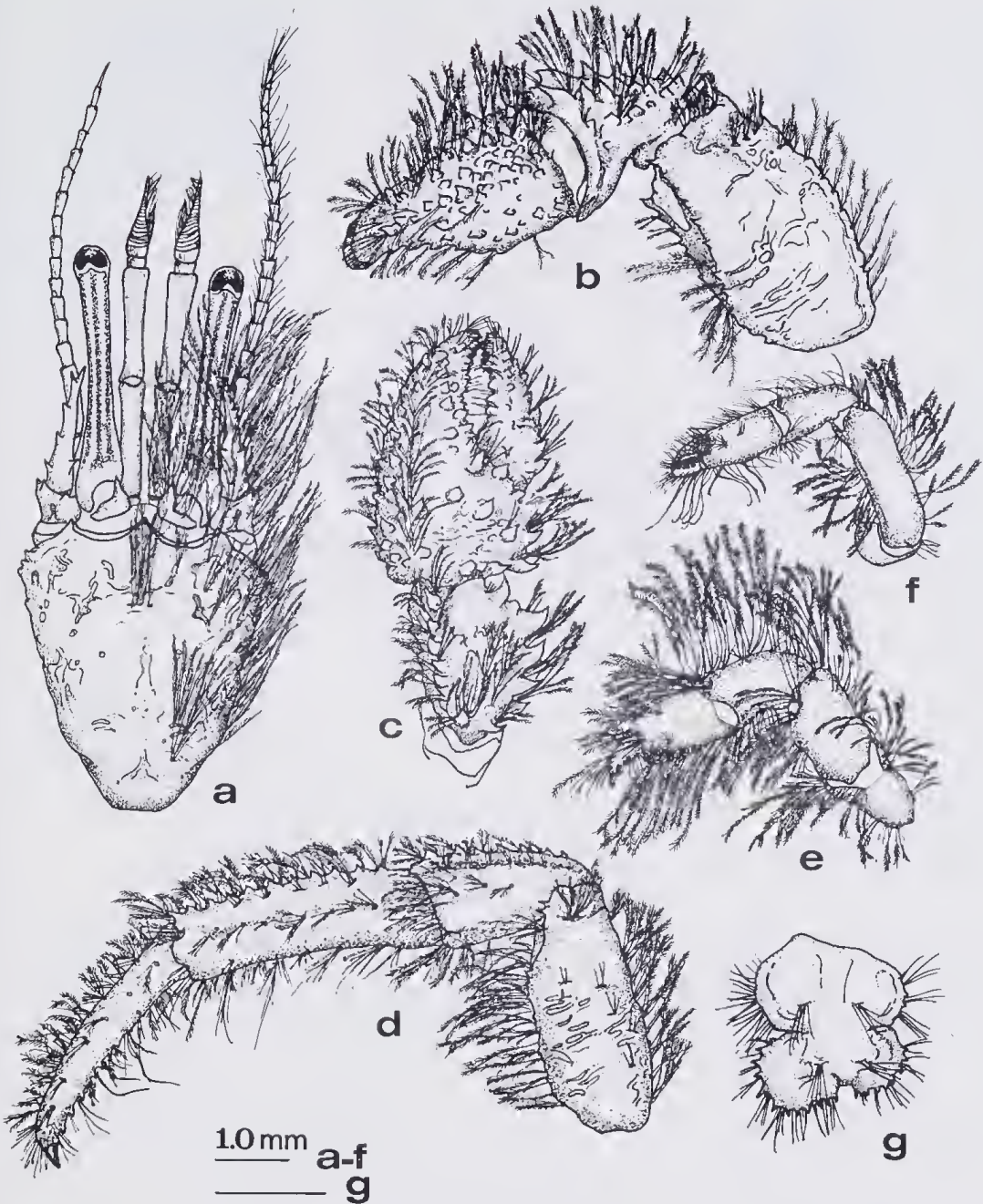
Figure 1   *Paguristes monoporus.* (a)-(c), (g) holotype ♂; (d)-(f) paratype ♂ SL 3.8 mm. (a) shield and appendages, dorsal view, setae on left side omitted; (b) left cheliped, lateral view; (c) left cheliped, dorsal view; (d) second left pereiopod, lateral view; (e) fourth left pereiopod, lateral view; (f) fifth left pereiopod, lateral view; (g) telson, dorsal view.
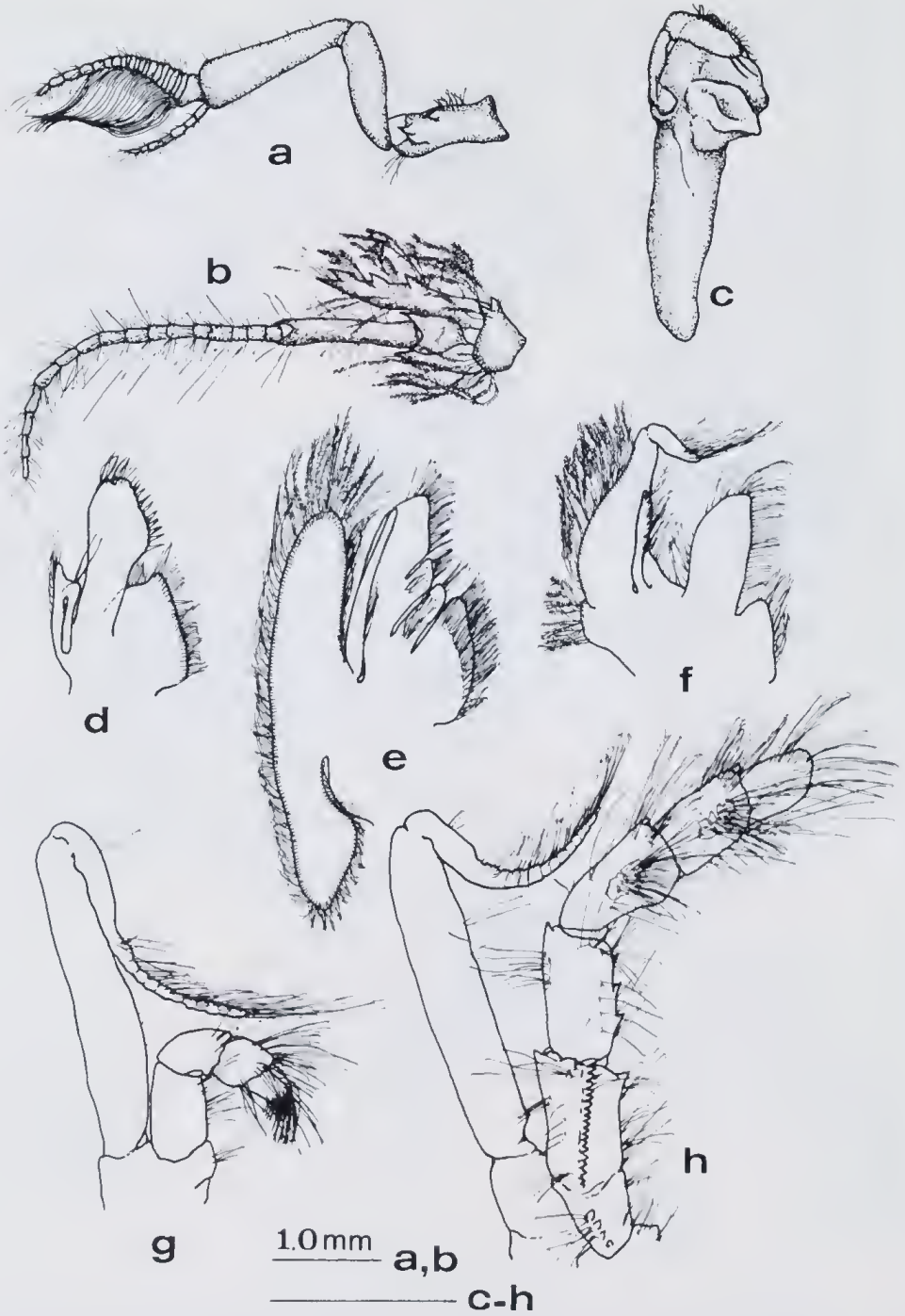
Figure 2   *P. monoporus.* Paratype ♂ SL 3.4 mm. (a) left antennule, lateral view; (b) left antenna, lateral view; (c)-(h) mouthparts, left, mesial view, (c) mandible, (d) maxillule; (e) maxilla; (f) first maxilliped; (g) second maxilliped; (h) third maxilliped.
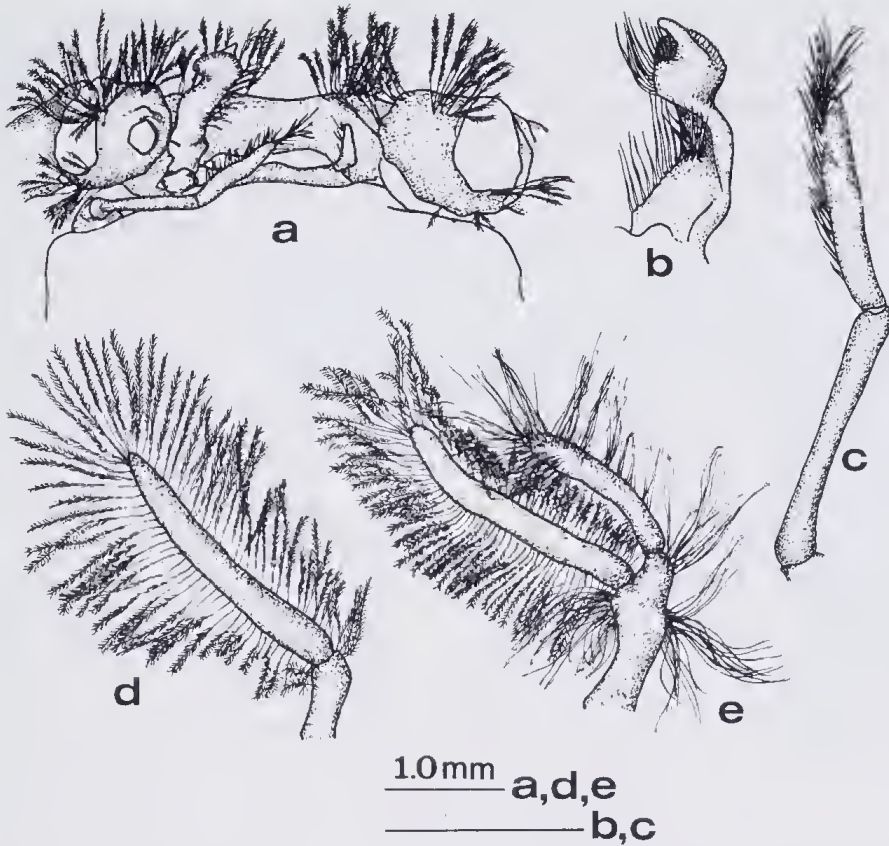
Figure 3   *P. monoporus* (a)-(d) paratype ♂ SL 3.8 mm; (e) paratype ♀ SL 3.1 mm. (a) fifth coxae and copulatory pleopods of male, ventral view; (b) first pleopod of male, dorsolateral view; (c) second pleopod of male, ventral view; (d) third pleopod of male, mesial view; (e) second (first unpaired) pleopod of female, mesial view.

Chelipeds (Figure 1b, c) subequal; no distinct sexual dimorphism. Dactyl slightly longer than half length of propodus; cutting edge with about 4 large teeth and row of 14-15 corneous teeth distally and larger terminal corneous tooth; dorsal and mesial surfaces with irregular rows of spines and tubercles, larger dorsally, some corneous tipped. Dactyl tip hoof-shaped. Dactyl touching fixed finger only distally. Fixed finger with fairly evenly sized cutting teeth, smaller than those of dactyl; row of corneous teeth distally. Dorsal and lateral surfaces of fixed finger and palm with irregularly sized tubercles and spines, randomly distributed or in very irregular rows; some spines also on ventral surface of palm. Mesial margin of palm with three large spines and some smaller spines ventromesially. Palm slightly broader than long. Carpus subtriangular, slightly longer than broad, much shorter than merus; dorsolateral edge with row of spines, mesial edge with 4 large spines, scattered spines on dorsal surface, large spine near distal articulation with pro-

podus. Merus slightly compressed laterally; lightly denticulate along dorsal edge, rows of spines along ventromesial and ventrolateral edges. Dactyl, propodus and carpus heavily setose along dorsolateral and dorsomesial margins, some setal tufts on dorsal surface and ventrally; merus less setose; most cheliped setae plumose, some simple especially ventrally.

Second pereiopod (Figure 1d) longer than cheliped. Dactyl similar length to propodus, terminating in strong corneous claw, row of corneous spines ventrally, row of smaller corneous spines dorsomesially. Propodus with dorsal row of non-corneous spines. Carpus much shorter than merus, dorsal row of large spines, distinct lateral groove. Merus laterally compressed, with ventral row of spines, some spinules dorsally. Long plumose setae along dorsal and ventral edges of pereiopod segments, some setal tufts laterally, and mesially on propodus.

Third pereiopod similar to second, but dactyl with additional irregular row of small corneous spines on ventromesial surface. Fourth and fifth pereiopods heavily setose (Figure 1e, f).

Sternite of third pereiopod with very weakly produced anterior lobe.

First pleopods, and second pleopod of male on right side, illustrated in Figure 3a-c. Three unpaired pleopods on left side uniramous (Figure 3d). Paired first pleopods on female; first three unpaired pleopods biramous (Figure 3e), last unpaired pleopod uniramous. Brood pouch absent.

Tailfan asymmetrical, left uropods much larger than right. Telson (Figure 1g) with posterior lobes separated by medial cleft, left lobe larger than right. Lateral and posterior margins of both lobes with large spines, 7-12 spines on left lobe, 6-9 on right. Anterior lobes naked or with few spinules. Telson and uropods fringed with setae.

Coloration in life

Shield cream or pale brown with darker brown mottling. Ocular peduncles white or cream with ventral, mesial, dorsal and lateral red-brown longitudinal stripes continuing onto cornea. Antennular peduncles with penultimate segment brown, ultimate segment distally bright blue; flagella orange. Antennal peduncles cream and pale brown; flagella banded in cream and brown. Chelipeds mottled cream and brown, finger tips cream. Pereiopods 2 and 3 with merus and carpus cream mottled with red-brown and with thin longitudinal lateral red-brown stripe; propodus similar, but also with diffuse red-brown bands proximally and sub-distally; dactyl similar to propodus but longitudinal lateral line sometimes obsolete. Occasionally a vague ventrolateral line on propodus and carpus. Pereiopods 4 and 5 irregularly banded with cream and red-brown. Setae grey or pale brown, obscuring colours of chelipeds.

Eggs

Ovigerous female (SL 3.6 mm) with 14 subspherical eggs, maximum diameter 0.8 mm. Eggs attached to non-plumose setae of pleopods, especially on endo-podites.

Distribution

The species is known from the Northern Territory, Australia, and has also been collected from Phuket, Thailand and Cebu, Philippines (J. Forest, pers. comm.).

Etymology

The specific name is derived from the Greek for 'single pore' and refers to the single male genital opening.

Remarks

Paguristes monoporus resembles other members of *Paguristes* in most characters including form of the carapace and of cephalic and thoracic appendages. The species is unique in the absence of a gonopore and of a modified second pleopod on the left side of males. The first left pleopod is very small and represented by a single lobe. On several specimens, including the holotype, the pleopod is not visible. It is uncertain whether the appendage is absent on these animals, or has been lost through trauma. Males of all other species of *Paguristes* have paired gonopores and first and second pleopods, and first pleopods are equal in size. The presence in females of the gonopore on one (left) side only is relatively uncommon in Indo-West Pacific species of *Paguristes* but occurs in many east Atlantic, and some Red Sea, species (Forest 1954).

Eggs carried by one female of *P. monoporus* are relatively large which may indicate some level of abbreviated development as shown by some species of *Paguristes* (Dechancé 1963; Morgan 1987).

Habitat of the species in the Northern Territory is relatively shallow (4-17 m) coastal waters, associated with coral or soft sandy bottoms. Shells of the gastropod *Cronia avellana* are most commonly utilised by the species.

Paguristes is a very large and variable genus. Variation is particularly evident in the number of pleopods and gonopores in females, though the male complement is more conservative. The genus requires revision, and this may result in its subdivision into several genera. Given the apparently unique condition of the male gonopore in *P. monoporus*, its separation from *Paguristes sensu stricto* may be warranted.

Acknowledgements

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Four new Serranid Fishes of the genus *Epinephelus* (Perciformes: Epinephelinae) from Western Australia

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Abstract

Four new species of serranid fishes are described from northern Western Australia. *Epinephelus stictus* is named from six specimens (four from the South China Sea) collected by trawling. It is similar to *E. diacanthus* Valenciennes and *E. sexfasciatus* Valenciennes with which it shares two greatly enlarged serrae at the corner of the preopercle; *E. stictus* is distinctive in having numerous dark brown dots dorsally on the head and anterodorsally on the body. *E. timorensis* (one specimen) and *E. trophis* (two specimens) were obtained from 130 m at the base of an experimental drilling rig at Dillon Shoals in the Timor Sea. *E. timorensis* was blue-grey with yellow spots on the head and body and faint dark spots posteriorly on the body, caudal fin, and soft portions of the dorsal and anal fins. *E. trophis* is distinctive in its high lateral-line scale count (67-69), deep body (depth 2.45 in SL) and uniform brown colour. *E. bilobatus* is represented by five specimens taken off Western Australia between latitudes 16 and 21° S; it is closely related to the dark spotted, Western Pacific *E. maculatus* (Bloch), differing in usually having 16 instead of 17 dorsal soft rays, fewer scales in longitudinal series, fewer gill rakers, and in its possession of three, large, bilobed, dark brown spots or close-set pairs of spots along the base of the dorsal fin.

Introduction

The serranid fishes of the subfamily Epinephelinae, widely known as groupers (gropers or rock cods in Australia), are among the most important food fishes of inshore waters in the tropical and subtropical regions of the world. They are usually associated with coral reefs or rocky substrata, though some species are taken by trawling on open sedimentary bottoms. Depending on the species, they occur from shallow water to 300 m or more. The adult size varies from less than 20 cm TL to at least 270 cm. Larger species are major predators at or near the top of food chains, feeding principally on fishes and crustaceans.

Because groupers are readily caught by hook and line, they were available to early naturalists who made collections of marine animals throughout the world. One would expect, therefore, that the classification of the group would be essentially complete by now. It has approached the definitive level for the New World

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Epinephelinae, but taxonomic problems remain for the Indo-Pacific region. Randall (1987) recognised 99 species among 11 genera in a preliminary synopsis of Indo-Pacific members of the subfamily. The largest genus is *Epinephelus* with 63 valid named species in the Indo-Pacific and at least seven additional undescribed species. The purpose of the present paper is to name four of these new fishes which occur off Western Australia. Two were taken from an experimental drilling rig temporarily stationed at Dillon Shoals in the Timor Sea. After a number of weeks the operation ceased and the drill was slowly lifted from the seabed (130 m) over a period of several hours. Evidently many of the fishes living around the drill shaft followed it towards the surface, eventually floating upwards because of expansion of their gas bladders. The specimens were netted on the surface in the open centre section of the drilling barge by Lynn Harris, the vessel's medical officer. The third species is described from six specimens collected off north-western Australia, Hong Kong, and the South China Sea; it also occurs in relatively deep water. Twenty-seven species of *Epinephelus* are currently known from West Australian seas. Many of these were reported and/or illustrated for the first time from this area in the recent works of Gloerfelt-Tarp and Kailola (1984), Sainsbury, Kailola, and Leyland (1985), Allen (1985), and Allen and Russell (1986). A key is presented below to these 27 species, including the four species described herein.

We have reidentified the figure of *E. magniscuttis* in Gloerfelt-Tarp and Kailola (1984) as *E. epistictus* and also their figures of *E. malabaricus* and *E. tauvina* as *E. suillus*. Three *Epinephelus* names in Sainsbury *et al.* were corrected in their separate addendum as follows: *E. malabaricus = suillus, E. rankini = multinotatus,* and *E. homosinensis = rivulatus. Promicrops lanceolatus* of Allen (1985) and many other authors is here classified in *Epinephalus*. Mention should be made of the small grouper from 132 m off Barrow Island identified as *Cephalopholis* sp. by Allen (1985: fig. 118). This is one of a series of four specimens, WAM P26175-008, 36-55 mm SL. We tentatively identify this fish as *C. sonnerati* (Valenciennes, 1828). The meristic data, including the high lateral-line scale counts of 68-75, are the same as found in *sonnerati;* the body proportions and other morphological characters seem correct as well. The mottled pink colour is unusual, but we have no specimens of *sonnerati* this small or from this depth for comparison. Kyushin *et al.* (1977) recorded *C. sonnerati* from 22-110 m at several Indian Ocean localities. Their colour illustration of a 312-mm specimen is correctly identified as *sonnerati,* but their figure of a 124-mm specimen is *C. nigripinnis* (Valenciennes, 1828).

Materials and methods

The length given for specimens is standard length (SL); this is the straight-line measurement from the front of the upper lip (with the upper jaw pushed back if protruded) to the base of the caudal fin (end of hypural plate). Head length and snout length are taken from the same anterior point, the former to the posterior end of the opercular membrane and the latter to the fleshy edge of the orbit.

Body depth is the greatest depth from the base of the dorsal fin, adjusting for any malformation of preservation; body width is the maximum width just posterior to the gill opening. Orbit diameter is the greatest fleshy diameter; the interorbital width is the least fleshy width. Maxilla depth is the greatest depth of the expanded posterior end of the bone plus the supramaxilla. Caudal peduncle depth is the least depth, and caudal peduncle length is the horizontal distance from the posterior of the anal fin base to the caudal-fin base. The lengths of the spines and rays of the median fins are measured to their extreme bases (for which radiographs are helpful). The pectoral-fin length is the length of the longest ray; pelvic-fin lengths are measured from the base of the spine to the tip of the longest ray.

The last dorsal and anal rays, though divided to the base, are counted as one ray. Pectoral-ray counts include the uppermost rudimentary ray. Lateral-line scale counts are made from the upper end of the gill opening to the base of the caudal fin. The longitudinal scale series is the number of diagonal rows of scales counted just above the lateral line to the caudal-fin base. Gill-raker counts are made on the first gill arch and include all rudiments; the raker at the angle is contained in the lower-limb count.

Type specimens of the new species are deposited at the following institutions: Bernice P. Bishop Museum, Honolulu (BPBM); Division of Fisheries and Oceanography, Commonwealth Science and Industrial Research Organisation, Hobart (CSIRO), Western Australian Museum, Perth (WAM); and Department of Zoology, University Museum, University of Tokyo (ZUMT; ABE, the latter indicates the private collection of Tokiharu Abe).

In the descriptions below, data in parentheses refer to paratypes. Proportional measurements are given in the tables as percentages of the standard length. Many of these proportions are also presented in the text as quotients of larger measurements such as standard length and head length; these are rounded to the nearest 0.05.

Systematics

Key to the species of *Epinephelus* from Western Australia

1a Caudal fin emarginate to truncate...2

1b Caudal fin rounded...4

2a Membranes of spinous portion of dorsal fin incised; lateral line scales 49-53; depth 2.9-3.3 in SL; caudal fin emarginate to truncate; colour whitish with numerous, small, brown to yellowish brown spots 3

2b Membranes of spinous portion of dorsal fin not incised; lateral-line scales 64-80; body depth 2.6-3.0 in SL; caudal fin truncate; purplish grey with irregular, whitish spots and blotches and numerous, small, brown spots (Indian Ocean) ....*E. multinotatus* (Peters, 1876)

3a   Anal fin rounded to slightly angular, the longest rays 2.0-2.6 in head; dorsal soft rays usually 16; pectoral fins relatively long, 1.6-1.8 in head; lower-limb gill rakers 14-16 (usually 15) (Red Sea and East Africa to western Pacific) .... *E. areolatus* (Forsskål, 1775)

3b   Anal fin angular, the longest rays 1.85-2.3 in head; dorsal soft rays usually 17, pectoral fins not long, 1.7-2.0 in head; lower-limb gill rakers 15-18 (usually 16 or 17) (Red Sea and East Africa to the western Pacific) .... *E. chlorostigma* (Valenciennes, 1828)

4a   Anal soft rays 9 (rarely 10); one to four spines on lower margin of preopercle separated from the enlarged spinules of the preopercular angle; brown with seven or eight broad dark bars on body, the one on caudal peduncle broadest and darkest, especially dorsally (Indo-Pacific, in deep water) .... *E. septemfasciatus* (Thunberg, 1793)

4b   Anal soft rays 8 (rarely 7 or 9); no spines on lower margin of preopercle; colour not as in 4a. 5

5a   Dorsal soft rays 12-13; young with two, broad, longitudinal, black-edged whitish bands that disappear in adults, the dark edges in adults first breaking into dashes and spots (Red Sea to southern Japan). .... *E. latifasciatus* (Temminck and Schlegel, 1842)

5b   Dorsal soft rays 14-18 (except *radiatus*, rarely with 13); colour not as in 3a 6

6a   Lateral-line scales with branched tubules; eye very small, varying from about 8 in head of 20 cm SL individuals to about 9 for 35 cm ones, and 13 for 145 cm fish; maximum total length about 270 cm (Indo-Pacific). .... *E. lanceolatus* (Bloch, 1790)

6b   Lateral-line scales with a single tubule (except large *E. suillus*); eye not very small, less than 7 in head for 20 cm individuals and less than 8 for 35 cm ones; maximum total length less than 150 cm. 7

7a   Head, body, and fins with numerous, small, dark spots. 8

7b   Dark spots, if present, not numerous and not on head, body, and fins .... .18

8a   Lateral-line scales 47-52 9

8b   Lateral-line scales 52-74 .... .12

9a   Longitudinal scale series 86-96; pectoral fins relatively long, 1.2-1.5 in head; two diagonal dark bands on thorax anterior to pectoral-fin base (uppermost band may consist of two elongate dark spots) (western Pacific to southwest Thailand and Western Australia) .... *E. quoyanus* (Valenciennes, 1830)

9b   Longitudinal scale series 94-120; pectoral fins not long, 1.5-1.95 in head; no diagonal dark bands on thorax .... .10

10a Longest dorsal spine 2.05-2.30 in head; three, large, bilobed or close-set pairs of spots along base of dorsal fin; dark spots on pectoral fins moderate to large, approaching pupil diameter in size, (Western Australia). . . . .
. . . . *E. bilobatus*, new species

10b Longest dorsal spine 2.7-3.3 in head; no large dark brown or blackish area anteriorly in dorsal fin; dark spots on pectoral fins small 11

11a Dorsal soft rays 15-17 (usually 16); gill rakers 21-24; no black, saddle-like spot on caudal peduncle; spots on body dark brown, larger than pupil, round to hexagonal, and close-set (some merging to form short bands) (Indo-Pacific) . . . .*E. merra* Bloch, 1793

11b Dorsal soft rays 14-15; gill rakers 24-27; a black, saddle-like spot dorsally on caudal peduncle; numerous, very small, blackish spots on body superimposed on a pattern of large brown blotches (Indo-Pacific). . . . .
. . . . *E. microdon* (Bleeker, 1856)

12a Most dark spots on body polygonal and very close-set, only narrow pale lines or white dots separating individual spots. 13

12b Most dark spots on body round or oblong and well-separated. 14

13a Second anal spine relatively long, 2.10-2.35 in head; longest dorsal spine 2.55-2.90 in head; dorsal soft rays usually 16; dark spots of head and body merging or tending to merge, separated mainly by white dots at angular corners of spots; a series of five dark blotches along back; a large yellow-brown spot behind eye sometimes linked to but usually separate from another horizontally elongate spot of the same colour on opercle (Indo-Pacific) . . . . .
. . . . *E. hexagonatus* (Schneider, 1801)

13b Second anal spine not long, 2.75-3.55 in head; longest dorsal spine 2.9-3.5 in head; dorsal soft rays usually 15; dark spots on head and body fully separated by a network of pale lines; a single large black spot on back at rear base of spinous portion of dorsal fin; no large yellow-brown spot behind eye or on opercle (East Africa to the Line Islands and Phoenix Islands). . . . .
. . . . *E. melanostigma* Schultz, 1953

14a Lateral-line scales 52-65 15

14b Lateral-line scales 65-74 17

15a Gill rakers 29-31; posterior nostril subtriangular, more than four times larger in greatest dimension than anterior nostril in large adults; body depth 2.6-3.1 in SL; light yellowish brown with large, irregular, blotches on head and body, and numerous small dark brown spots on head, body, and fins; a saddle-like black spot on caudal peduncle (Indo-Pacific) . . . .
. . . .*E. fuscoguttatus* (Forsskål, 1775)

15b Gill rakers 23-29; nostrils subequal or posterior nostril enlarged but vertically elongate; body depth 2.7-3.8 in SL; dark spots on head and body not very small and not close-set; no black spot dorsally on caudal peduncle 16

16a Pectoral fins 1.50-1.75 in head; posterior nostril of adults vertically elongate, its length two to three times longer than diameter of anterior nostril; tubules of lateral-line scales simple; body depth 2.7-3.2 in SL; no obvious dark bars on body (a large dusky to blackish spot containing two or more black spots on back below rear of spinous portion of dorsal fin and two lesser dusky spots at base of soft portion of fin); maximum length 32 cm (Western Australia, Queensland to Taiwan) . . . . . . *E. corallicola* (Valenciennes, 1828)

16b Pectoral fins 1.75-2.25 in SL; posterior nostril not vertically elongate; tubules of anterior lateral-line scales of large adults branched; body depth 3.1-3.8 in SL; body with five diagonal dark bars (sometimes broken and/or faint) that bifurcate ventrally; maximum length at least 100 cm (Indo-Pacific) . . . .
. . . .*E. suillus* (Valenciennes, 1828)

17a Longitudinal scale series 98-113; scales on body mainly cycloid; auxiliary scales present; lower-limb gill rakers 18-20; pale with numerous, well-spaced, orange-red to dark brown spots on body, and five larger dusky spots on back (Indo-Pacific) . . . . *E. tauvina* (Forsskål, 1775)

17b Longitudinal scale series 113-135; scales on body ctenoid; no auxiliary scales present; lower-limb gill rakers 16-19; brown to grey with large, round to horizontally elliptical dark brown spots in four or five rows on body and smaller dark brown spots on head and fins (East Africa to western Pacific) . . . . *E. tukula* (Morgans, 1959)

18a Head and body dark with numerous, small, whitish spots, and often with large whitish blotches as well (small pale spots on head and nape of *timorensis* but dark spots posteriorly on body) 19

18b Head and body without small whitish spots and larger blotches 20

19a Pectoral rays 15-17 (rarely 17); lateral-line scales 48-53; two or three rows of teeth on midside of lower jaw; nostrils subequal; whitish spots in adults coalesced to form irregular longitudinal bands (Indian Ocean to western Pacific and Caroline Islands) . . . .*E. ongus* (Bloch, 1790)

19b Pectoral rays 17-19 (usually 18); lateral-line scales 51-61; three to five rows of teeth on midside of lower jaw; posterior nostril of adults vertically elongate, its length 2-4 times that of diameter of anterior nostril; whitish spots not coalesced to form longitudinal bands (Indian Ocean to central Pacific) . . . .*E. caeruleopunctatus* (Bloch, 1790)

20a Corner of preopercle with one to four (usually two) very large serrae (generally three or more times longer than lowermost serrae of posterior preopercular margin) 21

20b Corner of preopercle with slightly to moderately enlarged serrae (large on *E. epistictus, heniochus* and *radiatus,* but not three times longer than serrae above corner) 22

21a Dorsal soft rays 14-16 (usually 15); auxiliary scales present on body; six, near-vertical, dark bars or double bars on body (one on nape, four beneath dorsal fin, and one on caudal peduncle); caudal fin and soft portions of dorsal and anal fins with numerous blackish spots; no dark brown dots on nape and anterodorsally on body (north-western Australia, Indonesia, south-east Asia, and Philippines). . . . . *E. sexfasciatus* (Valenciennes, 1828)

21b Dorsal soft rays 16; no auxiliary scales on body; dark bars, if present on body, faint; no blackish spots on caudal, dorsal, or anal fins; numerous dark brown dots on nape and anterodorsally on body (north-western Australia to South China Sea). . . . . *E. stictus,* new species

22a Vertical or near-vertical dark bars on body (faint or absent on some preserved *E. rivulatus*); auxiliary scales present on body; lateral-line scales 46-53 (except *fasciatus* with 50-58) 23

22b No dark bars on body; auxiliary scales not present on body; lateral-line scales 53-69. 25

23a Scales on nape and anteriorly on body above lateral line very small; dorsal soft rays 16-18 (usually 17); each scale of body with a whitish dot (may not persist in preservative) (Indian Ocean and western Pacific) . . . .*E. rivulatus* (Valenciennes, 1830)

23b Scales on nape and dorsoanteriorly on body not very small; dorsal soft rays 15-17 (rarely 17); each scale of body without a whitish dot 24

24a Posterior nostril of adults about three times larger than anterior nostril; lateral-line scales 46-52; body depth 2.65-2.95 in SL; edges of dark bars on body with small black spots; outer part of membranes of spinous portion of dorsal fin not black or red (north-western Australia through Indonesia to Fiji and southern Japan) . . . . *E. amblycephalus* (Bleeker, 1857)

24b Nostrils subequal; lateral-line scales 50-58; body depth 2.9-3.3 in SL; no black spots on edges of dark bars or elsewhere on body; triangular outer part of membranes of spinous portion of dorsal fin black (or red in individuals from deep water) (Indian Ocean and western Pacific). . . . . *E. fasciatus* (Forsskål, 1775)

25a Lateral-line scales 53; numeorus, close-set, dark spots larger than pupil on caudal fin and soft portion of dorsal fin (dark spots also present on soft portion of anal fin but mostly smaller than pupil); yellow spots on head and body in life (most evident on head) (north-western Australia) . . . . *E. timorensis,* new species

25b Lateral-line scales 54-69; dark spots, if present on caudal and dorsal fins, smaller than pupil and not close-set; no yellow spots on head and body in life. 26

26a Dorsal soft rays 16-17; lateral-line scales 67-69; longitudinal scale series 143-145; body depth about 2.45 in SL; uniform dark brown (north-western Australia) . . . .*E. trophis,* new species

26b Dorsal soft rays 13-15; lateral-line scales 54-66; longitudinal scale series 91-120; body depth 2.6-3.3 in SL; pale, with or without prominent dark markings on body 27

27a Longitudinal scale series 91-95; lower-limb gill rakers 14-15; light brown with three longitudinal brown bands on head (two passing posteriorly from eye and one from upper edge of maxillary groove); no dark bands or spots on body or fins (north-western Australia and Indonesia to southern Japan) . . . .*E. heniochus* Fowler, 1904

27b Longitudinal scale series 100-120; lower-limb gill rakers 15-18; head with or without three longitudinal dark bands (if present, upper band bifurcate); dark bands or spots present on body. 28

28a Nostrils subequal; pelvic fins short, 2.15-2.70 in head; no dark bands on body; upper half to two-thirds of body with very small dark brown spots (scattered in adults, in three longitudinal rows in juveniles and subadults) (Indian Ocean to western Pacific) . . . .*E. epistictus* (Temminck and Schlegel, 1842)

28b Posterior nostril larger than anterior in adults; pelvic fins not short, 1.8-2.15 in head; five, irregular, diagonal, dark brown bands on body (with age only the edges remain dark), the first from nape to eye, the last three broadly branching ventrally; small dark spots in one or two irregular rows in pale interspace between bands (Red Sea and Indian Ocean to western Pacific). . . . .*E. radiatus* (Day, 1867)

Epinephelus stictus sp. nov.

Figure 1; Table 1

Epinephelus diacanthus (non Valenciennes) Fourmanoir, 1965: 26, fig. 10 (Nha Trang, Viet Nam).

Epinephelus sp. Gloerfelt-Tarp and Kailola, 1984: 135, 325, lowermost fig. of p. 134 (north-western Australia).

Holotype

WAM P28277-001, 328 mm, Western Australia, about 20 km S of Heywood Shoals (13°33′S, 124°02′E), 138-142 m, trawl, R/V *Courageous* Sta. 50/1103, K. Sainsbury, 3 June 1979.

Paratypes

BM(NH) 1939.1.17.10, 170 mm, Hong Kong, donated by G.A.C. Herklots (no other data); ABE 10701, 252 mm, South China Sea, T. Abe; BPBM 30913, 231 mm, South China Sea, T. Abe; ZUMT 52224, 199 mm, South China Sea, T. Abe; CSIRO CA886, 131 mm, Western Australia, 15°32′S, 124°02′E, 61 m, trawl, R/V *Soela*, 18 July 1980.

Diagnosis

A species of *Epinephelus* characterised by the following combination of features: dorsal soft rays 16; anal soft rays 8; pectoral 18-20 (usually 19); lateral-line scales 48-51; longitudinal scale series 84-96; no auxiliary scales on body; caudal fin rounded; corner of preopercle with 1-4 (usually 2) enlarged serrae; eye large, the orbit diameter 4.0-4.8 in head; colour brown, sometimes with faint dark bars, with dark brown dots dorsally on head and anteriodorsally on body.

Description

Dorsal rays XI,16; anal rays III,8; pectoral rays 19 (18-20); pelvic rays I,5; principal caudal rays 17, the upper and lower unbranched; procurrent caudal rays 8 or 9; lateral-line scales 50 (48-51); longitudinal scale series 91 (84-96); scales above lateral line to origin of dorsal fin about 15; scales below lateral line to origin of anal fin about 39; circumpeduncular scales 38; gill rakers 7 + 14 (7-8 + 14-15); pseudobranchial filaments 49 (40-65); branchiostegal rays 7; pyloric caecae 12; predorsal bones 2; vertebrae 24.

Body moderately elongate, the depth 2.9 (2.9-3.35) in SL, and compressed, the width 1.75 (1.75-2.3) in depth; dorsal profile of head convex; head length 2.3 (2.25-2.35) in SL; eye large, the orbit diameter 4.65 (4.0-4.8) in head; snout 4.7 (4.1-4.8) in head; interorbital space flat, the least width 7.0 (6.9-7.6) in head;

Figure 1   *Epinephelus stictus*, holotype, 328 mm SL, 20 km south of Heywood Shoals, Western Australia (painting by R. Swainston).

Table 1   Proportional measurements of type specimens of *Epinephelus stictus* expressed as percentages of the standard length.

	Holotype	Paratypes				
	WAM P28277-001	CSIRO CA866	BM(NH) 1939.1.17.10	ZUMT 52224	BPBM 30913	Abe 10701
Standard length (mm)	328.0	131.0	170.0	199.0	231.0	252.0
Body depth	34.6	34.8	30.6	31.7	30.7	30.0
Body width	19.8	15.2	17.7	18.3	15.1	17.2
Head length	43.9	43.5	44.1	44.4	44.2	42.5
Snout length	10.7	9.3	9.8	9.5	9.4	8.9
Orbit diameter	9.4	10.8	9.2	9.6	9.4	9.2
Interorbital width	6.3	6.1	6.4	6.1	5.8	5.9
Suborbital depth	3.7	2.6	3.3	3.0	3.1	3.0
Upper jaw length	19.6	19.5	20.1	20.2	19.8	19.9
Caudal peduncle depth	11.2	10.5	11.2	10.8	11.1	11.0
Caudal peduncle length	16.7	16.8	15.1	16.6	15.8	15.1
Predorsal length	32.7	39.0	38.4	38.5	38.5	37.6
Preanal length	72.7	69.0	70.1	70.4	69.5	72.3
Prepelvic length	42.8	39.2	41.0	39.0	40.1	37.6
Length of dorsal fin base	56.8	57.0	54.5	58.7	56.5	54.8
Length of first dorsal spine	6.7	6.7	7.0	6.2	5.7	5.9
Length of second dorsal spine	11.2	12.2	12.9	11.4	11.4	10.7
Length of longest dorsal spine	13.6	14.8	14.6	13.7	13.0	13.2
Length of last dorsal spine	10.4	11.5	12.1	11.6	10.4	10.5
Length of longest dorsal ray	16.2	17.5	17.2	17.4	16.2	16.1
Length of anal fin base	15.8	15.2	17.3	15.9	16.8	16.0
Length of first anal spine	6.8	8.1	7.3	6.9	7.0	7.2
Length of second anal spine	12.1	14.9	15.2	14.6	14.5	13.9
Length of third anal spine	11.8	13.9	13.8	13.6	13.0	12.5
Length of longest anal ray	17.1	18.6	17.6	18.2	17.2	17.0
Caudal fin length	23.6	25.7	23.8	24.9	23.6	23.9
Pectoral fin length	22.8	25.0	24.7	24.1	23.4	23.4
Pelvic spine length	9.4	12.0	12.4	12.0	10.8	11.4
Pelvic fin length	17.1	20.2	19.6	18.7	18.0	17.1

suborbital depth 11.8 (13.5-16.5) in head; caudal peduncle depth 3.9 (3.85-4.2) in head, 1.5 (1.35-1.6) in peduncle length.

Mouth large, slightly oblique, forming an angle of about 20° to the horizontal, the maxilla reaching to or slightly posterior to rear edge of orbit, the upper jaw length 2.25 (2.15-2.25) in head; depth of maxilla about 2.8 in orbit diameter; a pair of moderately small canine teeth anteriorly in jaws, the gap between the upper pair contained about 2.8 times in orbit diameter; teeth of upper jaw mainly in three rows, the outer row of about 25 fixed teeth on each side longest and stoutest; band of teeth lingual to upper canines in five or six rows, the median inner teeth notably the longest; two rows of teeth along side of lower jaw, the inner row about twice as long as the outer and depressible; inner row of teeth

expanding to five or six rows anteriorly in lower jaw, the most medial of which extend into the symphyseal gap as far forward as the canines; villiform teeth in three or four irregular rows on vomer and palatines, those on vomer forming a V. Tongue moderately slender, the tip rounded. Longest gill raker on first gill arch at angle, its length clearly greater than longest gill filaments, 2.55 (2.5-2.6) in orbit diameter; no small bony platelets on side of gill arch. Nostrils small, subequal, in front of centre of eye, and close together; anterior nostril not tubular but with a well-developed membranous flap on its rear margin which just reaches or extends slightly beyond front edge of posterior nostril.

Opercle with three broad spines, the uppermost small, only slightly above base of middle spine, and difficult to detect; middle and lower spines very large, their tips about equally posterior and closer together than the distance from middle to upper spine; corner of preopercle with two to four (usually two) very large serrae, three or more times longer than largest upper preopercular serrae; ventral edge of preopercle smooth, the posterior margin with 40 (25-41) serrae; margins of subopercle and interopercle usually smooth (holotype with eight subopercular serrae and two interopercular serrae on one side, none on other); opercular membrane moderately pointed, the upper edge slightly convex.

Lateral line slightly arched over pectoral region, then paralleling contour of back to straight peduncular part; scales cycloid on head, thorax, abdomen, and anterodorsally on body, ctenoid elsewhere on body; no auxiliary scales on body; no scales on maxilla; very small scales extending about half way to outer margin of median and pectoral fins; a narrow band of very small scales on first two membranes of pelvic fins extending about two-thirds distance to outer margin.

Origin of dorsal fin over third or fourth lateral-line scales; membranes of spinous portion of dorsal fin moderately incised; first dorsal spine about half length of second spine; second dorsal spine contained about 1.2 times in third spine, third or fourth dorsal spines longest, 3.2 (2.95-3.4) in head; all dorsal and anal rays branched, the last to base; tips of posterior dorsal soft rays not reaching or just reaching a vertical through caudal-fin base; tips of posterior anal soft rays distinctly short of caudal-fin base; fifth or sixth dorsal soft rays longest, 2.7 (2.5-2.7) in head. Origin of anal fin below base of second dorsal soft ray; first anal spine 1.8 (1.85-2.1) in second spine; second anal spine slightly longer than third spine, 3.6 (2.8-3.05) in head; second or third anal soft ray longest, 2.55 (2.35-2.55) in head. Caudal fin rounded, 1.85 (1.7-1.85) in head. Pectoral fins not fleshy, the rays branched except the short uppermost and lowermost rays; seventh to ninth pectoral rays longest, 1.9 (1.75-1.9) in head. Origin of pelvic fins below lower pectoral-fin base; pelvic fins not approaching anus, 2.55 (2.15-2.5) in head.

Colour of holotype in alcohol light brown, slightly darker on head and dorsally on body, with numerous dark brown dots (average diameter 1.5 mm) middorsally on head (including snout), on nape, and anterodorsally on body; a dark line along base of dorsal fin (indistinct anteriorly); fins pale except margins of dorsal and anal fins and posteriorly on caudal fin which are blackish (best developed on

caudal fin where the breadth is 4-5 mm and least developed on anal fin where only the tips of the fifth to seventh rays are dark).

The 131- and 170- mm paratypes have five faint dark bars on body, broader than interspaces, which angle slightly forward as they pass ventrally; an intensification of pigment exists about half way down each bar, forming an irregular squarish blotch of dark brown; a brown band from posterior edge of preopercle at level of lower part of eye passing to rear of opercle, its edges at middle and lower opercular spines; fins light brown, the membranes lighter than rays, the triangular outer part of each interspinous membrane hyaline.

Gloerfelt-Tarp and Kailola (1984: 134-135) illustrated this species (as *Epinephelus* sp.) and gave the following colour note: "Olive-yellow, white below; top of head and back with many orange-brown spots, more numerous in larger fish; 5-6 faint broad darker bands across body; maxillary groove brown; a thin dark line along base of dorsal fin. Soft dorsal and caudal fin margins dark brown." Although Gloerfelt-Tarp and Kailola stated that the illustrated specimen was lost, it was found at the Western Australian Museum; we have designated it as the holotype of *E. stictus.*

Fourmanoir (1965: 26, Fig. 10) examined four specimens (misidentified as *E. diacanthus*) from Nha-Trang, Viet Nam. He noted the numerous brownish black dots dorsally on the head and body to the origin of the caudal peduncle; the brownish black opercular band which passes between the two lower opercular spines; three distinct lateral brown spots beneath dorsal spines I-IV, VII-X, and under the anterior part of the soft dorsal; indistinct oblique dark bars; maxilla, mandible, and all the lower region of the head and body rose red; border of anal fin violet, the distal part grey-rose, the base olive; lower caudal rays violet.

Remarks

The most important colour character by which this grouper can be identified is the sprinkling of dark brown dots on the upper part of the head and dorso-anteriorly on the body. We have named it *stictus* from the Greek *stiktos,* meaning punctured or spotted, in reference to these tiny spots.

The specimens of this species have come from two areas, north-western Australia and the South China Sea, one in the Northern Hemisphere and the other in the Southern, the two broadly separated by Indonesia. As it has been taken by trawling, it may be primarily a continental shelf species less apt to be caught in insular regions with limited trawling grounds. Nevertheless, we expect that it will ultimately be found in the Indonesian region. The two depth records we have for *E. stictus,* 61 m and 138-142 m, indicate that it is a species of moderately deep water, which partly explains the paucity of specimens.

E. stictus appears to be most closely related to *E. diacanthus* Valenciennes, which occurs from Sri Lanka to Oman, and to *E. sexfasciatus* Valenciennes, which ranges from north-western Australia to the Philippines. Characters shared by the three species include the presence of 1-4 (usually 2) very large, serrae

at the corner of the preopercle, similar fin ray counts, and a similar pattern of dark bars on the body (faint or absent in *E. stictus*). They also show a predilection for deeper water and are often taken by trawling, hence they must occur on open sedimentary substrata. *Epinephelus stictus* differs from the others in lacking auxiliary scales on the body and in having a distinctive colour pattern of dark dots. *Epinephelus diacanthus* has a higher lateral-line scale count (52-60) than *E. stictus* and small scales on the maxilla; *E. sexfasciatus* usually has 15 instead of 16 dorsal soft rays, and it has black spots on the median fins.

Epinephelus timorensis sp. nov.

Figure 2; Table 2

Holotype

WAM P24794-001, 141 mm SL, Timor Sea, Western Australia, Dillon Shoals (11°S, 124°E), base of drilling rig, 130 m, L. Harris. 25-28 May 1974.

Diagnosis

A species of *Epinephelus* characterised by the following combination of features: Dorsal soft rays 16; anal soft rays 8; pectoral rays 17; lateral-line scales 53, each with a single tube; longitudinal scale series 108; caudal fin rounded; corner of preopercle with 3 enlarged serrae; colour blue-grey with yellow spots smaller than pupil on head and body, faint dark spots larger than pupil posteriorly on body, close-set dark spots mostly larger than pupil on caudal fin and soft portions of dorsal and anal fins.

Description

Dorsal rays XI,16; anal rays III,8; pectoral rays 17; pelvic rays I,5; principal caudal rays 17, the upper and lower unbranched; procurrent caudal rays 10; lateral-line scales 53; longitudinal scale series 108; scales above lateral line to origin of dorsal fin 18; scales below lateral line to origin of anal fin 32; circumpeduncular scales 48; gill rakers 9 + 15; pseudobranchial filaments 48; branchiostegal rays 7; pyloric caecae 14; predorsal bones 2; vertebrae 24.

Body moderately deep, the depth 2.7 in SL, and compressed, the width 2.1 in depth; dorsal profile of head convex with a slight indentation dorsoanterior to eye; head length 2.65 in SL; snout length 3.8 in head; eye relatively small, the orbit diameter 4.9 in head; interorbital space convex, the least width 5.25 in head; suborbital depth 10.8 in head; caudal peduncle depth 3.15 in head, 1.5 in peduncle length.

Mouth oblique, forming an angle of about 45° to the horizontal, the maxilla nearly reaching a vertical at rear edge of orbit, the upper jaw length 2.15 in head; depth of maxilla 1.7 in orbit diameter; a pair of moderate canines anteriorly in upper jaw separated by a gap which is contained 2.6 times in orbit diameter; a

Figure 2   *Epinephelus timorensis*, holotype, 141 mm SL, Dillon Shoals, Western Australia.

pair of smaller canine teeth anteriorly in lower jaw, medial to the uppers when mouth is closed; a series of about 20 slender, fixed, incurved, conical teeth on each side of jaws posterior to canines; upper jaw with a band of villiform teeth, much broader anteriorly, the inner medial teeth as long as canines but more slender; side of lower jaw with an inner row of slender, depressible, conical teeth about twice as long as outer row; a band of small depressible teeth anteriorly in lower jaw lingual to canines, the innermost elongate; a band of villiform teeth on palatines and vomer, forming a V-shape on vomer. Tongue slender, the upper surface somewhat rugose. Longest gill raker (at angle) longer than longest gill filament on first gill arch, its length half orbit diameter; small bony platelets on side of first two gill arches, one or two in each space between gill rakers. Nostrils small, subequal, the anterior a short membranous tube with an elevated posterior flap directly anterior to upper edge of pupil, a pupil diameter anterior to orbit; posterior nostril diagonally above and behind the anterior, without a rim.

Opercle with three flat spines, the upper obtuse and poorly defined; middle opercular spine the most posterior, equidistant to upper and lower spines on one side and slightly closer to lower spine on the other; opercular membrane pointed, the upper margin slightly angular above upper opercular spine, then nearly straight; ventral margin of preopercle fleshy, the posterior margin with 36 serrae, the corner with three enlarged serrae; margins of subopercle and interopercle partially serrate.

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Table 2   Proportional measurements of the holotype of *Epinephelus timorensis* expressed as percentages of the standard length.

	WAM P24794-001
Standard length (mm)	141.0
Body depth	37.2
Body width	17.6
Head length	37.9
Snout length	9.9
Orbit diameter	7.7
Interorbital width	7.2
Suborbital depth	3.5
Upper jaw length	17.6
Caudal peduncle depth	12.1
Caudal peduncle length	18.1
Predorsal length	33.6
Preanal length	67.4
Prepelvic length	54.0
Length of dorsal fin base	55.3
Length of first dorsal spine	5.9
Length of second dorsal spine	11.3
Length of longest dorsal spine	13.5
Length of last dorsal spine	12.0
Length of longest dorsal ray	12.9
Length of anal fin base	17.0
Length of first anal spine	5.3
Length of second anal spine	11.1
Length of third anal spine	11.3
Length of longest anal ray	17.4
Caudal fin length	24.1
Pectoral fin length	23.5
Pelvic spine length	11.1
Pelvic fin length	20.3

Lateral line slightly arched over pectoral region, then following upper contour of body to straight peduncular portion; scales finely ctenoid on body, cycloid on head, nape, and thorax (largely missing from abdomen); auxiliary scales not present on body, but a few apparent on nape; most of maxilla above upper lip covered with very small scales; very small scales extending onto median fins about three-fourths distance to outer margins, about half distance on pelvic fins, and one-fourth distance on pectorals.

Origin of dorsal fin over third lateral-line scale; membranes of spinous portion of dorsal fin moderately incised; first dorsal spine about half length of second; second dorsal spine 1.2 in length of third spine; fourth dorsal spine longest, slightly longer than third and fifth spines, 2.8 in head length; all dorsal and anal rays branched, the last to base; fourth dorsal ray longest, 2.95 in head; posterior ends of dorsal and anal rays not reaching a vertical of caudal-fin base. Origin of anal fin below base of second dorsal soft ray; first anal spine about half length

of second; third anal spine slightly longer than second, 3.35 in head; fourth and fifth anal rays longest, 2.2 in head. Caudal fin slightly rounded, the uppermost branched rays slightly produced, the fin length 1.55 in head. Pectoral fins not fleshy; all pectoral rays branched except short uppermost ray; middle pectoral rays longest, 1.6 in head. Origin of pelvic fins below lower base of pectoral fins; pelvic fins short, not approaching anus, 1.85 in head.

Colour in alcohol brown, slightly paler ventrally, with pale spots smaller than pupil dorsally on head from snout to nape; median fins light brown, the spinous portion of dorsal fin with a narrow blackish margin, the soft portion with three rows of brown spots, larger than pupil, posteriorly on soft portion; caudal fin with numerous, close-set, brown spots the size of pupil or larger; pectoral fins pale; pelvic fins with pale membranes and dusky brown rays.

Colour when fresh blue-grey with small yellow spots on head and body; some faint dark spots larger than pupil posteriorly on body.

Remarks

This small grouper is known only from the single type specimen taken in 130 m from the base of an experimental drilling rig at Dillon Shoals in the Timor Sea. It is named *timorensis* in reference to the type locality.

E. timorensis appears to be most closely related to another yellow-spotted, deep-dwelling grouper from the Samoa Islands, Phoenix Islands, and Fiji that remains undescribed; it is currently under study by the senior author and Phillip C. Heemstra. The two species share the same meristic data except that *E. timorensis* has 53 lateral-line scales compared to 50 or 51 for the other species. The latter differs notably from *timorensis* in having a slightly emarginate caudal fin and a more elongate body (depth 2.8-3.3 in SL, compared to 2.7 for *timorensis*).

Epinephelus trophis sp. nov.

Figure 3; Table 3

Holotype

WAM P24795-001, 104.5 mm, Timor Sea, Western Australia, Dillon Shoals (11°S, 124°E), base of drilling rig, 130 m, L. Harris, 25-28 May 1974.

Paratype

BPBM 30279, 125 mm, same data as holotype.

Diagnosis

A species of *Epinephelus* characterised by the following combination of features: dorsal soft rays 16 or 17; anal soft rays 8; pectoral rays 17-18; caudal fin rounded; lateral-line scales 67-69, each with a single tube; longitudinal scale series 143-145; corner of preopercle with 2-3 enlarged serrae; body depth 2.45 in SL; colour uniform dark brown.

Description

Dorsal rays XI,17 (16); anal rays III,8; pectoral rays 18 (17); pelvic rays I,5; principal caudal rays 17, the upper and lower unbranched; procurrent caudal rays 10 or 11; lateral-line scales 69 (67); longitudinal scale series 145 (143); scales above lateral line to origin of dorsal fin about 38; scales below lateral line to origin of anal fin about 77; circumpeduncular scales about 65; gill rakers 10 + 16 (10 + 15); pseudobranchial filaments 44 (43); branchiostegal rays 7; pyloric caecae about 35; predorsal bones 2; vertebrae 24.

Body very deep, the depth 2.45 in SL, and compressed, the width 2.2 in depth; dorsal profile of head convex with a slight indentation dorsoanterior to eye; head length 2.4 (2.5) in SL; snout length 3.95 (3.85) in head; eye relatively small, the orbit diameter 5.35 (5.45) in head; interorbital space convex, the least width 5.25 (4.9) in head; suborbital depth 10.5 (10.0) in head; caudal peduncle depth 3.35 (3.4) in head, 1.35 (1.4) in peduncle length.

Mouth oblique, forming an angle of about 55° to the horizontal, the maxilla reaching or extending slightly beyond a vertical through centre of eye, the upper jaw length 2.0 (2.1) in head; depth of maxilla 1.3 (1.4) in orbit diameter; a pair of moderate, incurved, canine teeth anteriorly in upper jaw separated by a gap which is contained 2 times in orbit diameter; a pair of similar canines at front of lower jaw which are medial to uppers when mouth closed; a series of about 18, slender, incurved, conical teeth on each side of upper jaw posterior to canines, with an inner band of small, depressible, villiform teeth medial to the outer row,

Figure 3   *Epinephelus trophis*, holotype, 104.5 mm SL, Dillon Shoals, Western Australia.

Table 3   Proportional measurements of type specimens of *Epinephelus trophis* expressed as percentages of the standard length.

	Holotype WAM P24793-001	Paratype BPBM 30279
Standard length (mm)	104.5	125.0
Body depth	41.8	40.7
Body width	18.4	18.3
Head length	41.7	40.1
Snout length	10.5	10.4
Orbit diameter	7.8	7.4
Interorbital width	7.9	8.2
Suborbital depth	4.0	4.0
Upper jaw length	21.0	20.5
Caudal peduncle depth	12.1	12.0
Caudal peduncle length	15.9	16.0
Predorsal length	35.4	34.8
Preanal length	74.8	76.0
Prepelvic length	42.7	43.6
Length of dorsal fin base	56.4	57.1
Length of first dorsal spine	6.4	6.3
Length of second dorsal spine	11.9	12.0
Length of longest dorsal spine	14.3	14.0
Length of last dorsal spine	12.4	12.2
Length of longest dorsal ray	16.3	16.2
Length of anal fin base	16.1	16.0
Length of first anal spine	5.4	5.3
Length of second anal spine	11.9	12.0
Length of third anal spine	12.5	12.3
Length of longest anal ray	18.4	18.2
Caudal fin length	23.6	23.7
Pectoral fin length	21.6	20.7
Pelvic spine length	12.5	12.6
Pelvic fin length	20.8	20.5

this band much broader anteriorly where the most medial and inner teeth are very large (some longer than canines); front of lower jaw lingual to canines with three irregular rows of slender conical teeth, continuing as two rows along side of jaw, the teeth of the inner row depressible and about twice as long as those of outer row; a narrow band of two or three irregular rows of villiform teeth on vomer and palatines, those on vomer forming a V. Tongue slender and narrowly rounded at tip, the upper surface finely ridged. Longest gill raker (at angle) equal in length to longest gill filament on first gill arch, 1.7 in orbit diameter; a small bony platelet in each space between bases of gill rakers on first gill arch. Nostrils small, subequal, the anterior a membranous tube with posterior flap, lying directly in front of upper edge of pupil by a distance equal

to one-third orbit diameter; posterior nostril elliptical without a fleshy rim, lying in line between anterior nostril and upper edge of orbit, the distance between nostrils contained 7-8 times in orbit diameter.

Opercle with three flat spines, the upper obtuse and not conspicuous, middle opercular spine the most posterior and closer to lower than upper spine; opercular membrane pointed, the upper edge angular above upper opercular spine, then nearly straight; ventral margin of preopercle fleshy, the upper margin with 26 serrae which are progressively larger ventrally, the corner with two or three enlarged serrae; margins of subopercle and interopercle smooth or with a few small serrae.

Lateral line slightly arched over pectoral region, then paralleling contour of back to straight peduncular portion; scales cycloid on head, anterodorsally on body, on thorax and abdomen, finely ctenoid elsewhere; auxiliary scales not present on body; a few very small embedded scales on maxilla of holotype (present on most of upper half of maxilla of paratype); very small scales on median fins extending about three-fourths distance to outer margin, about one-third on pectoral fins, and in a narrow band about half way to outer margin on each pelvic membrane.

Origin of dorsal fin above third lateral-line scale; membranes of spinous portion of dorsal fin slightly incised; first dorsal spine 1.85 (1.9) in second spine; second dorsal spine 1.2 (1.15) in fourth spine; fourth dorsal spine longest, 2.9 (2.85) in head; all dorsal and anal rays branched, the last to base; tips of posterior dorsal and anal soft rays not reaching a vertical at caudal-fin base (dorsal rays nearly reaching caudal base in paratype); fourth to sixth dorsal soft rays longest, 2.55 (2.5) in head. Origin of anal fin below base of fifth dorsal soft ray; first anal spine 2.2 in second spine; third anal spine slightly longer than second, 3.35 (3.3) in head; third or fourth anal soft ray longest, 2.25 (2.2) in head. Caudal fin slightly rounded, 1.75 (1.7) in head. Pectoral fins not fleshy; all pectoral rays branched except short uppermost ray; seventh to ninth pectoral rays longest, 1.95 in head. Pelvic fins not approaching anus, 2.0 (1.95) in head.

Colour of holotype in alcohol uniform dark brown, a little paler ventrally; median fins coloured like body, the margins of the soft portions of the dorsal and anal fins and the posterior edge of the caudal fin narrowly pale; pectoral fins pale; pelvic fins blackish.

The paratype is coloured like the holotype except for a broad submarginal part of the caudal fin and the posterior soft portions of the dorsal and anal fins which are darker brown.

The holotype when fresh was recorded as "charcoal coloured".

Remarks

Only two specimens of this grouper were obtained; they were collected from the same Dillon Shoals locality and 130 m depth as the holotype of *E. timorensis*. They appear to be immature.

The species is named *trophis* from the Greek meaning well-fed and plump, in reference to its robust body. Its body depth is equalled only by occasional specimens of *E. cyanopodus, E. flavocaeruleus,* and *E. multinotatus.* It is also distinctive in its high scale counts and uniform dark brown colouration. It does not seem to be closely reelated to any known species of the genus.

Epinephelus bilobatus sp. nov.
Figure 4; Tables 4-6

Epinephelus maculatus (*non* Bloch) Allen, 1985: 2301, fig. 121 (Rosemary Island, Dampier Archipelago).

Holotype
WAM P25119-008, 156 mm, Western Australia, Dampier Archipelago, Rosemary Island (20°28'S, 116°36'E), 4 m, rotenone, G.R. Allen and R.C. Steene, 18 November 1974.

Paratypes
WAM P14924-001, 101 mm, Western Australia, Yampi Sound (16°8'S, 123°36'E), A. Robinson, 14 September 1959; BPBM 31041, 99.5 mm, same data as preceding; WAM P14948-001, 79.5 mm, Western Australia, Port Wolcott (20°39'S, 117°11'E), 14 m, R.D. Royce, 3 June 1960; WAM P24358-001, 238 mm, Western Australia, Dampier Archipelago, Kendrew Island (20°29'S, 116°32'E), spear, J.B. Hutchins, 22 November 1974.

Diagnosis
A species of *Epinephelus* characterised by the following combination of features: dorsal soft rays 17-18 (usually 17); anal soft rays 8; pectoral rays 17-19; lateral-line scales 49-52; longitudinal scale series 94-102; auxiliary scales present on body; caudal fin rounded; longest dorsal spine (third) 2.05-2.3 in head; pectoral fins not long, 1.5-1.75 in head; head, body, and fins with numerous dark brown spots of moderate size, those on pectoral fins about size of pupil; three, large, bilobed, dark brown spots or close-set pairs of spots along base of dorsal fin.

Description
Dorsal rays XI, 17 (17-18, only one paratype with 18); anal rays III,8; pectoral rays 17 (17-19); principal caudal rays 17, the upper and lower unbranched; procurrent caudal rays 9; lateral-line scales 51 (49-52); longitudinal scale series 94-102; scales above lateral line to origin of dorsal fin about 17; scales below lateral-line to origin of anal fin about 46; circumpeduncular scales 39 (39-43); gill rakers 8 + 15 (7-9 + 14-16); pseudobranchial filaments 50 (32-69, increasing with size); branchiostegal rays 7; predorsal bones 2; vertebrae 24; pyloric caecae 23 (holotype).

Body moderately elongate, the depth 2.9 (2.85-3.25) in SL, and compressed, the width 2.3 (1.85-2.5) in depth; dorsal profile of head slightly convex; head length 2.45 (2.45-2.50) in SL; snout length 4.5 (3.85-5.05) in head; orbit diameter
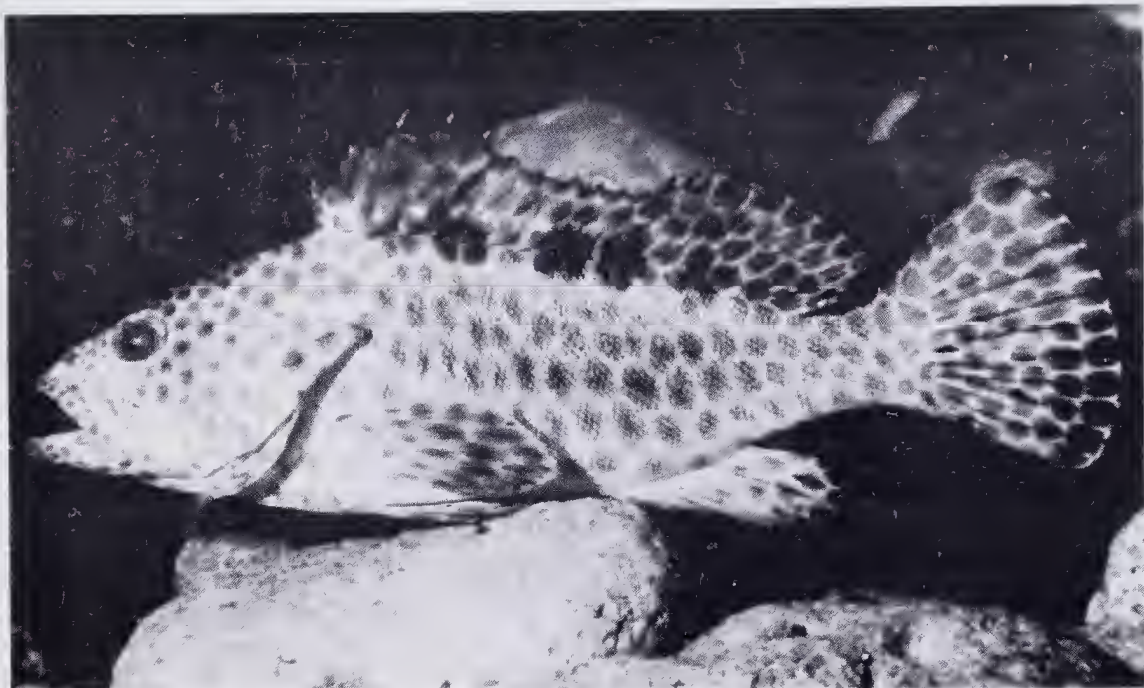
Figure 4   *Epinephelus bilobatus*, holotype (freshly dead, photographed underwater), 156 mm SL, Rosemary Island, Dampier Archipelago, Western Australia.

4.95 (4.35-5.65) in head; interorbital space slightly convex, the least width 6.45 (6.45-7.0) in head; suborbital depth 10.5 (9.2-13.5) in head; caudal peduncle depth 3.25 (3.35-3.55) in head, 1.5 (1.50-1.65) in peduncle length.

Mouth large, slightly oblique, forming an angle of about 20° to the horizontal, the maxilla nearly reaching or just reaching a vertical at posterior edge of orbit, the upper jaw length 2.2 (2.1-2.2) in head; depth of maxilla 1.75 (1.4-1.9) in orbit diameter; a pair of moderately large canine teeth anteriorly in jaws, the gap between the upper pair contained 2.5 times in orbit of holotype; upper jaw of holotype with an outer row of 27 slender, incurved, fixed, conical teeth and an inner band of depressible villiform teeth which consists of four or five rows anteriorly and narrows to a single row posteriorly (the median inner teeth of this band anteriorly in jaw as long as upper canines); lower jaw with two rows of slender, recurved and incurved conical teeth for most of its length, expanding to four rows anteriorly in jaw, the teeth of the inner row nearly twice as long as those of the outer and depressible; vomer with a V-shaped band of villiform teeth in four or five irregular rows; palatines with a band of villiform teeth in from two to five irregular rows. Tongue slender, the tip rounded. Longest gill raker (at angle) clearly longer than longest filament of first gill arch, 1.5 (1.3-1.95) in orbit diameter; a small bony platelet between bases of gill rakers on first arch (sometimes two on upper-limb, but none at rakers next to angle).

Nostrils small, subequal or the posterior slightly larger, in front of or slightly above centre of eye; anterior nostril a short membraneous tube with a posterior flap which reaches beyond front edge of posterior nostril.

Table 4   Proportional measurements of type specimens of *Epinephelus bilobatus* expressed as percentagages of the standard length.

Character	Holotype WAM P25119-008	Paratypes			
		WAM P14948-001	BPBM 31041	WAM P14924-001	WAM P24358-001
Standard length (mm)	156.0	79.5	99.5	101.0	238.0
Body depth	34.6	35.2	32.0	30.7	32.3
Body width	15.1	14.2	14.0	14.5	17.5
Head length	40.5	39.8	39.7	40.6	40.7
Snout length	9.0	7.9	9.1	10.4	10.6
Orbit diameter	8.2	9.2	8.7	8.7	7.2
Interorbital width	6.3	5.7	5.8	5.8	6.3
Suborbital depth	3.8	2.9	3.3	3.6	4.4
Upper jaw length	18.5	18.9	18.0	19.0	18.5
Caudal peduncle depth	12.4	11.3	11.1	11.9	12.2
Caudal pedunele length	18.9	18.6	18.2	18.4	18.3
Predorsal length	36.0	36.9	35.0	34.9	34.1
Preanal length	65.5	66.2	68.1	68.0	69.4
Prepelvic length	39.5	42.2	42.5	42.5	43.5
Length of dorsal fin base	61.0	60.8	59.1	58.5	58.0
Length of first dorsal spine	8.5	9.5	8.6	9.8	8.3
Length of second dorsal spine	15.6	abnormal	16.2	16.3	15.1
Length of longest dorsal spine	18.0	18.8	19.0	19.8	17.7
Length of last dorsal spine	12.5	13.8	13.4	13.7	12.6
Length of longest dorsal ray	16.4	17.8	17.1	17.6	15.9
Length of anal fin base	18.5	17.7	18.1	18.6	17.6
Length of first anal spine	8.0	8.8	7.9	8.8	6.8
Length of second anal spine	15.1	16.3	15.7	16.8	11.8
Length of third anal spine	15.4	14.6	14.9	15.7	12.4
Length of longest anal ray	19.7	20.5	19.6	20.2	16.9
Caudal fin length	26.1	26.4	24.8	26.9	24.3
Pectoral fin length	25.7	26.8	26.2	26.4	23.3
Pelvic spine length	12.8	13.9	13.9	14.2	11.4
Pelvie fin length	21.4	22.4	22.3	22.8	19.4

Table 5   Counts of dorsal soft rays of *Epinephelus maculatus* and *E. bilobatus*.

Species	Dorsal soft rays			
	15	16	17	18
E. maculatus	2	11	2	
E. bilobatus			5	1

Table 6   Gill-raker counts of *Epinephelus maculatus* and *E. bilobatus*.

Species	Upper-limb rakers				Lower-limb rakers				Total gill rakers					
	7	8	9	10	14	15	16	17	22	23	24	25	26	27
E. maculatus		4	8	3		3	11	1		2	3	7	2	1
E. bilobatus	1	3	2		2	3	1		2	2	2			

Opercle with three, broad, flat spines, the uppermost inconspicuous and distinctly anterior to the other two; middle opercular spine largest and most posterior, its tip nearer lower than upper spine; three or four serrae at corner of preopercle slightly enlarged, the longest about twice as long as largest serrae just above corner; posterior preopercular margin with a slight concavity above corner and 34 (28-40) serrae, increasing with size; ventral preopercular margin smooth; margins of subopercle and interopercle smooth; opercular membrane pointed, the upper margin nearly straight.

Lateral line slightly arched over pectoral fin, then following contour of back to straight peduncular portion; scales cycloid on head, thorax, and anterodorsally on body, ctenoid elsewhere; auxiliary scales present on body (best developed on largest paratype); a long triangular band of very small scales on maxilla; very small scales extending more than three-fourths distance to margins of median and pelvic fins and about half way on pectoral fins.

Origin of dorsal fin over third lateral-line scale; membranes of dorsal fin moderately incised; first dorsal spine about half length of second; second dorsal spine contained 1.15 (1.15-2.0) in third dorsal spine; third dorsal spine longest, 2.25 (2.05-2.3) in head; all dorsal and anal soft rays branched, the last to base; tips of posterior dorsal and anal soft rays not reaching base of caudal fin; fifth or sixth dorsal soft rays longest, 2.45 (2.25-2.55) in head. Origin of anal fin below base of second dorsal soft ray; first anal spine about half length of second spine; second and third anal spines subequal, the longest 2.6 (2.45-3.25) in head; third or fourth anal soft rays longest, 2.05 (1.95-2.4) in head. Caudal fin rounded, 1.55 (1.5-1.65) in head. Pectoral fins not fleshy, all rays branched except short uppermost ray; ninth pectoral ray longest, 1.55 (1.5-1.75) in head. Origin of pelvic fins below lower base of pectorals, their length 1.9 (1.8-2.1) in head.

Colour of holotype in alcohol light brown with numerous, close-set, dark brown spots the size of pupil or slightly larger in six rows on deepest part of body and four rows on caudal peduncle; head with similar spots posteriorly, but progressively smaller ones anteriorly; a close-set pair of dark brown spots as large as eye, half on back and half extending into base of dorsal fin, between ninth dorsal spine and fourth dorsal soft ray; a similar but less prominent pair of spots between third and seventh dorsal spines, and a third, fainter pair between sixth and thirteenth dorsal soft rays (better developed on paratypes); fins with close-set, round to

polygonal, dark brown spots except first five interspinous membranes of dorsal fin which are largely covered with a dark brown area.

The ground colour of the holotype when fresh was pale bluish, shading ventrally to whitish, and the spots orange-brown; the narrow interspaces among the spots on the dorsal and caudal fins were pale blue, on the pectoral fins whitish, and on the anal and pelvic fins blue.

Remarks

The holotype was illustrated in colour by Allen (1985: fig 121).

We have named this species *Epinephelus bilobatus* in reference to its most characteristic colour markings, a series of three bilobed or close-set pairs of dark brown spots along the base of the dorsal fin.

A sixth specimen of *E. bilobatus,* CSIRO CA1972, 115 mm SL, was collected at Monte Bello Islands (20°30'S, 115°41'E) in December 1979. It was sent on loan by the Division of Fisheries and Oceanography, Commonwealth Science and Industrial Research Organisation, Hobart. Unfortunately the specimen has been lost. Meristic data from it, however, are included in the description above.

All of our specimens have come from Western Australia between latitudes 16°8' and 20°39'S. *E. bilobatus* is a shallow-water species of coral reefs or rocky bottom.

This species is closely related to *E. maculatus* (Bloch) which occurs from southern Japan south to the Great Barrier Reef and east to the Marshall Islands and Samoa Islands. It differs from *maculatus* in usually having 17 instead of 16 dorsal soft rays (see Table 5), fewer gill rakers (Table 6), fewer scales in longitudinal series (97-102, in contrast to 103-120 for *maculatus*), longer dorsal spines, the longest 2.05-2.3 in head (compared to 2.2-2.7 for *maculatus*) and in colour. *E. maculatus* lacks the series of large dark spots along the dorsal-fin base; it has instead two large blackish areas in the fin, one anteriorly on the spinous portion and one centred at the origin of the soft portion.

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Reproductive patterns in chromosomally distinct races of *Phyllodactylus marmoratus* (Lacertilia: Gekkonidae) in south-western Australia

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Abstract

An examination of 677 museum specimens of three chromosomal races of *Phyllodactylus marmoratus* in south-western Australia showed different reproductive patterns in the two adjacent and abundant races, 2n=34 and 2n=36. Data for the 2n=32 race are very limited.

Females of all races were gravid in spring, but yolky follicles may occur in all seasons except mid-summer; the 2n=34 race also had gravid females in winter. Females with both eggs and yolky follicles were recorded in 2n=34 and 2n=36 races; over 30% of females had single egg clutches. Males of the 2n=36 race had largest testicular volumes in summer-autumn, a pattern similar to previous studies; males of the 2n=34 race had maximum testicular volumes in spring.

Introduction

The gekkonine gecko *Phyllodactylus marmoratus* has a wide distribution across southern Australia, a distribution that includes four discrete chromosomal races (King and Rofe 1976, King and King 1977).

In south-western Australia three races, 2n=36, 2n=34 and 2n=32, occur along the southern and western coasts in the dominant winter rainfall areas. The 2n=32 race is confined to a small area around Broke Inlet, central to the distribution of the 2n=34 race that occurs from the Abrolhos Is in the north around to Cape Arid in the east. The 2n=36 race extends from east of Cape Arid along the coast and into South Australia (King and King 1977).

An examination of reproduction in *P. marmoratus* was undertaken by King (1977) in South Australia, a region representing the 2n=36 and 2n=36 ZZ/ZW chromosome races (King and Rofe 1976). This histological assessment of the male and female reproductive cycles showed a reproductive strategy based on delayed fertilisation with females employing oviducal sperm storage over winter. A detailed analysis of meiosis in males revealed that chiasmata frequency was seasonally

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cyclic for both interstitial and terminal chiasmata. Sperm used for insemination and fertilisation had the lowest total chiasma frequency but greatest range in interstitial chiasma frequency. This suggests that sperm with the greatest range in genetic variation are used for fertilisation (King and Hayman 1978).

A recent examination of the three chromosomal races of *P. marmoratus* in south-western Australia has resulted in the description of the 2n=36 race as a separate subspecies *P. m. alexanderi* (Storr 1987).

It has been the purpose of this study to examine the broad reproductive patterns of the three chromosomal races in the south-west and compare them with the data presented from South Australia (King 1977).

Materials and methods

This study is based on the examination of 677 specimens of *Phyllodactylus marmoratus* from south-western Australia. Specimens have been collected opportunistically over a 50 year period and represent 155 individuals of the 2n=36 race, 477 of the 2n=34 race and 45 of the 2n=32 race. The 2n=34 and 2n=36 races were distinguished by the criteria of Storr (1987). The 2n=32 individuals were those collected from the Mt Chudalup-Walpole area.

Snout-vent length (SVL) was measured on all specimens. Mid-ventral and lateral incisions were then made to examine reproductive tracts. Maximum length and width of testes, ovarian follicles, and oviducal eggs were measured by one of us (SJG) using dial vernier calipers to the nearest 0.1 mm.

Females were judged as adult by the presence of thickened or convoluted oviducts and/or the presence of enlarged yolked follicles or eggs; reproductively active females were those with yolky follicles, eggs or both. Females with oviducts previously removed were excluded from analysis. Males showed considerable variation in testicular size but were deemed adult by expanded efferent ducts and enlarged testes. Reproductive information was assessed by month regardless of year of collection.

The volume of testes, follicles or eggs was estimated to the nearest 0.1 mm using the equation for a prolate spheroid $V = 4/3 \ (1/2) \ (w/2)^2$ where l is length and w is width.

Data are summarised as mean ± standard deviation and sample size. Significance differences were determined from t-tests comparing means.

Results

Comparisons of male and female monthly reproductive activity were made for island and mainland groups and south coast and west coast groups of the 2n=34 race. No significant differences were detected in number of reproductively active individuals for those months where n≥5, consequently data are combined for this

race. Females on south coast islands were gravid in winter, but there was no comparative mainland data over the same period.

Females

The period of reproductive activity of different chromosome races is presented (Figure 1). Eggs or developing yolky follicles were present in all months for the 2n=34 race except February and March. Samples of the 2n=36 race, *P. m. alexanderi*, were less representative of the year, but also suggest lower reproductive activity over the late summer-autumn period. Data for the 2n=32 were inadequate to determine the extent of the period of reproductive activity.
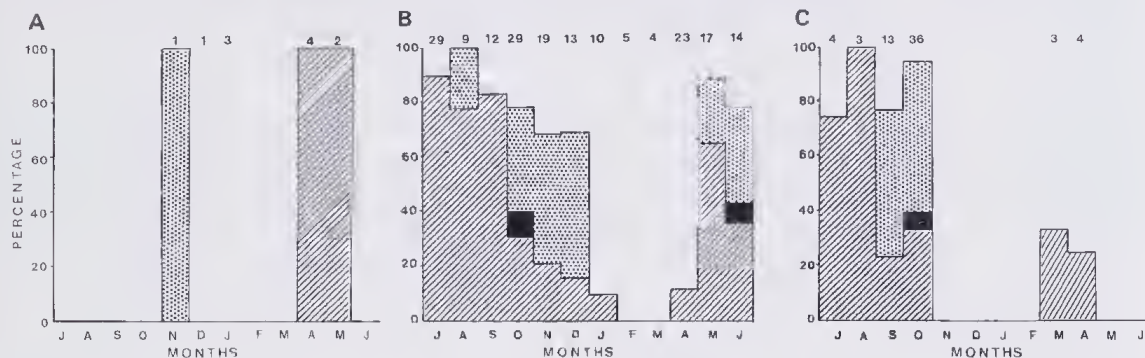
Figure 1   Percentage of reproductively active *Phyllodactylus marmoratus* females, proportioned according to presence of yolky follicles (cross hatching), eggs (stippling) or both (blocked) on a monthly basis. Number of adult females examined for each month is given for [A] 2n=32, [B] 2n=34 and [C] 2n=36.

Table 1   Size of reproductively active females and mean clutch volume in the three chromosomal races of *Phyllodactylus marmoratus* in south-western Australia.

Race	SVL of Smallest Reproductive ♀ (mm)	Mean SVL of Gravid ♀♀ (mm)	Mean Clutch Volumes (mm^3)		Maximum Clutch Volume (mm^3)
			1 egg	2 eggs	
32	49.3	55.0 (1)		474.4 (1)	474.4
34	39.4	48.1 ± 4.1 (43)	285.9 ± 106.1 (20)	597.7 ± 198.6 (23)	1015.4
36	37.5	447.5 ± 3.5 (29)	203.1 ± 88.7 (9)	469.5 ± 208.2 (20)	1017.2

Single egg clutches were recorded in 20 of the 43 (46.5%) gravid 2n=34 females and 9 of the 29 (31%) gravid 2n=36 females; the only gravid 2n=32 had a two egg clutch (Table 1). Females with both oviducal eggs and yolked ovarian follicles were recorded in the 2n=34 race during October and June and in the 2n=36 race during October (Figure 1). Single yolky follicles were recorded in 21 of the 83 (25.3%)

females with developing follicles in the 2n=34 race, 2 of the 25 (8%) females in the 2n=36 race and 1 of the 6 (16.7%) females in the 2n=32 race. Three 2n=34 females had 3 yolked follicles of similar size.

Mean clutch volumes in the 2n=34 (Table 1) were larger than those in 2n=36 for both single and double egged clutches; this difference was significant ($p<0.05$) for double egg clutches. However, the maximum calculated volumes in both races were almost identical (Table 1). There was no difference in SVL of females with single or double egg clutches for either the 2n=34 [48.0 ± 3.2(20) v. 49.1 ± 3.2(23)] or 2n=36 [48.2 ± 2.3(9) v. 47.1 ± 3.9(20)] races. Females with longer SVLs had larger clutches in the double egged ($r = 0.511$, $n = 23$, $p<0.01$), but not single egged groups of the 2n=34 race; no significant correlations existed in the 2n=36.

Males

Testicular volumes for the three chromosomal races are presented in Figure 2.

The general pattern of the 2n=34 race was for highest volumes during spring and a decrease over summer. The highest volumes in the 2n=36 race occurred in summer and autumn; data for 2n=32 are inconclusive. In September ($p<0.05$) and
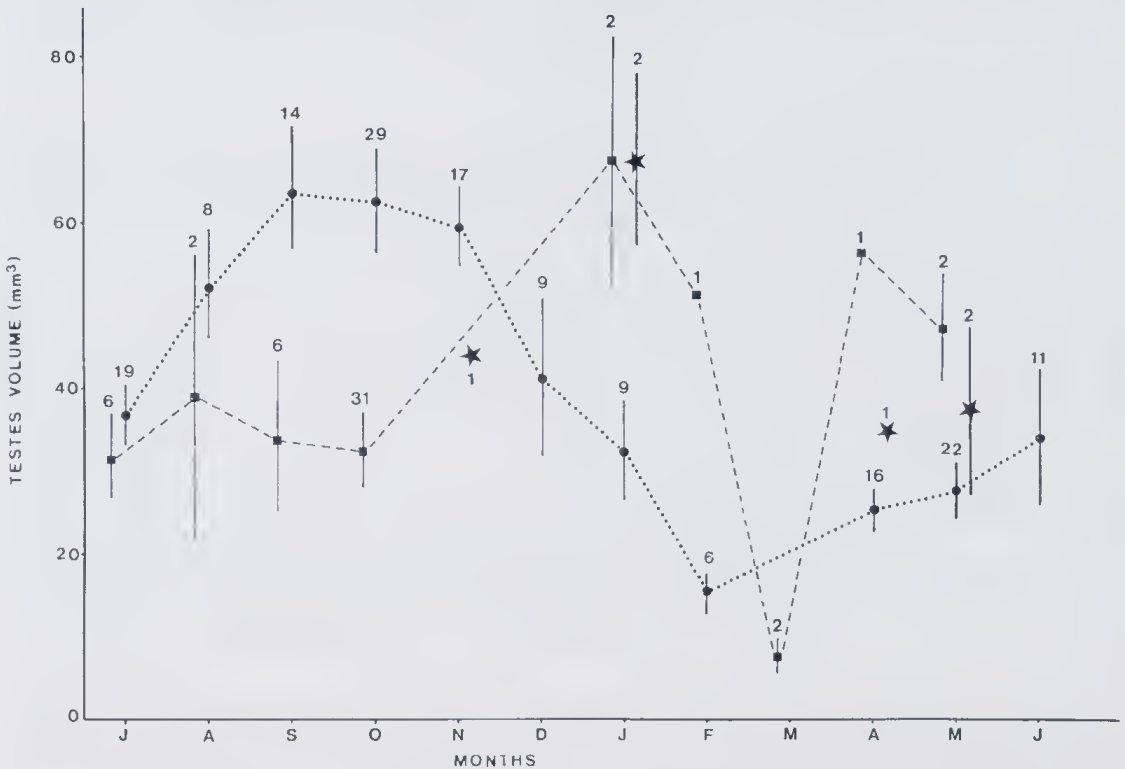

Figure 2   Monthly variation in testes volume (mm^3) of *Phyllodactylus marmoratus* from 2n=32 (stars), 2n=34 (circles) and 2n=36 (squares). Data are presented as means ± SE (n).

October (p<0.01) the 2n=34 race had larger volumes, while in May (p<0.05) the 2n=36 race had the greater volume; all other comparisons between species did not differ significantly.

Discussion

In a detailed histological examination of reproduction, King (1977) determined that *P. marmoratus* had oviducal sperm storage and delayed fertilisation. The examination of testes weight and meiotic activity suggested maximum spermiogenesis and insemination in late summer and autumn with fertilisation occurring in spring and early summer from the stored sperm (King 1977).

Our examination of the broad reproductive pattern in the 2n=36 subspecies, *P. m. alexanderi,* is in close agreement with King's earlier findings for this and that of the 2n=36 ZZ/ZW races. Males have maximum testicular volume in summer and autumn (Figure 2) whereas oviducal eggs occur in females in the spring (Figure 1). Our data are insufficient, however, to record the extent or intensity of the entire cycle as samples are not available from throughout the year.

Paired oviducal eggs that were laid simultaneously were recorded by King (1977) for *P. m. alexanderi* in South Australia. In the Western Australian data, 31% of gravid females had single oviducal eggs and there was no distension of contralateral oviducts to suggest monoallochronic laying, thus representing a major difference in this subspecies over its geographic range.

The endemic Western Australian 2n=34 race of *P. m. marmoratus,* displays a markedly different male reproductive pattern from *P. m. alexanderi.* The testicular volumes were maximal over the spring-early summer period (Figure 2) and corresponded with maximal levels of gravid females (Figure 1). However gravid females were also recorded in winter (May-June) indicating fertilisation at a time corresponding to low testicular volumes. All gravid females collected during winter occurred on islands off the southern coast and there was little temporally comparative data from the adjacent mainland.

The information available on the highly localised 2n=32 race was sparse but indicated gravid females in spring. D. King (pers. comm.) collected seven visibly gravid 2n=32 females in a sample of 40 on 3 November 1979; two eggs were seen in four individuals and a single egg in the remaining three. The pattern of the reproductive cycle in both sexes of this race remains conjectural.

Both the 2n=34 and 2n=36 race of *P. marmoratus* in south-western Australia showed evidence of seasonal sequential clutching with individual females possessing both oviducal eggs and enlarged ovarian follicles (Figure 1). Females of both races also showed a peak of reproductive activity in the spring-early summer, a pattern characteristic of geckos in winter rainfall areas of south-western Australia (How and Kitchener 1983; How, Dell and Wellington 1986). The occurrence of gravid 2n=34 females during winter could reflect a response to favourable rainfall in

autumn; a response similar to that documented for summer rainfall in the diplodactyline geckos of the subgenus *Strophurus* (How, Dell and Wellington 1986). Over 30% of females in both races had a single oviducal egg and several had only a single developing ovarian follice; suggesting a high proportion of single egg clutches.

Despite the inadequacy of monthly male samples, there was a pronounced difference in the male cycle between the 2n=34 and the 2n=36 races, the former having significantly greater testicular volumes in spring (September-October) and lesser volumes in autumn (May). The pattern determined for 2n=36 males in this study is in general agreement with that for this race in South Australia (King 1977), however, 2n=34 males have a pattern characteristic of spring breeding geckos (How and Kitchener 1983; How, Dell and Wellington 1986).

Most 2n=34 females were gravid during the period of highest testicular volumes (August-December), consequently, there is no evidence to suggest overwinter oviducal sperm storage by females in this race. It is possible that sperm storage occurs however, as some females were gravid during winter (May and June) when male volumes are lower. This anomaly is in need of a detailed histological examination in an area of parapatry to determine if reproductive patterns in the 2n=34 and 2n=36 races are sufficiently divergent to suggest the subspecies are reproductively isolated and hence species.

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The holasteroid echinoid *Echinocorys* from the Maastrichtian of Western Australia

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Abstract

Echinocorys stomias sp. nov. is described from Maastrichtian strata of the Giralia Range, Western Australia. This represents the first description of any holasteroid genus from the Cretaceous of Australia. The species is large and can be distinguished from all other described species of the genus on the basis of its large peristome. This is considered to be a paedomorphic character, resulting from changes to growth allometry of the peristome.

Introduction

The holasteroid echinoid *Echinocorys* is a common, geographically widespread genus which has been collected from Turonian to Paleocene strata in Belgium, Germany, England, France, Poland, Denmark, Spain, Turkey, USSR, USA, Cuba, Madagascar and Australia (Lambert & Thiéry 1924; Kier & Lawson 1978; Foster & Philip 1978). In Australia this genus has previously been described only from the Paleocene Wadera Calcarenite in the Giralia Range in Western Australia (Foster & Philip 1978).

In this paper I describe what is the first known Cretaceous holasteroid from Australia, and only the second species of *Echinocorys* to be described from the Southern Hemisphere. Cretaceous echinoids are very rare in Australia, only two species, *'Micraster' sweeti* Etheridge, 1892 and *Goniocidaris comptoni* (Glauert, 1926) (see McNamara 1986), having been described. The Cretaceous species of *Echinocorys* described herein is from the Late Maastrichtian Miria Formation of the Giralia Range in Western Australia. It represents the first echinoid to be described from the Maastrichtian of Australia.

The Miria Formation is a thin (0.6-2.0 m) very fossiliferous calcarenite, that occurs over a strike length of about 80 km on the eastern and western flanks of the Giralia Range immediately south of Exmouth Gulf, Western Australia. The fauna of the Miria Formation is dominated by molluscs, in particular ammonites (Brunnschweiler 1966; Henderson & McNamara 1985a) and to a lesser extent, brachiopods, corals, sponges, bryozoans and shark teeth. Echinoids form a very

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minor part of the fauna. In addition to the *Echinocorys* the only other echinoids known are two very poorly preserved internal moulds of possible phymosomatids.

Preservation

The fossils of the Miria Formation are generally preserved as phosphatic steinkerns. Analysis of the preservation of the cephalopods of the Miria Formation has revealed a complex preservational history, with repeated episodes of burial and exhumation (Henderson & McNamara 1985b). The *Echinocorys* specimens are preserved either as incomplete phosphatic steinkerns, often with some weathered calcite test remaining, or, in one case, as an incomplete calcitic adoral surface.

The presence of burrows within the steinkerns (attributable to the action of crustaceans and worms) and epibionts (principally bryozoans and serpulids) on both the phosphatic steinkerns and on calcitic test, are evidence for a complex preservational history for these specimens, comparable with that experienced by the Miria Formation cephalopods. The incomplete nature of the tests is probably attributable to their breakage either prior to fossilisation or during a period of exhumation during the fossilisation process. There is evidence that the weathered nature of the calcitic test of some specimens occurred by partial dissolution of the test while it was exposed to sea water either prior to burial or during a period of exhumation. This is shown by the presence on one specimen (WAM 82.3088) of a serpulid attached to a partially dissolved interambulacral plate. Such partial dissolution must obviously have been instrumental in promoting subsequent mechanical breakage of the test.

The absence of other irregular echinoids in this fauna is likely to be a reflection not so much of their original absence, but of their thin tests. The test of the *Echinocorys* specimens is particularly thick (up to 3.5 mm), rendering this species more capable of withstanding the dissolution of calcium carbonate which was experienced by many other taxa.

Materials and methods

The collections, on which this study was made, are housed in the Western Australian Museum (WAM), the Museum of Victoria (MV), the Rijksuniversitair Centrum Antwerpen (RUCA) and the collection of Mrs B. Schekkerman (BS). Collections were made by the author, assisted by Prof. G.M. Philip, Mr G.W. Kendrick, Dr T.A. Darragh and Dr R.A. Henderson in 1979 and 1983, and by Dr J.F. Geys and Mrs B. Schekkerman in 1985.

Measurements were made with a vernier calliper to an accuracy of 0.1 mm. A number of parameters are expressed as percentages of either test length (%TL), test width (%TW) or test height (%TH).

Systematics

Class Echinoidea Leske, 1778
Order Holasteroida Durham & Melville, 1957
Family Holasteridae Pictet, 1857
Genus *Echinocorys* Leske, 1778

Type species
Echinocorys scutatus Leske, 1778, by subsequent designation of Lambert 1898, p. 179.

Echinocorys stomias sp. nov.

Figures 1-3

Holotype
WAM 84.442 (Figs 1A, 3B) from the Giralia Range, Western Australia; gully draining east, 3.8 km north of Bullara — Giralia Road; Giralia 1: 100 000 map sheet, G.R. KV 175950 (locality 17 of Henderson & McNamara 1985a, text-fig. 1).

Paratypes
WAM 82.3088, 84.420, 84.441, 84.443, 86.1388, MV P102120, P102398, RUCA 20152, from localities 12, 15, 20 and 26 of Henderson & McNamara 1985a in the northern part of the Giralia Range.

Other material
MV 101628, 102397, BS 5.148a, b.

Diagnosis
A very large species of *Echinocorys*, with conical test and relatively large peristome.

Description
Test very large, reaching a maximum known length of 103 mm, although one incomplete test (WAM 86.1388) would probably have exceeded this, reaching, perhaps, 106 mm in length; maximum width, 80-87%TL, at about mid-test length; height 71-78%TL. Test conical (Figure 2B), with ambitus situated close to adoral surface, at about 8%TH. Apical system poorly preserved; situated centrally (Figure 2A). Ambulacra 30%TL wide at ambitus; poriferous zone up to 18%TL wide. Pore pairs situated slightly perradially; more than 60 in each column; interambulacra occupy 35%TL at ambitus. At ambitus ambulacral plates 5.5 times wider than long; interambulacral plates nearly 4 times wider than long. In largest specimen (WAM 82.3088) there are an estimated 50 plates on the aboral surface in each ambulacral column.

Adoral surface relatively flat, apart from gently convex plastron, which rises to a rostrum posteriorly. Peristome appears very large in internal moulds (Figure 1A), reaching 25%TL in width and being 13-16%TL long. However, analysis of adoral

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Figure 1   *Echinocorys stomias* sp. nov., A, holotype, WAM 84.442, adoral surface. Note that the labrum and first ambulacral plates are missing, making the peristome appear slightly larger than its original size. B, paratype, WAM 82.3088, lateral profile; both x1.

Figure 2   *Echinocorys stomias* sp. nov., A, paratype, RUCA 20152, aboral surface; B, BS 5.148, posterior view; both x1.

plating shows that in these specimens some of the basicoronal plates are not preserved, giving the echinoid the appearance of having a larger peristome than it actually had. Evenso, where the adoral plating is complete near the peristome (Figure 3) the peristome can be seen to have been still relatively large, up to 15%TL in width. The peristome is moderately sunken, area between peristome and anterior ambitus (about one-fifth TL) being strongly convex. Labrum projects slightly anteriorly; strongly constricted close to peristome, but posteriorly broadens and becomes parallel-sided toward plastron (Figure 3). Meridosternous plastron narrow, width 16%TL. Form of periproct unknown.
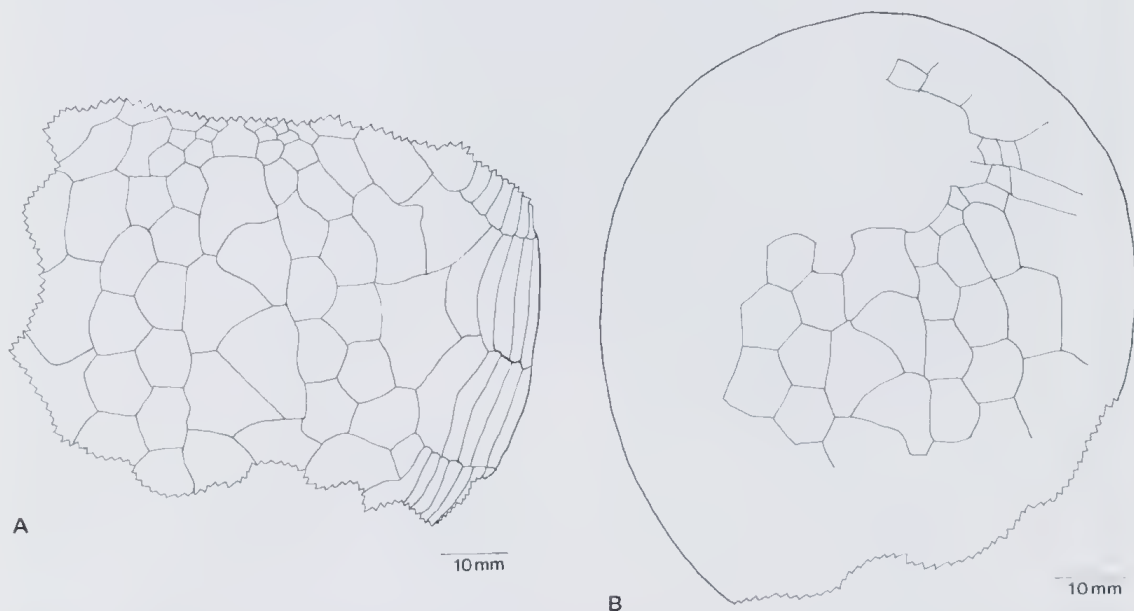
Figure 3   *Echinocorys stomias* sp. nov., A, drawing of adoral plating of WAM 86.1388, x1; B, drawing of adoral plating of WAM 84.442, holotype, x1.

Discussion

Echinocorys stomias can be distinguished from the Paleocene *E. australis* from the Wadera Calcarenite in the Giralia Range (Foster & Philip 1978) by its attainment of a much larger size; its broader and more conical test; and its relatively much larger peristome. Furthermore, it has a greater concentration of much broader, short ambulacral and interambulacral plates (compare Figure 2B with Foster & Philip 1978, pl. 92, fig. 3).

The most exhaustive works on *Echinocorys* are those by Lambert (1903) and Smiser (1935) on Belgian Senonian species. *E. stomias* compares with one of these species, *E. ovatus* (Leske), in size. However, the two species can be distinguished by test shape and peristome size. Unlike *E. stomias,* in which the test is conical,

the ambitus being very low, close to the adoral surface of the test, the test of *E. ovatus* is more hemispherical in shape, with a much higher ambitus (Smiser 1935, Fig 5).

In his analysis of the evolution of *Echinocorys* in Belgium, Smiser (1935, pl. 1) has shown how there was a tendency for an initial increase in test size, from the oldest, Turonian species, *E. gravesi,* to the Santonian-Campanian *E. ovatus.* Later Campanian species, however, tend to be smaller. These younger forms, though, do compare with the Maastrichtian *E. stomias* in their possession of a more conical test than in many earlier species. However, these species all possess a much smaller peristome than *E. stomias,* as well as being much smaller.

Of other Maastrichtian species of *Echinocorys,* such as *E. fakhryi* Fourtau, 1907, from Egypt, *E. tercensis* Lambert, 1907, from France, *E. darderi* Lambert, 1935, from Spain and *E. tenuituberculatus* Lermerie, 1851 *madagascarensis* Besairie, 1930, from Madagascar, *E. stomias* differs from all these species in its much larger size and, in particular, its very much larger peristome. There is some similarity between *E. stomias* and *E. darderi* (Lambert 1935, p. 363, pl. 42, figs 1, 2) in the lateral test profile, but *E. stomias* differs in its wider ambulacra, in addition to the features mentioned above.

The possession of a relatively larger peristome in *E. stomias* compared with other species of *Echinocorys,* probably arose by changes to growth allometry. McKinney (1984) has demonstrated how the evolution of a much larger peristome in an *Oligopygus* lineage in the Eocene of Florida occurred by an extrapolation of the ontogenetic trajectory to a larger size in the species with the largest peristome, *O. wetherbyi* de Loriol. Comparison of *E. stomias* with species of comparable test size, such as *E. ovatus,* shows that the large peristome size of *E. stomias* is not merely a function of the size of the test, as the peristome of *E. ovatus* is relatively smaller than in *E. stomias.* The large peristome of *E. stomias* probably reflects a change in growth allometry. In most echinoids the peristome develops with negative allometry, compared with test size; in other words it becomes relatively smaller as the test increases in size. The peristome of *E. stomias* may be considered to have undergone a reduction in degree of negative allometry compared with other *Echinocorys* species, approaching closer to, though not reaching, isometry. Such reduction in negative allometry resulted in the adult *E. stomias* probably resembling ancestral juveniles in its retention of a relatively large peristome, thus demonstrating the development of paedomorphosis by neoteny (reduction in negative allometry). The functional significance of the increased peristome size was the ability of the echinoid to ingest a greater volume of sediment, perhaps indicating a general reduction in the nutrient value of the food source.

Acknowledgements

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Revision of Australian *Eptesicus*
(Microchiroptera: Vespertilionidae)

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Abstract

A classical morphological approach has been used to clarify the taxonomy of Aust-ralian *Eptesicus*. Multivariate analyses of 37 morphological measurements were undertaken to determine the phenetic relationships between the nine species recog-nised in this study: *E. pumilus* (Gray, 1841); *E. caurinus* Thomas, 1914; *E. doug-lasorum* Kitchener, 1976; *E. finlaysoni* sp. nov.; *E. darlingtoni* Allen, 1933; *E. troughtoni* sp. nov.; *E. regulus* (Thomas, 1906); *E. vulturnus* Thomas, 1914 and *E. baverstocki* sp. nov.

In Australian *Eptesicus* there are two broad phenetic groups. The first includes those species with a northern or inland distribution; the second those with a south-ern or inland distribution.

Introduction

Miller (1907) details the nomenclatural history of the genus *Eptesicus* [type species of *E. melanops* Rafinesque, 1820 (= *Vespertilio fuscus* Beauvois, 1796)] of North America. Since recognition of this genus, 35 species have been recognised by Corbet and Hill (1986), including species from Europe, Africa, Australia and South Amcrica. These additions have resulted in a widening of the initial generic concept of *Eptesicus* such that, apart from the similar dental formula, many species have little in common with *E. melanops* Rafinesque.

The external morphology and skull of certain species groups of *Eptesicus* are very similar to certain species of *Pipistrellus* Kaup, 1929 (and *Vespertilio* Linnaeus, 1758) save for the usual absence of thc anterior upper premolar of *Pipistrellus*. As occasional *Eptesicus* specimens do havc this additional premolar, its presence or absence is a dubious character on which to base a generic distinction (Tate 1942, Ellerman and Morrison-Scott 1951, Hill and Topal 1974, Kock 1969 and Heller and Volleth 1984). Ellerman and Morrison-Scott (1951) conclude that *Pipistrellus* is no more than a subgenus of *Eptesicus*, which itself might be referred to *Vesper-tilio*. Heller and Volleth (1984) suggest a de-emphasis of the importancc of the presence or absencc of this anterior premolar to distinguish *Eptesicus* and *Pipis-trellus* because 'a multiply independent loss of the second premolar is easily

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imaginable'. They consider *Eptesicus* to be distinguishable from *Pipistrellus* (and *Vespertilio*) by the possession of 50 chromosomes (with a fundamental number of 48), a baculum that is relatively small and not stick-like and the presence of one or two pairs of upper premolars. On this basis Heller and Volleth (1984) consider the Australian species usually placed in *Eptesicus* belong to *Pipistrellus,* which they characterise as having a diploid chromosome number of 44 or less, a more or less stick-like baculum and one or two pairs of upper premolars. This view is somewhat appealing as the inclusion of the Australian species in *Eptesicus* results in a genus which has a peculiarly disjunct Oriental and Australian distribution, with no *Eptesicus* between southern Thailand *(E. demissus)* and Australia (see Koopman 1984). However, we recognise consistent differences between Australian *Eptesicus* and Australo-Papuan pipistrelles in the shape of the posterior palate and internal narial regions, the upper incisors and the morphology of the bacula and glans penis. As a consequence we are reluctant to consider these forms congeneric.

Troughton (1944*a*) proposed the generic name *Vespadelus* for the Australian species *Scotophilus pumilus* (= *Eptesicus pumilus*). This name was introduced without an accompanying diagnosis by Iredale and Troughton (1934). Troughton (1944*b*) proposed *Registrellus* for the composite specimen *Pipistrellus regulus* (= *Eptesicus regulus,* see Hill 1966) from southwestern Australia. Both *Vespadelus* and *Registrellus* are available names for a genus comprising the Australian forms currently placed in *Eptesicus,* but without a comprehensive phylogenetic appraisal of related Vespertilionidae, which is outside the scope of this study, we are unable to appraise the generic separability of the Australian species of *'Eptesicus'.*

The following eight forms of Australian *Eptesicus* have been recognised: *Eptesicus pumilus* (Gray, 1841); *E. pygmaeus* (Becker, 1858); *E. darlingtoni* Allen, 1933; *E. pumilus caurinus* Thomas, 1914; *E. pumilus vulturnus* Thomas, 1914; *E. regulus* (Thomas, 1906); *E. douglasorum* Kitchener, 1976 and *E. sagittula* McKean, Richards and Price, 1978. Until the mid 1970s workers [e.g. Tate (1942), Ride (1970)] considered all the described forms as subspecies of *Eptesicus pumilus.* Kitchener and Halse (1978) applied the available name *regulus* to the southwestern *Eptesicus,* a view supported by McKean *et al.* (1978) who also recognised *E. vulturnus.* At the time of this study the following five Australian *Eptesicus* species were generally recognised (e.g. McKean *et al.* 1978; Campbell and Kitchener 1980; Carpenter *et al.* 1978; Tidemann *et al.* 1981; Green and Rainbird 1984; Strahan 1984): *pumilus, regulus, vulturnus, douglasorum* and *sagittula.* *E. pygmaeus* (Becker, 1858; not Leach, 1825) was synonymised with *E. vulturnus* by McKean *et al.* (1978). Recent collections of Australian *Eptesicus* have revealed undescribed forms, necessitating this taxonomic revision. While we have applied classical morphological as well as modern numeric taxonomic techniques to identify species in this study, we acknowledge the co-operation of our colleagues at the South Australian Museum who have conducted a parallel electrophoretic study of Australian *Eptesicus.*

Methods

Morphology

Teeth — terminology of tooth structure follows Slaughter (1970) and is illustrated for upper and lower molars in Kitchener and Caputi (1985).

Measurements

Skull, dentary and externals — twenty seven measurements (in mm) of the skull and 12 external measurements were recorded from adult specimens only (listed in the sections 'Specimens Examined'). Measurements of holotypes or lectotypes or paratypes are listed in Appendix I. Subadults and juveniles were diagnosed on the basis of epiphyseal swellings of the metacarpal joints. The terminology used follows Kitchener and Caputi (1985). Colours of pelage and skin are capitalised where they follow the Ridgway (1912) colour charts.

All measurements were made with dial calipers. The positions of these measurements are indicated in Figure 1.

Coded characters and descriptive terms

The following coded characters were used in the phenetic analysis and where appropriate in the diagnoses and descriptions.

1. Anterior palatal emargination
    (o) - maximum width sited in the posterior one-third of emargination
    (i) - maximum width sited in the central one-third of emargination

2. Anterior palatal emargination
    (o) - wider than long
    (i) - maximum width equals length ("square")
    (ii) - longer than wide

3. Anterior palatal emargination (Figure 2a)
    (o) - shallow: does not extend beyond posterior margin of canine
    (i) - deep: terminates posterior to posterior margin of canine

4. Anterior narial emargination (Figure 2b)
    (o) - deep: extends to, or almost to, a line joining anterior margins of anteorbital foramina
    (i) - shallow: terminates well anterior to the above line

5. Relationship between basolateral pterygoid wing and foramen rotundum (Figure 2c)
    (o) - absent: wing absent or not extending to edge of foramen rotundum
    (i) - present: wing covers <1/3 of foramen rotundum
    (ii) - present: wing covers >1/3 <2/3 of foramen rotundum
    (iii)- present: wing covers >2/3 foramen rotundum

6. Dorsal inflation of cranium (Figure 2*d*)
   (o) - absent
   (i) - slight
   (ii) - moderate
   (iii)- pronounced

7. Crista M^1 and/or M^2 (Figure 3)
   (o) - absent LM^{1-2} and/or RM^{1-2}
   (i) - slight LM^{1-2} and/or RM^{1-2}
   (ii) - moderate LM^{1-2} and RM^{1-2}
   (iii)- large LM^{1-2} and RM^{1-2}

8. P^2
   (o) - present
   (i) - absent

9. I^2
   (o) - present
   (i) - absent

◀ Figure 1   Skull, dentary and external body measurements referred to in text and their record-
ing points. GL: greatest skull length; AOB: anteorbital width, between anteorbital
foramina; LOW: least interorbital width; LW: lacrymal width; ZW: zygomatic width;
ROL: rostrum length, from LOW to anterior edge of premaxilla; MW: mastoid
width, between mastoid processes; BW: braincase width, at centre of zygomatic-
squamosal contact; CH: cranial height, lower arm of calipers placed level with pre-
and basi-sphenoid, upper arm in contact with apex of skull; LCH: lambdoidal crest
height; PL: palatal length, excluding postpalatal spine; PPW: postpalatal width; BL:
basicranial length, between anterior edge of foramen magnum and anterior edge of
premaxilla; BUL: bulla length, excluding eustachian part; BB: width of basi-sphenoid
between cochlea; OB: distance outside bullae, caliper points in contact with antero-
dorsal edge of tympanic ring; CW: canine width, maximum diameter at base; RC^1-
LC^1: inter upper canine distance, at base of cusp; C^1-M^3: upper maxillary tooth
row crown length, anterior edge of C^1 to posterior edge M^3; M^{1-3}: upper molar
crown length, anterior edge M^1 parastyle to posterior edge M^3; M^2 L: upper second
molar crown length, anterior edge of parastyle to posterior edge of metastyle; M^2 W:
upper second molar crown width, lingual base of protocone to buccal face of para-
cone, at right angles to occlusal surface; M^3 W: upper third molar crown width, as for
M^2 W; RM^3-LM^3 inter upper third molar distance, across buccal face of paracone to
RM^3 and LM^3; LR: lower tooth row length, posterior edge M_3 to anterior edge of
dentary; RC: angular ramus to dentary condyle, blade of caliper along anterior
face of ramus and measuring to posterior edge of articular condyle; DL: dentary
length, from condyle to anterior tip of dentary; HV: body length, tip of rhinarium
to anus; TV: tail length, tip to anus; EL: ear length, apex to basal notch; EW: ear
width across basal lobes; TL: tragus length; RL: radius length; MCIII: metacarpal
III length; PI: digit III, phalanx I length; PII: digit III, phalanx II length; PIII:
digit III, phalanx III length; TIB: tibia length and PL: pes length.

Table 1a, b   Measurements in mm (see Figure 1 for code to characters) for adults of the nine species of *Eptesicus*. N, sample size; X̄, mean; SD, standard deviation; Mn, minimum and Mx, maximum, (a) skull, dentary and teeth and (b) externals.

Table 1a

Skull, Dentary and Teeth Characters

Species		GL	AOB	IOW	ALW	ROL	ZW	MW	BW	CH	LCH	PL	BL	PPW	BUL	BB	OB	CW	RC2-LC2	C2-M2	M2-M3	MPL	NFW	MFW	LMF	LR	DL	RC
E. pumilus	N	25	26	26	26	26	21	25	25	25	23	26	25	25	25	25	25	26	26	26	26	26	26	26	26	26	26	26
	X̄	12.1	3.8	3.6	5.0	5.2	8.0	6.9	6.3	1.6	2.1	5.6	10.1	1.7	2.7	1.2	6.5	0.7	3.7	1.3	2.8	1.1	1.2	1.2	5.1	5.3	8.6	2.5
	SD	0.27	0.14	0.16	0.17	0.19	0.21	0.22	0.14	0.11	0.22	0.17	0.21	0.19	0.12	0.08	0.18	0.06	0.15	0.09	0.05	0.05	0.04	0.11	0.13	0.20	0.10	
	Mn	11.3	3.5	3.6	4.5	4.8	7.6	6.3	6.0	1.1	1.8	5.9	9.8	1.2	2.3	1.1	6.1	0.6	3.1	1.1	2.7	1.0	1.1	1.0	1.8	5.0	8.1	2.3
	Mx	12.7	4.1	3.9	5.2	5.5	8.1	7.2	6.5	1.8	2.6	5.9	10.5	2.0	3.0	1.3	6.8	0.9	4.0	1.6	3.0	1.2	1.3	1.3	5.2	5.5	8.8	2.6
E. caurinus	N	11	12	11	11	12	25	10	11	40	10	37	11	11	12	10	10	12	12	12	12	12	42	42	42	41	11	12
	X̄	12.2	3.3	4.8	1.5	1.5	7.5	6.5	5.8	1.1	1.9	5.1	9.1	1.1	2.6	1.0	6.0	0.67	3.6	3.9	2.6	1.0	1.2	1.1	1.8	1.8	7.9	2.3
	SD	0.31	0.16	0.19	0.20	0.20	0.23	0.20	0.17	0.19	0.21	0.19	0.27	0.12	0.10	0.14	0.18	0.06	0.12	0.15	0.11	0.07	0.07	0.08	0.16	0.16	0.25	0.09
	Mn	10.6	3.6	3.3	1.1	1.1	7.1	6.2	5.5	1.0	1.2	4.8	8.9	1.2	2.1	0.7	5.6	0.6	3.1	3.6	2.5	0.9	1.0	1.0	4.5	4.5	7.1	2.1
	Mx	12.0	4.2	3.5	5.0	5.0	7.0	7.0	6.2	1.8	2.3	5.6	10.0	1.7	2.9	1.3	6.5	0.8	3.8	1.2	2.9	1.1	1.3	1.3	5.2	5.1	8.6	2.5
E. douglas-orum	N	12	13	13	13	13	10	12	13	12	12	12	12	13	11	13	13	13	13	13	13	13	13	13	13	13	13	13
	X̄	12.5	3.5	3.5	5.3	5.3	8.1	7.2	6.3	1.9	2.1	5.9	10.9	1.6	2.8	1.1	6.6	0.8	1.2	1.7	3.1	1.2	1.3	1.3	5.5	5.7	9.2	2.7
	SD	0.25	0.10	0.18	0.18	0.18	0.25	0.20	0.21	0.13	0.15	0.19	0.21	0.11	0.11	0.11	0.13	0.01	0.13	0.13	0.08	0.08	0.07	0.13	0.14	0.21	0.09	
	Mn	12.3	3.3	3.3	5.1	5.1	8.1	6.8	6.0	1.7	2.0	5.7	10.6	1.1	2.6	0.9	6.1	0.8	4.0	4.5	2.9	1.0	1.2	1.0	5.3	5.5	9.0	2.6
	Mx	13.2	3.6	3.6	6.0	6.0	8.8	7.1	6.7	2.4	2.3	6.3	11.1	1.8	3.0	1.2	6.8	0.9	5.0	3.2	3.2	1.3	1.1	1.3	5.8	6.0	9.6	2.9
E. finlaysoni	N	89	88	88	89	89	72	86	89	89	86	87	88	87	89	89	88	89	89	89	89	89	89	89	89	89	89	89
	X̄	12.4	4.1	3.4	5.4	5.0	8.3	7.1	6.2	1.7	2.1	5.6	10.5	1.6	2.8	1.1	6.5	0.8	1.1	3.0	3.0	1.1	1.3	1.3	5.3	5.3	8.8	2.6
	SD	0.19	0.23	0.16	0.26	0.29	0.37	0.28	0.26	0.19	0.16	0.32	0.36	0.12	0.13	0.12	0.23	0.08	0.23	0.16	0.16	0.07	0.08	0.09	0.25	0.26	0.43	0.16
	Mn	11.3	3.6	3.0	4.8	4.8	7.5	6.4	5.6	1.2	1.7	5.0	9.6	1.4	2.6	0.8	5.9	0.7	3.5	2.6	2.9	1.0	1.1	1.0	4.8	4.8	8.0	2.3
	Mx	13.5	4.6	3.9	5.9	5.8	9.2	8.1	7.0	5.2	2.4	6.1	11.7	1.8	3.1	1.3	7.3	1.0	5.0	3.4	3.2	1.3	1.5	1.5	6.0	6.0	9.8	3.1

Table 1a (continued)

Skull, Dentary and Teeth Characters

Species		GL	AOB	LOW	LW	ROL	ZW	MW	BW	CH	LCH	PL	BL	PPW	BUL	BB	OB	CW	RCL-LC^1	C^1-M^3	M-M^3	N^3L	N^2W	M^2W	LM^3	LR	DL	RC
E. darlingtoni	N	34	34	34	34	34	26	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
	X̄	13.4	4.1	4.0	5.5	5.7	8.7	7.6	6.8	5.0	2.3	6.1	11.4	1.9	3.0	1.3	7.1	0.8	4.2	4.9	3.3	1.2	1.4	1.4	5.7	5.9	9.6	2.7
	SD	0.34	0.16	0.09	0.19	0.26	0.28	0.24	0.19	0.11	0.18	0.22	0.37	0.14	0.15	0.15	0.23	0.07	0.15	0.18	0.13	0.07	0.08	0.11	0.21	0.22	0.30	0.11
	Mn	12.7	3.8	3.8	5.1	5.2	8.2	7.1	6.5	4.7	2.0	5.7	10.5	1.6	2.7	1.0	6.7	0.7	3.9	4.4	3.0	1.1	1.2	1.2	5.2	5.4	8.8	2.5
	Mx	14.1	4.5	4.1	5.9	6.2	9.3	8.0	7.2	5.2	2.8	6.5	12.0	2.3	3.3	1.6	7.6	0.9	4.4	5.2	3.6	1.3	1.5	1.6	6.1	6.3	10.1	3.0
E. troughtoni	N	24	25	25	25	24	14	25	25	25	23	24	24	25	25	25	24	25	25	25	25	25	25	25	25	25	25	25
	X̄	12.7	4.3	3.8	5.6	5.3	8.5	7.4	6.5	4.8	2.3	5.9	10.8	1.7	2.9	1.2	6.7	0.8	4.1	4.7	3.1	1.2	1.3	1.3	5.7	5.7	9.2	2.6
	SD	0.21	0.13	0.09	0.10	0.15	0.18	0.13	0.15	0.11	0.22	0.17	0.20	0.12	0.10	0.17	0.15	0.05	0.09	0.10	0.08	0.06	0.07	0.06	0.14	0.12	0.18	0.06
	Mn	12.2	4.1	3.6	5.3	4.9	8.2	7.2	6.2	4.6	1.7	5.6	10.3	1.5	2.7	1.0	6.5	0.7	4.0	4.5	2.9	1.0	1.2	1.2	5.4	5.5	8.8	2.5
	Mx	13.2	4.6	3.9	5.8	5.6	8.7	7.7	6.7	5.0	2.8	6.2	11.2	2.0	3.0	1.8	7.0	0.9	4.3	4.8	3.2	1.3	1.5	1.4	5.9	6.0	9.5	2.7
E. regulus	N	84	84	84	84	84	61	83	83	84	83	82	81	83	83	84	84	84	83	84	84	84	84	84	84	83	83	84
	X̄	12.7	4.1	3.5	5.3	5.4	8.3	7.3	6.4	4.4	2.2	5.8	10.8	1.6	2.8	1.3	6.7	0.8	4.0	4.5	3.0	1.1	1.3	1.2	5.2	5.6	9.1	2.6
	SD	0.30	0.17	0.18	0.20	0.22	0.27	0.21	0.24	0.20	0.21	0.21	0.30	0.12	0.11	0.14	0.19	0.08	0.19	0.16	0.11	0.07	0.08	0.08	0.21	0.18	0.28	0.13
	Mn	11.9	3.8	3.1	1.6	4.7	7.6	6.9	5.8	4.0	1.9	5.3	9.9	1.3	2.6	1.0	6.2	0.6	3.5	4.1	2.7	1.0	1.1	1.0	4.3	5.1	8.4	2.3
	Mx	13.4	4.6	4.0	5.7	5.8	8.9	8.0	6.9	4.9	2.9	6.4	11.5	1.9	3.0	1.6	7.2	1.0	4.5	4.8	3.3	1.4	1.5	1.4	5.6	5.9	9.7	2.9
E. vulturnus	N	34	34	34	34	34	31	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
	X̄	12.2	3.8	3.4	5.0	5.1	7.8	6.9	6.1	4.2	2.1	5.5	10.3	1.6	2.8	1.1	6.4	0.7	3.8	4.3	2.9	1.1	1.2	1.2	5.1	5.3	8.7	2.5
	SD	0.24	0.15	0.11	0.14	0.17	0.21	0.17	0.19	0.10	0.13	0.15	0.23	0.08	0.09	0.13	0.13	0.05	0.13	0.11	0.11	0.05	0.06	0.07	0.16	0.15	0.23	0.10
	Mn	11.8	3.5	3.2	4.8	4.7	7.3	6.6	5.9	4.0	1.9	5.2	9.8	1.5	2.6	0.8	6.2	0.7	3.6	4.1	2.5	1.0	1.1	1.1	4.8	5.1	8.3	2.3
	Mx	12.7	4.1	3.6	5.4	5.4	8.3	7.3	6.8	4.4	2.5	5.8	10.7	1.8	3.0	1.4	6.7	0.9	4.1	4.6	3.1	1.2	1.4	1.4	5.4	5.8	9.2	2.7
E. baverstocki	N	25	25	25	25	25	18	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
	X̄	12.1	3.8	3.2	5.0	5.0	7.9	6.9	6.0	4.1	1.9	5.4	10.3	1.4	2.8	1.2	6.3	0.7	3.8	4.2	2.9	1.1	1.3	1.2	5.0	5.1	8.6	2.5
	SD	0.27	0.16	0.08	0.21	0.14	0.25	0.19	0.16	0.14	0.13	0.17	0.25	0.10	0.10	0.15	0.17	0.05	0.19	0.14	0.10	0.07	0.09	0.09	0.16	0.20	0.29	0.11
	Mn	11.6	3.5	3.0	4.6	4.8	7.6	6.4	5.6	3.9	1.6	5.1	9.8	1.2	2.5	0.8	6.0	0.6	3.5	3.9	2.7	0.9	1.1	1.1	4.7	4.7	8.1	2.3
	Mx	12.5	4.2	3.3	5.5	5.3	8.4	7.2	6.3	4.4	2.1	5.7	10.6	1.6	2.9	1.5	6.6	0.8	4.2	4.5	3.0	1.2	1.1	1.4	5.4	5.5	9.2	2.7

Table 1b

| Species		HV	TV	EL	EW	TL	RL	MC4III	Pi	PII	PIII	TIB	PL
						External Characters							
E. pumilus	N	24	24	25	24	25	25	25	25	25	24	25	25
	X	39.1	30.7	10.5	8.0	5.3	30.6	29.4	11.5	8.9	7.7	12.6	5.2
	SD	2.32	1.43	0.70	0.44	0.52	1.14	1.21	0.49	0.54	0.47	0.53	0.48
	Mn	35.0	27.6	9.0	7.0	4.6	28.1	27.3	10.5	7.6	6.6	11.6	4.2
	Mx	44.2	33.7	11.9	8.8	6.5	32.9	32.2	12.4	9.8	8.6	13.8	6.4
E. caurinus	N	36	39	38	37	37	39	39	39	39	39	39	38
	X	36.7	30.2	10.1	7.3	5.3	29.5	28.6	10.6	10.1	5.5	11.4	4.3
	SD	2.06	2.01	0.87	0.19	0.64	1.08	1.24	0.51	0.72	0.50	0.48	0.39
	Mn	32.1	24.1	8.3	6.5	3.8	26.6	25.9	9.8	7.9	4.4	10.7	3.6
	Mx	40.0	34.8	12.3	8.3	6.5	31.7	31.9	12.0	12.1	6.8	12.4	5.5
E. douglasorum	N	13	8	13	13	13	11	13	13	13	12	10	10
	X	39.7	36.3	11.9	8.6	5.3	36.2	35.0	11.1	11.5	6.1	14.3	5.2
	SD	2.13	1.02	0.38	0.28	0.48	1.14	1.36	0.48	0.11	0.49	0.61	0.35
	Mn	35.3	35.2	11.3	8.1	4.9	34.3	32.7	10.0	10.8	5.3	13.6	4.8
	Mx	43.5	37.9	12.5	9.0	6.6	37.6	37.0	11.7	12.2	7.0	15.5	6.4
E. finlaysoni	N	83	79	84	84	84	84	84	84	83	82	82	82
	X	40.1	35.2	11.1	8.2	5.5	32.8	32.3	12.3	11.2	6.7	13.6	4.9
	SD	2.54	2.93	0.73	0.12	0.56	1.18	1.60	0.65	0.82	0.61	1.00	0.39
	Mn	34.3	30.7	9.3	6.9	4.1	29.8	29.3	11.0	9.2	5.0	11.4	4.0
	Mx	46.4	42.0	13.2	9.5	6.9	36.7	36.1	13.8	13.0	7.9	16.2	6.0
E. darlingtoni	N	30	29	31	31	31	32	33	33	33	31	31	30
	X	44.1	33.5	11.8	8.9	6.5	34.6	32.9	13.0	9.6	8.8	13.7	5.9
	SD	3.08	2.08	0.82	0.12	0.70	1.11	1.05	0.60	0.56	0.68	0.52	0.39
	Mn	38.1	29.2	10.1	7.9	4.9	32.5	30.9	11.8	8.7	7.6	12.3	5.2
	Mx	48.9	38.0	13.1	9.8	7.7	37.2	35.1	14.2	10.8	10.0	14.4	7.0
E. troughtoni	N	17	16	17	17	17	17	17	17	17	17	17	17
	X	41.5	35.3	11.1	8.4	5.6	34.8	31.0	12.6	11.0	7.1	13.6	5.4
	SD	1.74	2.25	0.66	0.38	0.73	0.89	0.72	0.54	0.73	0.59	0.42	0.37
	Mn	37.5	31.4	10.1	7.6	4.6	33.0	32.6	11.5	9.3	6.5	12.7	4.8
	Mx	44.2	37.9	12.5	9.2	7.4	36.4	35.1	13.5	12.6	8.3	14.2	6.2
E. regulus	N	75	72	77	76	77	77	77	77	77	75	77	76
	X	41.4	34.7	11.1	8.6	5.9	31.2	30.2	11.2	9.0	7.2	12.7	5.4
	SD	2.47	1.80	0.70	0.48	0.48	1.19	1.24	0.51	0.57	0.56	0.56	0.46
	Mn	36.2	28.5	9.0	7.4	4.4	28.0	27.0	9.8	7.5	6.0	11.4	4.3
	Mx	46.6	39.0	12.9	9.6	7.1	34.1	32.7	12.4	10.3	9.0	13.9	6.7
E. vulturnus	N	33	32	34	33	34	34	34	34	34	22	22	22
	X	40.2	30.9	10.6	8.4	5.5	28.1	27.6	11.5	8.9	6.7	11.8	5.0
	SD	2.74	1.86	0.72	0.45	0.45	1.20	1.42	0.48	0.60	0.60	0.52	0.39
	Mn	34.7	27.5	9.4	7.6	4.5	26.3	24.6	10.5	7.8	4.8	10.8	3.9
	Mx	48.0	34.2	12.2	9.2	6.5	32.8	31.1	12.1	10.8	7.8	13.0	5.5
E. baverstocki	N	25	24	25	25	25	24	25	25	25	25	25	25
	X	39.6	29.7	10.6	8.4	5.8	28.6	28.0	10.4	8.6	6.6	11.8	4.9
	SD	2.07	2.1	0.65	0.39	0.70	1.14	1.07	0.44	0.45	0.58	0.51	0.38
	Mn	35.4	26.5	9.1	7.5	4.4	26.5	26.0	9.4	7.9	4.8	10.8	3.9
	Mx	43.5	33.8	11.4	9.2	6.8	31.4	31.2	10.9	9.7	7.8	13.0	5.5
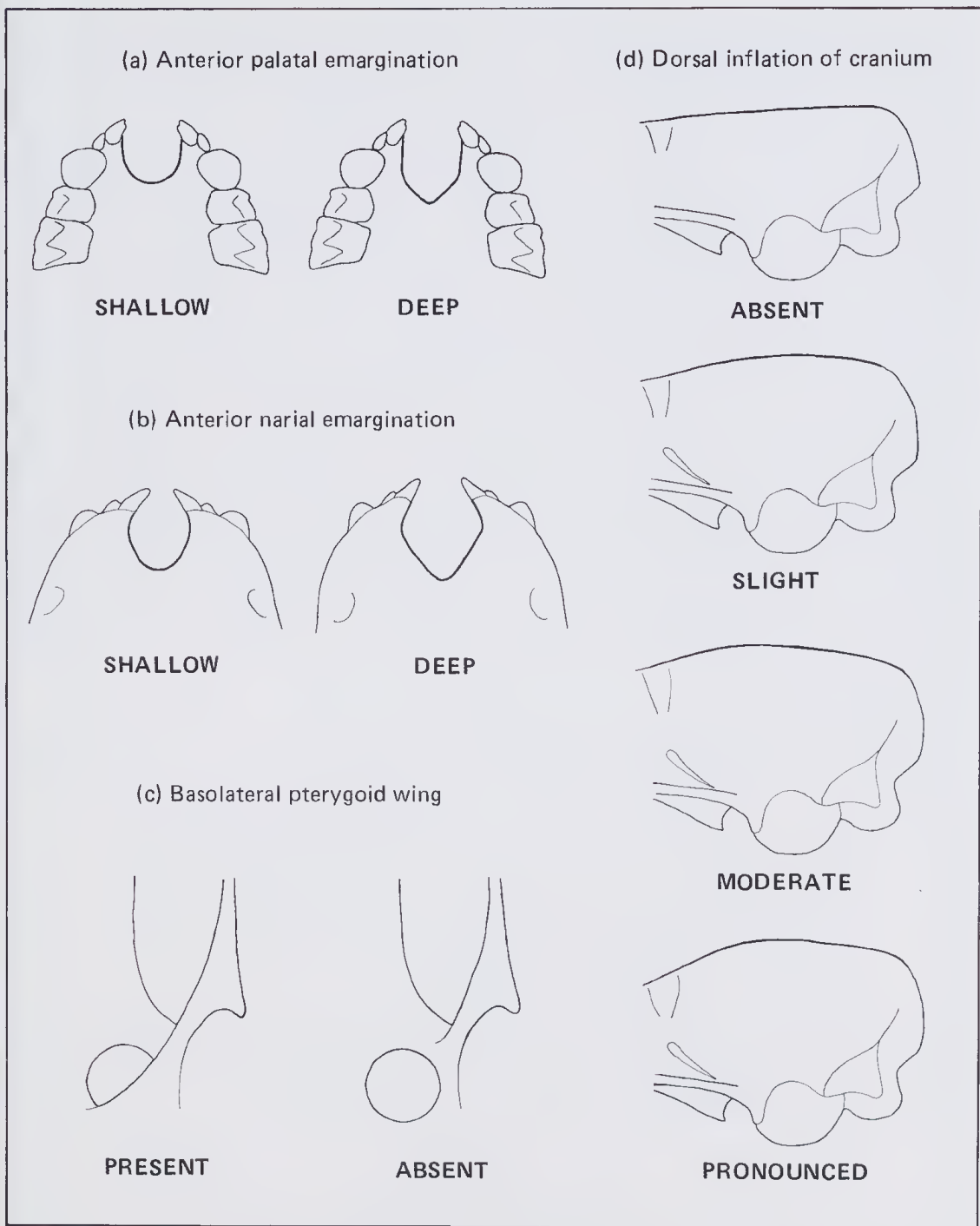
Figure 2   Coded skull characters referred to in text. Further explanation is given in Morphology section of Methods.

Morphometric analyses

Sexual dimorphism was examined using a two factor analysis of variance for measurements of each of the skull, dentary, teeth (skull characters) and external characters for the factors: species-area combinations and sex.

Canonical variate (discriminant) analyses, using both the skull and external measurements, were performed on the species using SPSS (Norusis 1985) and GENSTAT Package, Rothamsted Experimental Station. To obtain an unbiased estimate of the correct classification rate, the canonical variate analyses were repeated using only 80 per cent of the specimens; the canonical variate functions so obtained were then used to classify the remaining 20 per cent of the specimens.

In some of the canonical variate analyses, a Mahalanobis distance matrix was obtained and subjected to a minimum spanning tree analysis and a hierarchical cluster analysis using the unweighted pair group mathematical averaging method (UPGMA).

The above canonical variate and minimum spanning tree cluster analyses were also performed after attempting to correct for size in the 37 variables used. This was done by a principal component analysis of the within-species correlation matrix of the skull and external variables. The latent vectors of this analysis were then examined to determine if the first (and second) vectors had values which suggested that the vector(s) were size vectors. If this was the case then the Principal Component scores associated with these vectors were omitted from the canonical variate and other analyses.

Institutional specimens

To denote the institutional origin of specimens, their catalogue numbers are prefixed by the following abbreviations:

AM   : Australian Museum, Sydney
AMNH   : American Museum of Natural History, New York
C   : Museum of Victoria, Melbourne
CM   : CSIRO, Australian National Wildlife Collections, Canberra
JM   : Queensland Museum, Brisbane
SAM   : South Australian Museum, Adelaide
WAM   : Western Australian Museum, Perth
EBU   : Evolutionary Biology Unit, South Australian Museum, Adelaide
NTM   : Northern Territory Museum, Darwin
BMNH   : British Museum of Natural History, London

Systematics

Eptesicus Rafinesque, 1820

General Description of Australian *Eptesicus*

Small delicate skulls ranging in greatest length from 10.6 to 14.1 mm; braincase dorsal inflation grades from pronounced in *E. pumilus* and *E. caurinus* through to

absent in *E. baverstocki* sp. nov. (Figure 2d); variation in cranial inflation occurs within some species; sagittal crests absent; lambdoidal crests variably present, never strongly developed; supraorbital tubercles absent to slight, variable within species; postorbital swelling absent or very slight; curve of anterior edge of orbit subcircular, except in *E. darlingtoni* where it is oval; anterior nares outline ranges from broad U to V-shaped, somewhat variable within species, generally not extending posterior to line joining anterior edge of anteorbital foramen; lateral margin of sphenorbital sinus usually a smooth curve except for *E. pumilus* and *E. douglasorum* where it has a noticeable convex inflection; rostrum relatively short, ranges from 48-52 per cent of basicranial length, rostrum width as indicated by anteorbital width ranges from 70-85 per cent of rostrum length; least interorbital width moderate, ranges from 30-36 per cent of basicranial length; infraorbital foramen oval to subcircular, separated from orbit by slight to moderate lacrymal bar; zygomata slender; postpalatal width measured across outside of LM^3 - RM^3 moderately wide, ranging from 48 to 53 per cent of basicranial length; posterior margin of palate (posteropalatal margin of Kitchener *et al.* 1986) conceals openings of posterior nares when viewed vertically; postpalatal spine length small to moderate, shape thin to broadly spatulate; mesopterygoid fossa moderate, sides parallel, only partially conceals sphenorbital sinus; pterygoid process short, hastate, termination of posterior margin of palate ranges from the anterior edge of sphenorbital sinus to approximate mid point of this sinus; anterior palatal emargination variable in shape within species, terminates at a point between the mid point of C^1 and the anterior edge of P^4; foramen rotundum moderate, circular or subcircular, partially and variably concealed in some species by a basolateral pterygoid wing (Figure 2c); tympanic bulla moderate, covers two thirds to four-fifths of cochlea, eustachian part small, blunt; anterolateral wings of basioccipital moderate, pressed against edge of cochlea; glenoid fossa rectangular to subcircular; distance between cochlea approximately one-third width of cochlea; paraoccipital process short, does not extend below occipital condyle; anterolateral wing of ectotympanic extends to lateral edge of squamosal in most species except *E. pumilus,* variable in *E. troughtoni* and *E. regulus.* I^1 bilobed, outer cusp shorter than inner cusp, posterior and anterior cingulum slight; I^2 with single cusp, height just above I^1 cingulum to one-quarter height I^1, broad anterolingual basal flange closely pressed against basal part of posterior loph I^1 just below cingulum, anterolateral cingulum slight to moderate, variously with lateral cusplet; diastema between I^2 and C^1; C^1 much larger than P^4, posterolingual and posterolabial face slightly to moderately concave, forming a sharp posterior ridge in line with tooth row, encircled by cingulum which is slight on laterolingual surface, loosely contacts P^4 anterior cingulum; P^4 three-quarters height C^1, anterolingual cingular cusplet slight to moderate, anterior and labial cingulum slight to moderate; M^1 paracone shorter than metacone; M^2 paracone subequal in height to metacone; M^3 paracone much higher than M^3 metacone, paracrista length $M^1 < M^2 < M^3$; mesostyle height M^1 and M^2 subequal $> M^3$; protocone height $M^1 > M^2 > M^3$; hypocone slight to
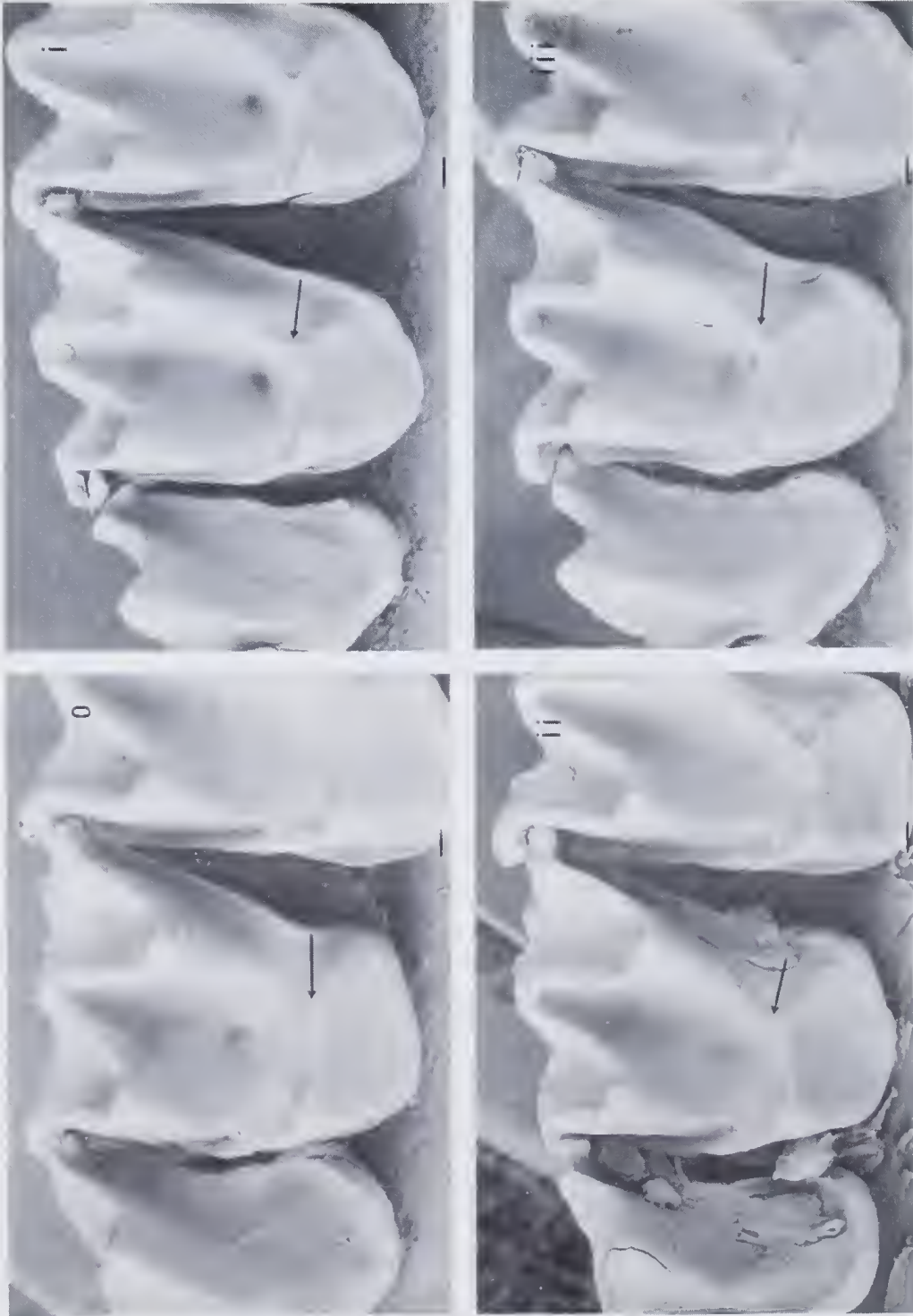
Figure 3   Showing the four grades of development of the metacone-hypocone crista. Illustrated here by an SEM photograph of the first upper molar. The crista is arrowed. Scale line, 100 μm. (○) absent, (i) slight, (ii) moderate, (iii) large.

moderate; crista linking base of metacone to hypocone M^{1-2} varies from absent to large (Figure 3); anterior, lingual and posterior cingulum well developed M^{1-2}; M^3 anterior and posterolingual cingulum only, moderate; M^{1-3} labial cingulum absent to slight; M^3 lacking metastyle and postmetacrista; upper molar rows parallel or slightly convex.

Dentary moderately dense; angular process beneath or external to condyle; coronoid process sharply or broadly triangular, erect or slightly sloping anteriorly; mental foramen below P_2 or posterior edge C_1; I_{1-3} trilobed, imbricate, approximately equal height; crown area $I_1 < I_2 < I_3$; C_1 tall, in contact with I_3 and P_2, anterior and labial cingulum moderate, posterior and lingual cingulum more developed with slight to pronounced antero — and posterolingual cingular cusplets; P_2 tightly wedged between C_1 and P_4, one-third to one-half C_1 height, encircled with slight to moderate cingulum with slight to moderate antero — posterolingual cusplets; P_4 three quarters height C_1, slight to moderate lingual cingulum with slight to moderate anterolingual cingular cusplet and moderate to absent posterolingual cusplet, labial cingulum slight to moderate; M_{1-3} protoconid and hypoconid decrease in height posteriorly; M_{1-3} paraconid, metaconid and entoconid height subequal, hypoconulid small, hypocristid links hypoconid and entoconid.

The body is small with snout-vent length ranging from 32-50 mm, always longer than tail tip to vent length; ear small, rounded triangular shape, anterior edge smoothly convex, posterior edge concave beneath tip, lower two-thirds smoothly convex; tragus narrow, anterior margin straight or slightly concave, tip rounded, posterior margin convex, posterobasal lobe slight; radius slightly longer or subequal to third metacarpal, length ranges from 26-38 mm; phalanx I/digit III generally shorter, occasionally longer than phalanx II/digit III; phalanx II/ digit III longer than phalanx III/digit III; lobe on calcar present or absent, variably developed within species; no colour patterning on fur, dorsal hairs similar colour or darker than ventral hairs, furring of uropatagium varies from well furred to mid point of femur to well furred to knee; patagia usually dark but occasionally a light colour; skin of face and ear varies from usually dark to an occasional light colour.

Glans penis laterally, dorsoventrally or not compressed; urethral opening ventral or terminal; urethral lobe single or bilobed; lateral urethral folds sometimes present, often absent (Figure 4); baculum length varies from 1.6-4.7 mm; dorsal outline rod shaped with expanded base, arrow shaped or dart shaped; lateral profile varies from essentially flat to bow shaped (Figure 5).

Figure 4   Oblique SEM photographs of the glans penis of the nine species of *Eptesicus*. (a) *E. pumilus*, (b) *E. caurinus*, (c) *E. douglasorum*, (d) *E. finlaysoni*, (e) *E. darlingtoni*, (f) *E. troughtoni*, (g) *E. regulus*, (h) *E. vulturnus* and (i) *E. baverstocki*. Scale lines, 100 μm.
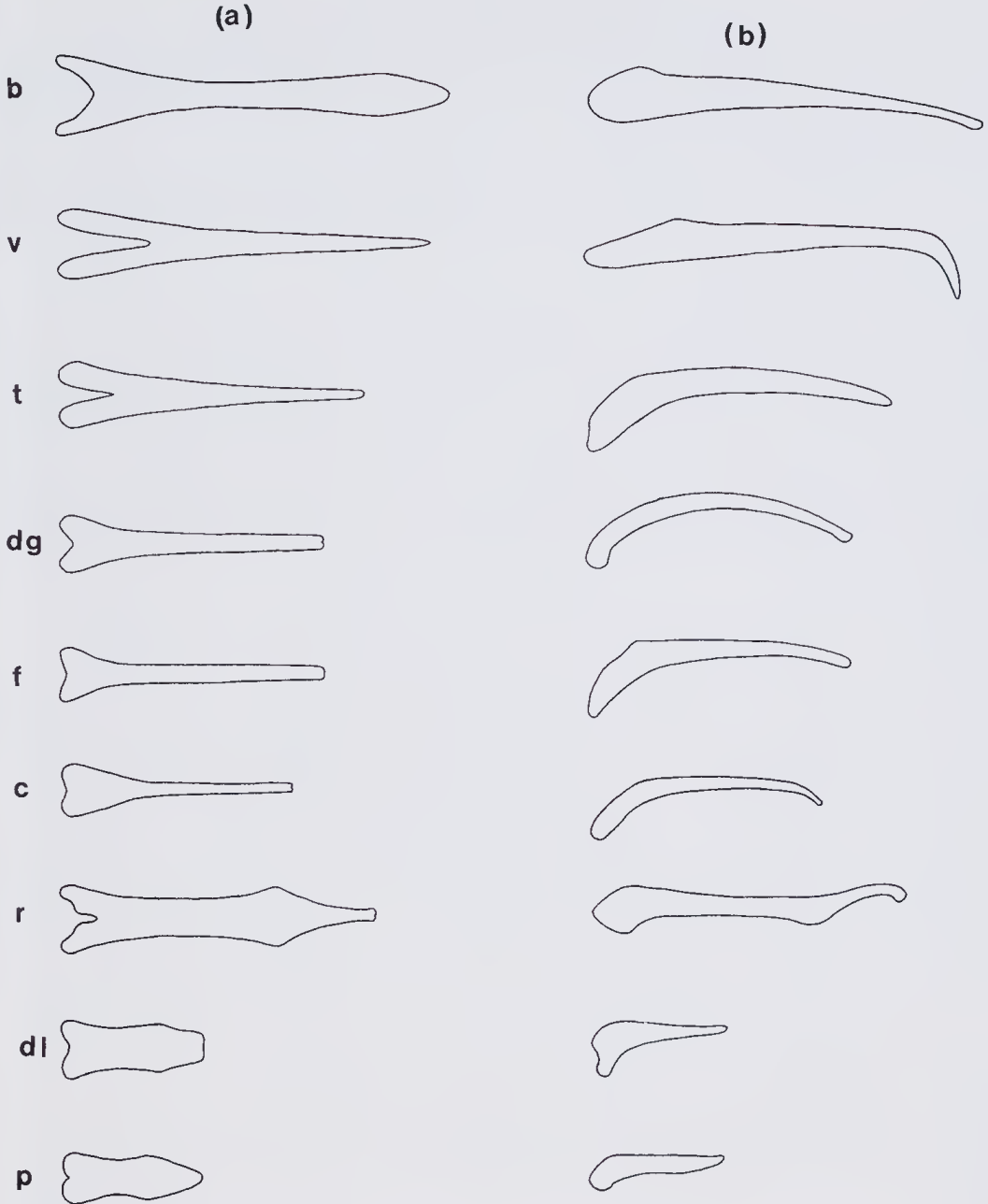
Figure 5   Baculum of the nine species of *Eptesicus*. (a) dorsal view, (b) lateral view.
The species code is b, *baverstocki;* v, *vulturnus;* t, *troughtoni;* dg, *douglasorum;*
f, *finlaysoni;* c, *caurinus;* r, *regulus;* dl, *darlingtoni;* p, *pumilus.*

Eptesicus pumilus (Gray, 1841)
Figures 4, 5, 6, 7a; Table 1

Scotophilus pumilus Gray, 1841: Journ. Two Exped. Australia (Grey), ii, App., p. 406.

Lectotype (herein designated, see Remarks)

BMNH 41.1523 (119c); adult male; skin and skull (anterior part only); from Yarrundi, on the Dartbrook River, a tributary of the Hunter River, New South Wales (*ca.* 32°00'S, 150°46'E).

Diagnosis (mean values)

Eptesicus pumilus differs from *E. caurinus*: rostrum narrower as indicated by anteorbital, lacrymal and RC^1-LC^1 widths relative to rostrum length (0.73 v. 0.84, 0.96 v. 1.07, 0.71 v. 0.80, respectively); anterior narial emargination deeper; anterolateral wing of ectotympanic further from lateral edge of squamosal; metacone-hypocone crista M^1 absent or slight or rarely moderate, rather than moderate or large; hypocone M^{1-2} larger; manus digit III with phalanx III longer relative to phalanx II (0.87 v. 0.55) and phalanx II shorter relative to phalanx I (0.77 v. 0.95); glans penis dorsoventrally rather than laterally compressed, urethral opening ventral rather than terminal; baculum shorter (1.6 v. 2.9), dorsal outline arrow shaped rather than rod shaped with expanded base, lateral profile less curved.

It differs from *E. douglasorum*: smaller in most skull, dental and external measurements (Table 1); rostrum narrower as indicated by anteorbital, lacrymal and RC^1-LC^1 widths relative to rostrum length (v. 0.83, v. 1.04, v. 0.79, respectively); anterior palatal emargination deeper; anterolateral wing of ectotympanic further from lateral edge of squamosal; metacone-hypocone crista M^1 absent or slight or rarely moderate rather than moderate; hypocone M^{1-2} larger; manus digit III with phalanx III longer relative to phalanx II (v. 0.54), and phalanx II much shorter relative to phalanx I (v. 1.04); skin of face, ears and radius darker; glans penis dorsoventrally rather than laterally compressed, urethral opening ventral rather than terminal; baculum shorter (v. 3.2), dorsal outline arrow shaped rather than rod shaped with expanded base, lateral profile less curved.

It differs from *E. finlaysoni*: smaller in most skull, dental and external measurements (Table 1); dorsal inflation of cranium pronounced rather than slight or moderate; rostrum narrower as indicated by anteorbital, lacrymal and RC^1-LC^1 widths relative to rostrum length (v. 0.82, v. 1.08, v. 0.80, respectively); anterior narial and palatal emarginations usually deeper; anterolateral wing of ectotympanic further from lateral edge of squamosal; manus digit III with phalanx III longer relative to phalanx II (v. 0.60) and phalanx II shorter relative to phalanx I (v. 0.91); glans penis dorsoventrally rather than laterally compressed, urethral opening ventral rather than terminal; baculum shorter (v. 3.1), dorsal outline arrow shaped rather than rod shaped with expanded base, lateral profile less curved.

It differs from *E. darlingtoni*: smaller in all skull, dental and external measurements (Table 1); dorsal inflation of cranium pronounced rather than slight or moderate; anterior narial emargination shallow rather than deep, anterior palatal emargination shallow rather than generally deep; sphenorbital sinus with lateral margin more smoothly curved; anterolateral wing of ectotympanic further from lateral edge of squamosal; manus digit III with phalanx III shorter relative to phalanx II (v. 0.92); baculum dorsal outline similar but distally pointed rather than square, base slopes more posteriorly in lateral profile.

It differs from *E. troughtoni*: smaller in most skull, dental and external measurements (Table 1); dorsal inflation of cranium pronounced rather than moderate; rostrum narrower as indicated by anteorbital, lacrymal and RC^1-LC^1 widths relative to rostrum length (v. 0.81, v. 1.06, v. 0.77, respectively); anterior palatal emargination deeper, outline oval rather than U shaped; manus digit III with phalanx III longer relative to phalanx II (v. 0.67) and phalanx II shorter relative to phalanx I (v. 0.87); glans penis dorsoventrally rather than laterally compressed, urethral opening ventral rather than terminal; baculum shorter (v. 3.7), dorsal outline arrow shaped rather than rod shaped with expanded base, lateral profile less curved.

It differs from *E. regulus*: dorsal inflation of cranium pronounced rather than absent to moderate; basolateral pterygoid wing present, rather than usually absent; anterior palatal emargination narrower, usually shallower; glans penis dorsoventrally compressed, urethral lobe small, simple, lacks lateral urethral folds; baculum shorter (v. 3.8), dorsal outline arrow rather than elongate dart shaped.

It differs from *E. vulturnus*: dorsal inflation of cranium pronounced rather than slight or absent; basolateral pterygoid wing present rather than usually absent; anterior palatal emargination narrower, usually shallower; postpalatal spine generally smaller; posterior margin of palate well posterior to anterior edge of sphenorbital sinus; anterolateral wing of ectotympanic further from lateral edge of squamosal; glans penis dorsoventrally compressed rather than bulbous, urethral opening ventral rather than terminal; baculum much shorter (v. 4.4), dorsal outline arrow shaped rather than rod shaped with expanded base.

It differs from *E. baverstocki*: dorsal inflation of cranium pronounced rather than slight or absent; basolateral pterygoid wing present; anterior palatal emargination narrower; postpalatal spine generally smaller; posterior margin of palate well posterior to anterior edge of sphenorbital sinus; anterolateral wing of ectotympanic further from lateral edge of squamosal; manus digit III with phalanx III longer relative to phalanx II (v. 0.78) and phalanx II shorter relative to phalanx I (v. 0.84); glans penis dorsoventrally compressed rather than funnel shaped, ventral urethral lobe single rather than bilobed; baculum much shorter (v. 4.7), base more deflected ventrally, dorsal outline arrow shaped rather than rod shaped with slight distal lateral wings and expanded base.

Description

Skull (Figure 6)

(see also 'General Description of Australian *Eptesicus*'). Greatest length short 12.1 (11.3-12.7); cranial inflation pronounced; lamdoidal crest slight to moderate; anterior narial emargination usually V-shaped, occasional narrow U-shaped, terminates well anterior to a line joining anterior edge of anteorbital foramina; rostrum long, averages 51.5 per cent of basicranial length; least interorbital distance wide, averages 35.6 per cent of basicranial length; anteorbital distance narrow averages 73.1 per cent of rostrum length; inter upper third molar distance moderate, averages 50.5 per cent of basicranial length; lacrymal bar moderately wide to wide; postpalatal spine broad to narrow spatulate, short; posterior margin of palate terminates well posterior to anterior edge of sphenorbital sinus; basolateral pterygoid wing covers foramen rotundum to the following extent: less than one-third (75 per cent) or between one — to two-thirds (25 per cent).

Dentition

Crista linking base of metacone and hypocone on M^1 absent (46 per cent) or slight (46 per cent) or moderate (8 per cent) and on M^2 absent (71 per cent) or slight (29 per cent).

Body size

Body length moderate 39.1 (35.0-44.2), much longer than tail 30.7 (27.6-33.0); relative wing measurements as follows: RL moderate 30.6 (28.1-32.9)>MCIII>> P1>P2>P3; tibia length small 12.6 (11.6-13.8).

Pelage and skin

Dorsal pelage medium dark with paler ventral surface. Hair on top of head and face monocoloured, Bister; cheeks, chin, anal region and patagia Snuff Brown and ears Bister; on neck have distal one-quarter Snuff Brown and base Clove Brown; on dorsum *ca.* 4.5 mm long, distal one-third Olive Brown and base Clove Brown; on chest, venter and sides of body distal one-quarter Snuff Brown and base Clove Brown; proximal one-third of humerus with sparse hairs; uropatagium lightly furred; plagiopatagium furred to *ca.* 4 mm from side of body. Skin of lips Wood Brown and of ear, radius and patagia Clove Brown.

Penis (Figure 5)

Long hairs, up to 3.3 mm on preputium; preputial skin attached to glans *ca.* 1.0 mm from distal end; glans dorsoventrally compressed; urethral opening in mid ventral region of head of glans, covered by upward triangular projection of skin from ventral margin of opening, dorsal outline obovate shape; dorsal surface of head of glans with shallow median longitudinal groove; lateral profile of glans a blunt rod shape.
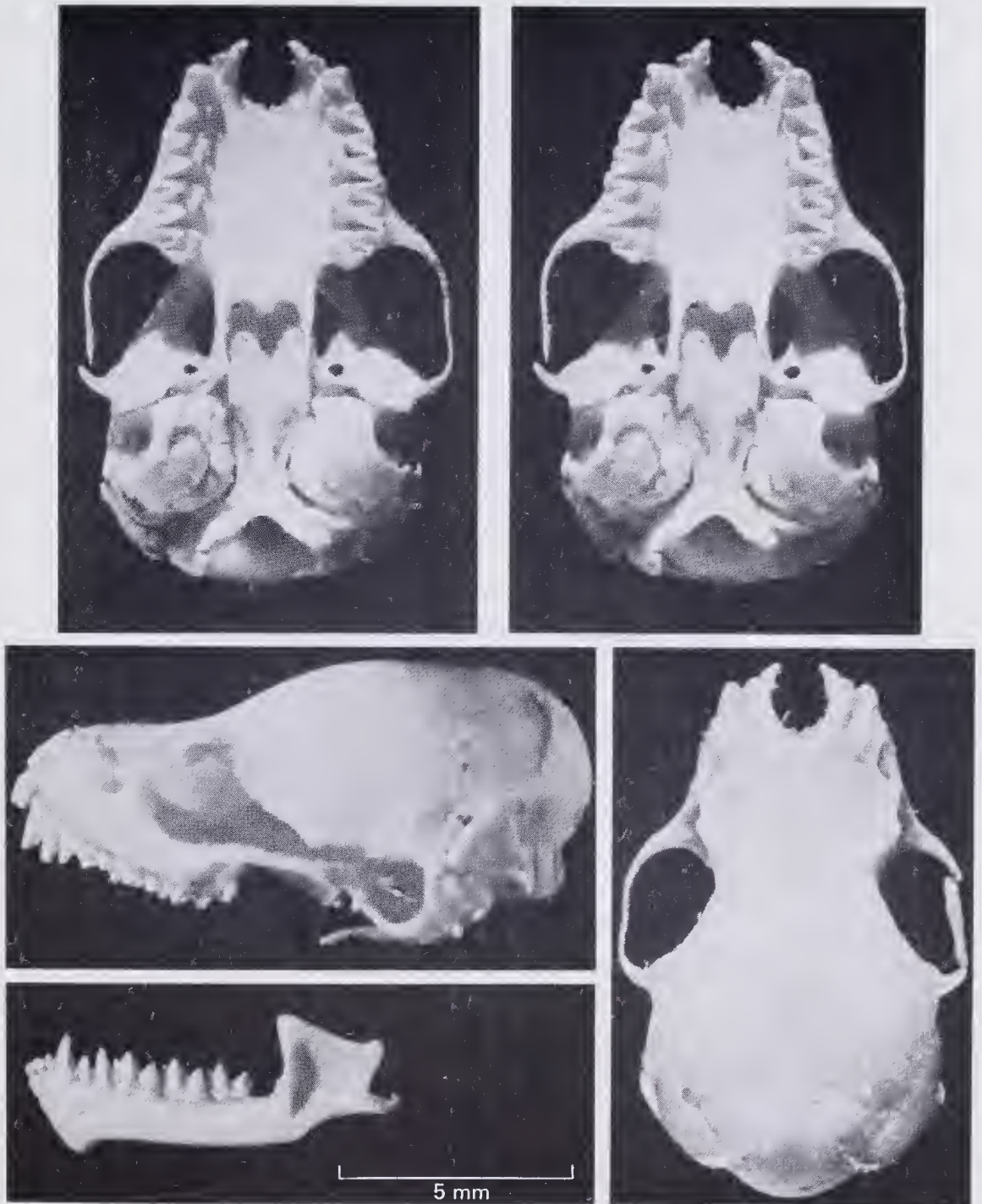
Figure 6   Skull and dentary of *Eptesicus pumilus* (EBU 006). The ventral view are stereopairs. Scale line 5 mm.

Figure 7   Distribution maps of the nine species of *Eptesicus*. (a) *pumilus*, (b) *caurinus*, (c) *douglasorum*, (d) *finlaysoni*, (e) *darlingtoni*, (f) *troughtoni*, (g) *regulus*, (h) *vulturnus*, (i) *baverstocki*. ●, localities of measured specimens. ○, localities of referred specimens. Geographic groups are numbered.

Baculum (Figure 4)

Baculum very short, dorsal outline arrow shaped, greates length 1.63 ± 0.111 (SD)(N=7) and basal width 0.64 ± 0.053 (SD)(N=7); lateral profile moderately flat, base with slightly thickened dorsoventral inflection.

Distribution

East of the Great Dividing Range, between latitudes $18°$ and $33°$S. In vegetation which covers the broad categories of subtropical rainforest and dry and wet sclerophyll forest (Figure 7a).

Remarks

Gray (1841) did not designate a holotype in his description of *Scotophilus pumilus* collected at Yarrundi, New South Wales. Dobson (1878) lists as the 'type' a specimen (adult, skin) from Australia "Figured in Voy. Erebus and Terror". Tate (1942) referred to the 'type' skull as BM. 41.1523(119c) from Yarrundi. This specimen is a skin and damaged skull from Yarrundi. Its label has written on it "lectotype, 1914" — perhaps by Oldfield Thomas. However, until now, this specimen has not been formerly designated a lectotype.

Specimens examined

Lectotype

BMNH 41.1523(119c)

New South Wales: Acacia Plateau ($28°20'$S, $152°18'$E) 1 ♀, 2 ♂, EBU (B341-3); Border Range National Park ($28°20'$S, $153°00'$E) 4 ♀, 5 ♂, AM13168, AM13179-80, AM13183-4, AM13187, AM13257, AM13262, AM13408; Coopernook State Forest ($31°50'$S, $152°36'$E) 1 ♀, EBU006; Iluka Nature Reserve ($29°24'$S, $153°22'$E) 1 ♂, AM13190; Newcastle ($33°00'$S, $151°19'$E) 1 ♂, EBU004; New England National Park (*ca.* $30°30'$S, $152°36'$E) 1 ♀, AM13201; Nightcap National Park ($28°35'$S, $153°18'$E) 2 ♀, 1 ♂, AM13233, AM13237, AM13242; "Sydney" 1 ♂, BM62.10.26.10; Watagan State Forest ($33°00'$S, $151°19'$E) 1 ♂, B354; near Byron Bay ($28°40'$S, $153°32'$E) 1 ♀, 1 ♂, EBU (008-9); Woolgoolga Flora Reserve ($30°07'$S, $153°09'$E) 1 ♂, AM13266.

Queensland: Kirrama State Forest ($18°10'$S, $145°40'$E) 1 ♂, EBU070.

Eptesicus caurinus Thomas, 1914

Figures 4, 5, 7b, 8; Table 1

Eptesicus pumilus caurinus Thomas, 1914: Ann. Mag. Nat. Hist. (8) xiii, p. 439.

Holotype

BMNH 14.3.9.1.10473; adult male; body in ethanol, skull separate; from Drysdale, Kimberley, Western Australia; collected by G.F. Hill.

Diagnosis (mean values)

Eptesicus caurinus differs from *E. pumilus* in having rostrum broader as indicated by anteorbital, lacrymal and RC^1-LC^1 widths relative to rostrum length

(0.84 v. 0.73, 1.07 v. 0.96, 0.80 v. 0.71, respectively); anterior narial emargination shallower; anterolateral wing of ectotympanic closer to lateral edge of squamosal; metacone-hypocone crista M^1 moderate or large rather than absent or slight or rarely moderate; hypocone M^{1-2} smaller; manus digit III with phalanx III shorter relative to phalanx II (0.55 v. 0.87) and phalanx II longer relative to phalanx I (0.95 v. 0.77); glans penis laterally rather than dorsoventrally compressed, urethral opening terminal rather than ventral; baculum longer (2.9 v. 1.6), dorsal profile rod shaped with expanded base rather than arrow shaped, lateral profile more curved.

It differs from *E. douglasorum*: much smaller in all skull, dental and external measurements (Table 1); anterior narial emargination deeper; manus digit III with phalanx I shorter relative to metacarpal (0.32 v. 0.37); skin of face, ears and radius darker; baculum generally shorter (v. 3.2), less curved in lateral profile.

It differs from *E. finlaysoni*: metacone-hypocone crista M^1 moderate or large rather than absent or slight or very rarely moderate; interorbital region generally broader relative to basicranial length (0.36 v. 0.32); baculum generally shorter (v. 3.1).

It differs from *E. darlingtoni*: much smaller in most skull, dental and external measurements (Table 1); curve of anterior edge of orbit subcircular rather than oval; rostrum broader as indicated by anteorbital, lacrymal and RC^1-LC^1 widths relative to rostrum length (v. 0.72, v. 0.96, v. 0.74, respectively); anterior narial emargination shallow rather than deep; anterior palatal emargination shallower; metacone-hypocone crista M^1 moderate or large rather than absent or slight; hypocone M^{1-2} smaller; manus digit III with phalanx III much shorter relative to phalanx II· (v. 0.92) and phalanx II longer relative to phalanx I (v. 0.74); glans penis laterally rather than dorsoventrally compressed, urethral opening terminal rather than ventral; baculum longer (v. 3.1), dorsal outline rod shaped with expanded base rather than blunt arrow shaped, more curved in lateral profile.

It differs from *E. troughtoni*: smaller in all skull, dental and external measurements (Table 1); anterior palatal emargination usually narrower; metacone-hypocone crista M^1 moderate or large rather than absent to moderate; hypocone M^{1-2} smaller; glans penis more pointed distally, much narrower dorsoventrally urethral opening terminal rather than ventral; baculum shorter (v. 3.7), basal notch shorter.

It differs from *E. regulus*: smaller in most skull, dental and external measurements (Table 1); dorsal inflation of cranium pronounced or moderate rather than slight or absent; basolateral pterygoid wing present rather than absent; anterior part of rostrum broader as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.76, v. 0.74, respectively); anterior narial and palatal emarginations shallower, usually narrower; upper tooth row more curved; metacone-hypocone crista M^1 moderate or large rather than absent or slight or rarely moderate; hypocone M^{1-2} smaller; manus digit III with phalanx III shorter relative to phalanx II (v. 0.80) and phalanx II longer relative to phalanx I (v. 0.87); glans

penis much narrower dorsoventrally, urethral opening terminal rather than ventral, lacks lateral urethral folds; baculum shorter (v. 3.8), dorsal outline rod shaped with expanded base rather than elongate dart shaped, curved rather than essentially flat in lateral profile.

It differs from *E. vulturnus*: smaller in most skull and dental measurements (Table 1); dorsal inflation of cranium pronounced or moderate rather than absent or slight; basolateral pterygoid wing present; anterior part of rostrum broader as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.75, v. 0.75, respectively); anterior narial and palatal emarginations narrower, usually shallower; posterior margin of palate terminates well posterior to anterior edge of sphenorbital sinus; upper toothrow more curved; metacone-hypocone crista M^1 moderate or large rather than absent or slight; hypocone M^{1-2} smaller; manus digit III with phalanx III shorter relative to phalanx II (v. 0.80) and phalanx II longer relative to phalanx I (v. 0.78); glans penis distally pointed rather than blunt, narrow dorsoventrally rather than bulbous, ventral urethral lobe a single fleshy tongue rather than two subcircular winged lobes; baculum much shorter (v. 4.4), distal tip less curved ventrally.

It differs from *E. baverstocki*: smaller in most skull and dental measurements (Table 1); dorsal inflation of cranium moderate or pronounced rather than absent or slight; basolateral pterygoid wing present; rostrum broader anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.76, v. 0.78, respectively); anterior narial and palatal emarginations narrower and shallower; posterior margin of palate well posterior to anterior edge of sphenorbital sinus; upper tooth row usually more curved; metacone-hypocone crista M^1 moderate or large rather than absent; hypocone M^{1-2} smaller; manus digit III with phalanx III shorter relative to phalanx II (v. 0.78) and phalanx II longer relative to phalanx I (v. 0.84); glans penis distally pointed rather than funnel shaped, ventral urethral lobe a single fleshy tongue rather than bilobed; baculum much shorter (v. 4.7), more curved in lateral profile.

Description
Skull (Figure 8)

(see also 'General Description of Australian *Eptesicus*'). Greatest skull length short 11.2 (10.6-12.0); cranial inflation moderate (59 per cent) or pronounced (41 per cent); lambdoidal crest slight to moderate; anterior narial emargination usually V-shaped, occasionally U-shaped, usually terminates close to (94 per cent) or well anterior to (6 per cent) a line joining anterior edge of anteorbital foramina; rostrum short, averages 47.8 per cent basicranial length; least interorbital distance wide, averages 35.1 per cent basicranial length; anteorbital distance wide, averages 84.4 per cent rostrum length; inter upper third molar distance moderate, averages 51.1 per cent basicranial length; lacrymal bar narrow to moderate; postpalatal spine broad to narrow spatulate or broadly triangular, long; posterior margin of palate terminates well posterior to anterior edge of sphenorbital sinus; basolateral
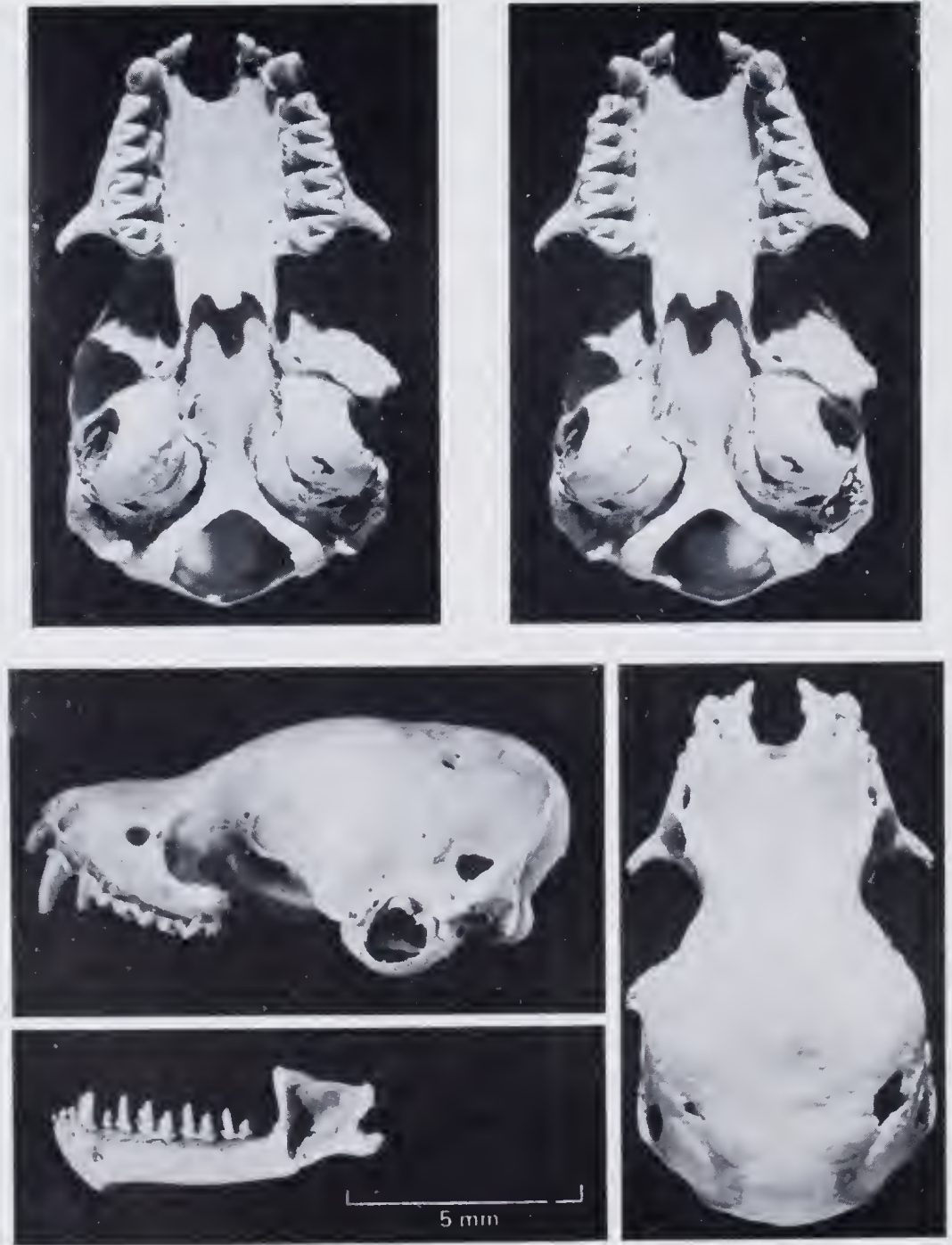
Figure 8   Skull and dentary of *Eptesicus caurinus* (WAM M17367, paratype). The ventral view are stereopairs. Scale line 5 mm.

pterygoid wing coverage of foramen rotundum less than one-third (19 per cent) or between one and two-thirds (68 per cent) or more than two-thirds (13 per cent).

Dentition

Crista linking base of metacone and hypocone on M^1 moderate (59 per cent) or large (41 per cent) and M^2 slight (9 per cent) or moderate (69 per cent) or large (22 per cent)

Body size

Body length small 36.7 (32.1-40.0), much longer than tail length 30.2 (24.4-34.8); relative wing measurements as follows: RL small 29.5 (26.6-31.7)>MCIII >>P1>P2>>P3; tibia length moderate 11.4 (10.7-12.4).

Pelage and skin

Dorsal pelage moderately pale with pale ventral surface. Hair on top of head has distal one-third Dresden Brown and base Chaetura Black; cheeks Isabella Color; face, chin, neck have distal one-quarter to two-thirds Isabella Color and base Chaetura Black; on dorsum *ca.* 5.5 mm long, distal one-quarter Isabella Color and base Chaetura Black; chest has distal one-quarter Isabella Color and base Chaetura Black; on venter *ca.* 5.2 mm long, distal one-quarter Cream Buff and base Chaetura Black; anal region has distal three-quarters Ivory Yellow and base Chaetura Black; sides of body Cream Buff; humerus sparsely haired to elbow, Ivory Yellow; femur furred to half length, Ivory Yellow; ear haired to one-third length, Cream Buff; uropatagium very sparsely furred, Ivory Yellow; plagiopatagium very sparsely furred to 2.5 mm from side of body. Skin of lips Fuscous Black; ear and patagia Fuscous and radius Bister.

Penis (Figure 4)

Long hairs up to 3 mm on preputium; preputial skin attached to glans at base of head *ca.* 1.5 mm from distal end; head of glans laterally compressed; urethral opening at distal end of glans, covered by upward projecting narrow tongue of skin from ventral lip of opening; dorsal surface of head of glans with deep median longitudinal groove, ventral surface with slight ventral keel; slight anterolateral elliptical swellings above ventral keel, covered with numerous very small spines, lateral profile an opiculate shape.

Baculum (Figure 5)

Moderately long, greatest length 2.86 ± 0.158 (SD)(N=10); dorsal outline rod shaped, proximal one-third gently expanded into a slightly bifurcated base with width 0.67 ± 0.095 (SD)(N=10); base and distal end gently curved ventrally — the base more so.

Distribution

More rugged terrain of the Kimberley district, Western Australia and northern parts of the Northern Territory. In vegetation which covers the broad categories of mixed tropical woodland and tropical layered woodland (Figure 7b).

Specimens examined

BMNH 14.3.9.1.10473 (holotype).

Northern Territory: Borroloola (16°04′S, 136°18′E) 2 ♂, C5216-7; Delamere Crk (15°51′S, 131°35′E) 1 ♀, NTM539; Jasper Gorge (16°02′S, 130°45′E) 4 ♀, 1 ♂, EBUB233-7; Keep R. (15°46′S, 129°05′E) 1 ♂, NTM540, (15°47′S, 129°06′E) 1 ♀, 1 ♂, NTM (549,557); Mt Brockman (12°45′S, 132°56′E) 1 ♂, CM4667; Nourlangie (12°46′S, 132°39′E) 1 ♂, CM4629; 70 km E Pine Crk (13°35′S, 132°15′E) 1 ♂, EBUB193; Skull Crk Major (*ca.* 15°44′S, 130°46′E) 4 ♀, EBUB223-6.

Western Australia: Barker Gorge (17°15′20″S, 124°43′45″E) 1 ♂, WAM18538; Beverley Springs (16°39′30″S, 125°30′00″E) 1 ♂, WAM18487; Drysdale R. (*ca.* 14°45′S, 126°57′E) 1 ♂, WAM17367 (paratype); Drysdale R. National Park (15°03′S, 126°44′E) 1 ♂, WAM14009; Gcike Gorge (18°05′S, 125°43′E) 2 ♀, CM125-6; Kununnurra (15°46′S, 128°48′E) 2 ♀, 1 ♂, EBUC128-9, CM4495; Lennard R. Gorge (17°10′50″S, 125°11′30″E) 1 ♂, WAM18539; Mitchell Plateau (14°53′40″S, 125°45′20″E) 1 ♀, 1 ♂, WAM (15756, 15758), (14°35′00″S, 125°43′15″E) 1 ♂, WAM18420; Parry Crk (15°38′S, 128°18′E) 1 ♀, 1 ♂, WAM19339-40; Spillway Cave (16°02′30″S, 128°44′30″E) 1 ♀, 1 ♂, WAM (11569, 11574); Tunnel Crk (17°36′30″S, 125° 08′40″E) 2 ♀, WAM (24050, 24053); Wotjulum Mission (16°11′S, 123°37′E) 2 ♀, 1 ♂, WAM3009-11.

Eptesicus douglasorum Kitehener, 1976

Figures 4, 5, 7c, 9; Table 1

Eptesicus douglasi Kitchener, 1976: Rec. West. Aust. Mus. 4: 295-301.

Holotype

WAM M3405C (= M3405.003); adult male; body in ethanol, skull separate; from Tunnel Creek, Napier Range, Western Australia (17°37′S, 125°09′E) at altitude *ca.* 140 m; mist-netted by D. Farner and D.L. Serventy on 10 October 1958 at entrance of cave.

Diagnosis (mean values)

Eptesicus douglasorum differs from *E. pumilus*: larger in most skull, dental and external measurements (Table 1); rostrum broader as indicated by anteorbital, laerymal and RC^1-LC^1 widths (0.83 v. 0.73, 1.04 v. 0.96, 0.79 v. 0.71, respectively); anterior palatal emargination shallower; anterolateral wing of ectotympanie nearer to lateral edge of squamosal; metaeone-hypocone erista M^1 moderate rather than absent or slight or rarely moderate; hypoeone M^{1-2} smaller; manus digit III with phalanx III shorter relative to phalanx II (0.54 v. 0.87) and phalanx II mueh longer relative to phalanx I (1.04 v. 0.77); skin of face, ears and radius lighter; glans penis laterally rather than dorsoventrally compressed, urethral opening terminal rather than ventral; baeulum longer (3.2 v. 1.6), lateral profile more eurved, dorsal outline rod shaped with expanded base rather than arrow shaped.

It differs from *E. caurinus*: much larger in all skull, dental and external measurements (Table 1); anterior narial emargination generally shallower; manus digit III with phalanx I shorter relative to metaearpal (0.32 v. 0.37); skin of faee, ears and radius lighter; baeulum generally longer (v. 2.9).

It differs from *E. finlaysoni*: metacone-hypocone crista M^1 moderate rather than absent or slight; hypocone M$^{1-2}$ smaller; manus digit III with phalanx I shorter relative to metacarpal (v. 0.38); skin of face, ears and radius lighter; baculum more curved in lateral profile.

It differs from *E. darlingtoni*: anterior narial and palatal emarginations shallow rather than deep; dorsal inflation of cranium pronounced or moderate rather than slight or moderate; curve of anterior edge of orbit more even, subcircular; metacone-hypocone crista M^1 moderate rather than absent to slight; hypocone M$^{1-2}$ smaller; manus digit III with phalanx III much shorter relative to phalanx II (v. 0.92) and phalanx II much longer relative to phalanx I (v. 0.74); skin of face, ears and radius lighter; glans penis laterally rather than dorsoventrally compressed, urethral opening terminal rather than ventral; baculum much longer (v. 1.7), dorsal outline rod shaped with expanded base rather than blunt arrow shaped, more curved in lateral profile.

It differs from *E. troughtoni*: anterior narial emargination narrower; hypocone M$^{1-2}$ smaller; manus digit III with phalanx II longer relative to phalanx I (v. 0.87) and phalanx I shorter relative to metacarpal (v. 0.37); skin of face, ears and radius lighter; glans penis more pointed distally; baculum shorter (v. 3.7).

It differs from *E. regulus*: dorsal inflation of cranium moderate or pronounced rather than slight or absent; basolateral pterygoid wing present rather than usually absent; rostrum broader anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.76, v. 0.74, respectively); anterior narial and palatal emarginations narrower, shallower; upper tooth row more curved; metacone-hypocone crista M^1 moderate rather than slight or absent or occasionally moderate; hypocone M$^{1-2}$ smaller; manus digit III with phalanx III shorter relative to phalanx II (v. 0.80) and phalanx II longer relative to phalanx I (v. 0.81); glans penis more pointed distally, urethral opening terminal rather than ventral, lateral urethral folds absent; baculum shorter (v. 3.8), dorsal outline rod shaped with expanded base rather than elongate dart shaped, lateral profile curved rather than flat.

It differs from *E. vulturnus*: larger in most skull, dental and external measurements (Table 1); dorsal inflation of cranium moderate or pronounced rather than slight or absent; basolateral pterygoid wing present; rostrum broader anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.75, v. 0.75, respectively); anterior palatal emargination narrower; posterior margin of palate terminates well posterior to anterior edge of sphenorbital sinus; metacone-hypocone crista M^1 moderate rather than slight or absent; hypocone M$^{1-2}$ smaller; manus digit III with phalanx III shorter relative to phalanx II (v. 0.80) and phalanx II longer relative to phalanx I (v. 0.78); glans penis distally pointed rather than blunt, ventral urethral lobe with a pronounced tongue-like projection rather than two small subcircular winged lobes; baculum shorter (v. 4.4), lateral profile bow shaped rather than distally curved.

It differs from *E. baverstocki*: larger in most skull, dental and external measurements (Table 1); dorsal inflation of cranium moderate or pronounced rather than

absent or slight; basolateral pterygoid wing present; anterior palatal emargination broader; posterior margin of palate well posterior to anterior edge of sphenorbital sinus; metacone-hypocone crista M^1 moderate rather than absent; hypocone M^{1-2} smaller; manus digit III with phalanx III shorter relative to phalanx II (v. 0.78) and phalanx II longer relative to phalanx I (v. 0.84); glans penis distally pointed rather than funnel shaped, ventral urethral lobe single rather than bilobed; baculum shorter (v. 4.7), distal end more curved ventrally.

Description
Skull (Figure 9)
(see also 'General Description of Australian *Eptesicus*'). Greatest skull length moderately long 12.8 (12.3-13.2); cranial inflation moderate (55 per cent) or pronounced (45 per cent); lambdoidal crest slight to moderate; anterior narial emargination generally V-shaped, occasionally U-shaped, terminates anterior to a line joining anterior edge of anteorbital foramina; rostrum short, averages 48.6 per cent of basicranial length; least interorbital distance narrow, averages 32.1 per cent basicranial length; anteorbital distance wide, averages 83.0 per cent of rostrum length; inter upper third molar distance moderate, averages 50.4 per cent basicranial length; lacyrmal bar moderate to wide; postpalatal spine broad to narrow spatulate and moderately long; posterior margin of palate terminates well posterior to anterior edge of sphenorbital sinus; basolateral pterygoid wing coverage of foramen rotundum: less than one-third (27 per cent) or between one and two-thirds (55 per cent) or more than two-thirds (18 per cent).

Dentition
Crista linking base of metacone and hypocone on M^1 moderate and on M^2 slight (18 per cent) or moderate (64 per cent) or large (18 per cent).

Body size
Body length moderate 39.7 (35.3-43.5), longer than tail 36.3 (35.2-37.9); relative wing measurements as follows: RL very large 36.2 (34.3-37.6)>MCIII>> P1≤P2>>P3; tibia length large 14.3 (13.6-15.5).

Pelage and skin
Overall pelage pale grey. Hair on top of head has distal one-half Drab Gray or Pale Orange and base Chaetura Black; cheeks, face and chin Drab Gray or Pale Orange; neck with distal one-quarter Pale Drab Gray and base Chaetura Black; on dorsum *ca.* 5.3 mm long, distal one-quarter Light Drab and base Chaetura Black; on chest and venter *ca.* 4.5 mm long, distal one-half Drab Gray or Pale Olive Buff and base Chaetura Black or Clove Brown; anal region Pale Drab Gray; sides of body with distal one-third Drab Gray and base Chaetura Black; humerus and femur sparsely haired for half their length, Pale Drab Gray; ear one-third furred, Light Drab; uropatagium very sparsely haired on proximal two-thirds; plagio-patagium very sparsely haired *ca.* 8 mm from side of body. Skin of lips Light
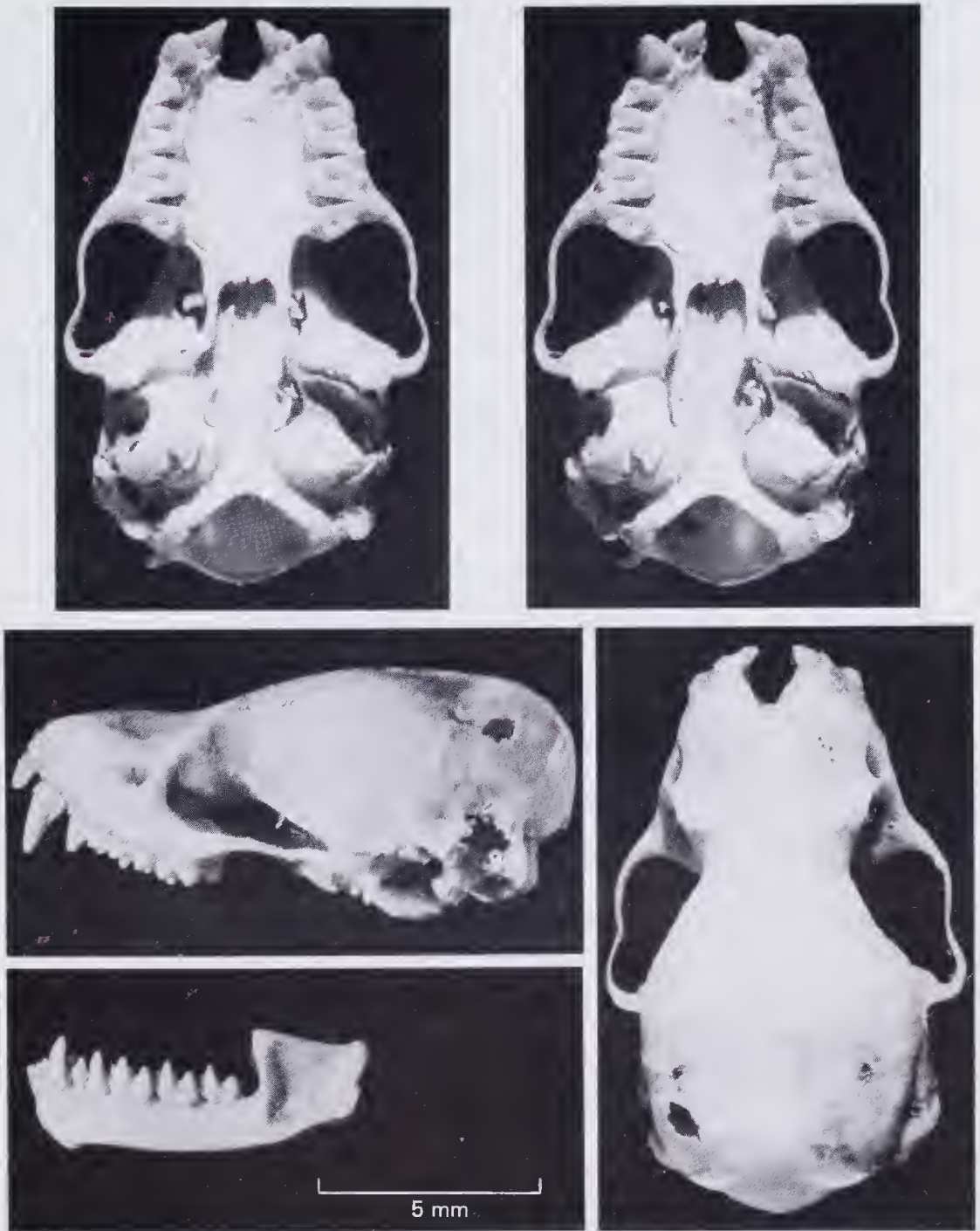
Figure 9   Skull and dentary of *Eptesicus douglasorum* (WAM M3405C, holotype). The ventral view are stereopairs. Scale line 5 mm.

Cinnamon Drab or Orange Buff; ear and uropatagium Hair Brown; wing and radius Fuscous.

Penis (Figure 4)

Long hairs, up to 3 mm on preputium; preputial skin attached to glans at base of head *ca.* 1.5 mm from distal end; head of glans covered by upward projecting narrow tongue of skin from ventral tip of opening; dorsal surface of head of glans with deep median longitudinal groove, ventral surface with slight ventral keel; slight anterolateral elliptical swellings above ventral keel, covered with numerous very small spines, lateral profile an opiculate shape.

Baculum (Figure 5)

Moderately long, greatest length 3.17 ± 0.153 (SD)(N=3), dorsal outline rod shaped shaft with basal one-third gently expanded into a slightly bifurcated base with width 0.73 ± 0.058 (SD)(N=3); evenly bow shaped in lateral profile.

Distribution

West Kimberley district, Western Australia. In tropical woodland (Figure 7c).

Specimens examined

WAM3405.003 (= WAM M3405C) (holotype).

Western Australia: Drysdale R. National Park (14°43'S, 126°54'E) 3 ♀, 1 ♂, WAM4015-8 (paratypes); Mitchell Plateau (14°47'25"S, 125°49'20"E) 1 ♀, WAM21851; Prince Regent R. Reserve (15°31'21"S, 125°12'46"E) 1 ♀, 1 ♂, WAM12250-1 (paratypes); Tunnel Crk (17° 37'S, 125°09'E) 1 ♀, 5 ♂, WAM3405.001(=3405A), WAM3405.002(=3405B), WAM14557-9 (paratypes).

Eptesicus finlaysoni sp. nov.

Figures 4, 5, 7d, 11; Table 1

Holotype

WAM M22407; adult male; body in ethanol, skull separate; liver, heart and kidney removed for electrophoresis, Cossack, Western Australia (20°41'S, 117°11'E) at altitude *ca.* 5 m, from roof of 'Customs House', collected by N.L. McKenzie on 7 August 1984.

Paratypes

See specimens examined.

Diagnosis (mean values)

Eptesicus finlaysoni differs from *E. pumilus*: smaller in most skull, dental and external measurements (Table 1); dorsal inflation of cranium slight or moderate rather than pronounced; rostrum broader as indicated by anteorbital, lacrymal and RC^1-LC^1 widths relative to rostrum length (0.82 v. 0.73, 1.08 v. 0.96, 0.80 v. 0.71, respectively); anterior narial and palatal emarginations usually shallower; anterolateral wing of ectotympanic closer to lateral edge of squamosal; manus digit III with phalanx III shorter relative to phalanx II (0.60 v. 0.87) and phalanx II

longer relative to phalanx I (0.91 v. 0.77); glans penis laterally rather dorsoventrally compressed, urethral opening terminal rather than ventral; baculum longer (3.08 v. 1.6), dorsal outline rod shaped with expanded base rather than arrow shaped, lateral profile more curved.

It differs from *E. caurinus*: metacone-hypocone crista M^1 absent or slight rather than moderate or large; interorbital region generally narrower relative to basicranial length (0.32 v. 0.36); baculum generally longer (v. 2.9).

It differs from *E. douglasorum*: metacone-hypocone crista M^1 absent or slight rather than moderate; hypocone M^{1-2} smaller; manus digit III with phalanx I longer relative to metacarpal (0.38 v. 0.32); skin of face, ears and radius darker.

It differs from *E. darlingtoni*: smaller in most skull, dental and external measurements (Table 1); curve of anterior edge of orbit more even, subcircular; rostrum broader as indicated by anteorbital, lacrymal and RC^1-LC^1 widths relative to rostrum length (v. 0.72, v. 0.96, v. 0.74, respectively); anterior narial emargination usually shallow rather than deep; anterior palatal emargination narrower, usually shallower; manus digit III with phalanx III much shorter relative to phalanx II (v. 0.92) and phalanx II longer relative to phalanx I (v. 0.74); glans penis laterally rather than dorsoventrally compressed, urethral opening terminal rather than ventral; baculum longer (v. 1.7), dorsal outline rod shaped with expanded base rather than blunt arrow shaped, lateral profile more curved.

It differs from *E. troughtoni*: smaller in most skull, dental and external measurements; radius shorter relative to tibia (Figure 10); glans penis more pointed distally, narrower dorsoventrally, urethral opening terminal rather than ventral; baculum generally shorter (v. 3.7), basal notch shorter.

It differs from *E. regulus*: dorsal inflation of cranium slight to pronounced rather than absent; rostrum broader anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.76, v. 0.74, respectively); anterior narial and palatal emarginations narrower, usually shallower; basolateral pterygoid wing present, rather than usually absent; upper tooth row more curved; manus digit III with phalanx III longer relative to phalanx II (v. 0.80) and phalanx II shorter relative to phalanx I and to metacarpal (v. 0.81, 0.35 v. 0.30, respectively); glans penis more pointed distally, much narrower dorsoventrally, lateral urethral lobes absent, urethral opening terminal rather than ventral; baculum generally shorter (v. 3.8), dorsal outline rod shaped with expanded base rather than elongate dart shaped, lateral profile more curved.

It differs from *E. vulturnus*: larger in most skull, dental and external measurements (Table 1); dorsal inflation of cranium slight to pronounced rather than absent or slight; rostrum broader anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.75, v. 0.75, respectively); anterior narial and palatal emarginations narrower, usually shallower; posterior margin of palate terminates well posterior to anterior edge of sphenorbital sinus; basolateral pterygoid wing present; upper tooth row more curved, manus digit III with phalanx III shorter relative to phalanx II (v. 0.80) and phalanx II longer relative

to phalanx I (v. 0.78); glans penis more pointed distally, narrower dorsoventrally, ventral urethral lobe single rather than bilobed; baculum shorter (v. 4.4), base more inclined ventrally, less deeply notched.

It differs from *E. baverstocki*: larger in most skull, dental and external measurements (Table 1); dorsal inflation of cranium slight to pronounced rather than absent or slight; anterior narial and palatal emarginations narrower; posterior margin of palate terminates well posterior to anterior edge of sphenorbital sinus; basolateral pterygoid wing present; upper tooth row more curved; manus digit III with phalanx III longer relative to phalanx II (v. 0.78) and phalanx II shorter relative to phalanx I and to metacarpal (v. 0.84, v. 0.30, respectively); glans penis distally pointed rather than funnel shaped ventral urethral lobe single rather than bilobed, baculum shorter (v. 4.7), lateral profile more curved, partcularly distal end, base less deeply notched.
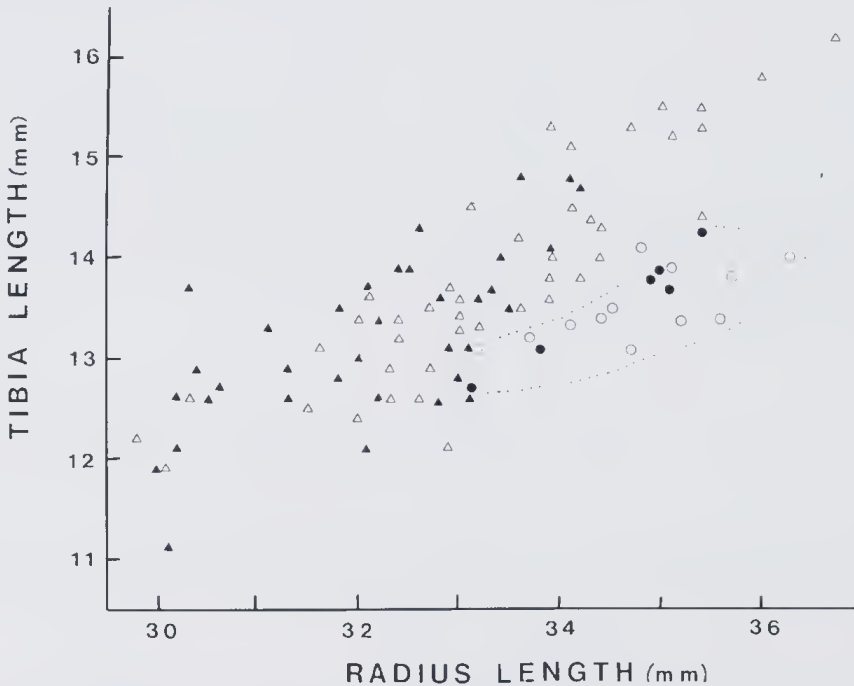
Figure 10   Plot of tibia length against radius length for *Eptesicus finlaysoni* (▲, male; △ female) and *E. troughtoni* (●, male; ○, female).

Description
Skull (Figure 11)

(see also 'General Description of Australian *Eptesicus*'). Greatest skull length moderately long 12.4 (11.3-13.5); cranial inflation varies with region (see Figure 7d for regions): in the Pilbara, Central East and Central West regions most specimens have a moderate inflation (70-85 per cent), some a slight inflation (10-15 per cent)

and some pronounced inflation (4-20 per cent) — in the North West Coastal region equal numbers have slight or moderate inflation and none are pronounced; lambdoidal crest slight to well developed in all regions; anterior narial emargination narrow U to V-shaped, similar in all regions, terminates well anterior to (77-80 per cent) or close to (10-23 per cent) a line joining anterior edges of anteorbital foramina; rostrum short, averages 47.6 per cent of basicranial length; least inter-orbital distance moderate, averages 32.4 per cent of basicranial length; anteorbital distance moderate, averages 82.0 per cent of rostrum length; inter upper third molar distance moderate, averages 50.5 per cent of basicranial length; lacrymal bar narrow to well developed; postpalatal spine broad to narrow spatulate or triangular, moderately long to long; posterior margin of palate terminates well posterior to anterior edge of sphenorbital sinus; basolateral pterygoid wing coverage of foramen rotundum varies with region: in the Pilbara, Central East and Central West regions it is absent (0-5 per cent) or less than one-third (57-85 per cent) or between one to two-thirds (10-35 per cent) or more than two-thirds (0-8 per cent) — in the North West Coast region it is less than one-third (45 per cent) or between one to two-thirds (50 per cent) or greater than two-thirds (5 per cent)

Dentition

Crista linking base of metacone and hypocone similar in all regions: on M^1 absent (70-75 per cent) or slight (15-30 per cent) or moderate (0-5 per cent) and on M^2 absent (69-80 per cent) or slight (20-32 per cent).

Body size

Body length moderate 40.1 (34.3-46.6), longer than tail length 35.2 (30.7-42.0); relative wing measurements as follows: RL moderate 32.8 (29.8-36.7)⩾MCIII>> P1>P2>>P3; tibia length moderate 13.6 (11.1-16.2).

Pelage and skin

Dorsal pelage medium dark, brown, with slightly lighter ventral surface. Hair on cheeks, chin, ear, limbs and patagia monocoloured, the rest bicoloured; on top of head and face distal half Olive Brown and base Clove Brown, on neck distal one-third Wood Brown with base Clove Brown; on dorsum and venter *ca.* 5.2 and 4.0 mm long, respectively; dorsal pelage with distal one-quarter Drab or Wood Brown and base Fuscous Black or Chaetura Black, respectively; chest, sides of body and venter with distal one-quarter to one-third Light Drab and base Fuscous Drab; anal region with distal half Light Drab and base Hair Brown or all Light Drab; cheek and chin Olive Brown and Buffy Brown, respectively; on humerus to elbow medium sparse, Light Drab; femur furred half way to knee, Light Drab; ear one-third haired, Olive Brown; uropatagium with proximal three-quarters extremely sparsely haired, Light Drab; plagiopatagium sparsely haired to *ca.* 10 mm from side of body. Skin of lips, ear, radius and patagia Fuscous.
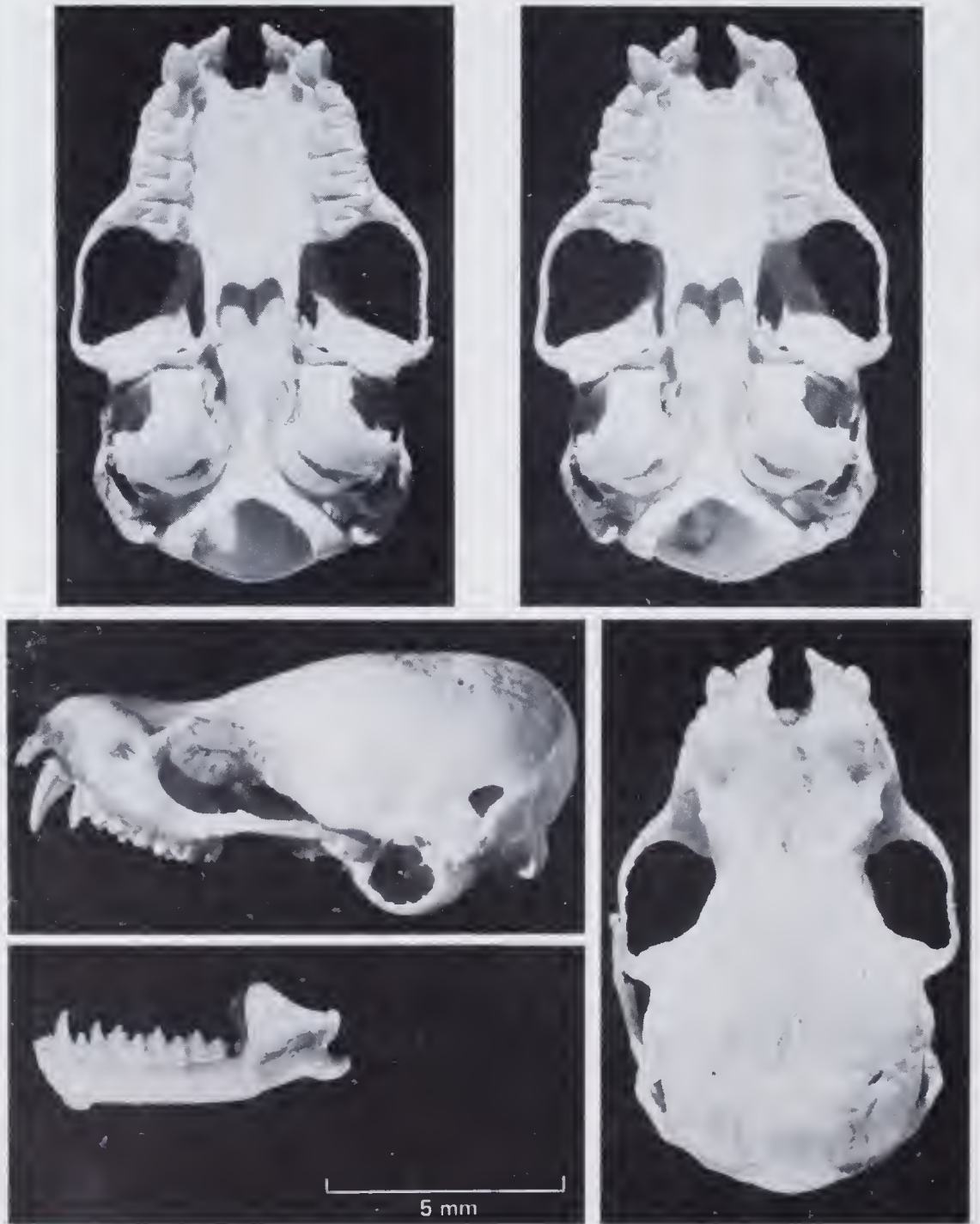
Figure 11   Skull and dentary of *Eptesicus finlaysoni* (WAM M22407, holotype). The ventral view are stereopairs. Scale line 5 mm.

Penis (Figure 4)

Long hairs, up to 3 mm, on preputium; preputial skin attached to glans at base of head *ca.* 1.5 mm from distal end; head of glans laterally compressed; urethral opening at distal end of glans, covered by upward projecting narrow tongue of skin from ventral lip of opening; dorsal surface of head of glans with deep median longitudinal groove – ventral surface with slight ventral keel; slight anterolateral elliptical swellings above ventral keel, covered with numerous very small spines, lateral profile an opiculate shape.

Baculum (Figure 5)

Moderately long, greatest length varies slightly with geographic region: Central East 3.23 ± 0.186 (SD)(N=16), Central West/Pilbara 2.85 ± 0.121 (SD)(N=7) and North West Coastal 3.19 ± 0.146 (SD)(N=8); shaft dorsal outline rod shaped, proximal one-quarter gently expanded into a slightly bifurcated base; basal width varies with region: Central East 0.67 ± 0.103 (SD)(N=6), Central West/Pilbara 0.66 ± 0.098 (SD)(N=7) and North West coastal 0.74 ± 0.92 (SD) (N=8); base and distal end gently curved ventrally, but the base more so.

Distribution

Widely distributed in inland arid parts of Australia: in grasslands and savannahs and shrub communities (Figure 7d).

Etymology

Named after H.H. Finlayson, formerly Curator of Mammals, South Australian Museum. Author of a number of papers on the inland mammals of Australia.

Specimens examined

Paratypes

Central Eastern Region

Northern Territory: Alice Springs area (23°47'S, 133°52'E) 1 ♂, CM5983, (23°54'S, 133°52'E) 1 ♂, CM2257; Arltunga (23°30'S, 134°37'E) 2 ♀, EBU (B263-4); Katherine (14°28'S, 132°16'E) 1 ♀, 1 ♂, CM1840, CM2123; 50 km SE Roper Bar (*ca.* 15°00'S, 134°50'E) 1 ♂, CM10862; Great Western Mine (19°27'S, 134°03'E) 4 ♂, EBU (B125-7), CM4169; The Granites (20°30'S, 130°21'E) 1 ♂, WAM19010.

Queensland: Cloncurry (20°42'S, 140°30'E) 4 ♀, J6553, J6557-8, J6562; 25 km E Georgetown (18°17'S, 143°46 E) 1 ♂, EBU B74.

South Australia: Arkaroola (31°47'S, 138°30'E) 2 ♀, 1 ♂, EBU B401-3; Brachina Gorge (31°21'S, 138°37'E) 1 ♀, EBU SP106; Mt Gee (*ca.* 30°20'S, 139°22'E) 3 ♀, SAM 9137-9; Oodnadatta (27°37'S, 135°34'E) 1 ♀, EBU B407.

Pilbara Region

Western Australia: Abydos Stn (21°26'00"S, 118°55'40"E) 1 ♂, WAM19323; Cossack (20°41'S, 117°11'E) 2 ♀, WAM (22406, 22408); Gallery Hill (21°40'20"S, 119°02'25"E) 1 ♀, WAM19325; Hammersley Range (22°23'22"S, 118°27'36"E) 1 ♀, 1 ♂ WAM (18689, 18720); Middle Crk (21°52'S, 120°16'E) 3 ♂, WAM (12666, 12668, 12671); Mt Meharry (23°12'00"S, 118°49'30"E) 1 ♀, WAM16830; Opthalmia Range (23°16'50"S, 119°11'20"E) 1 ♂, WAM 19505; Paraburdoo (23°13'30"S, 117°37'00"E) 1 ♀, WAM14940; Shay Gap (20°31'S, 120°08'E) 1 ♀, 4 ♂, WAM (16779, 16791-3, 16795); Yandicoogina Crk (22°47'10"S, 119°15'00"E) 1 ♀, WAM 18987.

NW Coastal Region

Western Australia: Cape Range (21°51'00"S, 114°06'30"E) 7 ♀, 2 ♂, WAM 19375-84; Carrarang HS. (26°22'50"S, 113°18'50"E) 1 ♀, WAM8749; Dirk Hartog Island (25°57'00"S, 113°09'45"E) 3 ♀, 1 ♂, WAM 10620-3, (25°43'15"S, 113°03'25"E) 1 ♂, WAM11915; Vlaming Head (21°48'30"S, 114°06'40"E) 1 ♀, 2 ♂, WAM (5042, 8723, 8726); 7.5 km NE Yardie HS. (21°51'05"S, 114°04'20"E) 2 ♀, 4 ♂, WAM (5147, 14562, 20933-6).

Central Western Region

Western Australia: Ankatell Ridge (20°37'20"S, 122°42'10"E) 1 ♂, WAM22819, (20°23'00"S, 122°06'50"E) 1 ♀, WAM22822; Bluff Point (28°08'S, 124°13'E) 1 ♂, WAM14619; Canning Stock Route (23°45'S, 122°31'E) 1 ♀, 1 ♂, WAM 14996-7; Charlies Knob (25°03'S, 125°00'E) 1 ♀, WAM14625; Dandaraga Stn (28°07'40"S, 119°40'20"E) 1 ♀, WAM18730; Durba Spring (23°45'20"S, 122°31'00"E) 3 ♀, WAM 14407-9; Edgar Range (18°25'10"S, 123°05'30"E) 1 ♂, WAM15059; Ghanda Rockhole (26°36'10"S, 125°51'30"E) 1 ♂, WAM 13375; Godfrey's Tank (20°15'S, 126°34'E) 1 ♂, WAM22823; Great Sandy Desert (22°50'S, 122°01'E) 1 ♀, 1 ♂, WAM (22814, 22816); Logue River (17°40'30"S, 123°22'30"E) 1 ♀, 1 ♂, WAM (19345, 19361); Miss Gibson Hill (26°52'S, 126°22'E) 1 ♀, 2 ♂, WAM (13333, 13335-6); Mt Anderson (18°02'00"S, 123°53'30"E) 1 ♀, 1 ♂, WAM 19335-6; Mt Charles (25°45'S, 126°11'E) 1 ♂, WAM14626; Mt Wardiacco (28°59'00"S, 118°13'20"E) 1 ♀, WAM13475.001; Mullewa (28°06'S, 115°42'E) 1 ♂, WAM15500; Peak Hill (25°38'S, 118°43'E) 1 ♂, WAM 12986; Wiluna Stn (26°36'00"S, 120°15'09"E) 2 ♂, WAM19106, CM4794.

Eptesicus darlingtoni Allen, 1933

Figures 4, 5, 7e, 12; Table 1

Eptesicus darlingtoni Allen, 1933: J. Mammal. 14: 150-151.

Eptesicus sagittula McKean, Richards and Price, 1978: *Aust. J. Zool.* 26: 529-537; 13 km NW Braidwood, New South Wales.

Holotype

Museum of Comparative Zoology No. 29113; adult female; skin and skull separate; Macpherson Ranges, Queensland, altitude *ca.* 915 m; collected by Dr Philip J. Darlington on 10 March 1932.

Diagnosis (mean values)

Eptesicus darlingtoni differs from *E. pumilus*: larger in all skull, dental and external measurements (Table 1); dorsal inflation of cranium slight or moderate rather than pronounced; anterior narial emargination deep rather than shallow; anterior palatal emargination generally deep rather than shallow; sphenorbital sinus with anterolateral margin convex rather than concave; anterolateral wing of ectotympanic closer to lateral edge of squamosal; manus digit III with phalanx III longer relative to phalanx II (0.92 v. 0.87); baculum dorsal outline similar, but distal end pointed rather than square, base more inclined ventrally.

It differs from *E. caurinus*: much larger in all skull, dental and external measurements (Table 1); anterior narial emargination deep rather than shallow; anterior palatal emargination shallower; curve of anterior edge of orbit oval rather than subcircular; rostrum narrower as indicated by anteorbital, lacrymal and RC^1-LC^1

widths relative to rostrum length (0.72 v. 0.84, 0.96 v. 1.07, 0.74 v. 0.80, respectively); metacone-hypocone crista M^1 absent or slight rather than moderate or large; hypocone M^{1-2} smaller; manus digit III with phalanx III much longer relative to phalanx II (v. 0.55) and phalanx II shorter relative to phalanx I (0.74 v. 0.95); glans penis dorsoventrally rather than laterally compressed, urethral opening ventral rather than terminal; baculum shorter (1.7 v. 2.9), dorsal outline blunt arrow shaped rather than rod shaped with expanded base, lateral profile less curved.

It differs from *E. douglasorum*: dorsal inflation of cranium slight or moderate rather than moderate or pronounced; anterior narial and palatal emarginations deep rather than shallow; curve of anterior edge of orbit oval rather than subcircular; metacone-hypocone crista M^1 absent or slight rather than moderate; hypocone M^{1-2} larger; manus digit III with phalanx III much longer relative to phalanx II (v. 0.54) and phalanx II much shorter relative to phalanx I (v. 1.04); skin of face, ears and radius darker; glans penis dorsoventrally rather than laterally compressed, urethral opening ventral rather than terminal; baculum much longer (v. 3.2), dorsal outline blunt arrow shaped rather than rod shaped with expanded base, lateral profile essentially flat rather than bow shaped.

It differs from *E finlaysoni*: larger in most skull, dental and external measurements (Table 1); curve of anterior edge of orbit oval rather than subcircular; rostrum narrower as indicated by anteorbital, lacrymal and RC^1-LC^1 widths relative to rostrum length (v. 0.82, v. 1.08, v. 0.80, respectively); anterior narial emargination deep rather than usually shallow; anterior palatal emargination broader, usually deeper; manus digit III with phalanx III much longer relative to phalanx II (v. 0.60) and phalanx II shorter relative to phalanx I (v. 0.91); glans penis dorsoventrally rather than laterally compressed, urethral opening ventral rather than terminal; baculum shorter (v. 3.08), dorsal outline blunt arrow shaped rather than rod shaped with expanded base, lateral profile less curved.

It differs from *E. troughtoni*: larger in most skull, dental and external measurements (Table 1); curve of anterior edge of orbit oval rather than subcircular; rostrum narrower as indicated by anteorbital, lacrymal and RC^1-LC^1 widths relative to rostrum length (v. 0.81, v. 1.06, v. 0.77, respectively); anterior narial emargination deep rather than usually shallow; manus digit III with phalanx III longer relative to phalanx II (v. 0.67) and phalanx II shorter relative to phalanx I (v. 0.87); glans penis dorsoventrally rather than laterally compressed; baculum shorter (v. 3.7), dorsal outline blunt arrow shaped rather than rod shaped with expanded base, lateral profile less curved, base less deeply notched.

It differs from *E. regulus*: larger in most skull, dental and external measurements (Table 1); dorsal inflation of cranium slight or moderate rather than absent or slight; curve of anterior edge of orbit oval rather than subcircular; anterior narial emargination usually narrower, deeper; basolateral pterygoid wing present rather than usually absent; manus digit III with phalanx III longer relative to phalanx II (v. 0.80) and phalanx II shorter relative to phalanx I (v. 0.81); glans

penis much narrower dorsoventrally, lateral urethral folds absent; baculum shorter (v. 3.08), dorsal outline blunt arrow shaped rather than elongate dart shaped.

It differs from *E. vulturnus*: larger in all skull, dental and external measurements (Table 1); dorsal inflation of cranium slight or moderate rather than absent or slight; basolateral pterygoid wing present; curve of anterior edge of orbit oval rather than subcircular; narial emargination deep rather than shallow; posterior margin of palate terminates well posterior to anterior edge of sphenorbital sinus; manus digit III with phalanx III longer relative to phalanx II (v. 0.80); glans penis dorsoventrally compressed rather than bulbous, urethral opening ventral rather than terminal; baculum much shorter (v. 4.4), dorsal outline blunt arrow shaped rather than rod shaped with expanded base, less deeply bifurcated, distal tip not inflected ventrally.

It differs from *E. baverstocki*: larger in all skull, dental and external measurements (Table 1); dorsal inflation of cranium slight or moderate rather than absent or slight; curve of anterior edge of orbit oval rather than subcircular; anterior narial emargination deeper, usually narrower; posterior margin of palate well posterior to anterior edge of sphenorbital sinus; basolateral pterygoid wing present; manus digit III with phalanx III longer relative to phalanx II (v. 0.78) and phalanx II shorter relative to phalanx I (v. 0.84); glans penis dorsoventrally compressed rather than funnel shaped; baculum much shorter (v. 4.7), dorsal outline blunt arrow shaped rather than rod shaped with expanded base and slight distal lateral wings, base less deeply notched.

Description
Skull (Figure 12)

(see also 'General Description of Australian *Eptesicus*'). Greatest skull length long 13.4 (12.7-14.1), cranial inflation in mainland specimens (N=19) slight (74 per cent) or moderate (26 per cent) — in small Tasmanian sample (N=7) slight (43 per cent) or moderate (57 per cent); lambdoidal crest slight to moderate; anterior narial emargination generally V-shaped, occasionally narrow U-shaped, terminates close to a line joining the anterior edge of anteorbital foramina; rostrum moderately long, averages 50 per cent of basicranial length; least interorbital distance wide, averages 35.1 per cent of basicranial length; anteorbital distance narrow, averages 71.9 per cent of rostrum length; inter upper third molar distance moderate, averages 50.0 per cent of basicranial length; lacrymal bar moderate to wide; postpalatal spine varies from spinous to broadly spatulate, moderately long; posterior margin of palate terminates well posterior to anterior edge of sphenorbital sinus; basolateral pterygoid wing (in mainland and Tasmanian specimens) covers the foramen rotundum to the following extent: less than one-third (71-79 per cent) or between one to two-thirds (21-29 per cent).

Dentition

Crista linking base of metacone and hypocone (in mainland and Tasmanian specimens) on M^1 absent (71-79 per cent) or slight (21-29 per cent) and on M^2
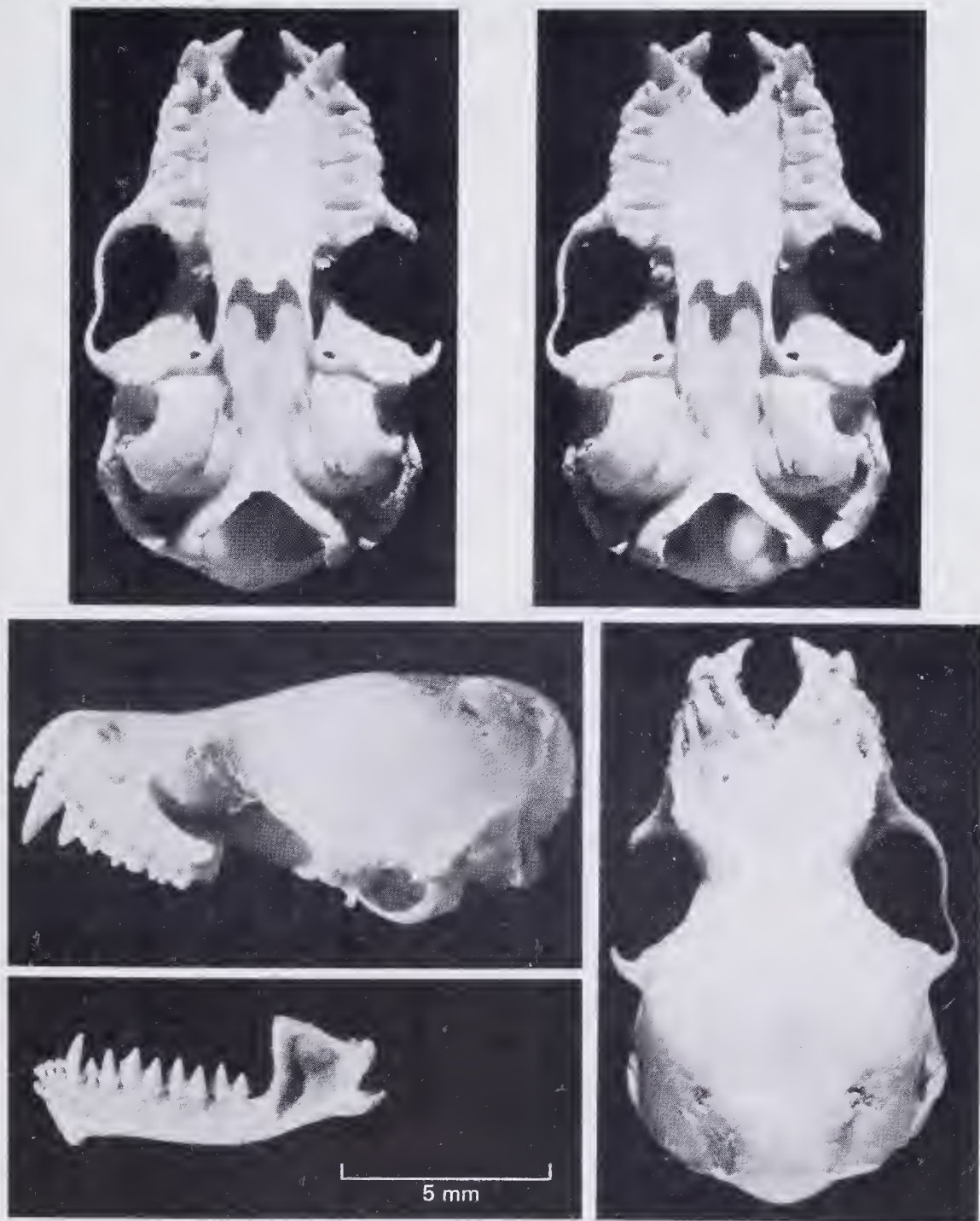
Figure 12   Skull and dentary of *Eptesicus darlingtoni* (J5476, paratype). The ventral view are stereopairs. Scale line 5 mm.

absent (89-100 per cent) or slight (0-11 per cent).

Body size

Body long 44.1 (38.1-48.9), much longer than tail 33.5 (29.2-38.0); relative wing measurements as follows: RL moderate 34.6 (32.5-37.2)>MCIII>>P1>> P2>P3; tibia length small 13.7 (12.3-14.4).

Pelage and skin

Slightly darker pelage on the dorsal than on ventral surface. Hair on head, cheeks, face, dorsum, sides of body and anal region monocoloured, Chestnut Brown; chin, chest, venter, lips and neck Brussels Brown; on humerus and femur sparse, on proximal half only, Buffy Brown; ear furred for one-third the length, Chestnut Brown; uropatagium sparsely furred, Brussels Brown; plagiopatagium sparsely furred *ca.* 5 mm from sides of body; on dorsum *ca.* 5.5 mm long, all Chestnut Brown or distal one-third Olive Brown with base Clove Brown or distal half Buffy Brown with base Fuscous Black; on ventral surface hairs *ca.* 5.2 mm long, all Brussels Brown or distal one-quarter Drab Gray with base Chaetura Black. Skin of lips Brussels Brown and of ear, patagia and radius Fuscous Black.

Penis (Figure 4)

Long hairs, up to 3.3 mm on preputium; preputial skin attached to glans *ca.* 1.0 mm from distal end; glans dorsoventrally compressed dorsal outline obovate shape urethral opening in mid ventral region of head of glans, covered by upward triangular projection of skin from ventral margin of opening; dorsal surface of head of glans with shallow median longitudinal groove; lateral profile of glans a blunt rod shape.

Baculum (Figure 5)

Short, greatest length 1.67 ± 0.047 (SD)(N=11); blunt arrow shaped dorsal outline with base little expanded laterally with width 0.66 ± 0.50 (SD)(N=11); shaft lateral profile straight, base sharply curved ventrally.

Distribution

The Great Dividing Range of eastern Australia south of latitude 28°, Adelaide hills area and Tasmania. Predominantly in sclerophyll forest (Figure 7e).

Specimens examined

Tasmania: Dip Falls (41°00'S, 145°10'E) 1 ♂, EBUE54; Fortescue Forest (43°10'S, 147° 50'E) 2 ♂, EBU (E21, E23); Maracoopa Caves Reserve (41°33'S, 146°15'E) 2 ♂, EBU (E12, E15); near Wet Caves (41°36'S, 146°20'E) 1 ♀, EBUE1; 12 km W Scottsdale (41°20'S, 147° 20'E) 1 ♂, EBUE39.

New South Wales: Acacia Plateau (28°20'S, 152°18'E) 1 ♀, 1 ♂, EBUB344-5; 13 km NW Braidwood (35°21'S, 149°44'E) 1 ♂, CM2290 (holotype *E. sagittula*); Mt Tinderry (35°42'S, 149°16'E) 1 ♀, CM2039; Watagan State Forest (33°00'S, 151°19'E) 3 ♀, EBU (B355-6, 003); Riverlea (35°16'S, 149°53'E) 1 ♀, CM6575; Spirabo State Forest (29°15'S, 152°02'E) 2 ♀, EBUB346-7.

Australian Capital Territory: Canberra (35°17'S, 149°13'E) 1 ♂, CM16022.

South Australia: Big Heath Conservation Park (37°10'S, 140°36'E) 1 ♂, EBUFBH3; Kuitpo Forest (35°09'S, 138°40'E) 1 ♂, EBUB411.

Victoria: Bendigo (36°45'S, 144°15'E) 5 ♀, 2 ♂, EBU (11282/01, 11282/03, 830226/03, 830226/06, 830226/09-11); Koetong (36°09'S, 147°29'E) 1 ♀, C25602.

Queensland: Macpherson Range, (*ca.* 28°12'S, 152°40'E) 1 ♀, J5476 (= MCZ29120 - paratype *E. darlingtoni*).

Lord Howe Island: 4 ♀, 1 ♂, AM2652, AM4741, AM8819 (paratype *E. sagittula*), AM10469, AM11761.

Eptesicus troughtoni sp. nov.

Figures 4, 5, 7f, 13; Table 1

Holotype

JM 5412; adult male; body in ethanol, skull separate; liver, heart, muscle and kidney removed for electrophoresis; from Yarramulla Lava Tunnels, Mt Surprise, Queensland (18°13'30"S, 144°40'30"E), altitude 840 m; collected by Terrance Brian Reardon on 8 August 1982.

Paratypes

See Specimens examined.

Diagnosis (mean values)

Eptesicus troughtoni differs from *E. pumilus*: larger in most skull, dental and external measurements (Table 1); dorsal inflation of cranium moderate rather than pronounced; rostrum broader as indicated by anteorbital, lacrymal and RC^1-LC^1 widths relative to rostrum length (0.81 v. 0.73, 0.77 v. 0.71, 1.06 v. 0.96, respectively); manus digit III with phalanx III shorter relative to phalanx II (0.67 v. 0.87) and phalanx II longer relative to phalanx I (0.87 v. 0.77); glans penis laterally rather than dorsoventrally compressed, urethral opening terminal rather than ventral; baculum longer (3.7 v. 1.6), dorsal outline rod shaped with expanded base rather than arrow shaped, lateral profile more curved, base more deeply notched.

It differs from *E. caurinus*: much larger in all skull, dental and external measurements (Table 1); anterior narial emargination usually broader; hypocone M^{1-2} larger; glans penis less pointed distally, much broader dorsoventrally; baculum longer (v. 2.9), base more deeply notched.

It differs from *E. douglasorum*: anterior narial emargination broader; hypocone M^{1-2} larger; manus digit III with phalanx II shorter relative to phalanx I (v. 1.04) and phalanx I longer relative to metacarpal (0.37 v. 0.32); glans penis less pointed distally, broader dorsoventrally; baculum generally longer (v. 3.2), base less deeply notched, lateral profile less curved.

It differs from *E. finlaysoni*: larger in most skull, dental and external measurements (Table 1); radius longer relative to tibia (Figure 10); glans penis less pointed distally, broader dorsoventrally, urethral opening ventral rather than terminal; baculum generally longer (v. 3.08), base less deeply notched.

It differs from *E. darlingtoni*: smaller in most skull, dental and external measurements (Table 1); curve of anterior edge of orbit subcircular rather than oval; rostrum broader as indicated by anteorbital, lacrymal and RC^1-LC^1 widths relative to rostrum length (v. 0.72, v. 0.96, v. 0.74, respectively); anterior narial emargination usually shallow rather than deep; manus digit III with phalanx III shorter relative to phalanx II (v. 0.54) and phalanx II longer relative to phalanx I (v. 0.74); glans penis laterally rather than dorsoventrally compressed; baculum longer (v. 1.7), dorsal outline rod shaped with expanded base rather than blunt arrow shaped, lateral profile more curved.

It differs from *E. regulus*: dorsal inflation of cranium moderate rather than absent or slight; rostrum broader anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.76, v. 0.74, respectively); anterior narial and palatal emarginations narrower, narial usually shallower; basolateral pterygoid wing present rather than usually absent; upper tooth row more curved; manus digit III with phalanx III shorter relative to phalanx II (v. 0.80); glans penis with urethral lobe ventral rather than terminal, lacks lateral urethral folds; baculum dorsal outline rod shaped with expanded base rather than elongate dart shape, curved rather than flat in lateral profile.

It differs from *E. vulturnus*: larger in most skull, dental and external measurements (Table 1); dorsal inflation of cranium moderate rather than absent or slight; rostrum broader anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.75, v. 0.75, respectively); anterior narial and palatal emarginations usually shallower; posterior margin of palate terminates well posterior to anterior edge of sphenorbital sinus; basolateral pterygoid wing present; upper tooth row more curved; manus digit III with phalanx III shorter relative to phalanx II (v. 0.80); glans penis laterally compressed rather than bulbous, ventral urethral lobe single rather than bilobed; baculum shorter (v. 4.4), base more inclined ventrally, distal tip less curved ventrally.

It differs from *E. baverstocki*: larger in most skull, dental and external measurements (Table 1); dorsal inflation of cranium moderate rather than absent or slight; posterior margin of palate terminates well posterior to anterior edge of sphenorbital sinus; basolateral pterygoid wing present; upper tooth row more curved; metacone-hypocone crista M^1 absent to moderate rather than always absent; manus digit III with phalanx III shorter relative to phalanx II (v. 0.78); glans penis laterally compressed rather than funnel shaped; baculum shorter (v. 4.7), base more inclined ventrally, lateral distal wings absent.

Description
Skull (Figure 13)
(see also 'General Description of Australian *Eptesicus*'). Greatest skull length moderately long 12.7 (12.2-13.2); cranial inflation slight (4 per cent) or moderate (96 per cent); lambdoidal crest slight to well developed; anterior narial emargination V or narrow U-shaped, terminates well anterior to a line joining anterior

edge of anteorbital foramina (82 per cent) or close to this line (18 per cent); rostrum short, averages 49.1 per cent of basicranial length; least interorbital distance wide, averages 35.2 per cent of basicranial length; inter upper third molar distance wide, averages 52.8 per cent of basicranial length; lacrymal bar narrow or moderate; postpalatal spine broad or narrow spatulate or triangular, short or moderately long; posterior margin of palate terminates well posterior to anterior edge of sphenorbital sinus; basolateral pterygoid wing absent in two specimens (9 per cent) — its coverage of the foramen rotundum to the extent of: less than one-third (69 per cent) or between one to two-thirds (22 per cent).

Dentition

Crista linking base of metacone and hypocone on M^1 absent (26 per cent), slight (43 per cent) or moderate (31 per cent) and on M^2 absent (30 per cent), or slight (61 per cent) or moderate (9 per cent).

Body size

Body length moderate 41.5 (37.5-44.2), longer than tail 35.3 (31.4-37.9); relative wing measurements as follows: RL moderate 34.8 (33.0-36.4)≥MCIII >>P1>P2>>P3; tibia length moderate 13.6 (12.7-14.2).

Pelage and skin

Dorsal pelage moderately dark with paler ventral surface. Hair on top of head has distal half Mummy Brown and base Bister; on cheek and chin Tawny Olive; on face Bister; on neck has distal three-quarters Mummy Brown and base Tawny Olive; on dorsum ca. 5.5 mm long with distal half Dresden Brown and base Clove Brown; on chest, venter and sides of body ca. 5 mm long with distal one-third Tawny Olive and base Fuscous Black; anal region Tawny Olive; humerus very sparsely haired to elbow, Light Buff; femur furred to two-thirds of length, Light Buff; ear furred on basal one-half, distal half Buffy Brown and base Olive Brown; proximal half of uropatagium extremely sparsely haired, Light Buff; plagiopatagium moderately furred to ca. 10 mm from side of body. Skin of lips Fuscous Black and of ear, radius and patagia Clove Brown.

Penis (Figure 4)

Long hairs on preputium; preputial skin attached at immediate base of glans head, ca. 1.7 mm from distal end; head of glans laterally compressed; opening of urethra at distal end of glans, covered by upward narrow triangular projection of skin from ventral lip of opening; dorsal surface of head of glans with shallow median longitudinal groove with two slight lateral swellings in the middle region of the head; lateral profile of glans approximately rectangular.

Baculum (Figure 5)

Moderately long, greatest length 3.69 ± 0.154 (SD)(N=11); dorsal outline of shaft rod shaped with moderately wide 0.96 ± 0.069 (SD)(N=11) base, moderately
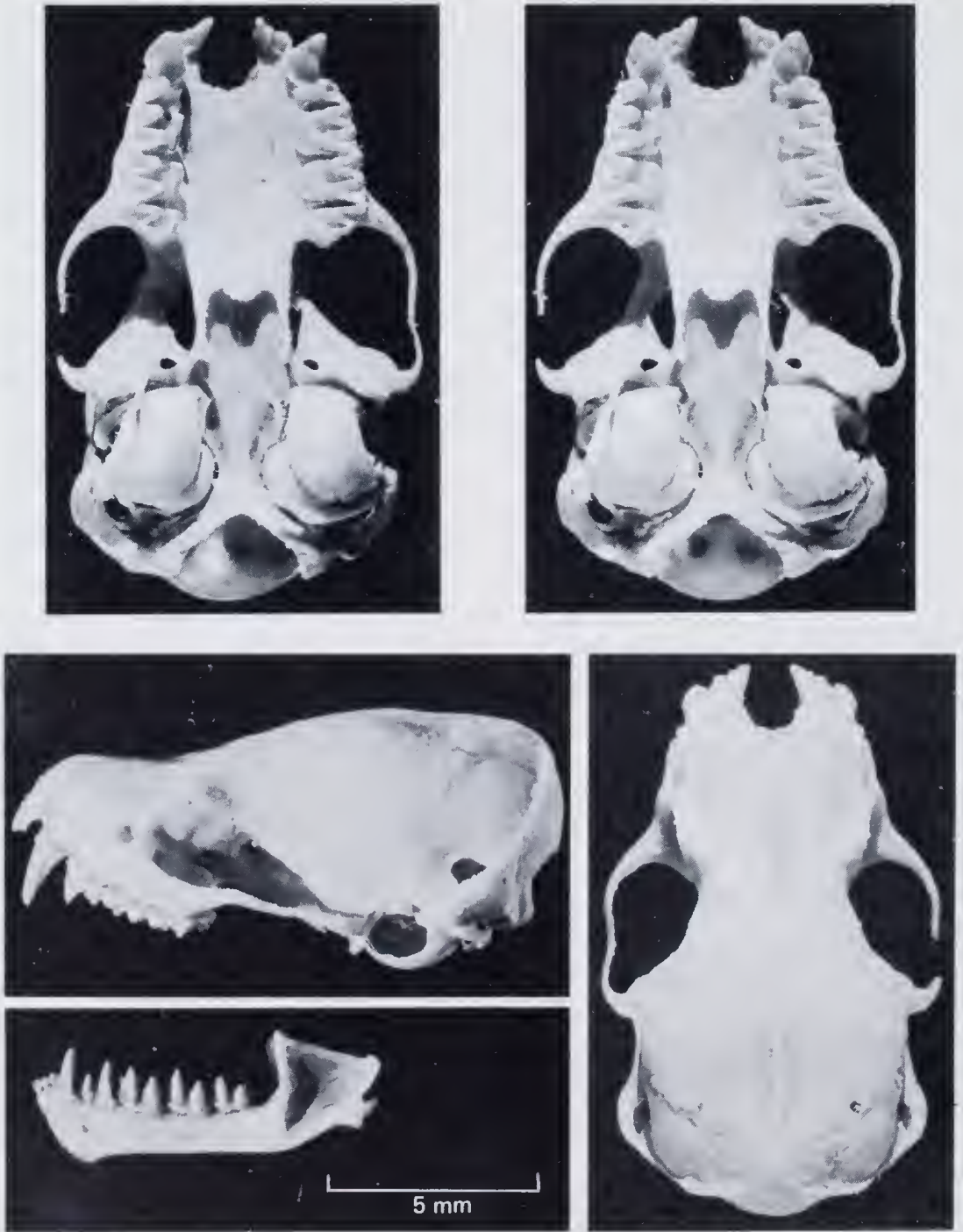
Figure 13   Skull and dentary of *Eptesicus troughtoni* (JM5412, holotype). The ventral view are stereopairs. Scale line 5 mm.

bifurcated; lateral profile bow shaped but with basal one-quarter much more inflected ventrally than distal end.

Distribution

Great Dividing Range of eastern Australia and more coastal country north of latitude 31°S. Predominantly in tropical mixed woodland (Figure 7f).

Etymology

Named after Ellis Le G. Troughton, late Curator of Mammals, the Australian Museum. Author of a number of taxonomic papers on Australian mammals.

Specimens examined
Paratypes

New South Wales: Bonalbo (28°44'S, 152°37'E) 1 ♀, 1 ♂, CM169, CM179; Warrumbungle Range (*ca.* 31°S, 149°E) 2 ♀, 1 ♂, CM2325, CM2330, CM2333.

Queensland: Cape Hillsborough National Park (20°51'S, 145°03'E) 2 ♀, JM759-60; Gin Gin (25°00'S, 151°57'E) 1 ♂, CM5980; Iron Range (12°44'S, 143°17'E) 1 ♀, 1 ♂, CM16005, CM16117; Mt Alford (28°04'S, 152°36'E) 1 ♀, J8830; "Mt Iron Pot", 24 km NE Rockhampton (*ca.* 23°10'S, 150°40'E) 5 ♀, AM10291, AM10294, AM10295, CM16081-2; Mt Molloy (16° 41'S, 145°20'E) 3 ♀, J19036-8; Yarramulla Lava Tunnels (18°13'30"S, 144°40'30"E) 2 ♀, 3 ♂, EBU B61-2, B64-6.

Referred specimens

New South Wales: Bonalbo (28°44'S, 152°37'E) 1 ♂, CM164; Rivertree (28°38'S, 152°18'E) 1 ♂, CM451.

Queensland: Chillagoe (17°09'S, 144°31'E) 1 ♂, CM10843; Iron Range (12°44'S, 143°17'E) 1 ♂, CM6672; "Mt Iron Pot", 24 km NE Rockhampton (*ca.* 23°10'S, 150°40'E) 3 ♂, CM16094, CM16100, CM16102; Ravenswood (20°06'S, 146°53'E) 1 ♂, CM6671; Salvator Rosa National Park (*ca.* 24°50'S, 147°15'E) 1 ♂, CM4384.

Eptesicus regulus (Thomas, 1906)

Figures 4, 5, 7g, 14; Table 1

Pipistrellus regulus Thomas, 1906: Proc. Zool. Soc. (Lond.) p. 470.

Lectotype

BMNH 6.8.1.18, adult, skull only, King River, King George Sound, South Western Australia. Lectotype designated by Hill (1968).

Diagnosis (mean values)

Eptesicus regulus differs from *E. pumilus*: dorsal inflation of cranium absent to moderate rather than pronounced; anterior palatal emargination broader, usually deeper; basolateral pterygoid wing usually absent rather than present; glans penis laterally rather than dorsoventrally compressed, lateral urethral folds present; baculum longer (3.8 v. 1.6), dorsal outline elongate dart shaped rather than arrow shaped.

It differs from *E. caurinus*: larger in most skull, dental and external measurements (Table 1); dorsal inflation of cranium absent to moderate rather than pronounced; rostrum narrower anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (0.76 v. 0.84, 0.74 v. 0.80, 0.98 v. 1.07, respectively); anterior narial and palatal emarginations deeper, usually broader; basolateral pterygoid wing generally absent rather than present; upper tooth row less curved; metacone-hypocone crista M^1 absent or slight or rarely moderate rather than moderate or large; hypocone M^{1-2} larger; manus digit III with phalanx III longer relative to phalanx II (0.80 v. 0.55) and phalanx II shorter relative to phalanx I (0.87 v. 0.95); glans penis broader dorsoventrally, urethral opening ventral rather than terminal, lateral urethral folds present; baculum longer (v. 2.9), dorsal outline elongate dart shaped rather than rod shaped with expanded base, lateral profile flat rather than curved, base more deeply notched.

It differs from *E. douglasorum*: dorsal inflation of cranium absent to moderate rather than moderate or pronounced, rostrum narrower anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.83, v. 0.79, respectively); anterior narial and palatal emarginations broader, usually deeper; basolateral pterygoid wing usually absent rather than present; upper tooth row less curved; hypocone M^{1-2} larger; metacone-hypocone crista M^{1-2} slight or absent or very rarely moderate rather than moderate only; manus digit III with phalanx III longer relative to phalanx II (v. 0.54) and phalanx II shorter relative to phalanx I (v. 1.04); glans penis less pointed distally, urethral opening ventral rather than terminal, lateral urethral folds present; baculum longer (v. 3.2), dorsal outline elongate dart shaped rather than rod shaped with expanded base, lateral profile flat rather than curved.

It differs from *E. finlaysoni*: dorsal inflation of cranium generally slight rather than generally moderate; rostrum narrower anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.82, v. 0.80, respectively); anterior narial and palatal emarginations broader, usually deeper; basolateral pterygoid wing usually absent rather than present; upper tooth row less curved; manus digit III with phalanx III shorter relative to phalanx II (v. 0.60) and phalanx II longer relative to phalanx I (v. 0.91); glans penis less pointed distally, broader dorsoventrally, urethral opening ventral rather than terminal, lateral urethral folds present; baculum longer (v. 3.1), dorsal outline dart shaped rather than rod shaped with expanded base, lateral profile less curved.

It differs from *E. darlingtoni*: smaller in most skull, dental and external measurements (Table 1); curve of anterior edge of orbit subcircular rather than oval; anterior narial emargination usually broader; basolateral pterygoid wing usually absent rather than present; manus digit III with phalanx III shorter relative to phalanx II (v. 0.92) and phalanx II longer relative to phalanx I (v. 0.74); glans penis broader dorsoventrally, lateral urethral folds present; baculum longer (v. 1.7), dorsal outline elongate dart shaped rather than blunt arrow shaped, base more deeply notched.

It differs from *E. troughtoni*: rostrum narrower anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.81, v. 0.77, respectively); anterior narial and palatal emarginations broader, narial usually deeper; basolateral pterygoid wing usually absent rather than present; upper tooth row less curved; manus digit III with phalanx III longer relative to phalanx II (v. 0.67); glans penis with urethral lobe terminal rather than ventral, lateral urethral folds present; baculum dorsal outline elongate dart shaped rather than rod shaped with expanded base, lateral profile flat rather than curved.

It differs from *E. vulturnus*: larger in most skull, dental and external measurements (Table 1); anterior narial and palatal emarginations usually deeper; posterior margin of palate well posterior to anterior edge of sphenorbital sinus; manus digit III with phalanx I shorter relative to metacarpal (0.37 v. 0.42); glans penis laterally compressed rather than bulbous, urethral opening terminal rather than ventral, lateral urethral folds present; baculum shorter (v. 4.4), dorsal outline elongate dart shaped rather than rod shaped with expanded base, lateral profile essentially flat rather than curved, base less deeply notched, distal end not inclined ventrally.

It differs from *E. baverstocki*: larger in most skull, dental and external measurements (Table 1); anterior narial and palatal emarginations usually deeper; posterior margin of palate generally well posterior to anterior edge of sphenorbital sinus rather than level with it; glans penis with lateral urethral folds rather than funnel shaped; baculum shorter (v. 4.7), dorsal outline elongate dart shaped rather than rod shaped with expanded base and slight distal lateral wings, lateral profile flat rather than curved.

Description
Skull (Figure 14)

(see also 'General Description of Australian *Eptesicus*'). Greatest skull length moderately long 12.7 (11.9-13.4); cranial inflation varies with region: specimens from the forested region of extreme southwestern Western Australia have the most inflated skulls with inflation absent (6 per cent), or slight (69 per cent) or moderate (25 per cent) — those from semi-arid woodland region of southwestern Western Australia and the southeastern mainland regions have cranial inflation absent (44-51 per cent), or slight (41-50 per cent), or moderate (6-8 per cent) — Tasmanian specimens have inflation absent (91 per cent) or slight (9 per cent); lambdoidal crest moderate to well developed; anterior narial emargination U-shaped, terminates well anterior to (50-65 per cent) or close to (35-50 per cent) a line joining anterior edges of anteorbital foramina in the mainland specimens—in the Tasmanian specimens 100 per cent terminated well anterior to this line; rostrum moderately long, averages 50.0 per cent of basicranial length; least interorbital distance narrow, averages 32.4 per cent of basicranial length; anteorbital distance moderate, averages 75.9 per cent of rostrum length; inter upper third molar distance narrow, 48.1 per cent of basicranial length; lacrymal bar usually moderate, occasionally narrow; postpalatal spine variable, spinous to broad spatulate,
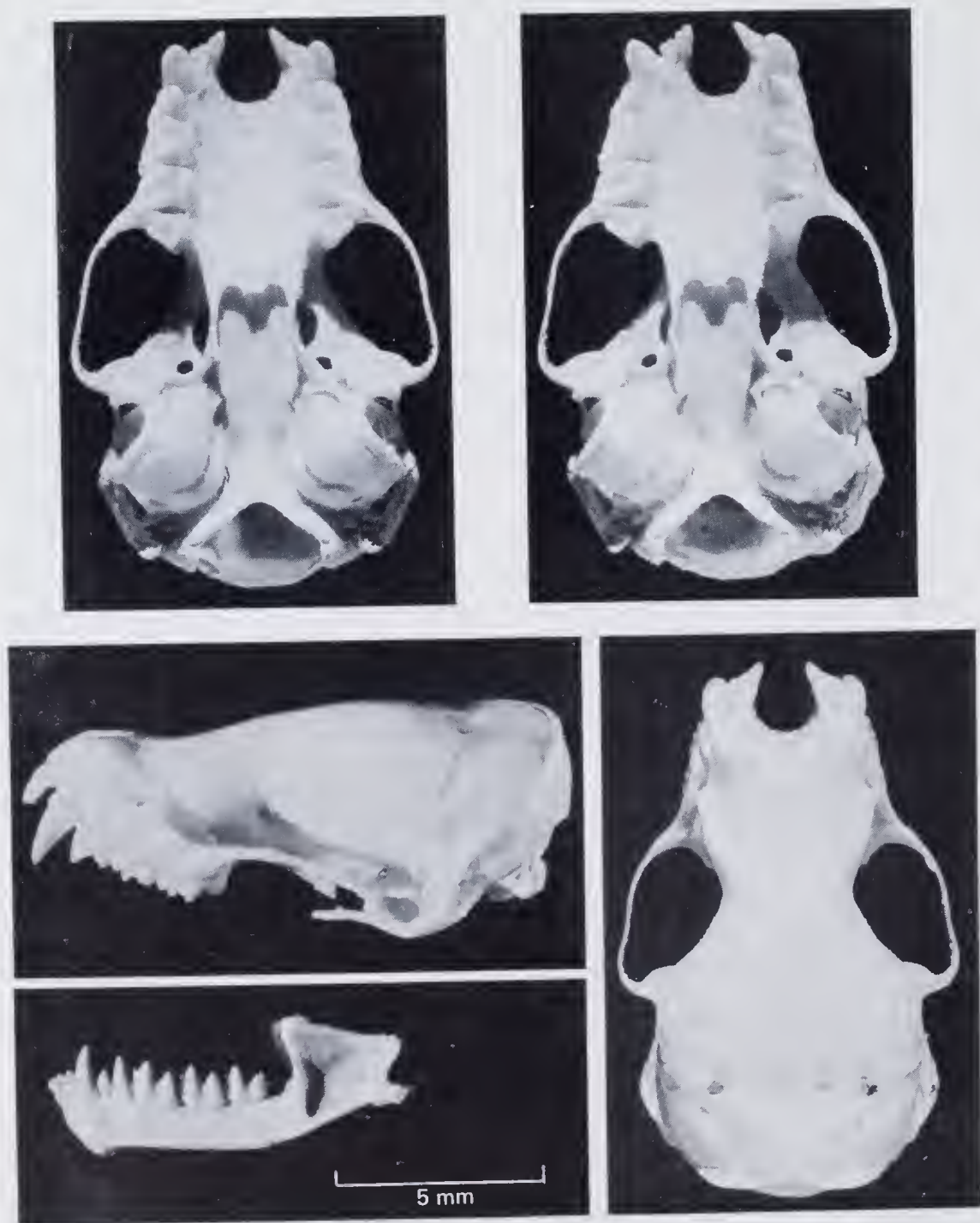
Figure 14   Skull and dentary of *Eptesicus regulus* (WAM M15167). The ventral view are stereo-
pairs. Scale line 5 mm.

short to long; posterior margin of palate generally terminates posterior to, or occasionally level with, anterior edge of sphenorbital sinus; in mainland specimens basolateral pterygoid wing generally absent or small and not extending to foramen rotundum (81-87 per cent) or present and covering less than one-third foramen rotundum (13-19 per cent) — absent or very small in Tasmanian specimens.

Dentition

Crista linking base of metacone and hypocone varies with region; in extreme southwestern Western Australia and Tasmania on M^1 absent (27-31 per cent) or slight (56-73 per cent) or moderate (0-13 per cent) and M^2 absent (62-82 per cent) or slight (18-38 per cent) — in the semi-arid southwest and eastern mainland regions on M^1 absent (86-94 per cent) or slight (6-14 per cent) and on M^2 absent (92-94 per cent) or slight (6-8 per cent).

Body size

Body length moderate 41.4 (36.2-46.6), much longer than tail length 31.7 (28.5-39.0); relative wing measurements as follows: RL moderate 31.2 (28.0-34.4) >MCIII>>P1>>P2>>P3; tibia length small 12.7 (11.4-13.9).

Pelage and skin

Dorsal pelage medium dark with paler ventral surface. Hair on cheek, face and chin Wood Brown; anal region Avellaneous; on top of head and dorsum distal one-quarter to one-third Buffy Brown or Bone Brown or with base Clove Brown and Fuscous Black, respectively; on dorsum and venter ca. 5.5 and 5.0 mm, respectively; neck, chest and venter have distal one-quarter Avellaneous with base Fuscous Black — side of body has the same colour patterning but the distal Avellaneous is one-half the length of hairs; proximal half of humerus with very sparse hairs, Avellaneous; femur moderately furred to knee, Avellaneous; ear furred to half length, Wood Brown; uropatagium extremely sparsely haired, Avellaneous; plagiopatagium furred to ca. 8 mm from sides of body. Skin of lips and ear Olive Brown and of patagia and radius Clove Brown.

Penis (Figure 4)

Moderate length hairs on preputium; preputial skin attached to shaft of glans ca. 2.3 mm from distal end of glans; head of glans laterally compressed; urethral opening ventral and approximately centrally located on head of glans, enclosed by a large lateral fold on either side which meet in the mid line for about 0.5 mm forming a partially enclosed urethral groove; secondary lateral folds are located at base of glans head; distal end of glans smooth and round with slightly raised dorsal hump; lateral profile club shaped.

Baculum (Figure 5)

Moderately long 3.8 ± 0.23 (SD)(N=10); dorsal outline elongate dart shaped, base moderately bifurcated, slightly expanded laterally 0.89 ± 0.057 (SD) (N=10) and dorsoventrally; lateral profile reasonably straight with dorsal inflection of distal one-quarter of shaft.

Distribution

Great Dividing Range of eastern Australia south of latitude 29°S and Tasmania (predominantly dry sclerophyll forest); southeastern South Australia (shrubland and low shrub woodland) and southwestern Western Australia (wet and dry sclerophyll forest, mixed temperate woodland and sclerophyll mallee) (Figure 7g).

Specimens examined

BMNH 6.8.1.18 (lectotype).

Tasmania: Dip Falls (41°00'S, 145°19'E) 1 ♂, EBUE53; Fortescue Forest (43°10'S, 147°50'E) 1 ♀, 1 ♂, EBU (E19-20, E24); Maracoopa Caves Reserve (41°33'S, 146°15'E) 1 ♀, 1 ♂, EBU (E7, E14); Wet Caves (41°36'S, 146°20'E) 1 ♂, EBUE3; Mt Field National Park (42°40'S, 146°30'E) 2 ♂, EBU (E30, E33); 12 km W Scottsdale (41°20'S, 147°20'E) 1 ♀, 1 ♂, EBU (E38, E49).

Eastern Mainland

New South Wales: Emu Plains (33°45'S, 150°41'E) 1 ♂, AM10317; Tenterfield (29°03'S, 152°01'E) 1 ♀, EBUB348.

South Australia: Chauncey's Line (*ca.* 35°13'S, 139°08'E) 1 ♂, SAM11089; Lake Gilles Conservation Park (32°58'S, 136°45'E) 2 ♀, 6 ♂, SAM (M10302, M10305, M10307, M10310-1, M10334, M10339, M10343); 25 km N Morgan (30°50'S, 139°42'E) 1 ♂, EBUE61; Sutherlands (34°10'S, 139°14'E) 1 ♂, SAM9832.

Victoria: Bendigo (36°46'S, 144°17'E) 8 ♀, 2 ♂, EBU (821120/01, 11282/04-6, 11282/10, 830226/01-2, 830226/04-5, 830226/08); Cheshunt (36°47'S, 146°26'E) 1 ♂, C25199; Chetwynd (37°17'S, 141°25'E) 1 ♂, C24872; East Gippsland 2 ♀, 2 ♂, C25898, C25917-8, C25977; Gembrook State Forest (*ca.* 37°58'S, 145°35'E) 4 ♀, 2♂, AM11875-79, C25022; Goulburn R. (36°19'30"S, 145°21'30"E) 1 ♂, C25638; Whitfield (36°46'S, 146°25'E) 1 ♂, C25207; Wingan R. (37°38'S, 149°29'E) 1 ♂, C24912.

Western Australia: Extreme SW region: Busselton (33°39'S, 115°20'E) 1 ♀, WAM24544; Contine Reserve (32°58'30"S, 116°52'30"E) 1 ♂, WAM19307; Donnelly R. (34°19'20"S, 115°57'30"E) 1 ♂, WAM15167; Dumbleyung Lk. (33°20'S, 117°40'E) 1 ♂, WAM19114; Fremantle (32°03'S, 115°44'E) 2 ♂, WAM921, WAM18003; Jarrahdale (32°16'45"S, 116°05'50"E) 1 ♀, WAM18998; Kalamunda (31°58'10"S, 116°07'30"E) 1 ♂, WAM6321; Mt Dale (32°07'30"S, 116°17'40"E) 1 ♂, WAM19187; Nannup (33°59'15"S, 115°46'00"E) 1 ♂, WAM19310; Sabina R. (33°39'S, 115°24'E) 1 ♂, WAM8154; Tarin Rock (33°05'30"S, 118°13'00"E) 1 ♀, WAM8220; Walpole (35°10'S, 116°40'E) 1 ♂, WAM14687; Woodlands (33°59'S, 117°29'E) 1 ♀, 1 ♂, WAM942, WAM990.

Western Australia: SW region: Beacon (30°04'S, 117°51'E) 1 ♂, WAM12555; Black Flag Stn (30°34'S, 121°14'E) 1 ♂, WAM20343; Bungalbin Hill (30°14'S, 119°49'E) 1 ♀, WAM17749; Cockleshell Gully (30°08'50"S, 115°07'20"E) 1 ♀, WAM10900; Die Hardy Range (29°57'30"S, 119°26'30"E) 1 ♀, WAM20699; Koorarawalyee Dam (31°15'30"S, 120°01'00"E) 1 ♂, WAM20139; Lake Cronin (32°22'50"S, 119°45'30"E) 2 ♀, WAM20109, WAM20112; Marda (30°12'45"S, 119°16'40"E) 3 ♀, 1 ♂, WAM17729-30, WAM17736, WAM17913; Newman Rocks (32°07'00"S, 123°10'25"E) 1 ♀, WAM16753; Woodline (31°57'S, 122°24'E) 1 ♀, WAM20159, (31°50'S, 122°19'E) 1 ♀, WAM20178, (31°55'S, 122°24'E) 1 ♀, WAM17970.

Eptesicus vulturnus Thomas, 1914

Figures 4, 5, 7h, 15; Table 1

Eptesicus pumilus vulturnus Thomas, 1914: Ann. Mag. Nat. Hist., (8) xiii, p. 440.

Vespertilio pygmaeus Becker, 1858 (not *Vespertilio pygmaeus* Leach, 1825): Trans. Phil. Inst. Vic., 111, pp. 38-40, Pl., Oakleigh, Dandenong Ranges, Victoria.

Holotype

BMNH 7.1.1.375, adult female; skin, skull separate; from Tasmania; obtained by Mr Tomes from J.P. Verreaux.

Diagnosis (mean values)

Eptesicus vulturnus differs from *E. pumilus*: dorsal inflation of cranium absent or slight rather than pronounced; anterior palatal emargination broader, usually deeper; postpalatal spine generally larger; posterior margin of palate terminates level with or slightly posterior to the anterior edge of sphenorbital sinus rather than well posterior to it; basolateral pterygoid wing generally absent rather than present; anterolateral wing of ectotympanic closer to lateral edge of squamosal; glans penis bulbous rather than dorsoventrally compressed, urethral opening terminal rather than ventral; baculum longer (4.4 v. 1.6), dorsal outline rod shaped with expanded base rather than arrow shaped, base more deeply notched and distal end more inclined ventrally.

It differs from *E. caurinus*: smaller in most skull and dental measurements (Table 1); dorsal inflation of cranium absent or slight rather than pronounced or moderate; rostrum narrower anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (0.75 v. 0.84, 0.75 v. 0.80, respectively); anterior narial and palatal emarginations broader, usually deeper; posterior margin of palate terminates level with or slightly posterior to the anterior edge of sphenorbital sinus rather than well posterior to it; basolateral pterygoid wing generally absent rather than present; upper tooth row less curved; hypocone M^{1-2} larger; metacone-hypocone crista M^1 absent or slight rather than moderate or large; manus digit III with phalanx III longer relative to phalanx II (0.80 v. 0.55) and phalanx II shorter relative to phalanx I (0.78 v. 0.95); glans penis distally blunt rather than pointed, bulbous rather than dorsoventrally compressed, ventral urethral lobe with two subcircular winged lobes rather than a single fleshy lobe; baculum longer (v. 2.9), lateral profile less curved, base more deeply notched.

It differs from *E. douglasorum*: smaller in most skull, dental and external measurements (Table 1); dorsal inflation of cranium absent or slight rather than moderate or pronounced; rostrum narrower anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.83, v. 0.79, respectively); anterior palatal emargination broader; posterior margin of palate terminates level with or slightly posterior to the anterior edge of sphenorbital sinus rather than well posterior to it; basolateral pterygoid wing generally absent rather than present; hypocone M^{1-2} larger; metacone-hypocone crista M^1 absent or slight rather than moderate; manus digit III with phalanx III longer relative to phalanx II (v. 0.54) and phalanx II shorter relative to phalanx I (v. 1.04); glans penis distally blunt rather than pointed, bulbous rather than laterally compressed, ventral urethral lobe with two subcircular winged lobes rather than a single fleshy lobe; baculum longer (v. 3.2), base more deeply notched and less inclined ventrally, distal end more inclined ventrally.

It differs from *E. finlaysoni*: smaller in most skull, dental and external measurements (Table 1); dorsal inflation of cranium absent or slight rather than generally moderate; rostrum narrower anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.82, v. 0.80, respectively); anterior narial and palatal emarginations broader, usually deeper; posterior margin of palate terminates level with or slightly posterior to anterior edge of sphenorbital sinus rather than well posterior to it; basolateral pterygoid wing generally absent rather than present; upper tooth row less curved; manus digit III with phalanx III longer relative to phalanx II (v. 0.60) and phalanx II shorter relative to phalanx I (v. 0.91); glans penis distally funnel shaped rather than pointed, ventral urethral lobe with two subcircular winged lobes rather than a single fleshy lobe; baculum longer (v. 3.1), base more deeply notched and less inclined ventrally, distal end more inclined ventrally.

It differs from *E. darlingtoni*: smaller in all skull, dental and external measurements (Table 1); dorsal inflation of cranium absent or slight rather than slight or moderate; curve of anterior edge of orbit subcircular rather than oval; narial emargination shallow rather than deep; posterior margin of palate terminates level with or slightly posterior to the anterior edge of the sphenorbital sinus rather than well posterior to it; basolateral pterygoid wing generally absent rather than present; manus digit III with phalanx III shorter relative to phalanx II (v. 0.92); glans penis bulbous rather than dorsoventrally compressed, urethral opening terminal rather than ventral; baculum longer (v. 1.7), dorsal outline rod shaped with expanded base rather than blunt arrow shaped, base more deeply bifurcated and less inclined ventrally, distal end more inclined ventrally.

It differs from *E. troughtoni*: smaller in most skull, dental and external measurements (Table 1); dorsal inflation of cranium absent or slight rather than moderate; rostrum anteriorly narrower as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (v. 0.81, v. 0.77, respectively); anterior narial and palatal emarginations usually deeper; posterior margin of palate terminates level with or slightly posterior to the anterior edge of sphenorbital sinus rather than well posterior to it; basolateral pterygoid wing generally absent rather than present; upper tooth row less curved; manus digit III with phalanx III longer relative to phalanx II (v. 0.67); glans penis bulbous rather than laterally compressed, ventral urethral lobe with two subcircular winged lobes rather than a single fleshy lobe; baculum longer (v. 3.7), base less inclined ventrally, distal end more inclined ventrally.

It differs from *E. regulus*: smaller in most skull, dental and external measurements (Table 1); anterior narial and palatal emarginations usually shallower; posterior margin of palate terminates level with or slightly posterior to anterior edge of sphenorbital sinus rather than well posterior to it; manus digit III with phalanx I longer relative to metacarpal (0.42 v. 0.37); glans penis bulbous rather than laterally compressed, urethral opening ventral rather than terminal, lateral urethral folds absent; baculum longer (v. 3.8), dorsal outline rod shaped with

expanded base rather than elongate dart shaped, lateral profile curved rather than flat, distal end much more inclined ventrally.

It differs from *E. baverstocki*: metacone-hypocone crista M^1 absent or slight rather than always absent; manus digit III with phalanx I longer relative to meta-carpal (v. 0.36); glans penis bulbous rather than funnel shaped, urethral opening terminal rather than ventral; baculum base narrower and more deeply notched, distal end without slight lateral wings.

Description

Skull (Figure 15)

(see also 'General Description of Australian *Eptesicus*'). Greatest skull length moderately long 12.2 (11.8-12.7); cranial inflation similar in mainland and Tasmanian specimens, absent (25-30 per cent) or slightly inflated (70-75 per cent); lamboidal crest slight to moderate; anterior narial emargination variable, narrow or broad U-shaped or V-shaped, in mainland and Tasmanian specimens terminates well anterior to a line joining anterior edges of anteorbital foramina (91-100 per cent) or close to this line in 9 per cent of mainland specimens; rostrum length moderate, averages 49.5 per cent of basicranial length; least interorbital distance moderate, averages 33.0 per cent of basicranial length; anteorbital distance moderate, averages 74.5 per cent of rostrum length; inter upper third molar distance moderate, averages 49.5 per cent of basicranial length; lacrymal bar usually moderate, occasionally narrow; postpalatal spine narrow or broadly spatulate, or triangular shaped; posterior margin of palate terminates level with or just posterior to anterior edge of sphenorbital sinus; basolateral pterygoid wing generally absent (91 per cent) but in 9 per cent of specimens present and covers less than one-third of foramen.

Dentition

Crista linking base of metacone and hypocone on M^1 absent (48 per cent) or slight (52 per cent) and M^2 absent (83 per cent) or slight (17 per cent).

Body size

Body length moderate 40.2 (34.7-48.0), much longer than tail 30.0 (26.5-33.8); relative wing measurements as follows: RL small 28.4 (26.3-32.8) ≥ MCIII>>P1>>P2>P3; tibia length small 12.0 (11.2-12.7).

Pelage and skin

Dorsal pelage dark with slightly paler ventral surface. Hair bicoloured except those on cheek, face, chin, ear, limbs, patagia, femur and anal region (Buffy Brown); on top of head with distal one-third Bone Brown and basal part Fuscous Black; neck with distal one-third Buffy Brown and base Fuscous Black; on dorsum *ca.* 5 mm long with distal one-quarter Fuscous or Buffy Brown and base Fuscous Black; on chest and venter *ca.* 5.5 mm long with distal one-quarter Buffy Brown and base Fuscous Black; side of body with distal one-third Buffy Brown and base
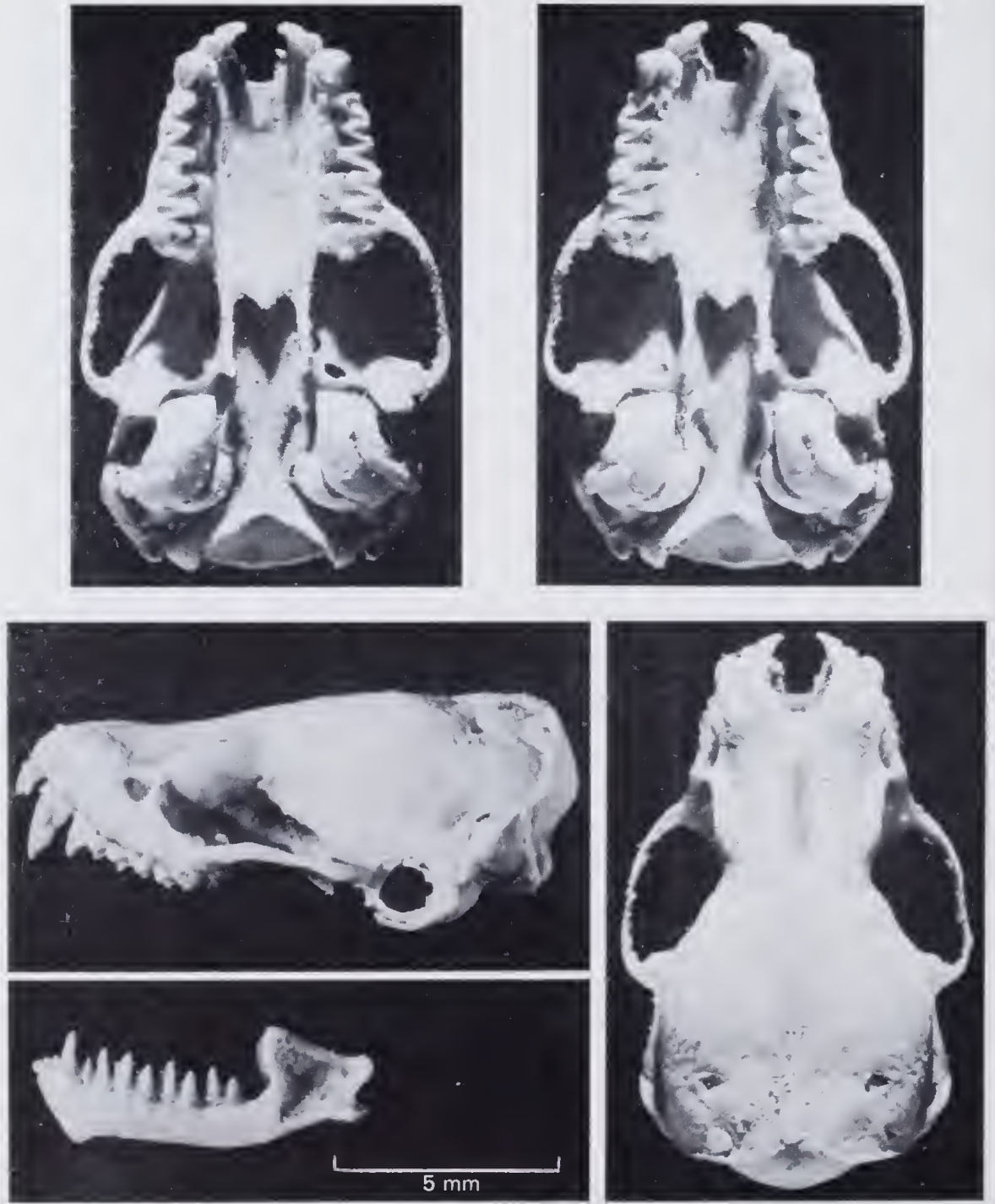
Figure 15   Skull and dentary of *Eptesicus vulturnus* (EBU E34). The ventral view are stereo-pairs. Scale line 5 mm.

Fuscous Black; humerus with very sparse hairs on proximal half, Buffy Brown; femur with extremely sparse hairs half-way to knee, Light Drab; ear with basal one-third haired, Bone Brown; uropatagium covered with extremely sparse hairs, Light Drab; plagiopatagium with very sparse hairs to 5 mm from side of body, Buffy Brown. Skin of lips Olive Brown; ear Clove Brown; radius and patagia Fuscous Black or Buffy Brown.

Penis (Figure 4)

Short hairs 1.5 mm long on preputium; attachment of preputial skin to glans shaft behind head *ca.* 2.3 mm from distal end; glans club shaped; urethral opening at anteroventral aspect of glans, opening covered by a spatulate lobe rising from either side of the mid ventral edge of this opening; dorsal and ventral surface of head with shallow median longitudinal groove.

Baculum (Figure 5)

Long 4.39 ± 0.129 (SD)(N=10), dorsal outline a rod shaped shaft with moderately expanded base 0.87 ± 0.048 (SD)(N=10), deeply bifurcated to 25 per cent greatest length; in lateral profile base little deflected ventrally, distal 10 per cent sharply deflected ventrally.

Distribution

The Great Dividing Range of eastern Australia and associated escarpments south of latitude 30°S and Tasmania. In temperate mixed woodland and wet and dry schlerophyll forest (Figure 7h).

Specimens examined

BMNH 7.1.1.375 (holotype).

Tasmania: Maracoopa Caves Reserve (41°33'S, 146°15'E) 2 ♂, EBU (E6, E13); Mt Field National Park (42°40'S, 146°30'E) 2 ♂, EBU (E31, E34); Risdon Vale (42°50'S, 147°20'E) 1 ♀, 1 ♂, EBUE17-8; 12 km W Scottsdale (41°20'S, 147°20'E) 1 ♀, 2 ♂, EBU (E42, E50-1).

New South Wales: Armidale (30°54'S, 151°08'E) 1 ♀, AM10604; Bulahdelah (32°25'S, 152°12'E) 1 ♀, AM7191; Cooranbong (33°05'S, 151°27'E) 1 ♀, AM11460; Glenbrook (33° 46'S, 150°37'E) 1 ♂, AM5265; Griffith (34°17'S, 146°03'E) 3 ♂, AM11796-8; Mumbulla State Forest (36°33'S, 149°52'E) 1 ♂, AM12772; Muswellbrook (32°16'S, 150°54'E) 3 ♀, 1 ♂, AM11164-67; Pilliga (30°21'S, 148°53'E) 2 ♀, 1 ♂, AM12522-4; 13 km W Coonabarrabran (31°16'S, 149°10'E) 2 ♂, AM10314, EBUB360; Willandra National Park (33°29'S, 145°32'E) 1 ♀, AM10822.

Australian Capital Territory: Canberra (35°17'S, 149°13'E) 1 ♂, CM10030.

South Australia: Big Heath Conservation Park (37°10'S, 140°36'E) 1 ♀, EBUFBH5.

Victoria: Gembrook State Forest: (*ca.* 37°58'S, 145°35'E) 4 ♂, AM11869-71, AM11874.

Eptesicus baverstocki sp. nov.

Figures 4, 5, 7i, 16; Table 1

Holotype

WAM M17812; adult male; body in ethanol, skull separate, baculum removed (broken); from Yuinmery area, Western Australian Goldfields (28°28'30"S, 119°17'15"E) at altitude *ca.* 450 m; shot by R.A. How on 17 February 1980.

Paratypes
   See Specimens examined.

Diagnosis (mean values)

Eptesicus baverstocki differs from *E. pumilus*: dorsal inflation of cranium slight or absent rather than pronounced; anterior palatal emargination broader; post-palatal spine generally larger; posterior margin of palate terminates level with or slightly posterior to anterior edge of sphenorbital sinus rather than well posterior to it; basolateral pterygoid wing absent; anterolateral wing of ectotympanic closer to lateral edge of squamosal; manus digit III with phalanx III shorter relative to phalanx II (0.78 v. 0.87) and phalanx II longer relative to phalanx I (0.84 v. 0.77); glans penis funnel shaped rather than dorsoventrally compressed, ventral urethral lobe bilobed rather than arrow shaped; baculum longer (4.7 v. 1.6), dorsal outline rod shaped with slight lateral distal flanges and expanded base rather than arrow shaped.

It differs from *E. caurinus*: larger in most skull and dental measurements (Table 1); dorsal inflation of cranium absent or slight rather than moderate or pronounced; rostrum narrower anteriorly as indicated by anteorbital and RC^1-LC^1 widths relative to rostrum length (0.76 v. 0.84, 0.78 v. 0.80, respectively); anterior narial and palatal emarginations broader and deeper; posterior margin of palate terminates level with or slightly posterior to anterior edge of sphenorbital sinus rather than well posterior to it; basolateral pterygoid wing absent; upper tooth row usually less curved; hypocone M^{1-2} larger; metacone-hypocone crista M^1 absent rather than moderate or large; manus digit III with phalanx III longer relative to phalanx II (v. 0.55) and phalanx II shorter relative to phalanx I (v. 0.95); glans penis distally funnel shaped rather than pointed, ventral urethral lobe bilobed rather than single; baculum longer (v. 2.0), lateral profile less curved, base less inclined ventrally and base deeply notched, distal end with slight lateral wings.

It differs from *E. douglasorum*: smaller in most skull, dental and external measurements (Table 1); dorsal inflation of cranium absent or slight rather than moderate or pronounced; anterior palatal emargination narrower; posterior margin of palate terminates level with or slightly posterior to anterior edge of sphenorbital sinus rather than well posterior to it; basolateral pterygoid wing absent; hypocone M^{1-2} larger; metacone-hypocone crista M^1 absent rather than moderate; manus digit III with phalanx III longer relative to phalanx II (v. 0.54) and phalanx II shorter relative to phalanx I (v. 1.04); glans penis funnel shaped rather than pointed distally, ventral urethral lobe bilobed rather than single; baculum longer (v. 3.2), lateral profile less curved, base more deeply notched, distal end with slight lateral wings.

It differs from *E. finlaysoni*: smaller in most skull, dental and external measurements (Table 1); dorsal inflation of cranium absent or slight rather than slight to pronounced; anterior narial and palatal emarginations broader; posterior margin of palate terminates level with or slightly posterior to anterior edge of sphenorbital

sinus rather than well posterior to it; basolateral pterygoid wing absent; upper tooth row less curved; manus digit III with phalanx III longer relative to phalanx II (v. 0.54) and phalanx II shorter relative to phalanx I (v. 0.91); glans penis distally funnel shaped, ventral urethral lobe bilobed rather than single; baculum longer (v. 3.1), lateral profile less curved, base more deeply notched, distal end with slight lateral wings.

It differs from *E. darlingtoni*: smaller in all skull, dental and external measurements (Table 1); dorsal inflation of cranium absent or slight rather than slight or moderate; curve of anterior edge of orbit subcircular rather than oval; anterior narial emargination shallower, usually broader; posterior margin of palate terminates level with or slightly posterior to anterior edge of sphenorbital sinus rather than well posterior to it; basolateral pterygoid wing absent; manus digit III with phalanx III shorter relative to phalanx II (v. 0.92) and phalanx II longer relative to phalanx I (v. 0.74); glans penis funnel shaped rather than dorsoventrally compressed; baculum much longer (v. 1.7), dorsal outline rod shaped with expanded base and slight lateral distal wings rather than blunt arrow shaped.

It differs from *E. troughtoni*: smaller in most skull, dental and external measurements (Table 1); dorsal inflation of cranium absent or slight rather than moderate; basolateral pterygoid wing absent; posterior margin of palate terminates level with or slightly posterior to anterior edge of sphenorbital sinus rather than well posterior to it; upper tooth row less curved; manus digit III with phalanx III longer relative to phalanx II (v. 0.67); glans penis funnel shaped rather than laterally compressed; baculum shorter (v. 3.7), base less inclined ventrally.

It differs from *E. regulus*: smaller in most skull, dental and external measurements (Table 1); anterior narial and palatal emarginations usually shallower; posterior margin of palate terminates level with or slightly posterior to anterior edge of sphenorbital sinus rather than generally well posterior to it; glans penis with lateral urethral folds absent; baculum longer (v. 3.8), dorsal outline rod shaped with expanded base rather than elongate dart shaped, lateral profile curved rather than flat.

It differs from *E. vulturnus*: metacone-hypocone crista M^1 always absent rather than absent or slight; manus digit III with phalanx I shorter relative to metacarpal (0.36 v. 0.42); glans penis funnel shaped rather than bulbous, urethral opening ventral rather than terminal; baculum with wider less deeply notched base, distal end less inclined ventrally.

Description
Skull (Figure 16)

(see also 'General Description of Australian *Eptesicus*'). Greatest skull length moderately long 12.1 (11.6-12.5); cranial inflation absent (63 per cent) or slight (37 per cent); lambdoidal crest weak; anterior narial emargination usually narrow U-shape, occasionally broad U-shaped, terminates well anterior to (58 per cent) or close to (42 per cent) a line joining anterior edges of anteorbital foramina;
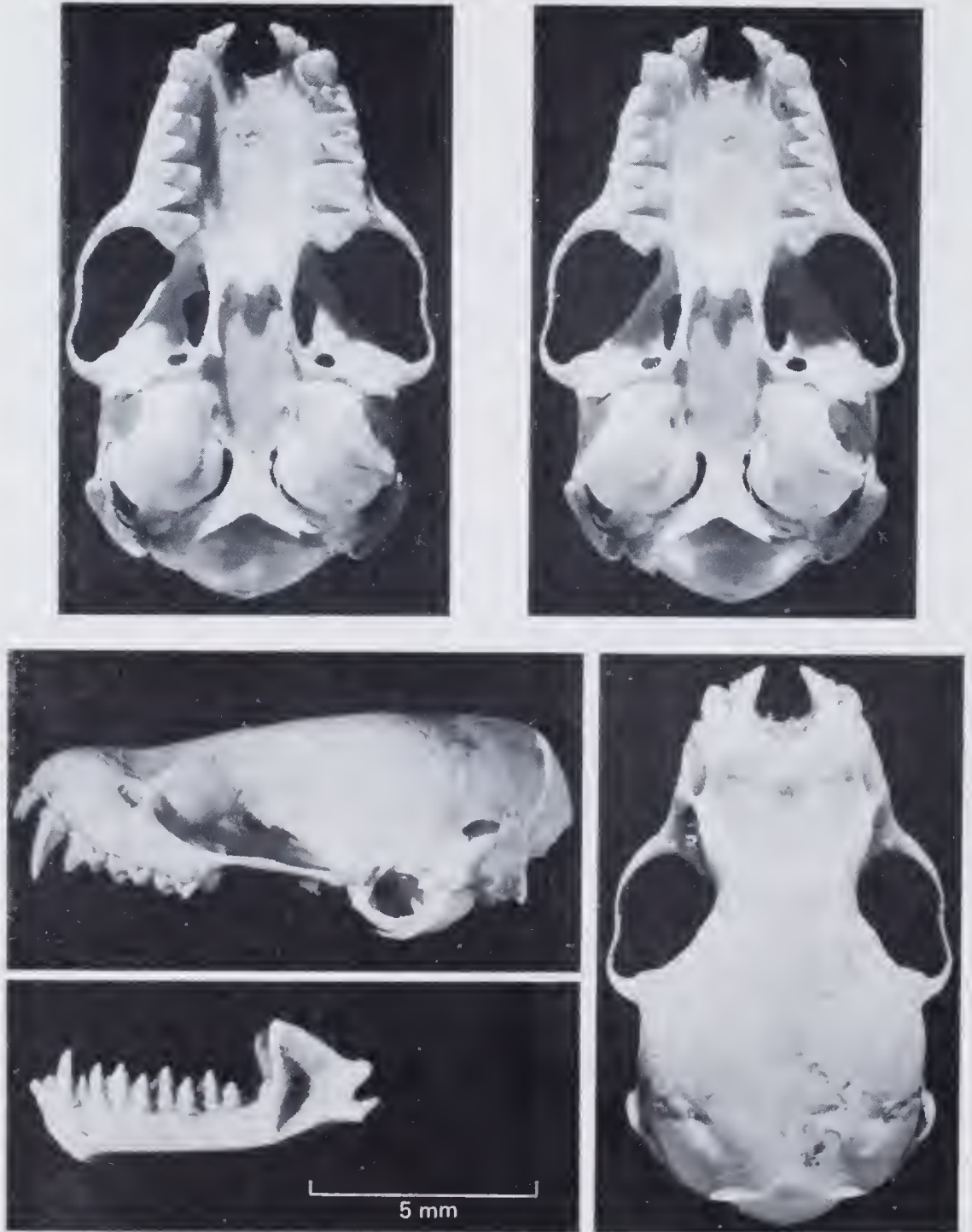
Figure 16 Skull and dentary of *Eptesicus baverstocki* (WAM M17812, holotype). The ventral view are stereopairs. Scale line 5 mm.

rostrum short, averages 48.5 per cent of basicranial length; least interorbital distance narrow, averages 31.1 per cent of basicranial length; anteorbital distance moderately wide, averages 76.0 per cent of rostrum length; inter upper third molar distance narrow, averages 48.5 per cent of basicranial length; lacrymal bar narrow or moderately wide; postpalatal spine narrow spatulate, moderately long; posterior margin of palate terminates level with or slightly posterior to anterior edge of sphenorbital sinus; basolateral pterygoid wing absent or very small, not extending to foramen rotundum.

Dentition

Crista linking base of metacone and hypocone on M^{1-2} absent.

Body size

Body length moderate 40.0 (36.0-43.5), much longer than tail 30.0 (26.5-33.8); relative wing measurements as follows: RL small 28.8 (26.7-31.4)$\geqslant$MCIII $>>$P1$>>$P2$>>$P3; tibia length small 11.8 (10.8-13.0).

Pelage and skin

Dorsal pelage moderately pale with pale ventral surface. Hair on top of head has distal half Drab and base Fuscous Black; on cheek Pale Smoke Gray; on face and chin Light Drab; on neck has distal one-third Drab Gray and base Fuscous Black; on dorsum between *ca.* 5.3-7.0 mm long, distal half Drab or Olive Brown and base Fuscous Black or Chaetura Black; on chest, venter (*ca.* 4.0 mm long) and side of body distal one-third Drab Gray and base Fuscous Black; anal region Drab Gray; humerus sparsely haired to elbow, Drab Gray; femur furred half way to knee, Drab Gray; ear haired to one-quarter length, Drab Gray; uropatagium very sparsely haired over much of area, Drab Gray; plagiopatagium very sparsely haired to 5 mm from side of body. Skin of lips Brussels Brown; ears and patagia Fuscous and radius Bister.

Penis (Figure 4)

Short hairs on preputium *ca.* 1.7 mm long; preputial skin attached to glans shaft *ca.* 2.3 mm from distal end of glans; glans head funnel shaped with moderately elevated median longitudinal ridge from distal tip to base of shaft, a low translucent semicircular lobe of skin projects from either side of the mid ventral distal rim of the funnel of the glans.

Baculum (Figure 5)

Longest *Eptesicus* baculum: 4.71 ± 0.183 (SD)(N=9); dorsal profile slightly arrow shaped with slight lateral distal wings, base wide 1.02 ± 0.083 (SD)(N=9) and moderately deeply bifurcated; in lateral profile base slightly expanded dorso-ventrally, shaft narrowing distally and gently arched ventrally.

Distribution

Widely distributed in inland arid parts of Australia in grasslands, savannah and shrub communities (Figure 7i).

Etymology

Named after Peter Raymond Baverstock, Head, Evolutionary Biology Unit, South Australian Museum, in recognition for his contribution to the understanding of the systematics of Australian mammals.

Specimens examined

Paratypes

New South Wales: Tarawi Stn (33°26'S, 141°07'E) 1 ♀, 1 ♂, EBU (B368, B369).

Northern Territory: Alcoota Stn (22°44'S, 134°24'E) 1 ♂, EBUB290.

Queensland: Babbiloora Stn (25°10'S, 147°19'E) 1 ♀, EBUB339.

South Australia: Nr Oraparrina (31°21'S, 138°37'E) 1 ♀, 2 ♂, EBU (SP105, SP107-8); Danggali Conservation Park (*ca.* 33°30'S, 140°42'E) 1 ♀, 8 ♂, EBU (D1, D2, D7, D10, D12, D17, D27, D23, E66); 25 km N Morgan (34°50'S, 139°42'E) 1 ♀, 1 ♂, EBU (SP62, SP65); North Mulga Stn (30°10'S, 139°40'E) 1 ♀, 1 ♂, EBU (B389, B390); 17 km S Oodnadatta (27°37'S, 135°34'E) 2 ♂, EBU B405-6.

Western Australia: Mt Elvire (29°30'30"S, 119°36'00"E) 1 ♀, WAM18293; White Quartz Dam (29°54'00"S, 121°15'05"E) 1 ♂, WAM17548.

Morphometric analyses: results and discussion

Univariate analyses

The means and standard deviations of the 39 skull and external measurements for the nine species are shown in Table 1.

The ANOVA revealed significant ($P<0.05$) sexual dimorphism in 23 of 39 measurements examined, with females larger in each of the 23 measurements. The 23 measurements consisted of 16 of the skull characters (GL, AOB, LW, ROL, ZW, MW, BW, PL, BL, BB, RC^1-LC^1, M^1-M^3, RM^3-LM^3, LR, DL, RC) and seven external measurements (HV, TV, EL, RL, MCIII, PI, PII).

The species-area combination were highly significant ($P<0.001$) for all characters and six of the 39 characters showed a siginificant ($P<0.05$) interaction between sex and species-area combinations. This indicates that the degree of sexual dimorphism may vary between species and area for the six characters (ZW, BL, BUL, C^1-M^3, M^1-M^3 and DL).

Phenetic analyses

Canonical variate analysis

Canonical variate analysis was used to examine the variation between 18 groups formed by separating the nine species by the sexes (Figure 17). All skull and external measurements were used in this analysis except for zygomatic width and tail length which were missing from many specimens. These two measurements have been omitted from all subsequent analyses. This analysis showed that the differences in group means for males and females were less than differences between species. As a result the sexes were combined for subsequent analyses.

A canonical variate analysis was carried out on the nine species based on skull and external characters. The scatter of the individual samples about the first two

Table 2 Standardised and unstandardised (in brackets) coefficient for the skull and external characters for the first two canonical variates shown in Figure 18a.

CHARACTER	Variate I	Variate II	Variate III
GL	.119 (.351)	−.216 (− .637)	.149 (.441)
AOB	−.544 (−3.195)	−.087 (− .509)	− .156 (− .917)
LOW	.371 (2.595)	.360 (2.517)	− .122 (− .852)
LW	−.155 (− .787)	−.048 (− .243)	.110 (.558)
ROL	.215 (.963)	.008 (.035)	.081 (.365)
MW	.062 (.295)	−.204 (− .972)	.486 (2.312)
BW	.276 (1.412)	−.028 (− .146)	.017 (.088)
CH	−.336 (−2.058)	.594 (3.642)	.016 (.101)
LCH	.245 (1.350)	.028 (.155)	.098 (.539)
PL	.100 (.455)	.318 (1.455)	− .201 (− .917)
BL	.035 (.103)	−.086 (− .256)	.275 (.814)
PPW	.146 (1.220)	.232 (1.933)	− .167 (− 1.393)
BUL	.048 (.442)	.053 (.485)	− .080 (− .734)
BB	.257 (1.917)	−.098 (− .730)	.038 (.282)
OB	−.072 (− .396)	−.097 (− .533)	− .099 (− .545)
CW	.013 (.196)	−.263 (−3.926)	.058 (.870)
RC^1-LC^1	−.102 (− .609)	−.232 (−1.379)	.349 (2.075)
C^1-M^3	.277 (1.624)	.088 (.519)	− .190 (− 1.117)
M^1-M^3	−.065 (− .512)	.102 (.804)	.511 (4.017)
M^2 L	−.077 (−1.170)	.107 (1.617)	− .147 (− 2.217)
M^2 W	.083 (1.110)	−.121 (−1.616)	.093 (1.241)
M^3 W	−.007 (− .085)	.041 (.532)	.025 (.326)
RM^3-LM^3	−.218 (−1.173)	.418 (2.251)	− .249 (−1.341)
LR	.089 (.455)	.302 (1.549)	− .337 (−1.731)
DL	.495 (1.622)	−.698 (−2.287)	.373 (1.224)
RC	−.087 (− .717)	.193 (1.581)	− .426 (−3.492)
HV	.026 (.011)	−.114 (− .047)	− .177 (− .074)
EL	−.075 (− .106)	−.064 (− .091)	.057 (.081)
EW	.176 (.410)	−.155 (− .363)	.286 (.667)
TL	−.021 (− .386)	−.051 (− .092)	− .093 (− .169)
RL	−.332 (− .260)	.519 (.407)	.529 (.415)
MCIII	−.551 (− .442)	−.035 (− .028)	.404 (.323)
PI	.523 (.944)	.468 (.846)	−1.011 (− 1.826)
PII	−.829 (−1.332)	−.134 (− .215)	.046 (.073)
PIII	.414 (.713)	.143 (.247)	− .260 (− .447)
TIB	.029 (.045)	−.131 (− .208)	.064 (.102)
PL	.265 (.643)	−.019 (− .047)	.310 (.754)
CONSTANT	− 12.344	− 25.271	− 25.721

mean canonical variates indicates that *E. caurinus*, *E. finlaysoni* and *E. troughtoni* are clearly separated from the other species (Figure 18a). Table 2 shows the characters (PII, MCIII, AOB, PI, DL) which were important in the separation of the first canonical variate. The unbiased estimate of correct classification for the analysis was 91 per cent. The UPGMA cluster analysis of the Mahalanobis matrix arising from this analysis and the Minimum Spanning Tree analysis shows a similar separation to the canonical variate analysis (Figure 19a & b, respectively). These relationships were little altered by inclusion of the coded characters or from the size-free treatment.
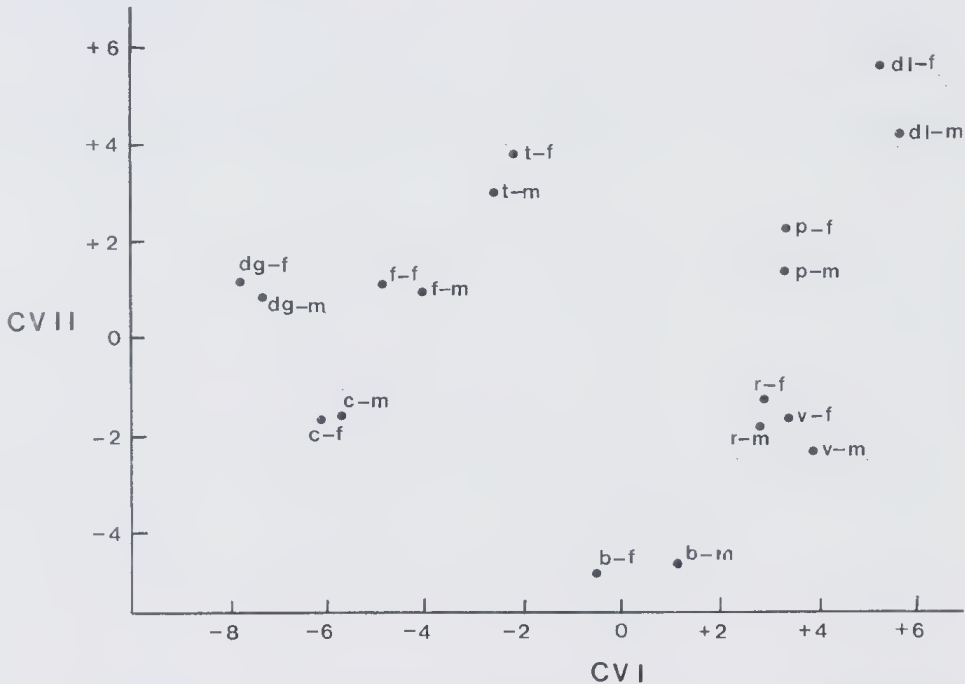
Figure 17   Canonical variate group mean values (●) using the first two variates for males (m) and females (f) of the ni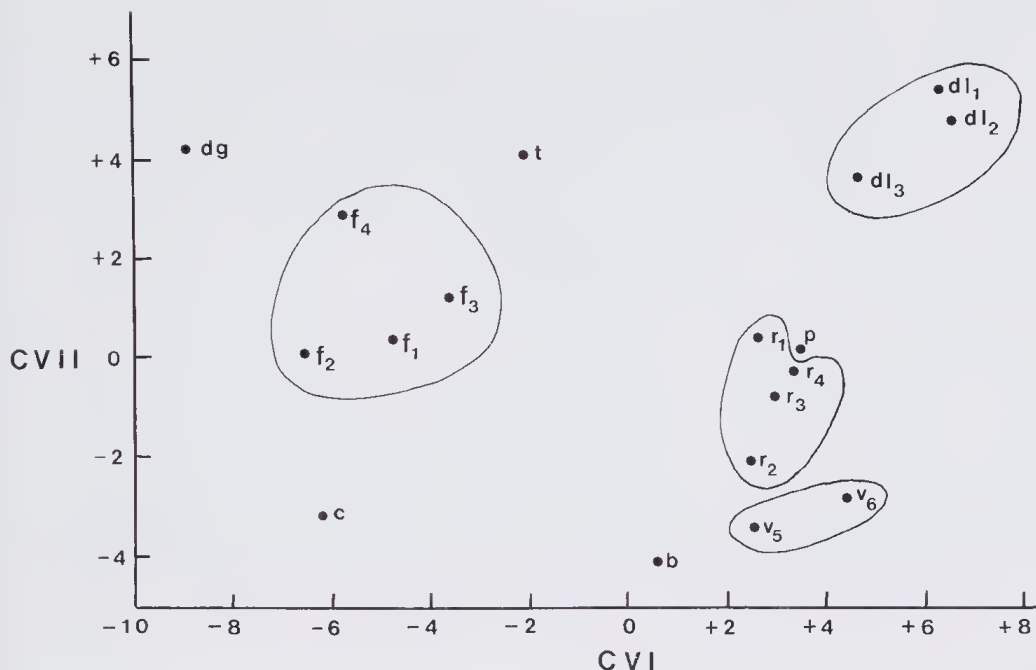ne species of *Eptesicus* using skull and external characters. *Eptesicus* species: p, *pumilus*; c, *caurinus*; dg, *douglasorum*; f, *finlaysoni*; dl, *darling-toni*; t, *troughtoni*; r, *regulus*; v, *vulturnus* and b, *baverstocki*.

The canonical variate analysis on the nine species was repeated for the external characters only and as expected the separation between species is reduced (Figure 18b) compared to the skull and external analysis. Table 3 shows the standardised and unstandardised canonical variate coefficients for this analysis.

To examine the effect of area on these analyses, species with more variable morphology were separated into geographical areas and the canonical variate analysis on the skull and external characters was again undertaken. In general, the mean canonical variates of species from different areas occur close to each other (Figure 20).
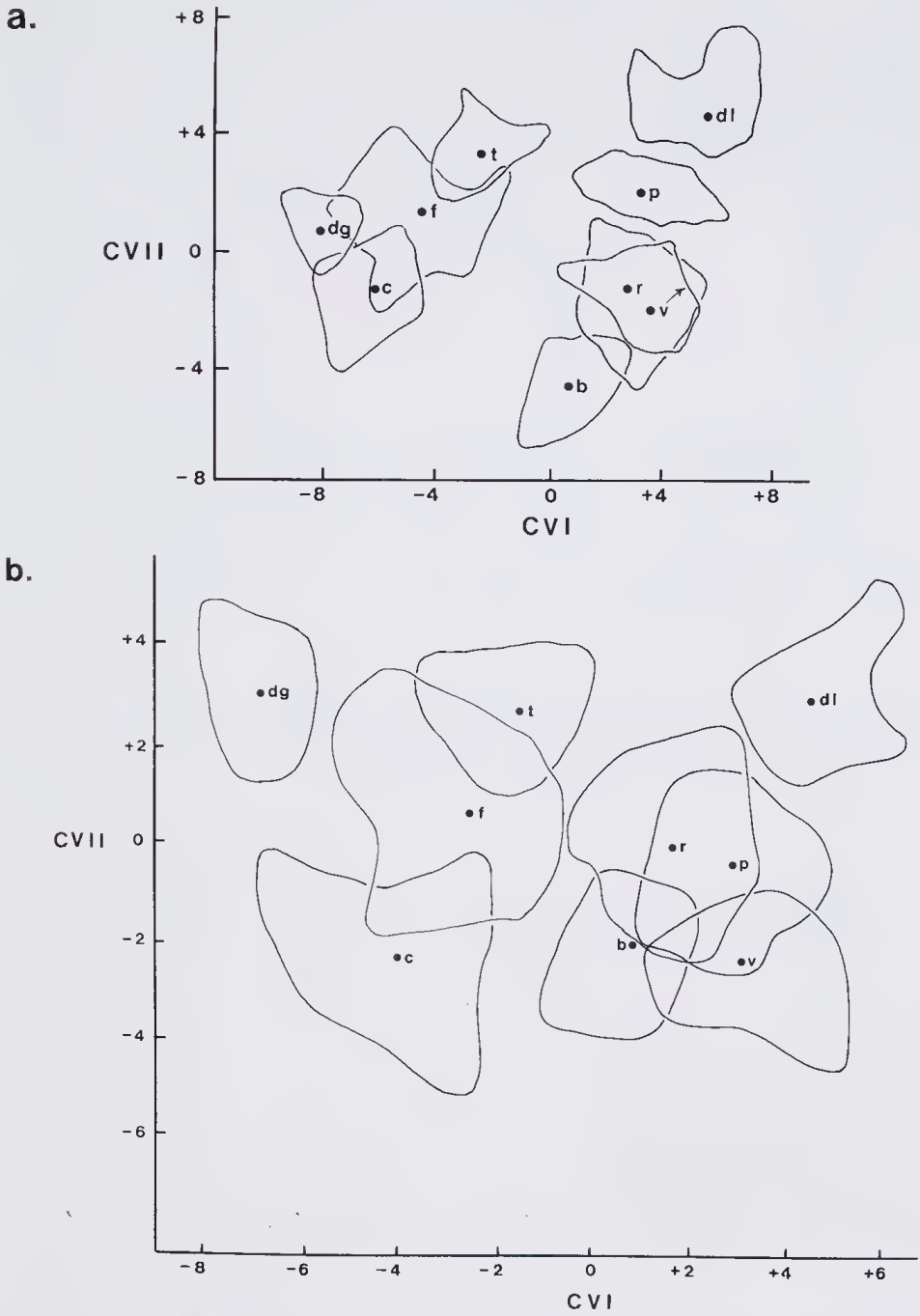
Figure 18   Canonical variate analyses on the nine species of *Eptesicus* (males and females combined) showing the scatter of individual samples about the first two mean canonical variates (●) for (a) skull plus external characters and (b) external characters only.
See Figure 17 caption for species code.

Table 3 Standardised and unstandardised (in brackets) canonical variate coefficients for the external characters for first two variates shown in Figure 18b.

CHARACTER	Variate I	Variate II
HV	.258 (.107)	−.122 (−.050)
EL	−.002 (− .003)	.045 (.063)
EW	.201 (.463)	.117 (.269)
TL	.033 (.060)	−.067 (−.119)
RL	−.187 (− .145)	.701 (.543)
MCIII	−.579 (− .456)	.313 (.247)
PI	.821 (1.466)	.024 (.042)
PII	−1.083 (−1.679)	−.079 (−.122)
PIII	.578 (1.002)	.149 (.258)
TIB	.164 (.253)	−.088 (−.136)
PL	.278 (.686)	.183 (.450)
CONSTANT	−4.202	−26.503
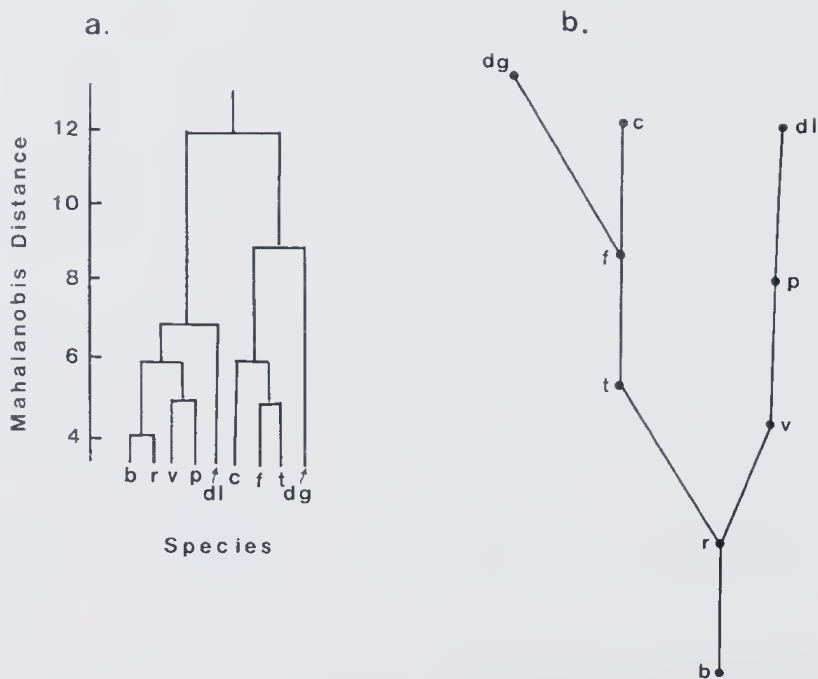
Figure 19 Phenetic relationships of the nine species of *Eptesicus* based on skull and external characters combined for males and females. (a) UPGMA cluster analysis, (b) Minimum Spanning Tree analysis. Species code is as for Figure 17.

Figure 20   Canonical variate group mean values (●) for the first two variates for males and females of the nine species of *Eptesicus* using skull plus external characters. After first separating the species with the more variable morphology *(finlaysoni, darlingtoni, regulus* and *vulturnus)* into broad geographic groups. See Figure 17 caption for species code. The species numerical subscript denotes the geographic areas which are listed on Figure 7.

To help discriminate the level of difference between *E. caurinus, E. finalysoni* and *E. troughtoni,* a canonical variate analysis of only these species was undertaken with the specimens of the widely distributed and variably sized *E. finlaysoni* separated into its four geographical areas (Figure 7d). This analysis, using the skull and external characters, shows a relatively clear separation of the species (Figure 21). Also, *E. finlaysoni* from area 4 (North West Coastal) is clearly separated from the specimens of *E. finlaysoni* from other areas. The characters which had the highest standardised canonical variate coefficients on the first canonical variate were GL (0.79), AOB (-0.68), LW (0.43), M^2 W (-0.41) and RL (-0.40), while the characters with largest coefficients on the second canonical variate were TIB (-0.86), LOW (0.75), PII (-0.72), RL (0.66) and LW (-0.57). The unbiased estimate of correct classification between the three species was 97 per cent confirming the separation evident in Figure 21.

A similar analysis was undertaken for *E. regulus, E. baverstocki* and *E. vulturnus* with the specimens of *E. regulus* and *E. vulturnus* separated by the areas they occurred in. Figure 22 shows a clear separation of the three species using the skull and external characters. The first canonical variate separates *E. vulturnus* from the other two species and has PI (1.76), MCIII (-0.86), LOW (0.83), LR (0.57) and
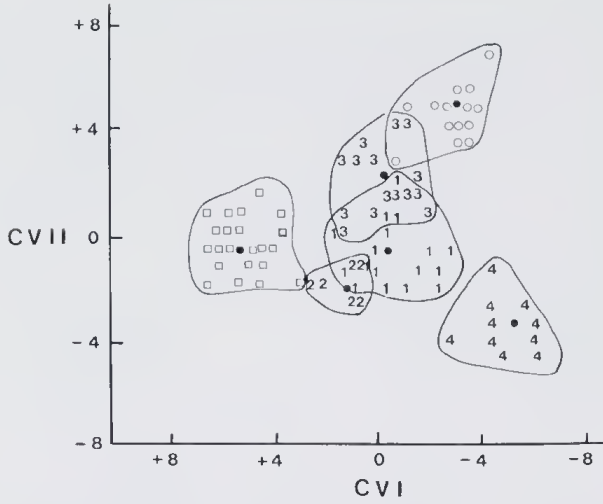
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Figure 21   Canonical variate values for the first two variates using skull plus external characters for males and females combined. □, *Eptesicus caurinus;* 1-4, *E. finlaysoni* and ○, *E. troughtoni. E. finlaysoni* geographic groups are 1, Central West; 2, Pilbara; 3, Central East and 4, North West Coastal — see Figure 7d. ●, group means.
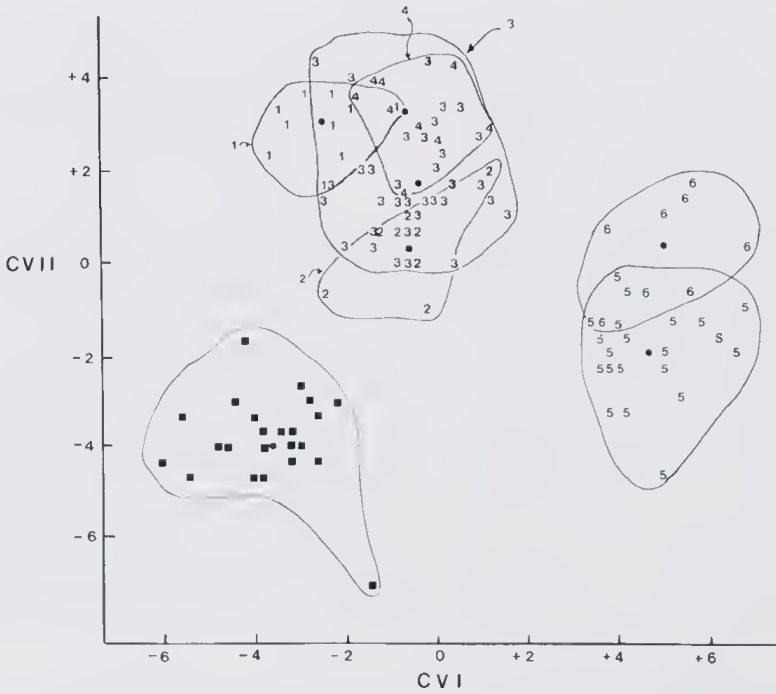

Figure 22   Canonical variate values for the first two variates using skull plus external characters for males and females combined. ■, *E. baverstocki;* 1-4, *E. regulus* and 5-6, *E. vulturnus. E. regulus* and *E. vulturnus* geographic groups are indicated on Figure 7g and h.

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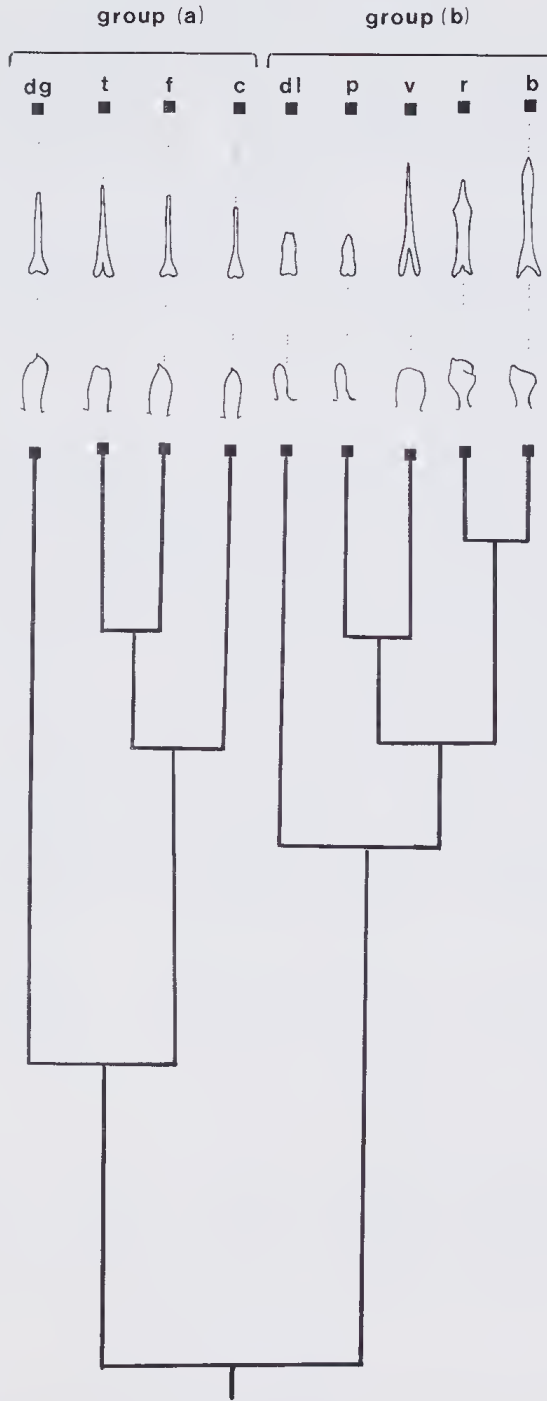
Figure 23   Phenetic relationship (see Figure 19a) of *Eptesicus* species and the outline of their associated baculum (upper row, dorsal view — see Figure 5) and glans penis (lateral view — see Figure 4).

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CH (-0.54) with the highest standardised coefficients. The second variate separates *E. regulus* from *E. baverstocki* with LOW (0.64), PII (-0.52), MW (0.50), C^1-M^3 (0.41) and LCH (0.39) having the highest coefficients. The unbiased estimate of correct classification between the three species was 98 per cent.

Discussion

Electrophoretic data are available for all species considered in this revision. These data which generally support the taxonomy proposed herein (M. Adams pers. comm.), will be published separately by our colleagues at the Evolutionary Biology Unit, South Australian Museum.

The taxonomy resulting from this study differs more from McKean *et al.* (1978) (the most recent revisers of *Eptesicus*) than may be immediately apparent. In addition to synonymising *E. sagittula* with *E. darlingtoni,* most, if not all, of the specimens which these authors attribute to *E. pumilus pumilus* are representative of *E. troughtoni.* Their more coastal specimens of *E. pumilus caurinus* represent *E. caurinus* – while the more inland specimens represent *E. finlaysoni.* Our concept of *E. vulturnus* and *E. regulus* is that of McKean *et al.* (1978).

The morphological variation in *E. finlaysoni,* as evidenced by the standard deviation values in Table 1, is much higher for most characters than is the case with other *Eptesicus* species. Grouping of specimens of *E. finlaysoni* into four broad geographic regions (Figure 7d) reduces considerably this variation within each region and attributes much of the overall variation in this species to the large North West Coastal form (see Figure 21). There may be future grounds for recognising this latter form as a distinct taxon but this consideration should not precede more extensive collection in areas intermediate between it and the Pilbara and Central West regions.

Individual *E. caurinus, E. finlaysoni* and *E. troughtoni* may on occasions be difficult to distinguish from each other. In these cases, measurements of skull and external characters enabled their classification with considerable confidence using the canonical variate analysis (Figure 21) – particularly when note is taken of the geographical area of the specimen. Similarly, the occasional difficult to identify specimens of *E. regulus, E. vulturnus* and *E. baverstocki* were correctly classified using the canonical variate analysis in Figure 22.

The phenetic analyses, using UPGMA and Minimum Spanning Tree procedures on continuous external and skull measurements are concordant in the relationships they show for the *Eptesicus* species. The UPGMA analyses more graphically shows the presence of two phenetic groups within *Eptesicus*. These are (a) *caurinus, finlaysoni, troughtoni* and *douglasorum* and (b) *baverstocki, regulus, vulturnus, pumilus* and *darlingtoni.* The integrity of these two phenetic groups are offered independent support by the morphology of the glans penis and baculum of these species (Figure 23). The four *Eptesicus* species in the phenetic group (a) all have a similar glans and baculum (*E. troughtoni* differs most but its glans and baculum

are clearly allied with group (a) rather than the other phenetic group). Within the phenetic group (b) there are three rather distinct glans and baculum types. That of *darlingtoni/pumilus, regulus/baverstocki* and *vulturnus*. The phenetic separation of *E. douglasorum* and *E. darlingtoni* within these two groups probably reflects their relative large size compared to the other species, although a 'size free' analysis did not alter these overall relationships.

These two *Eptesicus* phenetic groups relate to broad distribution patterns of the species. Those species with a northern distribution are members of the phenetic group (a) and those with a southern distribution are in group (b). Species with a wide inland distribution are in both groups (a) and (b).

Key to Australian *Eptesicus* species (measurements in mm)

1   Manus digit III with phalanx III: phalanx II length >0.75; distance between anteorbital foramina: rostrum length <0.78; anterior narial emargination deep or broad; basolateral pterygoid wing present or absent; baculum curved distally or flat in lateral profile; glans penis dorsoventrally compressed or not compressed 2

     Manus digit III with phalanx III: phalanx II length <0.75; distance between anteorbital foramina: rostrum length >0.78; anterior narial emargination narrow parabolic shape; basolateral pterygoid wing present; baculum bow shaped in lateral profile; glans penis laterally compressed 6

2   Manus digit III with phalanx III: phalanx II length generally >0.84; anterior narial emargination V-shaped; basolateral pterygoid wing present, partially conceals foramen rotundum; cranial height: basicranial length >0.42; baculum length <2 mm; glans penis dorsoventrally compressed 3

     Manus digit III with phalanx III: phalanx II length generally <0.84; anterior narial emargination broader, oval; basolateral pterygoid wing absent; cranial height: basicranial length <0.42; baculum length >3 mm; glans penis not dorsoventrally compressed 4

3   Radius length averages 34.6 (32.5-37.2); manus digit III with phalanx III: phalanx II length average 0.92; greatest skull length averages 13.4 (12.7-14.1); anterior narial emargination extends to (or almost to) a line joining anteorbital foramina; dorsal inflation of cranium slight to moderate; baculum distal end square. . . . . *E. darlingtoni*

     Radius length averages 30.6 (28.1-32.9); manus digit III with phalanx III: phalanx II length average 0.87; greatest skull length averages 12.1 (11.3-12.7); anterior narial emargination shallower, rarely extends to line joining anteorbital foramina; dorsal inflation of cranium pronounced; baculum distal end pointed . . . . *E. pumilus*

4   Manus digit III with phalanx I: metacarpal length >0.40 (averages 0.42); glans penis bulbous; baculum base notched to *ca.* 25 per cent its length. . . . . *E. vulturnus*

      Manus digit III with phalanx I: metacarpal length <0.40; glans penis not bulbous; baculum base notched <20 per cent its length 5

5   Posterior margin of palate terminates level with or slightly posterior to anterior edge of sphenorbital sinus. General size larger — greatest skull length averages 12.7 (11.9-13.4), radius length 31.2 (28.0-34.4); glans penis with large lateral urethral folds; baculum dart shaped . . . . *E. regulus*

      Posterior margin of palate terminates well posterior to the anterior edge of sphenorbital sinus; general size smaller — greatest skull length averages edge of (11.6-12.5), radius length 28.8 (26.7-31.4); glans penis funnel shaped, without lateral urethral folds; baculum narrow with broad base. . . . . *E. baverstocki*

6.   Radius length averages 29.5 (26.6-31.7);M^1 metacone-hypocone crista moderate or large; greatest skull length averages 11.2 (10.6-12.0); cranial height: basicranial length averages 0.47. Distribution does not include Pilbara region . . . . *E. caurinus*

      Radius length averages 34.6 (29.8-37.6) — only Pilbara *E. finlaysoni* <31.7; M^1 metacone-hypocone crista absent or slight to large 7

7   Manus digit III with phalanx I: metacarpal length <0.34 (averages 0.32); M^1 metacone-hypocone crista moderate; radius length averages 36.2 (34.3-37.6). . . . . *E. douglasorum*

      Manus digit III with phalanx I: metacarpal >0.34 (averages 0.37); M^1 metacone-hypocone crista usually absent, rarely slight to moderate 8

8   Radius shorter relative to tibia (Figure 10); glans penis distally pointed; baculum base notched to <10 per cent its length; M^1 metacone-hypocone crista always absent. . . . . *E. finlaysoni*

      Radius longer relative to tibia (Figure 10); glans penis not pointed; baculum base notched to *ca.* 25 per cent its length; M^1 metacone-hypocone crista absent to moderate . . . . *E. troughtoni*

Acknowledgements

Appendix

Measurement (in mm) of relevant type specimens examined. See Figure 1 for description of characters. Preservation code: SS – skull and dry skin; SA – dry skull and body in alcohol.

Species Catalogue No., Type, Sex, Preservation	Eptesicus pumilus, BMNH 41.1523 (119c) lectotype. A ♂, SS	Eptesicus caurinus, BMNH 11.3.9.1.10473. holotype. A ♂, SA	Eptesicus douglasorum, WAM M34035c, holotype A ♂, SA	Eptesicus finlaysoni, WAM M22407, holotype A ♂, SA	Eptesicus darlingtoni, J5476, paratype, A ♀, SS	Eptesicus sagittula, CM22990, paratype. A ♂, SS	Eptesicus troughtoni, JM5412. holotype A ♂, SA	Eptesicus regulus, BMNH 6.8.1.18, lectotype A ? sex, skull only	Eptesicus vulturnus, BMNH 7.11.375, holotype, A ♀, SS	Eptesicus baverstocki, WAM M178l2. holotype. A ♂, SA
GL	–	11.1	12.6	11.4	13.2	13.2	12.8	12.5	12.5	12.2
AOB	*3.9-4.2	3.8	4.3	3.9	4.2	4.1	4.4	3.9	4.0	3.7
LOW	3.5	3.1	3.4	3.3	3.8	4.1	3.6	3.4	3.6	3.2
LW	4.5	4.3	5.5	4.9	5.5	5.3	5.6	4.6	4.8	4.8
ROL	5.0	4.3	5.2	4.9	5.3	5.7	5.4	5.0	5.2	5.2
ZW	–	7.1	8.4	7.5	–	8.3	8.2	7.8	8.2	7.8
MW	–	6.3	–	6.7	7.8	7.6	7.4	7.2	7.4	6.9
BW	–	5.8	6.1	5.7	6.6	6.7	6.3	6.4	6.8	6.2
CH	–	4.4	4.9	4.5	4.8	5.0	4.8	4.7	4.2	4.4
LCH	–	4.5	2.2	4.8	2.2	2.2	2.3	2.1	2.4	2.0
PL	–	5.0	5.9	5.2	6.0	5.9	6.1	5.6	5.8	5.5
BL	–	9.3	10.7	9.8	11.0	11.2	10.9	10.7	10.5	10.4
PPW	–	4.4	4.5	4.6	4.8	4.9	4.6	4.5	4.7	4.4
BUL	–	2.7	2.7	2.6	3.0	3.1	2.9	–	2.8	2.7
BB	–	1.0	1.1	0.9	1.3	1.1	1.2	1.2	1.3	1.1
OB	–	5.8	6.4	–	7.3	7.0	6.5	6.5	6.7	6.3
CW	0.9	0.8	0.8	0.7	0.7	0.7	0.8	1.0	0.9	0.7
RC^1-LC^1	3.7	3.4	3.9	3.7	4.0	3.9	4.3	3.7	3.8	3.7
C^1-M^3	4.3	3.9	4.6	4.1	4.8	4.9	4.6	4.7	4.6	4.2
M^1-M^3	2.8	2.7	3.1	2.8	3.2	3.3	3.1	3.2	3.1	2.9
M^{2}L	1.1	1.1	1.2	1.0	1.3	1.3	1.1	1.4	1.2	1.4
M^{2}W	1.2	1.2	1.3	1.2	1.4	1.4	1.4	1.4	1.4	1.2
M^{3}W	1.3	1.2	1.2	1.2	1.3	1.4	1.3	1.4	1.4	1.2
RM^3-LM^3	5.0	4.7	5.3	5.2	5.6	5.5	5.5	4.3	5.4	4.9
LR	5.4	4.9	5.6	5.0	5.9	5.9	5.8	5.8	5.8	5.0
DL	8.5	8.0	9.4	8.0	9.4	9.7	9.3	8.9	9.0	8.2
RC	2.5	2.4	2.8	2.3	2.6	2.7	2.6	2.5	2.7	2.3
HV	–	36.5	39.6	36.0	–	–	41.6	–	–	37.5
TV	–	24.4	37.1	33.6	–	–	32.9	–	–	27.4
EL	–	9.5	11.6	11.6	–	–	12.4	–	–	9.8
EW	–	6.5	8.4	7.8	–	–	8.2	–	–	8.7
TL	–	4.4	6.4	4.9	–	–	6.2	–	–	4.6
RL	29.7	29.5	36.4	31.3	36.3	33.7	35.1	–	32.8	27.3
MCIII	30.3	27.6	36.3	30.6	34.5	33.6	34.6	–	31.1	27.6
PI	10.9	10.4	11.4	11.3	13.5	12.4	13.2	–	10.7	10.2
PII	9.4	10.0	11.9	9.5	10.3	9.7	11.2	–	8.2	9.3
PIII	–	5.9	6.5	6.7	–	–	7.8	–	6.0	6.6
TIB	12.8	11.2	14.4	12.9	–	–	14.2	–	12.6	11.3
PL	5.2	4.3	6.4	4.4	–	–	5.7	–	–	4.7

* 2 small left anteorbital foramina

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Upper Devonian conodonts associated with a large placoderm fish skull from the Canning Basin, Western Australia

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Abstract

Conodonts retrieved from limestone encasing the skull of a large placoderm fish, from an unknown location in the south-eastern Canning Basin, indicate an age of mid-Famennian (toIIB) because of the concurrent presence of the following taxa: *Nothognathella palmatiformis, Nothognathella* sp. nov. A. Druce 1976, *Palmatolepis glabra pectinata, P. quadrantinodosa inflexa, P. quadrantinodosa inflexoidea, P. marginifera* s.s., *Polygnathus triphyllatus, P. glaber* s.s. and *P. germanus* s.s. The assemblage represents a palmatolepid-polygnathid biofacies dominated by palmatolepids, and is typical of muddy outer shelf to sandy inner shelf environments. The occurrence of certain taxa which have only been previously recorded in the Canning Basin from the Virgin Hills Formation, together with the lithology of the specimen, and palaeoecological information afforded by the conodonts, suggests that the specimen was derived from the uppermost section of the Virgin Hills Formation.

Introduction

A large dinichthyid placoderm fish skull has recently been described as a new genus, *Westralichthys* Long (1987) even though the exact location and lithological source of the specimen is unknown. A limited conodont fauna of 76 elements was recovered from dilute acetic acid preparation of the dinichthyid skull. The fauna contains a number of age diagnostic species which have been used to narrow the possible age and stratigraphic source of the specimen. It is significant that the conodonts indicate a much younger age for the skull than the well known lower Frasnian Gogo fish fauna (Gardiner and Miles 1975), also from the same region.

The conodont faunas from the Canning Basin have been extensively described by Glenister and Klapper (1966), Druce (1976) and Nicoll and Druce (1979), with reviews of previous work found in the latter two publications. Revisions of some of Druce's (1976) identifications by Ziegler (1977, 1981) are here included. Age ranges quoted here for taxa are from Druce (1976). For brevity I include here additional comments only where a species or subspecies name has been changed since the last record of that taxon from the Canning Basin was published; or in the event that a particularly important age-diagnostic form may be of contentious identification or differs somewhat from the previously figured examples of that species.

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Systematics

Acodina cf. A. "sp. nov. A." Druce 1976 p. 50

Material
3 specimens (UWA 101712 figured, Figure 1-C).

Age range
toIIa-toIV (subzones 13-22)

Hindeodella corpulenta Branson and Mehl, 1934

Material
1 specimen, UWA 101687 (Figure 1-B).

Age range
toIa-toIV (subzones 3-22).

Hindeodella subtilis Ulrich and Bassler, 1926

Material
10 specimens (UWA 101706 figured, Figure 1-E).

Age range
Throughout the section.

Hindeodella sp.

Material
1 specimen (UWA 101708, Figure 1-G).

Remarks
The specimen differs from the other species of *Hindeodella* previously illustrated from the Canning Basin in having a very inclined apical denticle, three moderate-sized denticles separated by two small denticles anterior to the apical denticle, and the posterior region of the bar (as preserved) has small denticles of uniform size, each about one-third as large as the apical denticle.

Ligodina sp.

Material
1 specimen (UWA 101728, Figure 1-D).

Remarks
The specimen most closely resembles *Ligonodina* sp. figured by Druce (1976, pl. 39-2), but differs in having a longer posterior bar with relatively smaller denticles at its posterior end.

Neoprioniodus armatus-alatus group

Material
1 specimen (UWA 101732, Figure 1-1).

Remarks

The specimen has affinities to the *N. alatus* end of the species group which Druce (1976, p. 127) found to be a continuum of morphotypes between the two species in the Canning Basin samples. It has a massive apical denticle with six small denticles, but differs from *N. alatus* in being strongly arched through a right angle, and with a longer anterior bar. The apical denticle extends over the point of arch inflexion.

Age range
Throughout the section (Druce 1976).

Nothognathella palmatiformis Druce, 1976

Material
2 specimens (UWA 101696, 101735; Figure 1-L, M, N).

Age range
Middle toIIa-toIIIB (subzones 14-10).

Nothognathella sp. nov. A Druce, 1976

Material
1 specimen (UWA 101733, Figure 1-J).

Remarks

The specimen closely resembles *Nothognathella* sp. nov. A figured by Druce (1976, pl. 43-5) but difffers from the two illustrated examples in having a slightly longer posterior bar relative to the anterior bar, and in the apical denticle being proportionately larger than the anterior bar denticles.

Age range
Upper toIIB only (subzone 17).

Ozarkodina immersa (Hinde, 1879)

Material
1 specimen (UWA 101737, Figure 1-F).

Age range
Throughout the section (Druce 1976).

Ozarkodina macra Branson and Mehl, 1934

Material
1 specimen (UWA 101690, Figure 1-H).

Age range
Throughout the section (Druce 1976).
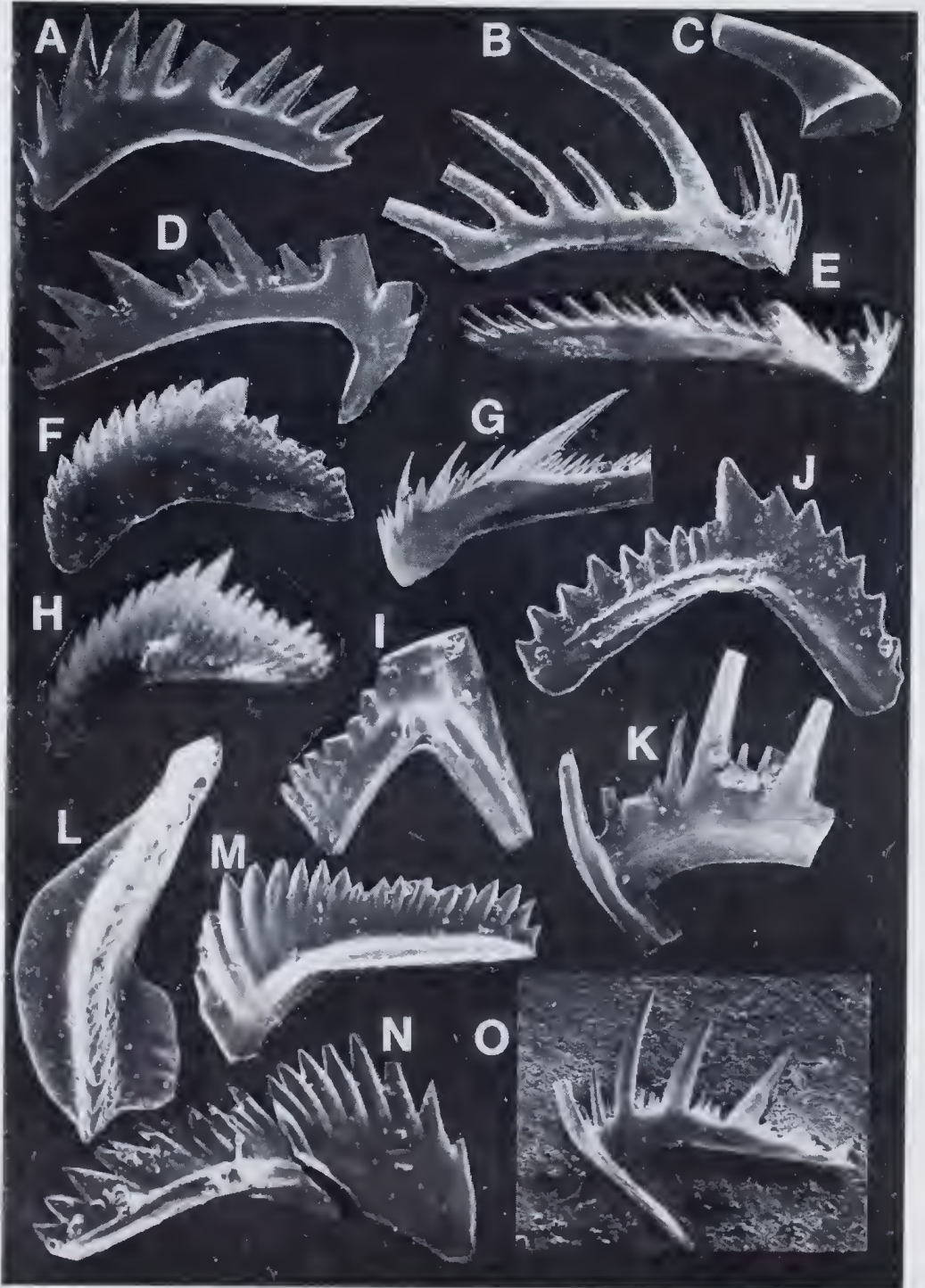
cf. *Ozarkodina? lacera* Helms, 1959

Material
   1 specimen (not figured).

Age range
   toIIB-toIIIB (subzones 17-20).

Ozarkodina sp.

Material
   1 specimen (UWA 101729, Figure 1-A).

Remarks

The specimen is somewhat similar to *Ozarkodina* sp. nov. A Druce 1976 in having relatively large, free needle-like denticles. It differs in being less strongly arched, in having five anterior denticles and four posterior denticles, and in having very small denticles situated between each of the large posterior denticles and between the apical denticle and the last anterior bar denticle. *Ozarkodina* sp. nov. A Druce 1976 comes from the Middle *Polygnathus asymmetricus* zone, which would be much older than the horizon this specimen came from.

Palmatolepis glabra pectinata Ziegler, 1962

Material
   Approx. 16 specimens (UWA 101694, 101714 figured, Figure 2-A, B, F, G).

Remarks

The specimens are easily recognised by comparison with those figured by Glenister and Klapper (1966), Druce (1969, 1976) and Ziegler (1977). The specimens most closely match the morphotype from the toIIB zone illustrated by Glenister and Klapper (1966, fig. 3) in which the parapet meets the blade at a right angle and is generally not denticulate, instead being composed of a smooth ridge with two or three low pinnacles.

Age range
   toIIB-toIIIB (subzones 16-20).

◀ Figure 1   A, *Ozarkodina* sp., (UWA 101729, X47). B, *Hindeodella corpulenta* Branson and Mehl, 1934 (UWA 101687, X33). C, *Acodina* sp. nov. A, Druce 1976 (UWA 101712, X37). D, *Ligonodina* sp. (UWA 101728, X40). E, *Hindeodella subtilis* Ulrich and Bassler, 1926 (UWA 101706, X43). F, *Ozarkodina immersa* (Hinde, 1879), (UWA 101737, X45). G, *Hindeodella* sp. (UWA 101708, X80). H, *Ozarkodina macra* Branson and Mehl, 19343 (UWA 101690, X34). I, *Neoprioniodus armatus-alatus* group (UWA 101732, X37). J, *Nothognathella* sp. nov. A, Druce 1976 (UWA 101733, X37). K, O, *Prioniodina? smithi* (Stauffer, 1935), (K, UWA 101698, X58; O, UWA 101731, X50). L, M, N, *Nothognathella palmatiformis* Druce, 1976 (L, M, UWA 101735, X53; N, UWA 101696, X50).
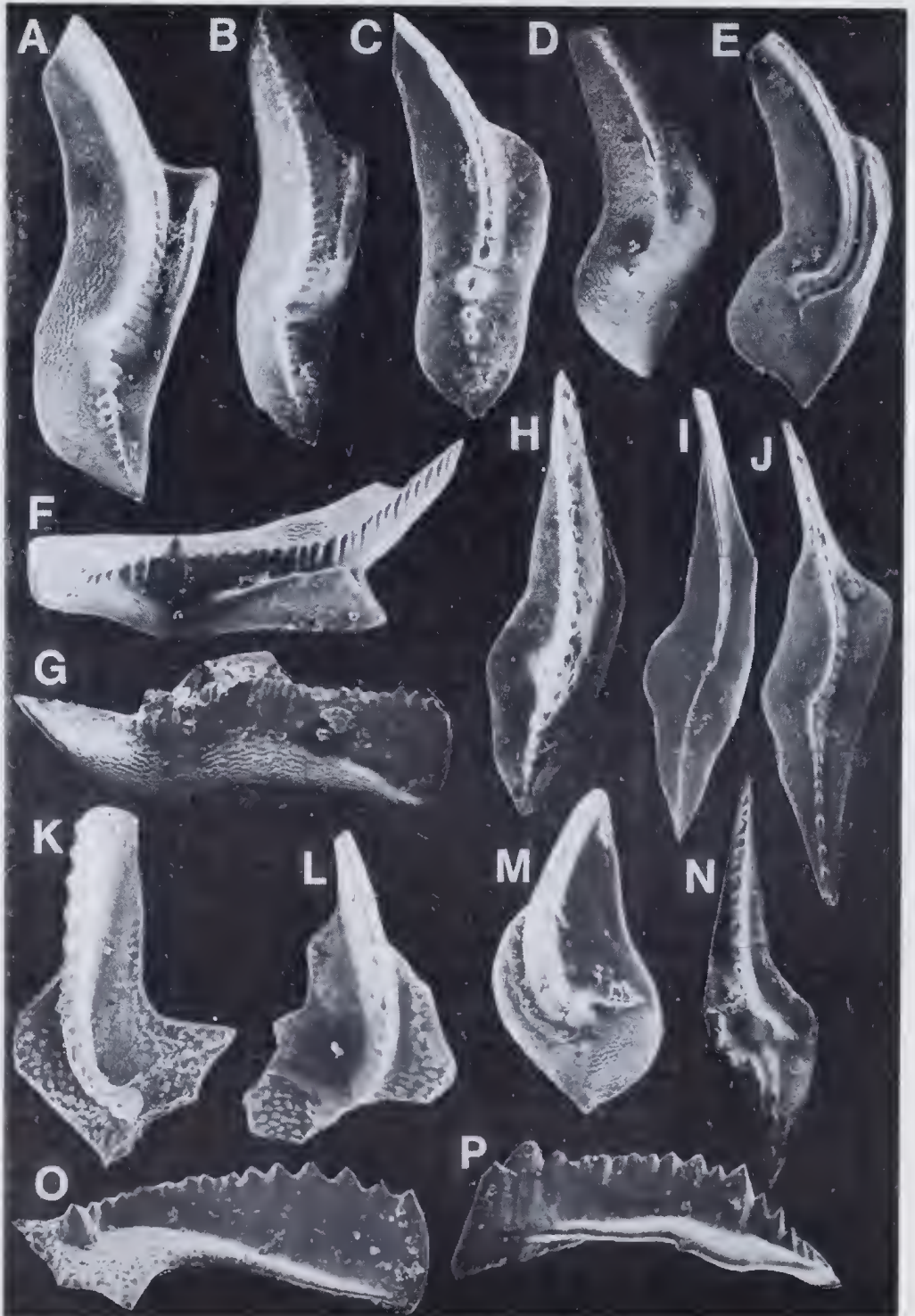
Palmatolepis marginifera marginifera Helms, 1959
Palmatolepis quadrantinodosa marginifera Druce, 1976, pl. 55, figs 1,3
Palmatolepis marginifera marginifera Ziegler, 1977, *Palmatolepis* plate 7,
figs 17-18, pl. 8, figs 1,2

Material
1 specimen (UWA 101725, Figure 2-E).

Remarks

The specimen is recognised by its broad platform with ridge like parapet on the outer platform, being distinguished from *P. quadrantinodosa* subspecies which bear nodes running parallel to the carina (Ziegler, 1977, p. 371).

Age range
toIIB-toIIIa (subzones 16-19).

Palmatolepis minuta minuta Branson and Mehl, 1934

Material
Approx. 9 specimens (UWA 101691, 101695 figured, Figure 2-H, J, N, P).

Remarks

The specimens studied here differ from typical *P. minuta* s.s. (Ziegler, 1981) in having a longer platform size relative to the length of the free blade, and in some specimens the central node may be slightly offset from the denticle row, almost approaching the condition seen in *Pa. minuta schleizia,* yet lacking the strong lateral lobe with raised margins. Druce (1976, pl. 67, 1) figured a similar form which he referred to *Pa. minuta schleizia,* which Ziegler (1981, p. 336) has placed back in *Pa. minuta* s.s The enormous range of variation exhibited by this common species is illustrated by Wolska (1967, fig. 13). One specimen (Figure 2-N) has an unusually long posterior carina and the outer platform margin is more lobed than other specimens, possibly representing a new subspecific variant.

Age range
toIIB-toIIIa (subzones 16-18).

◀ Figure 2   *Palmatolepis* species. A, B, F, G, *Palmatolepis glabra pectinata* Ziegler, 1962 (A, F, UWA 101714, X 57; B, G, UWA 101694, X60). C, D, *Palmatolepis quadrantinodosa inflexoidea* Ziegler, 1962 (C, UWA 101724, X41 D, UWA 101701, X35). E, *Palmatolepis marginifera marginifera* Helms, 1959 (UWA 101725, X31). H-J, N, P, *Palmatolepis minuta minuta* Branson and Mehl, 1934 (H, P, UWA 101691, X30; I, UWA 101695, X34; J, UWA 101736, X40; N, UWA 101692, X46). K, L, O, *Palma tolepis perlobata schindewolfi* Muller, 1956 (K, O, UWA 101723, KX32, OX36; L, UWA 101722, X27). M, *Palmatolepis quadrantinodosa inflexa* Muller, 1956 (UWA 101721, X30).

Figure 3   A, B, E, *Polygnathus triphyllatus* (Ziegler, 1960), (UWA 101700, A, E, X36, B, X33). C, D, F, G, K, *Polygnathus germanus germanus* Ulrich and Bassler, 1926 (C, G, UWA 101720, X43; D, UWA 101734, X40; F, K, UWA 101719, X42). H-J, *Polygnathus glaber glaber* Ulrich and Bassler, 1926 (H, I, UWA 101704, X 48; J, UWA 101740, X52). L, M, *Tripodellus robustus* Bischoff, 1957 (L, UWA 101726, X70; M, UWA 101727, X70).

Palmatolepis perlobata schindewolfi

Palmatolepis perlobata perlobata Glenister and Klapper, 1966, pl. 92,
figs 8, 13; pl. 93, figs 1-6
Palmatolepis perlobata perlobata Druce, 1976, pl. 67, figs 5 a-c
Palmatolepis perlobata schindewolfi Ziegler, 1977, *Palmatolepis* plate 11,
figs 1-7

Material
3 specimens (UWA 101722, 101723 figured, Figure 2-K, L, O).

Remarks
Although all three specimens are incomplete they are readily identified as this species by the strong inner lobe which forms almost a right angle on the outer margin, and development of a secondary crest on one specimen (as in Druce 1976, pl. 67, fig. 5b). The fine ornament indicates the subspecies variety (Ziegler 1977).

Age range
Middle toIIB-toV (subzones 17-23).

Palmatolepis quadrantinodosa inflexa Muller, 1956b

Palmatolepis quadrantinodosa cf. *marginifera* Glenister and Klapper, 1966,
pl. 91, figs 16-18
Palmatolepis quadrantinodosa inflexa Ziegler, 1977, *Palmatolepis*
pl. 12, figs 3-10

Material
1 specimen (UWA 101721, Figure 2-M).

Remarks
Druce (1976) did not find this subspecies in his study of the Canning Basin conodonts, yet Glenister and Klapper (1966) recorded two specimens both from the Virgin Hills Formation. All three known specimens from the Canning Basin are of the short oval morphotype illustrated by Ziegler (1977, Pa. plate 12, fig. 10).

Age range.
Worldwide: upper rhomboidea zone (subzone 16) — lower marginifera zone (subzone 17).

Palmatolepis quadrantinodosa inflexoidea Ziegler, 1962

Material
3 specimens (UWA 101701, 101724 figured, Figure 2-C, D).

Age range
toIIb (subzones 16, 17).

Polygnathus glaber glaber Ulrich and Bassler, 1926

Material
9 specimens (UWA 101703, 101704 figured, Figure 3 H-J).

Age range
toIIa-upper toIIB (subzones 14-17).

Polygnathus germanus germanus Ulrich and Bassler, 1926

Material

3 specimens, all figured (UWA 101719, 101920, 101734, Figure 3-C, D, F, G, K).

Age range

toIIa-toIIa (subzones 13-18).

Polygnathus triphyllatus (Ziegler, 1960)

Material

1 specimen (UWA 101700, Figure 3-A, B, E).

Remarks

The species is recognised by comparison with one specimen illustrated by Druce (1976, pl. 81-6) which has a broader platform with three or more rows of nodes as compared to the narrower platform types illustrated (e.g. Wolska, 1967, pl. 17-4; Druce (1976, pl. 81, 4-5). UWA 101700 is distinguished from *P. pennatuloidea*, of which one specimen is known from the Canning Basin (Glenister and Klapper, 1966, pl. 94-12, 13) by having a narrower basal cavity, the carina is not as strongly incurved, the platform is more elaborately ornamented, and meets the free blade at a deeper groove on the inner side, and also by the broader anterior end of the outer platform (from observation of UWA 35885).

Age range

toIIB (subzones 16-17). If this identification is incorrect the only other alternative is to assign the specimen to *P. pennatuloidea* Holmes, 1928, which also has a very narrow age range (lower to IIIa), although this would mean a slightly older occurrence if the age of this fauna, as deduced at the end of this paper (subzone 17), is correct.

Prioniodina? smithi (Stauffer, 1935)

Material

3 specimens (UWA 101698, 101731 figured, Figure I-K, O).

Age range

toId-toVI (subzones 14-21).

Scutula cf. *S. bipennata* Sanneman, 1955

Material

1 specimen (not figured, UWA 101707).

Age range

toIIB-toIIIB (subzones 16-20).

Tripodellus robustus Bischoff, 1957

Material

2 specimens (UWA 101726, 101727, Figure 3-L, M).

Age range

toIIIB-lower toIV (subzones 16-21).

Age and lithological source of the dinichthyid specimen

The dinichthyid specimen is determined as being of maximum age lower toIIB (rhomboidea zone) by the first entry in the Canning Basin conodont faunas of the following taxa: *Palmatolepis glabra pectinata, Pa. marginifera marginifera, Pa. quadrantinodosa inflexa, Pa. quadrantinodosa inflexoidea, Polygnathus triphyllatus* and *Tripodellus robustus*. The minimum age of the specimen is uppermost
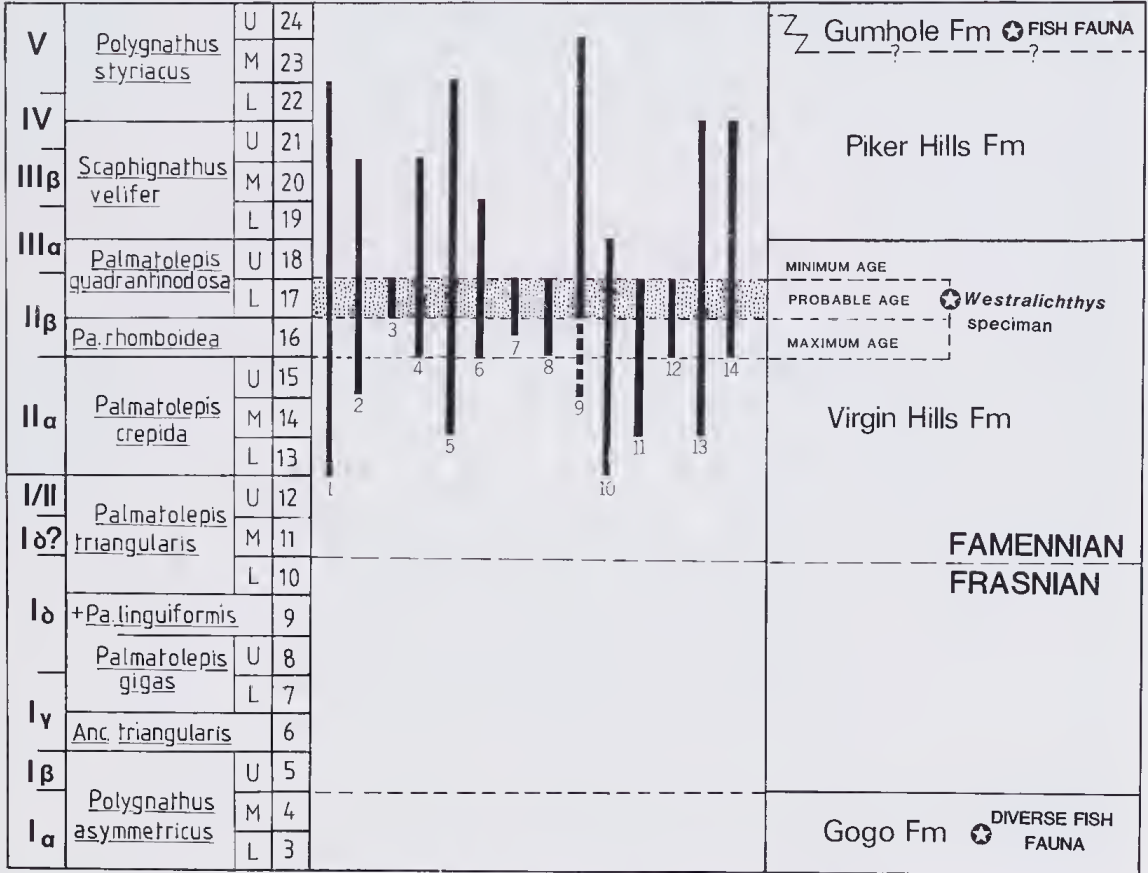

Figure 4   Age ranges of certain short-ranging conodont taxa found associated with the dinichthyid skull. Ages, ranges and subzones based on Druce (1976) for the Canning Basin only, except for *Palmatolepis quadrantinodosa inflexa* (7) which comes from Ziegler (1977) based on European occurrences. The Canning Basin formations representing basin facies are shown on the right with known fish faunas indicated by a star. 1, *Acodina* sp. nov. A, Druce 1976. 2, *Nothognathella palmatiformis* Druce, 1976. 3, *Nothognathella* sp. nov. A, Druce, 1976. 4, *Palmatolepis glabra pectinata* Ziegler, 1962. 5, *Pa. minuta minuta* Branson and Mehl 1934. 6, *Pa. marginifera marginifera* Helms, 1959. 7, *Pa. quadrantinodosa inflexa* Muller, 1956. 8, *Pa. quad. inflexoidea* Ziegler, 1962. 9, *Pa. perlobata schindewolfi* Muller, 1956. 10, *Polygnathus germanus germanus* Ulrich and Bassler, 1926. 11, *Pol. glaber glaber* Ulrich and Bassler, 1926. 12, *Pol. triphyllatus* (Ziegler, 1960). 13, *Prioniodina? smithi* (Stauffer, 1935). 14, *Tripodellus robustus* Bischoff, 1957.

toIIB (top of subzone 17) as indicated by the last appearance of the following taxa: *Nothognathella* sp. nov. A Druce 1976, *Palmatolepis quadrantinodosa inflexa*, *Pa. quadrantinodosa inflexoidea*, *Polygnathus glaber glaber* and *Pol. triphyllatus*. Further refinement of this range (from subzones 16-17 to only sub-zone 17; Figure 4) is indicated by the presence of *Nothognathella* sp. nov. A Druce 1976 which has only been recorded from the lower quadrantinodosa zone. The assemblage is typical of the lower marginifera zone of Ziegler and Sandberg (1984) in containing *Pa. marginifera* s.s. in association with *Pa. quadrantinodosa inflexa* and *Pa. quadrantinodosa inflexoidea*.

This conodont assemblage is typical of the palmatolepid-polygnathid biofacies (facies II, Sandberg and Dreesen 1984), although palmatolepids are distinctly dominant indicating a lean towards the deep water association (palmatolepid facies I, Sandberg and Dreesen 1984). The absence of *Icriodus* and *Peleksygnathus* in the sample corroborates this view. The depositional environment most favoured by this assemblage would be muddy outer shelf to sandier inner shelf.

The Virgin Hills Formation is the most likely source of the specimen, as suggested by Gilbert-Tomlinson (1968, p. 210), for three reasons. Firstly it agrees best with the lithology encasing the specimen in being a fine-grained carbonate with low fossil content, and in having tinges of orange colouring and deep red haematitic deposits on the bone surface (Playford and Lowry 1967). Secondly the conodont biofacies association and age determined from conodonts indicate that the source of the specimen was from basinal facies of mid Famennian (toIIB) age. Only the Virgin Hills Formation meets these two criteria. Finally several of the conodonts in the fauna have previously been found only from the Virgin Hills Formation (*Palmatolepis quadrantinodosa inflexoidea; Pa. perlobata* s.s., *Polygnathus triphyllatus, Pol. glaber glaber, Pol. germanus* s.s.). This indicates that they were either restricted in the Canning Basin to this facies, or that all of these forms recorded here represent new occurrences of these taxa from another formation. In conclusion it is most probable that the dinichthyid came from the lower *Palmatolepis quadrantinodosa* zone (subzone 17 of Druce 1976) in the upper section of the Virgin Hills Formation, south-eastern Canning Basin.

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A new dinichthyid fish (Placodermi: Arthrodira) from the Upper Devonian of Western Australia, with a discussion of dinichthyid interrelationships

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Abstract

A new dinichthyid arthrodire, *Westralichthys uwagedensis* gen. *et* sp. nov. is described from the Upper Devonian carbonates of the Canning Basin, Western Australia. Although the exact location of the specimen is unknown an associated conodont fauna indicates a mid-Famennian (toIIB) age, and suggests that the specimen may have come from the Virgin Hills Formation. *Westralichthys*, known from one incomplete skull roof, is characterised by having a skull roof pattern with a broad trapezoidal nuchal plate, weakly trilobate centrals and very elongated marginal and postorbital plates, whilst lacking dermal ornamentation. The visceral surface has massive nuchal and lateral thickenings, deep mesial pits on the paranuchals, and well developed ventral postocular processes. The braincase had a well developed supraorbital process. *Westralichthys* is regarded as more derived than *Eastmanosteus* and *Golshanichthys* in possessing elongated postorbitals, a broad nuchal plate, lacking dermal ornamentation and in having well developed inframarginal laminae, and is placed as the sister taxon to *Dunkleosteus* plus higher dinichthyids. Paedomorphosis may have played a role in the evolution of the dinichthyids from the Middle Devonian coccosteomorphs.

Introduction

Although fish fossils from the Upper Devonian reef complexes of the Kimberleys are well known from the Frasnian Gogo Formation (Gardiner and Miles 1975) reports of Famennian vertebrates are scarce. Radke and Druce (1979) refer to fish remains from the Late Famennian Gumhole Formation, including mention of large brachythoracid arthrodires. These remains, which are currently under study by Dr Gavin Young (Bureau of Mineral Resources, Canberra) are readily distinguished from the large dinichthyid skull described in this work by their coarse tubercular ornamentation. Aside from the Gumhole Formation fishes there have been recent discoveries of other Famennian vertebrates from the Canning and Bonaparte Basins which are under study by the author.

The large placoderm skull described herein was found inside the Geology Museum, at the University of Western Australia (henceforth UWA) in February 1986. The specimen had been allocated UWA number 32614, but no locality information was recorded. It had been collected in the late 1930s or early 1940s

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by Curt Teichert, and shortly after sent to Prof. Hills at Melbourne University for further study. Prof. Hills eventually returned the specimen to the UWA in 1973. Thus the specimen was overlooked by Mr Harry Toombs of the British Museum of Natural History who came to Western Australia in 1963 and recognised the scientific value of the Gogo fish material. Hills (1958 p. 90) cites Teichert (1949) and makes brief mention of the specimen as "a giant arthrodire of dinichthyid type from the *Cheiloceras* zone' . Teichert's paper lists assemblages of invertebrates and mentions fish remains in limestone concretions from the *Manticoceras* zone (Gogo Formation) and also from zone 2 (*Cheiloceras* zone; Teichert 1949, p. 17) but does not mention the spectacular dinichthyid skull. Gilbert-Tomlinson (1968, p. 210) mentions the dinichthyid skull from the *Cheiloceras* zone found by Teichert and states that it came from sediments then assigned to the Virgin Hills Formation. Unfortunately, despite recent correspondence, no further information could be obtained apart from "somewhere probably in the south-eastern part of the Canning Basin ' (Prof. Teichert, pers. comm.). The specimen is of scientific interest in being the first record of a large dinichthyid placoderm from Australia, and with an estimated size of up to 3 metres long, possibly the largest member of the Placodermi yet known from Australia. In addition the specimen indicates that further fish material might be obtained from younger horizons of the Upper Devonian reef complex in the Kimberley. Miles and Gardiner (1975) recorded *Eastmanosteus* sp., a medium-sized arthrodire intermediate in form between the coccosteids and the large dinichthyids, from the Gogo Formation. The phylogenetic position of this species and the new dinichthyid is discussed at the end of this paper.

During acetic acid preparation of the specimen samples of the residue were sieved and a conodont fauna extracted in order to determine the precise age of the specimen and its possible stratigraphic source (see Long 1987)). The skull was found in several pieces which were individually prepared from the rock resulting in some small gaps between the adjoining pieces in the reconstructed skull. As the skull had suffered some post-mortem damage prior to fossilisation the anterior margin, and the pineal-rostral plate region is missing. Despite this the visceral surface shows good preservation of important morphological features, and radiographs of the lateral sides of the roof have provided further details of suture patterns. Red iron oxides obscured much of the dorsal surface of the specimen necessitating removal of up to 1 mm of the external surface of the bone using a strip of sandpaper mounted to a drive belt. This enabled accurate determination of the plate boundaries and details of sensory-line canals.

Abbreviations used in figures

ant. po. pr	depression for anterior postorbital process of endocranium
ant. pr	antorbital process of endocranium
att. rhc	attachment area for rhinocapsular bone
att. SO	attachment area for suborbital plate
brl, 2	mesial grooves branching from saccular groove
CE	central plate
csl	central sensory line canal
cuc. f	cucullaris fossa
d. e	opening for endolymphatic duct
f. cuc	depression on skull roof for cucullaris muscles
font?	presumed orbitotemporal fontanelle
glf	glenoid fossa
gr. sac	groove in pre-endolymphatic thickening
ifo	infraorbital sensory-line canal
in. p	infranuchal pit
lam. im	inframarginal lamina
llc	main lateral line canal
MG	marginal plate
med. dep	median depression
med. nu. th	median nuchal thickening of endocranium
mes. p	mesial pit of paranuchal plate
mes. th	mesial thickening of endocranium
NU	nuchal plate
orb	orbit
P?	presumed pineal plate
pmc	posterolateral corner of headshield
PNU	paranuchal plate
pos. th	posterior thickening of supraorbital vault
ppl	posterior pit-line groove
pr. ant	antorbital process of endocranium
pr. art	para-articular process of paranuchal plate
pr. crs	craniospinal process of endocranium
PRO	preorbital plate
pr. p. a	anterior postorbital process of endocranium
pr. so	supraorbital process of endocranium
PTO	postorbital plate
pt. th	lateral postorbital thickening of skull roof
R?	presumed rostral plate
r	ridge
rhc	rhinocapsular bone
sac. th	thickening above sacculus on endocranium
soc	supraorbital sensory-line canal
suo. v	supraorbital vault
th. nu	nuchal thickening
th. pre	pre-endolymphatic thickening
v. po. pr	ventral postocular process

Systematics

Class Placodermi
Order Arthrodira Woodward 1891
Family Dinichthyidae Newberry 1885

Diagnosis

Moderate to large-sized pachyosteomorph arthrodires having powerful gnathal plates with prominent anterior cusps on the inferognathal and anterior superognathal, and anterior superognathal which is like an open ring when seen in dorsal view.

Remarks

The above diagnosis is taken from Lelievre *et al.* (1981) who discussed the relationships of the Dinichthyidae and determined the above synapomorphies defining the family as monophyletic. Denision (1978, p. 86) gave an expanded diagnosis of the family, but did not isolate synapomorphies, although in a later paper he discussed other specialised characters of the family (Denison 1984). *Westralichthys* is only known from the skull roof, and therefore does not show any of the characters of the gnathal plates listed above. However, in possessing a specialised lateral consolidated region on the visceral surface of the skull roof, large size and absence of tubercular ornament *Westralichthys* resembles *Dunkleosteus* and is provisionally placed within the family Dinichthyidae. The Dinichthyidae are presumably derived from Coccosteoidea (Denision 1975, 1978, 1984) by acquiring a specialised dentition with highly developed anterior cusps on the gnathal plates. It should be noted, however, that the group underwent a major secondary radiation in the Famennian, and many of the later species are known only from gnathal bones (Denison 1978). Some of the other specialised larger arthrodires of this time may be derived from the Dinichthyidae, but due to changes in feeding adaptations have lost the characteristic cusps on the gnathals (e.g. *Bungartius, Titanichthys, Dinomylostoma,* Denison 1978).

Westralichthys gen. nov.

Type species

Westralichthys uwagedensis sp. nov.

Diagnosis

An arthrodire with a skull roof length attaining at least 27 cm, and having an estimated breadth/length index of 122, and a moderately emarginate posterior margin; nuchal plate approximately trapezoidal, twice as broad as long and 43% as long as the mid-line length of the skull as preserved; centrals weakly trilobate with short posterior lobe; marginal and postorbital plates very long and narrow; postorbital plate being approximately half as long as skull roof. The visceral surface of the skull roof has massive nuchal thickenings which meet the paranuchal

plates to form deep mesial pits posterior to the pronounced pre-endolymphatic thickenings; lateral thickening of skull roof well developed into extensive infra-marginal lamina twice as long as the supraorbital vault, and with inframarginal crista present and mesial face having an embayment for the anterior postorbital process of endocranium; ventral postocular processes well developed. Supraorbital vault is 30% as broad as the transverse line through the postorbital corners of the skull roof. Endocranium with supraorbital processes developed. Dermal bones lacking ornamentation.

Westralichthys is distinguished from the primitive dinichthyids *Golshanichthys* and *Eastmanosteus* by its broader nuchal plate, lack of tubercular ornamentation, longer postorbital and marginal plates and by the massive thickenings and pits on the visceral surface of the skull roof. It is distinguished from *Dunkleosteus* by the trilobate centrals, broader skull roof, shape and relative size of the nuchal plate, and by the mesial pits of the visceral surface. The remaining dinichthyids for which the skull is known *(Hadrosteus; Gorgonichthys, Heintzichthys)* are readily distinguished from *Westralichthys* by their distinctive skull roof patterns, all featuring small triangular nuchal plates, and larger orbits. It is also noted that a supraorbital process on the endocranium is not developed for other dinichthyids (Stensio 1963, Dunkle and Bungart 1940, Lehman 1956).

The genus is named after the state of Western Australia and the Greek "ichthys", fish.

Westralichthys uwagedensis sp. nov.

Figures 1-9, 10C

A large dinichthyid from the *Cheiloceras* zone — Hills 1958: 90.

A dinichthid from the *Cheiloceras* zone — Gilbert-Tomlinson 1968: 210.

Holotype

WAM 86.9.664 (formerly UWA 32614), only specimen. South-eastern Canning Basin, Western Australia, probably Virgin Hills Formation, Late Devonian (Middle Famennian) age.

Diagnosis

As for genus.

Description

The specimen lacks the central and anterior regions of the skull roof (Figure 2), but is otherwise well preserved and has not undergone post-mortem compaction. The three-dimensional shape of the skull roof is clear. The anteriormost part of the left side of the specimen shows the recessed notches for the rhinocapsular bone and the antorbital process of the endocranium, indicating from comparison with most other arthrodires (e.g. Stensio 1963; Miles and Dennis 1979) that
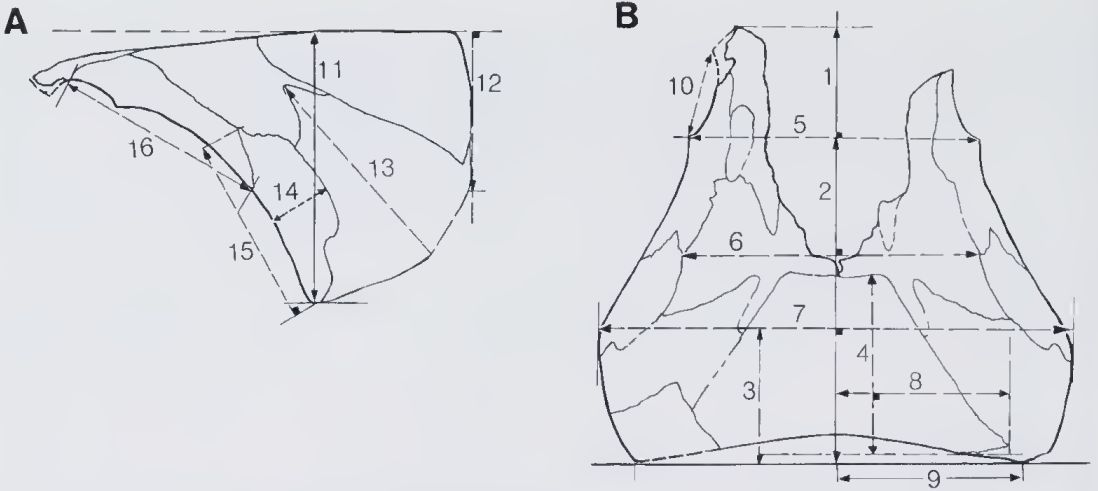
Figure 1   Measurements given in Table 1, taken on the holotype skull of *Westralichthys* gen. nov. A, lateral view. B, dorsal view.
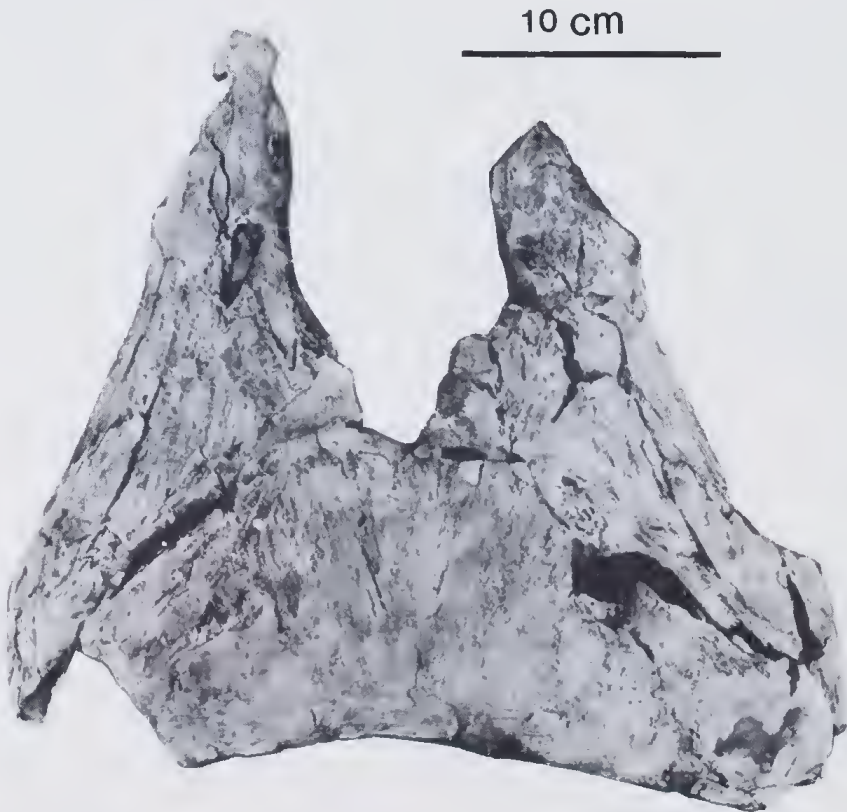

Figure 2   *Westralichthys uwagedensis* gen. *et* sp. nov., Late Devonian, Western Australia. Holotype. WAM 86-9-664, skull roof in dorsal view.

almost the entire length of the skull is preserved. The skull of *Golshanichthys asiatica* was found with a similar pattern of post-mortem damage (Lelievre *et al.* 1981). Measurements taken on the skull are shown in Figure 1 and listed with relevant proportional indices in Table 1. All proportional statements referred to in the diagnosis and description are based upon these measurements.

Table 1   Measurements and relevant proportions of *Westralichthys uwagedensis* gen. *et* sp. nov., holotype skull. All measurements (in mm) refer to points taken on Figure 1, measurements 1-10 refer to Figure 1-B, measurements 11-17 refer to Figure 1-A.

1.	midline length of skull as preserved	270
2.	midline length to postorbital corners	205
3.	length to postmarginial corners	90
4.	length of nuchal plate	115
5.	breadth across postorbital corners	173
6.	breadth across middle of central plates	177
7.	breadth of skull (postmarginial corners)	330
8.	half nuchal plate breadth	115
9.	half breadth of skull to glenoid fossa	140
10.	orbital diameter (from inside vault)	56
11.	depth of skull (postmarginial corner)	155
12.	depth to glenoid fossa	80
13.	greatest dimension of paranuchal plate	170
14.	greatest breadth of marginal plate	37
15.	maximum length of marginal plate	133
16.	maximum length of postorbital plate	152
17.	approximate length of obstantic margin	90-100

Some relevant proportions (indices multiplied by 100).

A. skull breadth/length index = 122 (as preserved).
B. nuchal breadth/length index = 200
C. orbit diameter/skull length = 21
D. skull depth/length = 57
E. length postorbital plate/skull length = 56
F. length marginal plate/skull length = 49

Overall the skull roof (Figures 2, 3, 7) is broad posteriorly and narrow anteriorly. In posterior view (Figure 4-A) it is inflected strongly downwards at the postero-lateral corners, so that the depth of the posterior region of the skull (Figure 7) is just over half of its length. The posterior margin of the skull roof (pm) is moderately emarginate, and the lateral margins are gently concave up to the well defined postorbital corner. In cross-section the posterior end of the skull is triangular as each side of the nuchal plate meets to form a mid-line angle of approximately 120°, before the skull table flattens out anteriorly. As the posterior margin of the skull was projecting out of the rock it has suffered some weathering, and there is no trace of a posterior median process on the nuchal plate. Despite
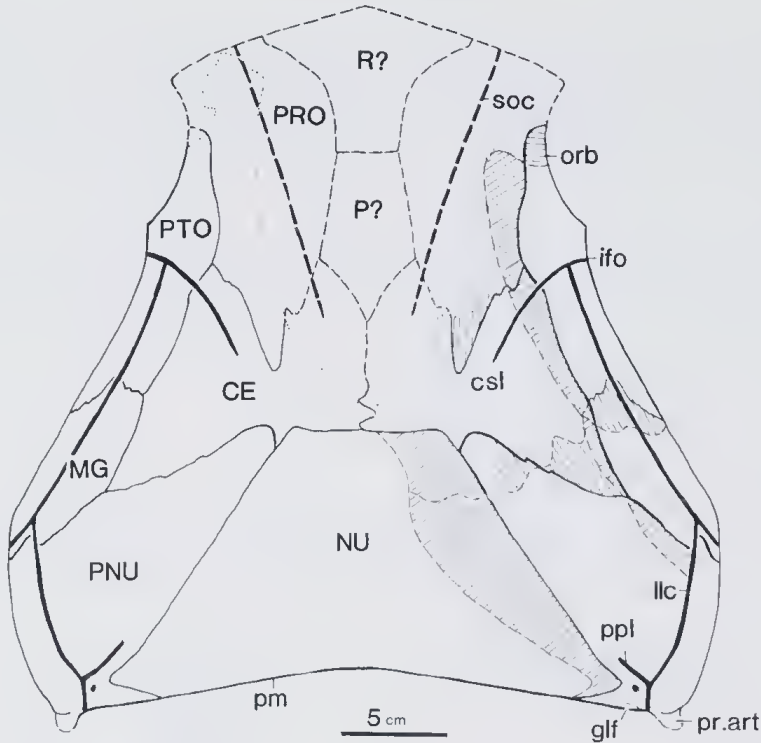
Figure 3   *Westralichthys uwagedensis* gen. *et* sp. nov., Late Devonian, Western Australia. Attempted restoration of skull roof in dorsal view, overlapping plate boundaries shown on right side. Shaded areas are restored after *Dunkleosteus* (after Heintz, 1932). Actual extent of specimen shown by a dotted line.

this the thick posterior margin of the nuchal plate is well preserved to show the shape of the posterior margin of the skull roof. Similarly the glenoid fossa (glf) is poorly preserved, although it can be seen to have been rather small and not elongated horizontally. There is a weak para-articular process (pr.art) present. The postmarginal corners (pmc) are situated one-third the length of the skull roof from its posterior margin, although as the posterior margin is moderately emarginate the postmarginal corners are only a short distance anterior of the posterior mid-line point of the skull roof.

In dorsal view the skull roof pattern (Figure 3) is characterised by the very broad nuchal plate (NU), which is 70% as broad as the roof, very large paranuchal plates (PNU), weakly trilobate centrals (CE) and elongated postorbital (PTO) and marginal (MG) plates. The nuchal is trapezoidal with a straight anterior margin one-third the plate's breadth in extent. It has broad overlap margins for the para-nuchal and also overlaps part of the central plates. The paranuchal is the longest plate on the skull roof, having a maximum dimension of 63% the length of the roof. It meets the central along a slightly irregular suture and is overlapped by that plate both mesially and laterally. The lateral corner of the paranuchal features

a short, rounded anterior lobe which projects into the rear of the marginal plate. The mesial division of the centrals is poorly preserved on the specimen although there are several smaller pieces of these plates which became detached during preparation. They indicate that the posteriormost contact between the central plates was along a slightly irregular suture. The posterior lobe of the centrals is very short and anteriorly there is a deep notch for the preorbital plate (PRO) which comes close to meeting the anterior margin of the paranuchal plate. The lateral margins of the centrals are quite straight where they overlap the postorbital and marginal plates. The marginal plate has a maximum breadth/length ratio of 28, and is approximately as broad as the postorbital plate, which is slightly longer than it. It has a well produced anterior point which has irregular suture with the postorbital, similar to, but not as well developed as in *Dunkleosteus marsaisi*
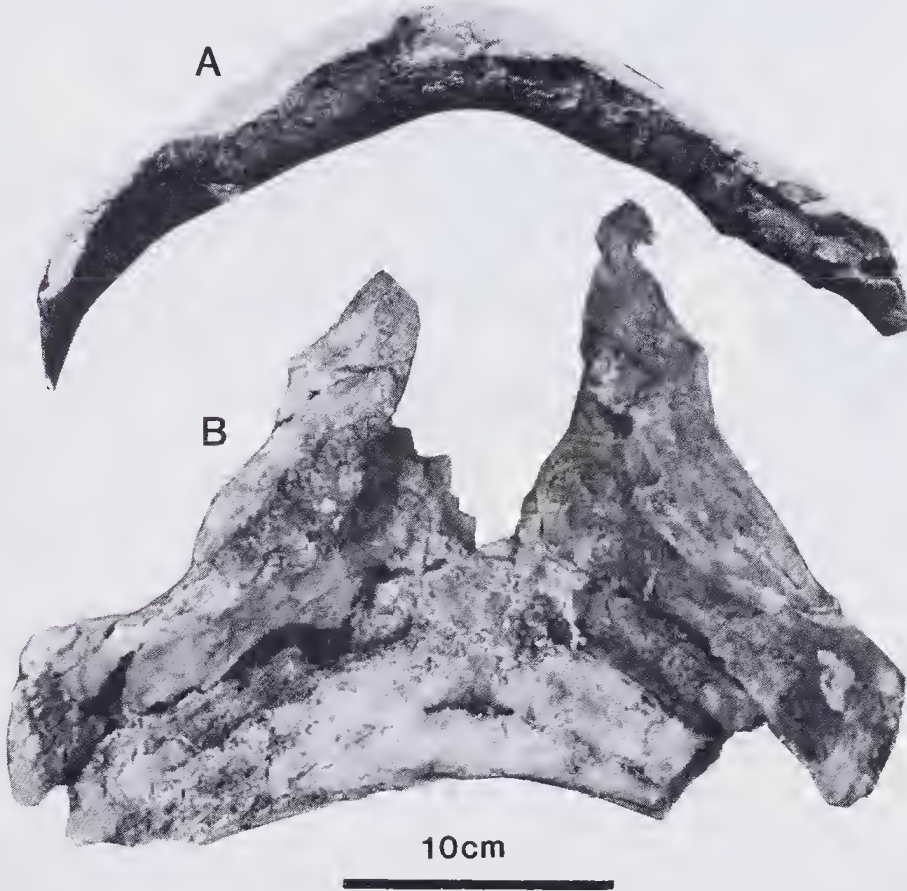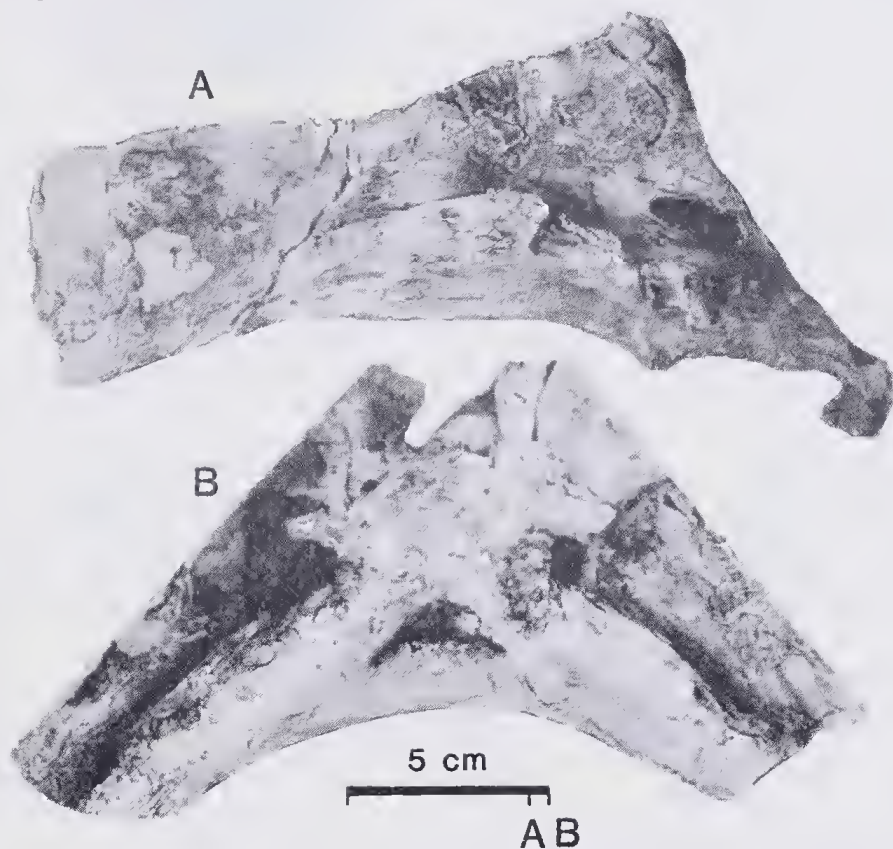

Figure 4   *Westralichthys uwagedensis* gen. *et* sp. nov., Late Devonian, Western Australia. Holotype. WAM 86-9-664, skull roof in A, posterior and B, ventral views. Whitened with ammonium chloride.
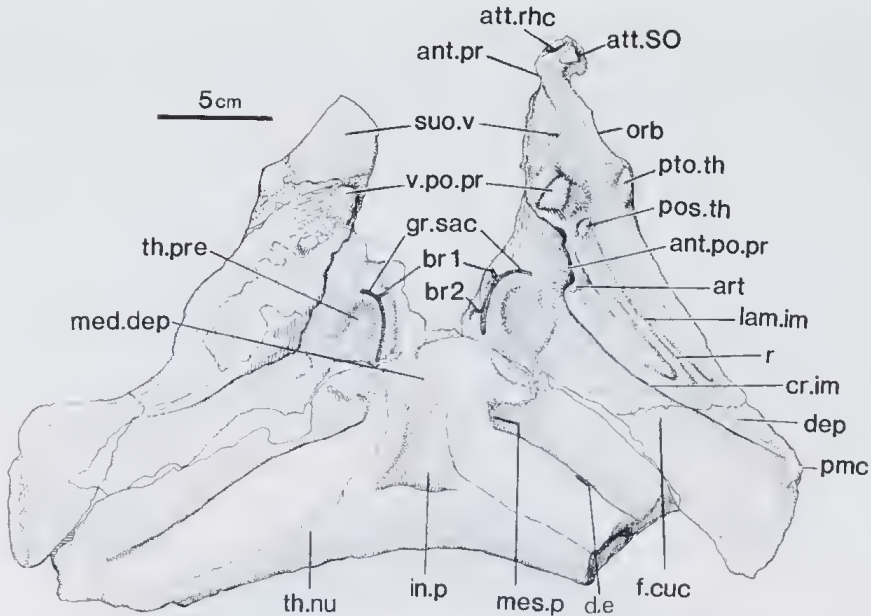
Figure 5   *Westralichthys uwagedensis* gen. *et* sp. nov., Late Devonian, Western Australia. Interpretation of visceral surface of the holotype skull roof, WAM 86-9-664.

(Lehman, 1956). The postorbital plate has a well developed postorbital corner and is broadest just posterior to the orbit, tapering anteriorly before meeting the preorbital plate. The anteriormost section of the postorbital overlaps the pre-orbital plate, although the latter overlaps most of the postorbital along its mesial margin. The junction of the infraorbital (ifo) and central (csl) sensory-line canal grooves can be seen on the specimen, although only faint traces of the supraorbital (soc), main lateral-line (llc) and posterior pit-line (ppl) grooves are preserved. Little is preserved of the preorbital plate, and its reconstructed shape is based on the margins of the known plates and the pattern seen in *Dunkleosteus*.

The visceral surface of the skull roof (Figures 4-B, 5, 6) shows massive thicken-ings along the posterior and lateral borders. The nuchal thickening (th.nu) inc-reases in breadth mesially before ending at two deep mesial pits (mes.p) situated posterior to the pre-endolymphatic thickenings (th.pre). These pits face laterally (Figure 6-B) and are deepest close to the dorsal wall of the skull roof. The function of the pits is not clear, although as they have a roughened internal surface they were either muscle insertion areas for cucullaris muscles which normally insert on the lateral wall of the endocranium in most arthrodires (Miles 1967) or for a mesial thickening of the endocranium (mes.th, Figure 9) to strengthen the attachment area for the cucullaris muscles. There is a deep infranuchal pit (in. p), lacking a median crista (Figure 6-B), located in the centre of the nuchal thickening and this pit expands in breadth posteriorly, presumably to brace the dorsal

median thickening of the braincase (not the craniospinal process of the endo-cranium, Schultze 1973). Anterior to the infranuchal pit there is a broad, smooth depression (med.dep) leading anteriorly to the pre-endolymphatic thickenings. The opening for the endolymphatic duct (d.e) is on the anterior face of the nuchal thickening (on the paranuchal plate) about midway along its breadth, but the dermal ridge of bone which braced the dorsal surface of the supravagal process is not seen as it is covered by iron oxide deposits. The pre-endolymphatic thicken-ings are very well developed and each shows a semicircular groove (gr.sac) with two small mesial branches (br1, br2) situated along its thickened mesial border. These grooves may have been for the supratemporal branch of the vagus nerve for innovation of the central and posterior pit-line organs (Young 1979, Stensio 1963). There are large nutritive foramina piercing the bone around the postocular process and behind the anteriorly-facing articulation area on the mesial margin of the inframarginal lamina.

Figure 6   *Westralichthys uwagedensis* gen. *et* sp. nov., Late Devonian, Western Australia. Holotype. WAM 86-9-664. A, mesial view of left side of skull roof in visceral view, showing features of the supraorbital vault and inframarginal lamina. B, anterior view looking into the infranuchal and mesial pits on the visceral surface of the skull roof. Whitened with ammonium chloride.
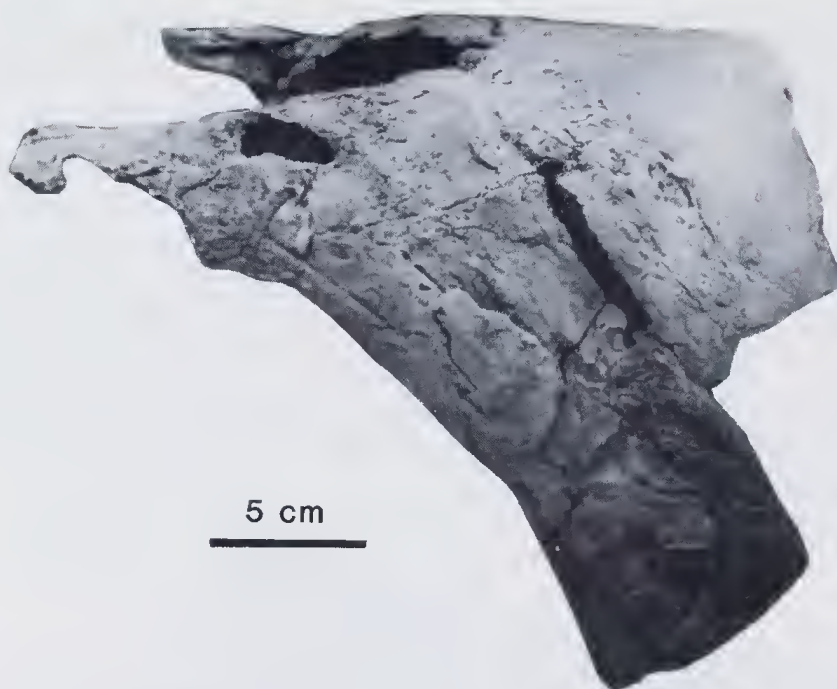
Figure 7 *Westralichthys uwagedensis* gen *et* sp. nov., holotype skull roof in oblique left lateral view, WAM 86-9-664. Whitened with ammonium chloride.
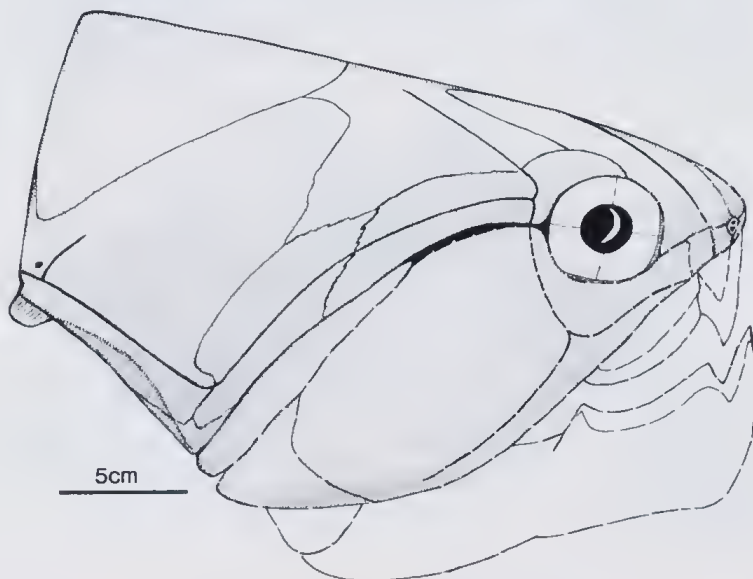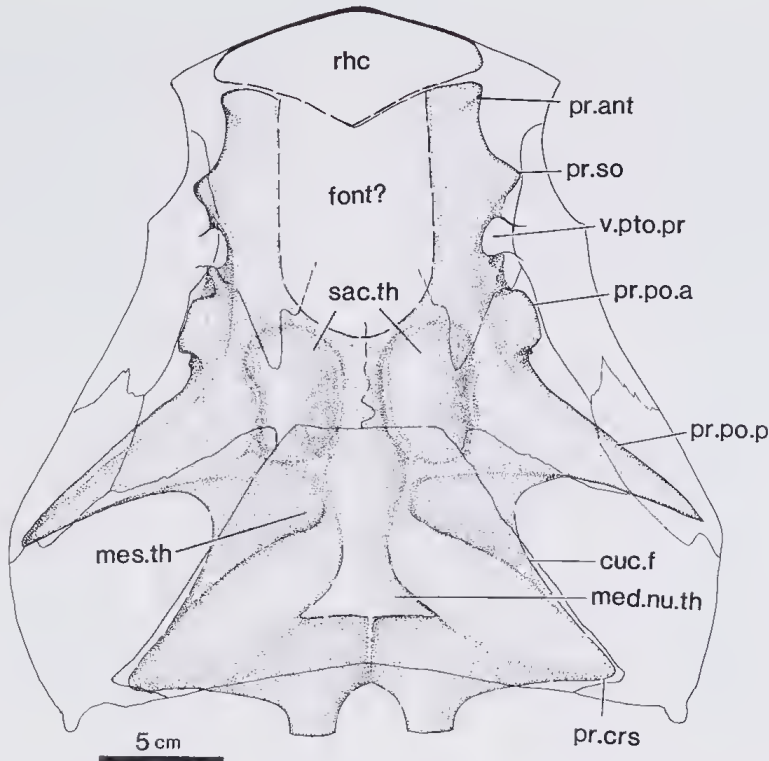

Figure 8 *Westralichthys uwagedensis* gen. *et* sp. nov., Late Devonian, Western Australia. Attempted restoration of the head in lateral view. Cheek complex inferred from similar lateral skull margin as in *Dunkleosteus* (after Stensio 1963), although gnathal plates and sclerotic ring are completely unknown and are included here to complete the restoration, based also on *Dunkleosteus*.

Figure 9   *Westralichthys uwagedensis* gen. *et* sp. nov., Late Devonian, Western Australia. Attempted restoration of dorsal endocranial shape in relation to skull roof pattern, based on features of the visceral surface of the skull roof and comparison with Stensio's (1963) restoration of the endocranium in *Dunkleosteus*.

The supraorbital vault (suo.v) is bounded anteriorly by a small process which bears two recessed concave notches, one facing anteromesially for abutment of the rhinocapsular cartilage (att.rhc) and one facing posteromesially for bracing the antorbital process of the endocranium (ant.pr). There is a roughened small area of bone facing ventrally on this prominence for attachment of the suborbital plate (att.SO). The roof of the supraorbital vault is smooth and relatively flat, not distinctly concave as in most arthrodires. There are three distinct processes developed at the posterior border of the supraorbital vault (Figure 10-A). One of these situated laterally at the postorbital corner, is a thickening for articulation of the suborbital plate (pto.th) The largest of the other two processes, on the posteromesial border of the supraorbital vault, is a ventral postocular process (v.po.pr) for bracing the endocranium, as also occurs in *Dunkleosteus* (Heintz 1932), *Harrytoombsia*, and some of the other Gogo arthrodires (Miles and Dennis 1979; Dennis and Miles 1980). It slopes evenly up from the posterior border of the supraorbital vault and has a broad base which extends anteriorly for a short distance. A smaller posterior thickening (pos.th) is located on the posterior side

of the base of the larger process, and as it does not extend ventrally very far, it would not have supported the lateral endocranial wall. It possibly served as an attachment site for ligaments connecting the palatoquadrate to the side of the skull roof, rather than having an endocranial articulation to the subocular shelf as in *Buchanosteus* (Young 1979, p. 336) and other arthrodires which lack a pronounced lateral thickening on the skull roof. The posterior division of the extensive lateral thickening (i.e. posterior to the supraorbital vault) is here termed the inframarginal lamina (lam. in). In *Westralichthys* this structure is very similar to that of *Dunkleosteus* ("lateral consolidated part", Heintz 1932, Lehman 1956) in
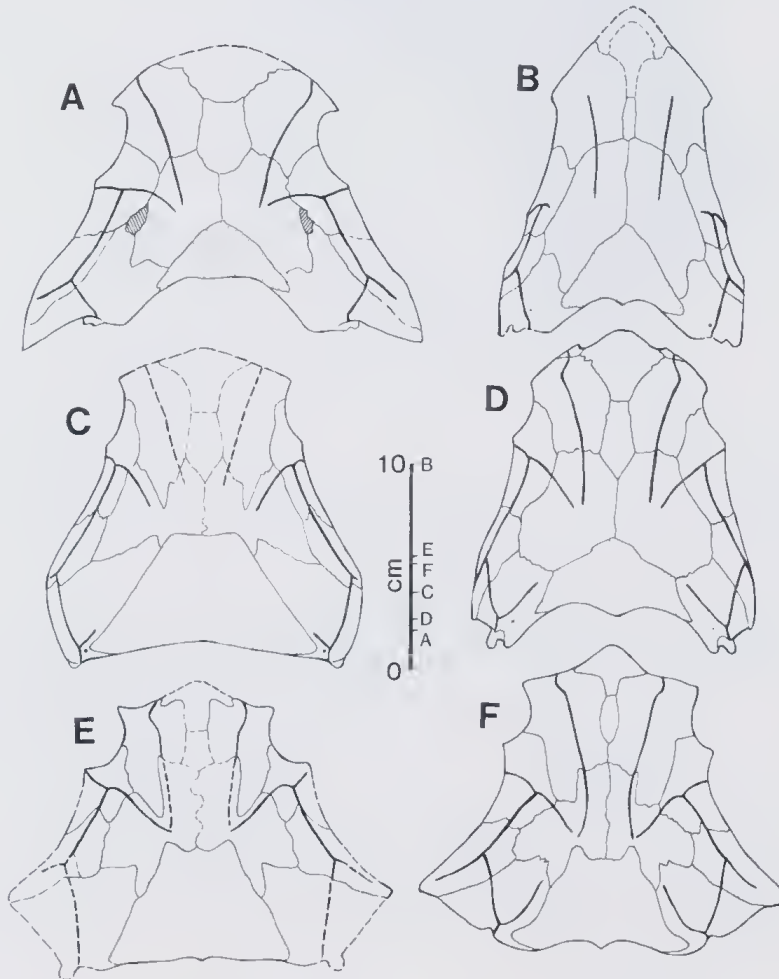

Figure 10   Comparison of skull roof features of certain Dinichthyidae. A, *Gorgonichthys clarki* (from Dunkle and Bungart 1940). B, *Hadrosteus rapax* (from Stensio 1963). C, *Westralichthys uwagedensis* gen. *et* sp. nov. D, *Dunkleosteus terrelli* (from Stensio 1963). E, *Golshanichthys asiatica* (from Lelievre *et al.* 1981). F, *Eastmanosteus pustulosus* (from Denison 1978). Nuchal plates stippled.

terms of its size relative to the lateral margin of the skull roof, breadth across the postorbital corners, and development of bony processes. It is bordered mesially by a ridge, the inframarginal crista (cr.im), which braced the posterior postorbital process of the endocranium. The inframarginal lamina has a concave medial division and thickened mesial margin which is indented lateral to the pre-endolymphatic thickenings for the anterior postorbital process of the endocranium (ant.po.pr). The posterior end of this embayment has an anteriorly-facing roughened articulation area (art, shown clearly in Figure 6-A), possibly an attachment area for arcus palatoquadratini muscles. These muscles attached from the dorsal lamina of the palatoquadrate in *Buchanosteus* (otic process) to the endocranium, although in *Holonema* they are inferred to attach onto the dorsal inner surface of the suborbital plate (Miles 1971). The extensive concave region of the inframarginal lamina may have braced the dorsal division of the palatoquadrate during jaw adduction, although the presumed presence of an opercular cartilage running from the submarginal anteromesially to its articulation on the anterior postorbital process, as occurs in other arthrodires (Young 1986), would obscure much of the area between the palatoquadrate and the inframarginal lamina unless the submarginal was particularly long and narrow as in *Dunkleosteus*. The posterior corner of the inframarginal lamina has development of weak ridges (r) and there are discrete concave surfaces (dep) possibly for insertion of the levator and dilator operculi muscles from the submarginal plate. Although the presence of these muscles in placoderms has not been discussed previously, all operculate fishes (including Holocephali) possess muscles to move the operculum, and it is assumed that they must have been present in placoderms. However, whether the submarginal was moved by dilator and adductor operculi, which attached onto the side of the skull roof (as in actinopterygians, Lauder 1980, Kesteven 1942) or whether the operculum was moved by simple modification of the dorsal constrictor muscles of the hyoidean arch (as in holocephalans, Kesteven 1942, Stahl 1967) would require further study of the cheek regions in placoderms and other fishes, beyond the scope of this work, to be resolved. A reconstruction of the head of *Westralichthys* in lateral view is shown in Figure 8, the cheek complex being restored based on similar lateral skull margins as in *Dunkleosteus*.

An attempt at reconstructing the dorsal form of the endocranium is shown in Figure 9, based on the morphology of the visceral surface of the skull roof and comparison with Stensio's restoration of the braincase of *Dunkleosteus* (Stensio, 1963, fig. 89A). The supraorbital processes (pr.so) are developed as thin triangular projections from high up on the lateral wall of the braincase, confluent with the dorsal surface abutting the skull roof. In their overall shape and size they are not unlike that process in actinolepids (Goujet 1984, fig. 107) a feature thought to characterise that group (Goujet 1984; Long 1984), although in *Westralichthys* the supraorbital processes are situated more anteriorly. Immediately posteroventral to them the braincase is buttressed by the ventral postocular processes, and the anterior postorbital processes (pr.po.a) emerge from mid-way along the lateral

endocranial wall behind these dermal buttresses. The relative shape and size of the anterior postorbital processes is here taken from the incised depression along the mesial thickening of the inframarginal lamina. At the posterior end of this embayment is the roughened articulation area possibly for muscle attachment (as described above), but as most of the embayment is smooth it is presumed to be for an endocranial process. The full lateral extent of the process is not known, but it probably did not extend far, as one of its functions, to meet the head of the opercular cartilage, could only be achieved if the submarginal was particularly elongated as it is in *Dunkleosteus*. An orbitotemporal fontanelle (font?) is restored after Stensio. As most of this region was caved in on the specimen, the presence of such a fontanelle is therefore possible. The deep mesial pits on the paranuchals are here restored as thickenings of the endocranium (mes.th) above the cucullaris fossa (cuc.f). Unlike Stensio's restoration in *Dunkleosteus* the saccular thickenings (sac.th) below the pre-endolymphatic thickenings of the skull roof are not confluent with the cucullaris fossa as the endocranium must have been raised well above the depression to insert mesially into the pits, then presumably shallowed out laterally into the cucullaris fossa. The posterior division of the endocranium apparently resembled that of *Dunkleosteus* in its development of a strong median nuchal thickening (med.nu.th), although there is no evidence for postulating an occipital fontanelle (cf. Stensio 1963).

Etymology

The species is named from a composite of the first letters from the University of Western Australia, Geology Department, where the specimen was uncovered in early 1986.

Relationships of *Westralichthys*

Relationships between the major dinichthyids were briefly discussed by Lelievre *et al.* (1981), and I have here modified their cladogram to include *Westralichthys* as well as some other taxa (Figure 11). Only taxa in which the skull is well known are considered. Newly prepared specimens of *Eastmanosteus* sp. and several coccosteids from the Gogo Formation have also been studied in order to clarify some of the morphological points raised. The following character states are utilised in competing hypotheses of dinichthyid interrelationships (Figure 11). The taxonomic distribution of these characters is shown in Table 2. Outgroup comparison with the Coccosteoidea is here used to establish plesiomorphy in dinichthyid characters, as most workers agree on the Dinichthyidae being derived from coccosteid stock (Denison 1975, 1978, 1984; Miles 1969, Moy-Thomas and Miles 1971, Lelievre *et al.* 1981).

1. Powerful gnathal plates with prominent anterior cusp on inferognathal, anterior superognathal like an open ring in dorsal view.

This character was discussed by Lelievre *et al.* (1981) as defining the family Dinichthyidae. Whilst there is no doubt about the distribution or development of the first of these features in most dinichthyids (*Dunkleosteus, Gorgonichthys,*
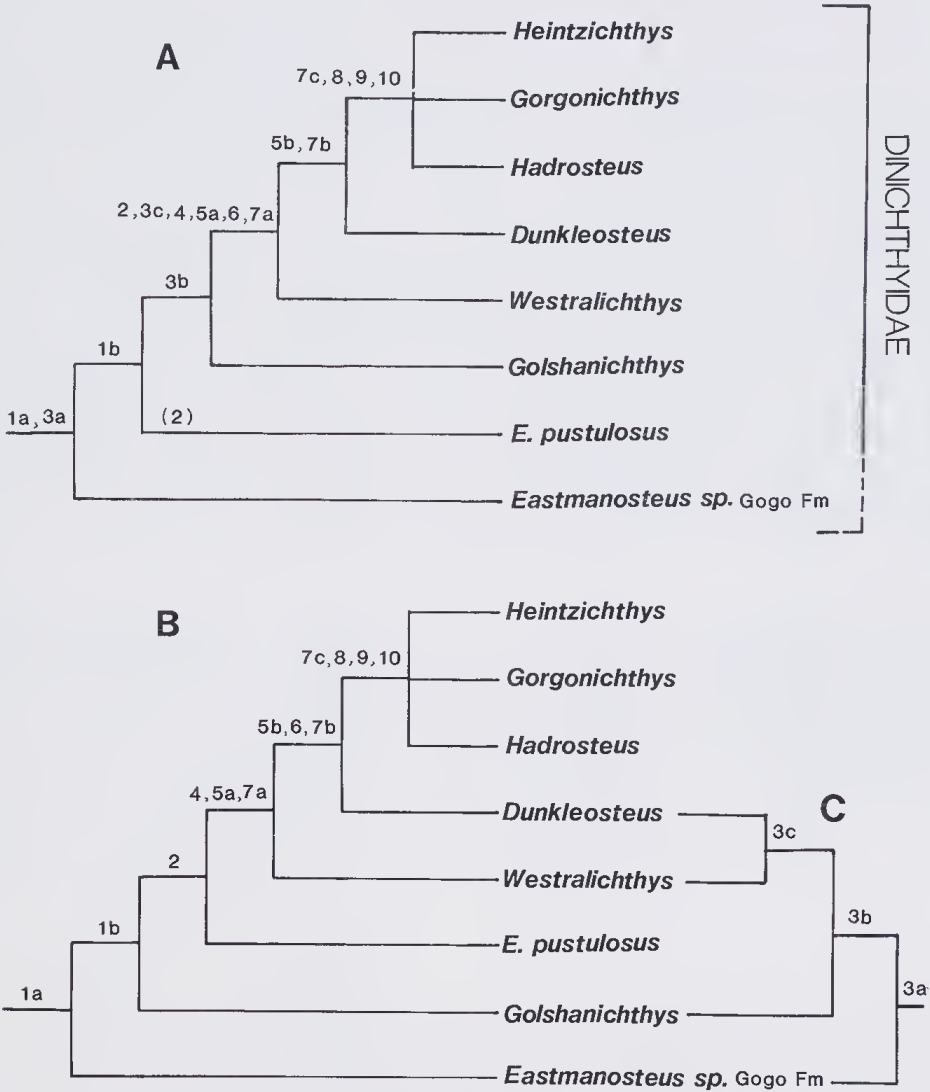

Figure 11   Hypotheses of dinichthyid interrelationships. Numbered synapomorphies are listed and discussed in the text, and taxonomic distribution of character states is summarised in Table 2. Hypothesis A assumes that the inframarginal lamina was primitively present in all higher dinichthyids (even if secondarily lost in some forms). Hypothesis B ignores the inframarginal lamina as a widespread dinichthyid character. Hypothesis C utilises only the development of the inframarginal lamina in taxa for which it is known.

Table 2   Distribution of character states in certain dinichthyids.

Character	*Eastmanosteus* sp. Gogo Fm	*E. pustulosus*	*Golshanichthys*	*Westralichthys*	*Dunkleosteus*	*Hadrosteus*	*Gorgonichthys*	*Heintzichthys*
1a. Inferognathal with well developed anterior cusp.	■							
1b. Powerful gnathal plates with prominent anterior cusp on inferognathal, anterior supragnathal with almost ring-like dorsal part.		■	■	?	■	■	■	■
2. Elongated postorbital plate.		■			■	■	■	■
3a. Lateral consolidated part of skull roof very thick.	■							
3b. Inframarginal lamina present.		?	■			?	■	?
3c. Inframarginal lamina extensive.				■	■			
4. Loss of ornamentation.					■	■	■	■
5a. Postmarginal corners more posteriorly situated than for normal arthrodires.					■			
5b. Neck-slit vertical or near vertical.					■	■	■	■
6. Central plates not trilobate.					■	■	■	■
7a. Nuchal plate twice as broad as long.					■			
7b. Nuchal plate broad, diminished in size and pentagonal.						■		
7c. Nuchal plate smaller, and triangular in form.						■	■	■
8. Spinal plates absent.			?	?		■	■	■
9. Orbits enlargened.						■	■	■
10. Suborbital plate with deep rounded postorbital blade.			?	?		■	?	■

Heintzichthys, Hadrosteus, Golshanichthys) there is some uncertainty about the gnathal plates in *Eastmanosteus. Eastmanosteus pustulosus* apparently had gnathals similar in form to those of *Dunkleosteus* (Denison 1978, Kulczycki 1957), and is therefore united with the other genera. *Eastmanosteus* sp. from Gogo, however, has only moderate development of the anterior cusps, and although they are clearly present as pointed fangs they are not very high relative to the level of the biting division of the blades (on both inferognathal and posterior superognathal).

In some respects they are comparable to the well developed cusps of some coccosteomorphs (e.g. *Plourdosteus*, Ørvig, 1980; Vezina, 1986) and certainly are not as prominent as cusps on the gnathals of some other placoderms (e.g. *Malerosteus*, Kulczycki, 1957). I therefore regard the development of this character in *Eastmanosteus* sp. from Gogo (character 1a) as being intermediate between that of coccosteids and that of other dinichthyids (character 1b). Although this character is not known for *Westralichthys*, it is assumed to be present due to overall similarities in skull features to *Dunkleosteus*, and in showing more derived cranial features than *Golshanichthys* or *E. pustulosus*, both of which possess this character. The character of the anterior superognathal having an open-ring shape in dorsal view is clearly seen in *Dunkleosteus* (Heintz, 1932, fig. 28-III) and *Eastmanosteus* sp. from Iran (Janvier 1977, fig. 2-C), and apparently present in higher dinichthyids (Lelievre *et al.* 1981). However it is not known for *Westralichthys* or *Golshanichthys*, and is not developed in *Eastmanosteus* sp. from Gogo, in which these bones are essentially like those of coccosteids. Using Lelievre *et al.*'s definition of the Dinichthyidae *Eastmanosteus* sp. from Gogo would have to be excluded from the family as it lacks both synapomorphies. It is noted that some of the most advanced dinichthyids are known only by their gnathal bones which show the distinctive cusp on the inferognathal (e.g. *Holdenius, Hussakoffia, Dinichthys*). Some forms also underwent specialisation of the dentition (e.g. *Hadrosteus*).

2.   Elongated postorbital plate.

In coccosteids the postorbital is a short, broad plate, as it is also in *Eastmanosteus* sp. from Gogo, and *Golshanichthys*. By contrast the postorbital of *E. pustulosus, Westralichthys, Dunkleosteus, Heintzichthys, Gorgonichthys* and *Hadrosteus* is elongate, being of similar shape and length as the marginal plate. This is seen as a derived condition for dinichthyids. In *Selenosteus* the postorbital is also elongated but quite unlike that of dinichthyids as the anterior division of the plate (forward of the junction of the infraorbital and main lateral line sensory grooves) is extended, not the posterior division as in dinichthyids.

3.   Well-developed inframarginal lamina.

The term "inframarginal lamina" is introduced to denote the smooth ventrally-facing extension of the supraorbital vault which is developed on the lateral consolidated region of the skull roof, equivalent to the "post-ocular division of supraorbital area", of Stensio (1963, fig. 112A). As such it is not found in any coccosteids (cf. Gogo coccosteids, Miles and Dennis 1979, Dennis and Miles 1979a, 1979b, 1982, 1983; *Coccosteus*, Miles and Westoll 1968, Obrucheva 1962; *Protitanichthys*, Miles, 1966) as in this group the lateral consolidated region of the cheek is present as a moderate thickening of bone along the inside edge of the skull margin. In *Westralichthys, Dunkleosteus terrelli* (Heintz, 1932) and *D. marsaisi* (Lehman, 1956) the inframarginal lamina is well developed, being approximately twice the

length of the supraorbital vault. *Golshanichthys* appears to have a short infra-marginal lamina present (ep. lat, Lelievre *et al.* 1981, fig. 2) which is approximately the same length as the supraorbital vault. The condition in *Eastmanosteus pus-tulosus* is not clear. Kulzycki (1957, p. 307) described part of the inside of the skull roof of *E. pustulosus* and this together with his illustration indicates that the inframarginal lamina was not fully developed in this species. In *Eastmanosteus* sp. from Gogo the lateral consolidated region has a middle region comprising a bulbous rounded thickening, anterior to which is a well defined depression bor-dered anteriorly by the supraorbital vault. Posterior to the middle thickening is another depressed area, possibly a muscle insertion area, where the lateral consoli-dated region merges evenly with the postmarginal corner of the skull. In the largest specimens examined the median division becomes quite flatter, but is still dis-continuous with the depressions anterior and posterior to it. I therefore regard the condition in *Eastmanosteus* sp. from Gogo, and possibly in *E. pustulosus,* as being a more derived state of the lateral consolidated part of the skull (character 3a) relative to coccosteids, but not as specialised as the short inframarginal lamina in *Golshanichthys* (character 3b) or the long, broader inframarginal lamina present in *Westralichthys* and *Dunkleosteus* (character 3c). The visceral surface of the skull roof of *Gorgonichthys* has been badly distorted (Dunkle and Bungart 1940, p. 34) but shows that an inframarginal lamina might have been present (cf. "descending orbital exoskeletal bone lamina," Stensio 1963, fig. 112B). The condition in *Hadrosteus* and *Heintzichthys* is not certain, so at most this character might be useful to denote a relationship between *Westralichthys* and *Dunkleosteus* (Figure 11-C), or be inferred to be a synapomorphy of higher dinichthyids which might be diminished or lost in some forms (Figure 11-A). A similar type of infra-marginal lamina occurs in the durophagous Gogo arthrodires *Kendrickichthys* and *Bullerichthys* (pers. observ.). It is assumed to have developed in parallel with that of dinichthyids due to similar adaptation of a powerful jaw adduction, one for predatory actions (dinichthyids) and one for durophagy. More detailed study of this region in arthrodires is required to determine the function of the lamina and its depressions and pits.

4. Loss of tubercular ornamentation.

A tubercular ornamentation is primitively present in all arthrodires, and typifies the coccosteids and some dinichthyids. The loss of tubercular ornament in some dinichthyids is here considered a specialised condition. *Eastmanosteus* sp. from Gogo has a well developed tubercular ornamentation, but in *E. pustulosus* the tubercles are scarce and restricted to ossification centres when at all present (Kulzcycki 1957, Schultze 1973). *Golshanichthys* has a fine ornamentation, but all the other dinichthyids dealt with here have smooth bone surfaces.

5. Vertical or near vertical neck-slit.

The obstantic margin of the skull in most arthrodires is inclined anterolaterally, thus giving the skull its characteristic broad postmarginal corners (a synapomorphy

once used to define the Arthrodira, Young 1979, but also present in antiarchs, Young and Gorter 1981, Dennis and Miles 1983). In dinichthyids, brachydeiroids, trematosteids and some other forms the neck slit has a vertical orientation. The development of this condition is assumed to have arisen only once within the Dinichthyidae as it is shared by certain higher dinichthyids *(Dunkleosteus, Gorgonichthys, Heintzichthys, Hadrosteus)*. *Eastmanosteus* sp. from Gogo, *E. pustulosus* and *Westralichthys* all possess anteriorly inclined obstantic margins, although in *Westralichthys* the postmarginal corners are more posteriorly situated than for the other two species. I regard the condition in *Westralichthys* (character 5a) as more derived than for the *Eastmanosteus* species, which show a regular coccosteid type of neck-slit, but not as derived as that of higher dinichthyids (character 5b). Correlated with this character is the enlargement of the nuchal gap in higher dinichthyids *(Gorgonichthys, Heintzichthys, Hadrosteus, Dunkleosteus)*.

6. Central plates not trilobate.

Trilobate central plates typify the coccosteids (Denison 1978) and are retained in *Eastmanosteus* spp., *Golshanichthys* and *Westralichthys*. The derived condition is seen in *Dunkleosteus, Gorgonichthys, Heintzichthys* and *Hadrosteus* where the centrals are not trilobate and have fairly straight margins. They are large bones, generally equivalent in size to the preorbital plates (Denison 1978).

7. Nuchal plate diminished and of triangular shape.

A trapezoidal nuchal plate is a characteristic feature of the Brachythoraci (Young 1979) and is found in all known coccosteids. It is retained in *Eastmanosteus* sp. from Gogo, *E. pustulosus* and other species (Schultze 1973), *Golshanichthys* and *Westralichthys*, and in these forms it is long, occupying more than 40% of the skull length. In *Westralichthys* however it is considerably broader than is normal for coccosteids and this is considered more derived (character 7a) than for the afore-mentioned dinichthyids. *Dunkleosteus* and higher dinichthyids show diminution of the nuchal plate which only occupies approximately one-quarter or so of the skull length, and is very broad (character 7b). In *Gorgonichthys, Heintzichthys* and *Hadrosteus* the nuchal is smaller and has an approximately triangular outline (character 7c).

8. Spinal plates absent.

Stensio (1959, 1969) argued for a division of the Arthrodira into forms lacking a spinal plate (Aspinothoracidi) and those with a spinal plate (Spinothoracidi). A major problem with this scheme was the presence and absence of spinals in members of the Dinichthyidae. Stensio tried to resolve this by arguing that the spinal plates in some dinichthyids were "pseudospinals" not homologous to those of other arthrodires as they lacked an internal endoskeletal component. This was refuted by Heintz (1968) using *Dunkleosteus* and *Homosteus* as examples. The

presence of spinal plates in dinichthyids is therefore regarded as a primitive feature shared with coccosteids, but generally differing in their relative sizes (cf. *Eastmanosteus* sp. Gogo, Gardiner and Miles 1975). The spinals are lost in advanced forms *(Hadrosteus, Gorgonichthys* and *Heintzichthys)*, although it should be noted that they are not known for *Westralichthys* or *Golshanichthys*, but are assumed to be present in these species as they are present in *Dunkleosteus.*

9. Large orbits.

The diameter of the orbits in *Eastmanosteus* sp. from Gogo, *E. pustulosus, Golshanichthys, Westralichthys* and *Dunkleosteus* all fall within the common size range for coccosteids (average about one-fifth skull length). *Hadrosteus, Gorgonichthys* and *Heintzichthys* show relatively large orbits, here considered a derived condition within the family.

10. Suborbital plate having a rounded deep postorbital section.

The previous character (enlarged orbits) is also correlated with the change in shape of the postorbital region of the suborbital plate from being relatively long and rectangular to almost rounded in form. As the cheek bones are not known for some dinichthyids, the shape of the suborbital can be inferred from the lateral margin of the cheek. In *Dunkleosteus* and *Eastmanosteus* the suborbital is elongated, typical of its form in coccosteids, and this type of suborbital is inferred to be present in *Golshanichthys* and *Westralichthys* (restored in Figure 8). Similarly *Heintzichthys* is inferred to have had a deep rounded suborbital similar to that of *Gorgonichthys* due to its enlarged orbits.

The following characters may be of use when more is known of their distribution in dinichthyids: interolateral plate with smooth, non-denticulated ascending lamina (present in *Dunkleosteus*, not present in *Eastmanosteus* sp. from Gogo, uncertain for others); and parasphenoid with posterolateral processes (present in *Dunkleosteus*, Stensio, 1969, fig. 141; absent in *Eastmanosteus* sp. from Gogo, unknown in others). In addition Lelievre *at al.* (1981) have used the loss of lateral and nuchal thickenings on the visceral surface of the skull roof (to unite *Heintzichthys* and *Gorgonichthys*) although this character is discussed in detail above. The tritorial type of inferognathal is also used to unite *Dunkleosteus* with *Heintzichthys* and *Gorgonichthys* by Lelievre *et al.* (1981) although this condition is difficult to resolve from that in *Golshanichthys* and is unknown for *Westralichthys.*

The average coccosteids were small fishes no more than about half a metre or so in length, although some forms were considerably larger (Miles 1964, Obrucheva 1966). The dinichthyids include some of the largest known placoderms, a condition which is clearly specialised. The maximum sizes for headshield length in the dinichthyids are: *Eastmanosteus* sp. from Gogo – about 27 cm, *Golshanichthys* – up to 25 cm; *E. pustulosus* – up to 30 cm; *Westralichthys* – 27 to 30 cm estimated

maximum length; *Dunkleosteus* — up to 65 cm; *Hadrosteus* — 16 cm; *Gorgon-ichthys* — to 70 cm; *Heintzichthys* — 25 cm. Size is here not correlated with number of acquired synapomorphies. Some species of an individual genus may be variable in size (e.g. *Dunkleosteus marsaisi*, skull length 35 cm; *D. terrelli* up to 65 cm), and at most, this character may be useful at this level for determining species relationships.

The most plausible hypotheses of dinichthyid interrelationships using the above character states are shown in Figure 11. The first scheme (Figure 11-A) is based on the assumption that the inframarginal lamina is well developed in *Golshanichthys* and present in higher dinichthyids, even if secondarily modified or degenerated. One problem with this scheme is the assumed independent acquisition of a long postorbital plate in *E. pustulosus* and certain higher dinichthyids. The second hypothesis (Figure 11-B) ignores the inframarginal lamina (characters 3a, 3b, 3c) as a valid synapomorphy, and thereby places *Golshanichthys* as a sister taxon to *Eastmanosteus* sp. from Gogo by virtue of their absence of a long postorbital plate. Figure 11-C shows a conservative hypothesis based on the distribution of the inframarginal lamina in dinichthyids, leaving out taxa in which the develop-ment of this character is not known. In either of the two major schemes the position of *Westralichthys* is as a sister taxon to the higher dinichthyids *Dun-kleosteus, Gorgonichthys, Heintzichthys* and *Hadrosteus*.

Dinichthyid evolution and paedomorphosis

There is little known data on the ontogenetic development of advanced arthrodiran fishes (*Coccosteus*, Miles and Westoll, 1968; *Incisoscutum*, Dennis and Miles, 1981) and amongst other placoderm groups it has only been discussed for antiarchs (Stensio 1948, Werdelin and Long 1986). Some of the characters described in juveniles of *Coccosteus cuspidatus* agree with observations for juveniles of *Incisos-cutum*, and within these characters are found some traits of the dinichthyids. These characters are (1) the retention of a straight median suture between the centrals, (2) neck-joint is proportionally larger, (3) sensory-line deeply incised, (4) smooth anterior face on ascending laminae of the interolateral plate. In addition the presence of well defined (i.e. unworn) cusps on juvenile gnathal bones may have preceded the development of strongly developed anterior cusps on dinichthyid gnathals by transition of wear surfaces area, thereby preventing wear on the anterior biting edge of the jaws. If the dinichthyids are derived from coccosteid stock, as is generally accepted (Denision 1978, 1984, Lelievre *et al.* 1981, Moy-Thomas and Miles 1971), then it is feasible that retention of some juvenile characters (paedomorphosis, McNamara 1986) with increased overall size may have been the evolutionary mechanism by which the dinichthyids arose. Character development is seen as most accelerated from the transition between *Eastmanosteus* and higher dinichthyids whereby the central plates retain a straight

suture, the nuchal changes shape and diminishes in size, the ornamentation is lost or not developed, the neck-joint becomes vertical, the interolateral plate loses rows of tubercles on its ascending lamina, the spinal plate is lost, the sensory-line canals become deeply incised and the gnathal plates have an accentuated anterior cusp. Although examples of heterochrony for fossil invertebrates may show a clear trend between change in environmental conditions and retardation (paedomorphosis) or continued development of ontogenetic trends (peramorphosis, e.g. McNamara 1982), examples within fossil fishes (e.g. Bemis 1984) do not show a connection between speciation and gradual environmental changes. One would suspect that the major factors influencing the evolution of dinichthyids would include changes to vertebrate faunas across the Frasnian-Famennian boundary (and therefore changes in competition and food sources) and increased competition resulting from a secondary radiation of advanced dinichthyids (Famennian). Both of these factors may be causally related.

Acknowledgements

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Frogs of the Gibb River Road, Kimberley Division, Western Australia

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Abstract

Sampling the frog fauna along a 390 km transect between Derby and Gibb River Station resulted in the collection of 28 species; representing 74% of the frog fauna of the Kimberley Division. Three assemblages could be recognised: a ubiquitous group common to all sampling sites, one restricted to the area around Derby, and a further group confined to rocky creeks in the Phillips Range area. Comparison of the fauna of each site along the transect suggests that a major change occurs between Lennard River and the King Leopold Ranges.

Notes are provided on species representing significant range extensions. Morphometric and osteological data for *Uperoleia mjobergi* and *U. crassa*, and a summary of call variation in these two species and *U. lithomoda* are provided. *U. variegata* is referred to the synonymy of *U. lithomoda*.

Introduction

Since 1977 zoologists from the Universities of Adelaide and Melbourne have made eight visits to the Kimberley Division of Western Australia to study and collect frogs. The visits have occurred in the wet season, supplemented by two dry season visits by one of us (M.J.T.) to Derby and the Mitchell Plateau respectively. In consequence of these visits the known frog fauna of the Kimberley has been increased to its present figure of 38 species (Tyler, Smith and Johnstone 1984).

Previously, our collecting activity has occurred on the periphery of the Kimberley, but in January-February 1985 we travelled 390 km from Derby, in the south-western Kimberley, to Gibb River Station near the centre of the Division. A major purpose of the exercise was to examine the frog fauna, seeking the northern limits of distribution of the fauna of the Derby area which contains elements not known from other localities. (Tyler, Davies and Martin 1981a). We also were able to supplement biological knowledge of some of the species and, from a study of the collections made, add to knowledge of morphological and call variation.

Materials and methods

Details of transect

The transect extended along the entire length of the Gibb River Road. The road starts at the southern outskirts of the coastal town of Derby, 16 km SW of

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the town centre and trends north-east for a distance of 374 km to Gibb River Station in the centre of the Kimberley. It runs through high country separating the north-western coastal drainages (e.g. Isdell River) from the tributaries of the Fitzroy River, which initially trends south-east, and then west forming the southern boundary of the Kimberley.

Major geographic features of likely biogeographic significance to frog distribution are the King Leopold Range and the blacksoil plains at its southern flank, and the Phillips Range further inland (Figure 1). In addition, the creeks with rocky floors provide a habitat for species adapted to lotic conditions.
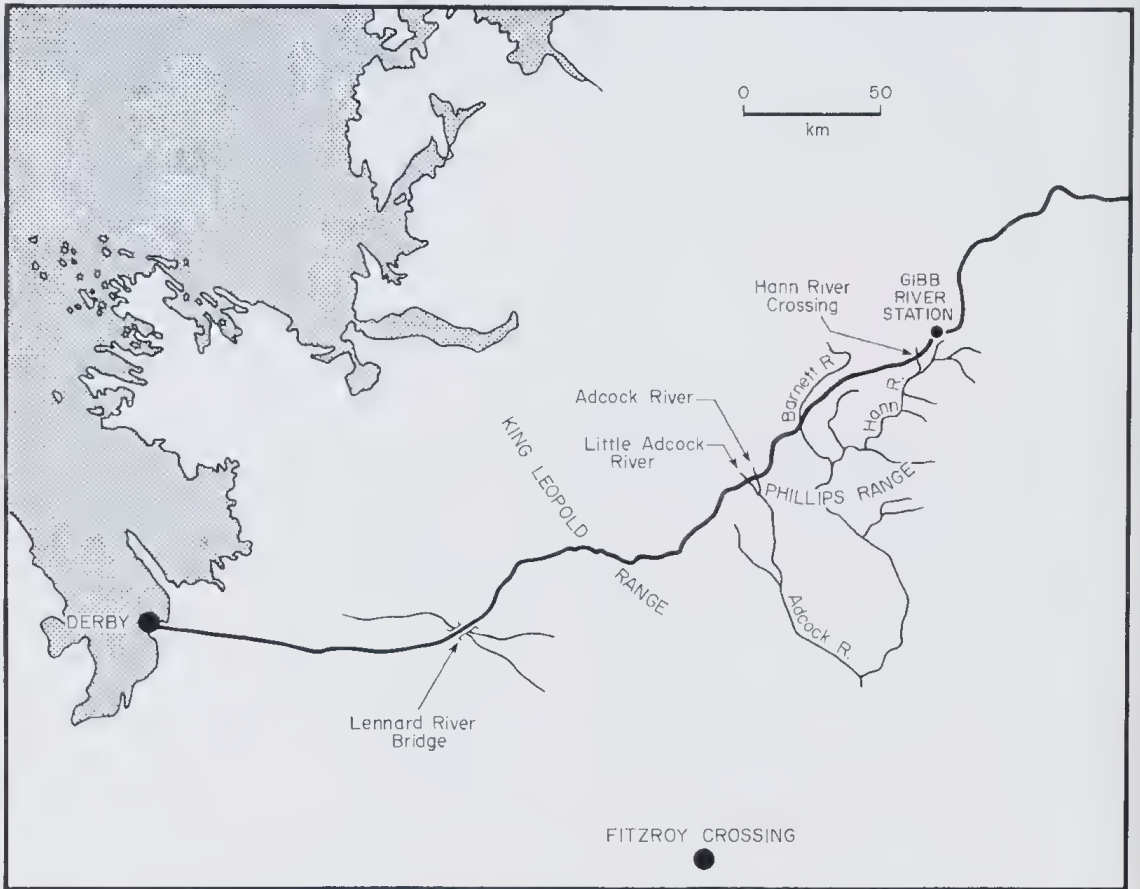

Figure 1   Gibb River Road, Kimberley Division, Western Australia. Collecting sites are indicated.

Collecting stations

Collecting stations were grouped into four separate geographic areas (see Figure 2):

Derby: Township to 40 km S. Roadside pools and gravel scrapes.

Lennard River: Gibb River road *c*. 30 km SW and NE of bridge over river. Open grassland largely inundated on our return journey.

Little Adcock River: Located at sourthern foot of Phillips Range. Boulder-strewn, with rocky floor. Adjacent areas of open grassland in undulating country. Collections principally at Little Adcock River and area 20 km N.

Gibb River Station: Collecting activities concentrated upon a recently-filled billabong adjacent to the homestead, supplemented by road transects to the north bank of the Hann River, 11 km SW of the station entrance.

SPECIES	DERBY	LENNARD RIVER	LITTLE ADCOCK RIVER	GIBB RIVER STATION
Cyclarana australis	———	———	———	———
C. cryptatis	———	———	———	
C. longipes	———	———	?	———
C. vagitus	———	———		
Litoria bicolar			———	
L. caerulea	———	———	———	———
L. coplandi			———	
L. inermis		———	———	———
L. meiriana			———	
L. nasuta			———	———
L. pallida		———		
L. rothii	———	———	———	———
L. rubella	———	———	?	———
L. tarnieri				———
L. wotjulumensis			———	
Limnodynastes canvexiusculus			———	———
L. ornatus	———	———	———	———
Megistalotis lignarius			———	
Neobatrachus aquilanius	———			
Nataden melanoscaphus			———	
N. nichallsi	———	———	———	
Nataden sp. nov.				———
Ranidella bilingua			———	———
Uperaleia aspera	———			
U. crassa			———	
U. lithamada		———	———	———
U. mjobergi	———	———		
U. talpa	———			

Figure 2 Distribution of species of frogs between Derby and Gibb River Station. Data for Derby are derived from Tyler *et al.* (1981a). Question marks indicate expectations of the occurrence of species, and may reflect inadequate collecting.

Collecting activities

Most specimens were collected at night either on the road, or located by their vocalisation from choruses in areas adjacent to the road.

Samples

Voucher specimens were taken wherever possible and are lodged in the collections of the South Australian Museum (SAM), University of Adelaide, Department of Zoology (UAZ) and Western Australian Museum (WAM).

Morphology

Methods of measurement follow Tyler (1968) and osteological descriptions follow Trueb (1979). Measurements are expressed as mean ± standard deviation with range in parentheses. Osteological specimens were cleared and stained for bone after the technique of Davis and Gore (1947) and for bone and cartilage after Dingerkus and Uhler (1977).

Call data

Male advertisement calls were recorded with either a Sony tape recorder (TC-510-2) or Sony cassette recorder (WM-D6) using either a Beyer M88 dynamic microphone or Sennheiser ME88 microphone head with K3U powering module. Wet-bulb air temperatures, measured close to the calling site of males were obtained with a Schultheis quick-reading thermometer. Calls were analysed using a digital processing oscilloscope (Norland 3001/DMX) after playback on a Revox B7711 stereo tape recorder or Nakamichi Dragon cassette deck.

Results

The 28 species found at the four major collecting sites are listed in Figure 2. The following species accounts are confined to those that represent significant extensions to known distributions, or for which we can now provide supplementary biological or morphological data.

Family: Hylidae
Cyclorana vagitus Tyler, Davies and Martin

Previous records of this species in the Kimberley have been confined to the Great Northern Highway between Derby and Kununurra. The species extends into the Northern Territory at Newry Station (Tyler *et al.* 1983). On 4 February 1985 a single adult male (SAM 29085) was collected 22.1 km N of the Lennard River bridge, following torrential rain.

Litoria inermis (Peters)

In the redefinition of the species by Davies, Martin and Watson (1983), WA records comprise Mitchell Plateau and sites around Kununurra. We encountered

the species calling at the Lennard River, Little Adcock River and Gibb River Station, so extending the known range of the species significantly.

The records comprise SAM R29089-90, WAM R94323-26: Gibb River Station 1-2.2.85; WAM 94327: 6.2 km NE Gibb River Station; WAM R94330: 7.4 km N Adcock River; WAM R94329: 0.6 km N Adcock River; WAM R94328: 22.1 km NW Lennard River.

Litoria pallida Davies, Martin and Watson

In the original description Davies *et al.* (1983) record the species from three sites in WA: between Broome and Derby and at Camballin and Kununurra.

These localities are bridged by our collection of a single specimen 15.4 km NW of Lennard River (WAM R94315).

Litoria tornieri (Nieden)

The two previous records of this species in WA are at Pago Mission Ruins, Mission Cove Napier Broome Bay and Drysdale River N.P. (Davies *et al.* 1983). We collected a single specimen (WAM R94313) at Gibb River Station bridging the gap in this distribution.

Family: Leptodactylidae
Notaden melanoscaphus Hosmer

Throughout Australia the species of *Notaden* are allopatric. Within WA, records of *N. melanoscaphus* are confined to the area round Kununurra and Wyndham (Tyler *et al.* 1984, Fig. 56). We took a single specimen (WAM R94341) on 3 February 1985, 2.2 km N of Little Adcock River, so extending the known range of the species by 300 km W.

Notaden nichollsi Parker

This species is abundant at Derby which has been considered the northern limit of its distribution (Tyler *et al.* 1984). We obtained a single specimen (WAM R94340) on 4 February 1985, 15.4 km NW of the Lennard River. The significance of this locality is its proximity (133 km) to the site at which we obtained *N. melanoscaphus* (see above). This may represent the shortest distance between congeners.

Notaden sp. nov.

Two specimens of an undescribed species of *Notaden* (WAM R83428-29) were collected by Harry Ehmann 24 km NW of Mt Elizabeth HS, on 29 November 1982. A third specimen (WAM R77419) has been taken at Mitchell Plateau.

Uperoleia crassa Tyler, Davies and Martin

The only previous record of this species is the material from the type locality on the Mitchell Plateau (Tyler *et al.* 1981b).

We located a large chorus in flooded grassland 2.4 km N of Little Adcock River on 3 February 1985 (SAM R28839-59, WAM R94353-55, UAZ A869-70, B871). The site extends the geographic range of the species by 250 km and the specimens permit the following redefinition. Also examined was a topotype, UAZ B483, for comparison.

Redefinition

Small to relatively large species (males 17-30 mm S-V, females 30-31 mm S-V) lacking maxillary teeth; frontoparietal fontanelle moderately widely exposed; toes fringed with basal webbing; six carpal elements present; anteromedial processes of anterior hyale of hoid short and slender; no ilial crest; advertisement call a rasping note of 6-8 pulses, with a call repetition rate of 41 calls min^{-1}.

External morphology

The series of frogs from 2.4 km N of Little Adcock River is smaller in length than the type series and has relatively longer hind limbs (TL/S-V 0.35 ± .02 [0.31 - 0.40] as opposed to 0.32 ± .02 [0.29 - 0.35] in the type series). The eye to naris distance is greater than the internarial span (E-N/IN 1.28 ± .18 [1.00 - 1.75]).

Osteology

Nasals moderately well ossified, widely separated posteromedially in all specimens except UAZ B483 in which moderately separated. Anterior extremities of nasals not crescentic; maxillary processes truncate or acuminate in equal proportions. Frontoparietal fontanelle always widely exposed, frontoparietal elements moderately slender with no anteromedial divergence on orbital edges. Anterior extremities of these elements extend just beyond anterior extremities of sphenethmoid.

Epiotic eminences of crista parotica moderately developed and incompletely ossified in about two-thirds of material. Zygomatic ramus of squamosal tiny and bifid in one specimen. Otic ramus short in two-thirds of specimens and slightly longer in other one-third. Pars facialis of maxillary always shallow, preorbital process usually small but occasionally more prominent. Palatines moderately acutely angled to ventral sphenethmoid, reduced laterally to extent that do not extend beyond maxillary process of nasals.

Vomers absent. Anterior ramus of pterygoid in long contact with prominent pterygoid process of palatal shelf of maxillary. Medial process long, acute, in bony content with prootic region. Cultriform process of parasphenoid broad, but occasionally slightly more slender; alae at right angles.

No ilial crest developed. Dorsal prominence well developed and wedge-shaped. Dorsal protuberance laterally placed. Pubis calcified. Hoid plate longer than wide. Anteromedial processes of anterior hyale slender and short. Alary processes

of plate not pedunculate. Postcrolateral processes moderately broad, moderately long. Posterior cornua ossified.

Carpus of six elements with considerable torsion. Three distal tarsal elements present. Distal prehallical element small and slender extending from 1/3 - 1/2 length of O. metatarsus I.

Male advertisement call

Comparative call data are given in Table 1. The call is a rasping note of 6-8 pulses with a call repetition rate of 41 calls/minute. A second call was recorded in the Phillips Range population of *U. crassa*. This call is given infrequently and has a similar number of pulses as the advertisement call but is of much shorter duration and thus has a higher pulse repctition rate (Table 1). The function of this second call type is not known.

Uperoleia lithomoda Tyler, Davies and Martin

This species is the most widespread and morphologically most variable member of the genus, ranging from the vicinity of Kununurra to northern Queensland and southern New Guinea (Tyler and Davies 1984).

The material obtained by us represents a significant extension of range further west: Gibb River Station (SAM R28744-56, WAM R94346-47) and 22.1 km NW of Lennard River (SAM R28757, WAM R94348-50).

Uperoleia variegata Tyler, Davies and Martin, (1981) was described from a series of specimens taken at Gibb River Station and characterised by a smooth to sparsely tubercular skin, poorly developed inguinal and coccygeal glands, a very poorly-cxposed frontoparietal fontanelle, no carotid canal groove and basally-webbed toes.

The collection of additional specimens indicates that *U. variegata* is, in reality, conspecific with *U. lithomoda*. Davies, McDonald and Corben (1986) have examined external morphology and osteology of *U. lithomoda* across its entire range and have established the limits of diversity within the species. *U. variegata* falls within those limits, its external morphology being influenced by the fact that the type series was collected from underground during the dry season (Tyler, *et al.* 1981b) and hence glandular development was minimal.

The characteristics of the calls of *U. lithomoda* from Gibb River Station are shown in Table 1 together with comparative data from other sites. The advertisement calls of the population from the Gibb River Station show some differences to calls of *U. lithomoda,* principally in the rcduction in number of pulses per note which, in these very short calls, results in a considerable lowering in pulse repetition rate (Table 1). The reduction in number of pulses appears to be a continuation of an east-west trend seen in comparisons between populations from Katherine, NT and Lake Argyle, WA (Table 1). Despite these structural differences, the overall similarity of calls from the population at Gibb River Station indicate that they are conspecific with *U. lithomoda.*

Table 1 Physical characteristics of calls of *Uperoleia crassa*, *U. lithomoda* and *U. mjobergi*. Where appropriate, mean values are given with ranges in parentheses.

Species and Locality	N	No. of Pulses	Duration (msec)	Pulse repetition rate (pulses/sec)	Call repetition rate (calls/min)	Dominant Frequency (Hz)	Wet bulb temperature (°C)
U. crassa							
Amax Mining Camp, Mitchell Plateau, WA*	7	7.3 (7-8)	173.4 (170-180)	41.9 (40.0-44.4)	-	2356 (2100-2800)	24.0
2.4 km N of Little Adcock River, WA+	5 (long call)	6.8 (6-7)	186.8 (169-203)	31.2 (25.9-35.5)	40.7 (38.5-42.9)	2540 (2400-2700)	29.0
	1 (short call)	6	55.0	90.9	-	2700	29.0
U. lithomoda							
6.4 km N of Katherine, NT**	3	5.3 (5-6)	16.3 (13.0-20.0)	342 (250-462)	-	3250 (3150-3400)	26.5
11.5 km N of Lake Argyle Village, WA**	5	4.6 (4-5)	11.6 (9.0-13.0)	401 (333-456)	-	3420 (3200-3600)	26.0
Gibb River Station, WA+	5	3.2 (2-6)	17.5 (15.8-21.3)	118.9 (62.5-234.7)	86.8 (72.0-96.2)	3020 (2900-3100)	24.2-26.3
U. mjobergi							
28 km S of Derby, WA++	3	22.1 (20-25)	225 (210-240)	98.1 (94.5-102.1)	-	3272 (3166-3350)	25.6
12.4 NW of Lennard River, WA+	1	22	123	170.7	34.0	3100	29.0

*Tyler et al. (1981b)   +Present study   **Tyler et al. (1981c)   ++Tyler et al. (1981a)

We therefore refer *U. variegata* Tyler, Davies and Martin 1981 to the synonymy of *U. lithomoda* Tyler, Davies and Martin 1981.

Uperoleia mjobergi (Andersson)

Our records represent the most northerly for this species: 12.4 km NW of Lennard River, SAM R28865, 19.3 km NW of Lennard River, SAM R28860-2, WAM R94352; 27.9 km NW of Lennard River, SAM R28863-4. Previous records are clustered around Derby and the Fitzroy River (Tyler *et al.* 1981a).

Examination of this material allows the following redefinition.

Redefinition

A small species (males 19.0-25.1 mm S-V, females 21.0-23.0 mm S-V) possessing maxillary teeth; toes fringed but unwebbed; inguinal glands hypertrophied; prominent tubercle on ventral surface of proximal head of tarsus; frontoparietal fontanelle poorly to moderately exposed; carpus of six elements; anteromedial processes of anterior hyale of hyoid slender and short; no ilial crest; call a short rasp of 20-25 pulses with a pulse repetition rate of 94-170 pulses sec $^{-1}$.

Morphology

Uperoleia mjobergi is conservative morphologically. Snout short, slightly rounded or truncated when viewed from above in approximately equal numbers of specimens. Eye to naris distance slightly greater than internarial span (E-N/IN 1.12 ± .12 [1.00 - 1.31]).

Fingers moderately long, slender, slightly fringed, with prominent subarticular tubercles. Palmar tubercles vary in prominence: both can be prominent, neither prominent, or tubercle on heel of hand prominent. These three states occur in approximately equal proportions.

Hind legs moderately long (TL/S-V 0.35 ± .02 [0.32 - 0.38]). Toes moderately long, moderately fringed, unwebbed with conical subarticular tubercles. Both inner and outer metatarsal tubercles prominent. Inner metatarsal tubercle oriented along long axis of first toe, outer metatarsal tubercle angled slightly to long axis of foot. Prominent tubercle present on skin overlying ventral surface of proximal head of tarsus.

Parotoid, inguinal, coccygeal and submandibular glands always well developed; inguinal glands hypertrophied to extend along flanks. Pair of lyrate skin folds occasionally occur between scapulae. Ventral surface granular. Dorsum moderately rugose with prominent markings. Pigmentation usually absent ventrally, but if present in form of fine suffusion of granules.

Osteology

Material examined: UAZ A582, 18 km S Derby; UAZ A880-9, 28 km S Derby, WA.

Sphenethmoid not ossified medially and not in bony contact with nasals. Epiotic eminences of crista parotica moderately prominent and completely ossified.

Frontoparietal fontanelle poorly exposed, elongate with slight medial expansion but occasionally shows slightly greater exposure. Orbital edges of frontoparietal elements curved anteromedially. Anterior extremities of frontoparietals barely reach posterior level of sphenethmoid dorsally, leaving substantial expanse of sphenethmoid to form anteromedial rim of orbit.

Nasals triangular, moderately ossified, moderately separated medially. Anterior edges not crescentic; maxillary processes not acuminate. Palatines slender, elongate bones extending laterally beyond extremities of maxillary processes of nasals; either poorly or moderately angled to sphenethmoid medially. Parasphenoid moderately robust with slender cultriform process. Alae at right angles to cultriform process.

Anterior ramus of pterygoid in long contact with well-developed pterygoid process of palatal shelf of maxillary. Squamosal moderately robust with prominent knobbed zygomatic ramus, bifid in one specimen. Otic ramus moderately long.

Maxillary and premaxillary dentate; vomers absent. Pars facialis of maxillary shallow with extremely prominent preorbital process.

No ilial crest. Dorsal prominence papillate, very prominent. Dorsal protuberance lateral.

Hyoid plate about as broad as long. Anteromedial processes on anterior hyale slender and short. Alary processes of hyoid plate not pedunculate; posterolateral processes moderately long, moderately slender. Posterior cornua ossified.

Carpus of six elements. Little torsion occurs.

Three distal tarsal elements present. Distal prehallical element large, extending 2/3 length of O. metatarsus I.

Advertisement call

Comparative call data are presented in Table 1. The advertisement call of the individual recorded near the Lennard River is similar to published values for this species except that the note duration is shorter with a consequent increase in pulse repetition rate. Differences in temperatures at the recording sites (Table 1) may account for the observed differences in these temperature-dependent characteristics.

Discussion

With the suppression of *Uperoleia variegata* but recognition of the existence of an undescribed species of *Notaden*, the frog fauna of the Kimberley remains a total of 38 species. It follows that the collection of 28 species along the transect from Derby to Gibb River Station is a substantial component (74%) of that fauna.

The data in Figure 2 demonstrate that there are significant differences in the frog fauna at each of the sites examined, and that the fauna can be divided into a series of components. The first component comprises species common to all sites: *Cyclorana australis, Litoria caerulea, L. rothii, Limnodynastes ornatus* and probably

C. longipes and *L. rubella.* Each of these species has an extensive pattern of distribution throughout northern Australia.

Three species are restricted to the Derby area: *Neobatrachus aquilonius* (which also occurs at similar latitudes in the NT), *Uperoleia aspera* and *U. talpa,* one to the Lennard River site *(Litoria pallida),* whilst a further four species are common to the Derby and Lennard River sites but do not (on this transect) extend further north-west *(C. cryptotis, C. vagitus, Notaden nichollsi and U. mjobergi).*

The Little Adcock River site has more unique components (in terms of our transect) than any other examined. Seven species were located only there: *Litoria bicolor, L. coplandi, L. meiriana, L. wotjulumensis, Megistolotis lignarius, Notaden melanoscaphus* and *U. crassa.* The first five of those listed are typical inhabitants of permanent creeks in rocky country. In contrast, only two species are confined to the Gibb River Station site: *L. tornieri* and the *Notaden* sp. nov. from Mt Elizabeth, and only two species *(L. nasuta* and *Limnodynastes convexiusculus)* are restricted to Little Adcock River and Gibb River Station.

It follows that the major barrier to amphibian dispersal is situated between Lennard River and Little Adcock River. We consider the most significant feature in that area to be the blacksoil plains located west of the King Leopold Range, and approximately 60 km NW of Lennard River.

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The ground vertebrate fauna of coastal areas between Busselton and Albany, Western Australia.

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Abstract

Coastal areas between Busselton and Albany have been altered substantially since European settlement in the 1830s. Previous studies show that the mammalian fauna in parts of the region changed significantly prior to European settlement; subsequently several additional species have disappeared.

This study, using Museum records and local area sampling, indicates most mammalian populations are small and often isolated. The Ringtail Possum *Pseudocheirus occidentalis* and Quokka *Setonix brachyurus* persist but are rapidly diminishing. The herpetofauna has not previously been documented and it appears that assemblages in the Busselton-Margaret River areas differ from those further south and east. A positive correlation between the percentage of viviparous reptiles in subregional assemblages and the annual number of rainy days, suggests that viviparity probably confers a reproductive advantage in these cool moist climates.

Environmental factors such as predation, competition, disease and particularly habitat fragmentation and fire will continue to threaten many species of birds and mammals with local extinction.

Introduction

The near-coastal areas of the lower south-west of Western Australia between Busselton and Albany have come under increasing pressures since European settlement. In the last decade the region has become the focus of major developments for agriculture, mining and tourism; these have exacerbated the fragmentation of the unique landforms and biota of the region.

Reviews of the literature on vertebrate fauna (Daze 1984), invertebrate fauna (Majer and Chia 1980) and aquatic fauna (Chiffings and Brown 1977) in Western Australia, coupled with the records and collections of the WA Museum, have highlighted the paucity of collections and publications on the fauna of most near-coastal areas of the lower south-west.

Considerable historical information was collected by early navigators (see Beard 1981), and data collected by early naturalists has been summarised for plants (Beard 1981), mammals (Shortridge 1909, 1936, Kitchener *et al.* 1978) and birds (Whittell 1954a). Most of these collections were made around regional centres of population, e.g. Albany and Busselton, or on trips from Perth.

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Our study concentrated on the ground vertebrate fauna (mammals, terrestrial birds, reptiles and amphibians), principally in the areas from Busselton to Augusta, which face the greatest pressure from development and tourism, and from Augusta to Walpole, which has received limited attention in the past and contains the major south coastal reserve (D'Entrecasteaux National Park).

Study area and methods

The study region encompasses a 15-25 km wide coastal strip from south and east of Busselton to Two Peoples Bay east of Albany (Figure 1). The geomorphology, geology and vegetation of this area has been reviewed by Smith (1973) and Beard (1981).

The area around Busselton lies on the extreme southern end of the Quaternary sands of the Swan Coastal Plain. The coastal strip to the west lies on the Leeuwin-Naturaliste Ridge and consists of sands and calcarenite overlying Precambrian granites and granulites. The most extensive geomorphological unit in the study region is the Scott Coastal Plain, these active and lithified sand dunes extend from east of the Blackwood River to the extreme east of the study region where they
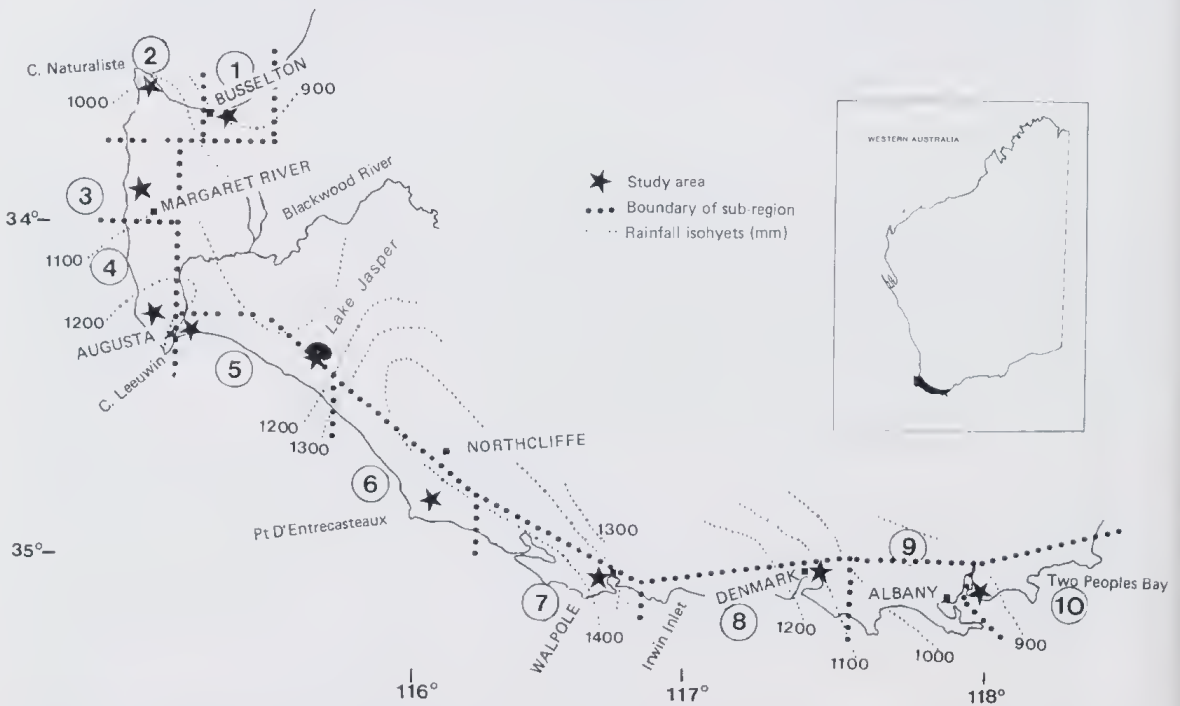

Figure 1   Map of the south-west coast of Western Australia. The ten subregions used in this study are outlined by dotted lines and identified by numbers in circles. The sites studied are indicated by star symbols and the isopleths for mean annual rainfall (mm) are indicated together with the major regional centres.

are replaced by dunes of the Albany Slopes. The interdunal areas of the Scott Coastal Plain are characterised by numerous swamps.

The entire region lies within the Darling Botanical District of the South-West Botanical Province and principally within the Warren Sub-district (Beard 1980). Small areas in the north and north-east are within the Drummond and Menzies Sub-districts, while the area east of Albany also lies within the Menzies Sub-district.

In the present study, 10 areas were selected (Figure 1) to document the terrestrial vertebrate fauna; the location of these study areas was determined by examining vegetation and soil maps. Five sites representing the major edaphic and vegetation heterogeneity within each area were selected, and fenced pitlines and metal traplines were established. Additional opportunistic collections were made from the study area. Each study area was examined over a 4-5 day period in either March 1985, October-November 1985 or January-February 1986. Three study areas were examined twice, in late summer and spring.

Data in the collections in the Western Australian Museum were separated into 10 subregions of roughly similar area (Figure 1). The subregions identified by a major geographical feature or locality are:-

1	Busselton	6	Point D'Entrecasteaux
2	Cape Naturaliste	7	Walpole
3	Margaret River	8	Denmark
4	Augusta	9	Albany
5	Scott River	10	Two Peoples Bay

The species listed in Appendix I and II are referable to these subregions.

Climatic data (Anon 1975) were taken from the recording station closest to the centre of the subregion.

Subregional assemblage dendrograms were produced by WPGMA cluster analysis on Jaccard's indices of association for presence/absence data (Southwood 1978). The indices were clustered using the WPGMA method (Sneath and Sokol 1973). The statistical significance of the clusters was determined following Strauss (1982) by taking the 95% occurrence of each node level following the accumulations of about 3500 nodes using the same clustering procedure derived from randomizing the data matrix. In the randomization process the number of species per site was kept constant but the species present were randomly allocated. Regression analysis was carried out using least-squares method.

Data and discussion

Mammals

Species represented in the collections of the Western Australian Museum are presented by subregions in Appendix I. Nine marsupial families representing 16 species, and seven orders of eutherian mammals comprising 14 families and 32

species have been collected within the region and lodged in the collection. The eutherians include Cetacea (12 spp.), Pinnipedia (2), Lagomorpha (1), Carnivora (3), Artiodactyla (2), Chiroptera (7) and Rodentia (5).

Records of the twelve whale species result from skeletal remains of beached specimens that have been lodged in the WA Museum. Seals are generally confined to islands (Abbott 1979) but skeletal material has been collected from some main-land beaches. Both ungulates (Roe Deer and Pig), two carnivores (Fox and Cat), the lagomorph (Rabbit) and two rodents (Mouse and Black Rat) were introduced since European settlement and have subsequently become feral. Domestic sheep, goats, cattle and horses are widespread in the study region but are not included in Appendix I.

Only 14 species of mammal were recorded during the present field study. These species (with the subregional study areas in which they were recorded or collected) were *Sminthopsis griseoventer* (5, 10), *Macropus fuliginosus* (2, 4, 5, 6, 8, 10), *M. irma* (10), *Setonix brachyurus* (6?), *Isoodon obesulus* (6, 8, 10), *Pseudocheirus occidentalis* (1, 5, 9, 10), *Trichosurus vulpecula* (1, 2), *Tarsipes rostratus* (2, 6, 10), *Mus musculus* (2, 5, 6, 8, 10), *Pseudomys albocinereus* (10), *Rattus fuscipes* (2, 5, 6, 8, 10), *R. rattus* (2, 8, 10), *Eptesicus regulus* (8), *Falsistrellus mackenziei* (6). The most significant is the southernmost record of *Pseudomys*, the first time it has been collected live in the region. The newly described *F. mackenziei* (Kit-chener *et al.* 1986) was relatively common near water in Karri forest north of Point D'Entrecasteaux in March 1985. Few bats were observed and very few captured during the study.

Most mammal species were infrequently recorded and consequently extensive effort is required to ascertain the complete assemblages at the subregional level. This is supported by the fact that only five species of marsupial have been collected from the D'Entrecasteaux subregion, an area with considerable environmental heterogeneity and where *Macropus irma*, *Isoodon obesulus* and *Trichosurus vulpecula* have recently been observed (G. Gardner pers. comm.).

Comparisons of trapping success for mammals between this study and other surveys (How *et al.* 1984 and unpubl.) show that capture rates for south-coastal assemblages are low (Table 1). Capture in pitfall traps is the lowest recorded in any of our recent surveys and significantly ($p < 0.001$) less than that recorded along the Great Australian Bight. Capture in aluminium Elliot traps is significantly ($p < 0.001$) higher than along the Great Australian Bight but similar to that recorded in the sparse populations of the semi-arid Eastern Goldfields (Table 1). Capture rate on the south coast is significantly lower ($p < 0.001$) than that recorded in Elliotts (7372 traps/423 captures) for a relatively sparse small mammal assemblage in north-eastern New South Wales (Barnett *et al.* 1978). Of the 60 individuals caught in Elliott traps on the south coast, *Rattus fuscipes* (31), *Mus musculus* (21) and *Rattus rattus* (4) predominated: the preferential capture of rodents in Elliott traps has been recorded previously (How *et al.* 1984).

Table 1   Comparison of trapping success in recent WA Museum surveys for mammals in both Elliott and fenced pitfall traps. Capture rate per 100 trapnights is bracketed.

Survey	Elliotts/Captures	Pitfalls/Captures
South Coastal WA	2054/60 (2.92)	967/16 (1.66)
Great Australian Bight WA[1]	1050/8 (0.76)	732/25 (3.42)
Eastern Goldfields WA[2]	4311/75 (1.74)	8780/169 (1.93)

Data from   (1) our unpublished
            (2) How, Humphreys and Dell 1984

The Chuditch *Dasyurus geoffroii* is the only dasyurid known to have changed status significantly within the study region. Shortridge (1909) found abundant tracks along the coast at Margaret River and assumed the species to be plentiful there but observed that it did not appear to extend far inland. He noted that it was being actively killed by farmers. There is no museum record from the study region in the last 20 years although several sightings have been reported from the Leeuwin-Naturaliste Ridge between 1984-1986 (P. Lambert pers. comm.). The status of the Mardo *Antechinus flavipes,* Brush-tailed Wambenger *Phascogale tapoatafa* and Coastal Dunnart *Sminthopsis griseoventer* appears to have changed little in recent years.

The record of the numbat *Myrmecobius fasciatus* from the Albany subregion is of doubtful provenance. It is based on a very early specimen sent from the Torbay District but possibly not collected there.

The Brown Bandicoot *Isoodon obesulus* occurs around swamps within the study region, although many of the populations in the Busselton-Margaret River areas may have been severely fragmented by land clearance.

The Ringtail *Pseudocheirus occidentalis* and Brushtail *Trichosurus vulpecula* Possums have changed status considerably since European occupation. The Ringtail, once abundant in most *Agonis* forests and along banks of rivers and swamps (Shortridge 1909), has declined alarmingly over much of its former range and is now abundant in only a few areas. We examined several natural areas where *P. occidentalis* previously occurred and noted all nests appeared to be unused or abandoned. Apparently viable populations occur within the towns of Busselton, Quindalup, Dunsborough and Albany, in several forest locations (Christensen *et al.* 1985) and in Two Peoples Bay Reserve (Hopper 1981). The Brushtail Possum was once common throughout the south-west and extended inland to the woodlands of the Eastern Goldfields; hunting and predator pressure, disease, land clearance and fire have all probably had a pronounced influence on reducing its range. Nowhere within the study area are dense populations of either possum species known to occur.

The Western Pygmy Possum *Cercartetus concinnus* has been intermittently recorded from the study region over the last 20 years but is probably widespread,

being trapped mainly in fenced pitfall traps, a technique that is still infrequently used. The Honey Possum *Tarsipes rostratus* is the most widespread marsupial and is abundant in the floristically rich heaths and understories of the region.

The Woylie *Bettongia penicillata* has not been recorded in the study region within the last 50 years and is now confined to the forests at Perup (Christensen *et al.* 1985). It was abundant in the Yallingup-Margaret River area around the turn of the century when it was destructive to crops (Shortridge 1909). *Potorous tridactylus* is known only from cave material, although Shortridge (1909) thought it occurred at Cape Leeuwin.

Of the five rodents known from the region, the introduced Mouse *Mus musculus* and the Black Rat *Rattus rattus* and endemic Bush Rat *R. fuscipes* are widespread and common. The Bush Rat is the most abundant of all ground mammals in the study region. The Water Rat *Hydromys chrysogaster* is infrequently captured but from the evidence of feeding sites appears to be widespread along watercourses. The Ash-grey Mouse *Pseudomys albocinereus* is regionally known from only one locality.

The bats have never been documented systematically in near-coastal areas, and only since 1950 have specimens been regularly lodged in the Museum (Appendix I). Christensen *et al.* (1985) documented the bat fauna of the more inland forested areas. They reported that the Great Pipistrelle *Falsistrellus mackenziei (Pipistrellus tasmaniensis* in Christensen *et al.)* and the King River Eptesicus *Eptesicus regulus* were both widely distributed.

Assessment of Western Australian Museum records from within the study region over the last 35-40 years show only slight faunal changes (Table 2). The number of marsupial species has declined slowly, although the rodents show an increase with our record of the Ash-grey Mouse. Three species of marsupial have not been lodged in the collection since 1950, viz. *Macropus eugenii* (1931), *Myrmecobius fasciatus* and *Bettongia penicillata* (1933), while *Dasyurus geoffroii* was represented only by skeletal material in 1964-65. The bat *Nyctophilus gouldii* has similarly not been collected since 1965, and then only as skeletal material from caves near August. There are no records of the Echidna *Tachyglossus aculeatus*.

Shortridge (1909, 1936) made several statements on the status of species. He thought that the Brush Wallaby *Macropus irma* did not occur in southern coastal

Table 2   Number of species of recent mammals represented in the Museum collections from the near-coastal areas of the lower south-west of Western Australia.

Order	Period		
	<1950	1950-1975	1975-1986
Marsupialia	15	12	11
Rodentia	4	4	5
Chiroptera	2	7	6

districts between Cape Naturaliste and Leeuwin, an area where it now occurs in low numbers. By 1930 the Tammar *M. eugenii* was rapidly disappearing from cultivated lands; it has not since been represented in Museum collections from near-coastal sites. Both species have been recorded in forests inland from the present study region (Christensen *et al.* 1985), although the Tammar was found in only one locality. The Quokka *Setonix brachyurus* was common in swampy patches along the coast in the early 1900s but is currently much more restricted having suffered a major epidemic in the 1920s (White 1952, G. Gardner pers. comm.); but footprints sighted near Point D'Entrecasteaux during the present survey were probably of this species.

Comparisons between the prehistoric mammalian fauna of caves in the Augusta area (Archer and Baynes 1972) with that recorded and collected between 1904 and 1907 by Shortridge (1909, 1936) around Margaret River and with the more recent records of the WA Museum show considerable changes in status and distributions. Species represented in the Augusta cave fauna but not collected live have been summarised by Archer and Baynes (1972); they include the marsupials *Sarcophilus harrisii*, *Potorous tridactylus* and *Bettongia lesueur*, the bat *Nyctophilus timoriensis*, and the rodents *Pseudomys albocinereus*, *P. shortridgei*, *P. praeconis* and *Rattus tunneyi*. More recent Museum information indicates that *N. timoriensis (=N. major)* survives on the Leeuwin-Naturaliste Ridge.

The major change to the mammal fauna between 25 000 and 12 000 B.P., as examined in deposits of Devils Lair, was a consequence of either glacio-eustatic changes in sea level altering the extent of habitats, or such changes acting in concert with climate and increased regional rainfall to alter the environment (Baynes *et al.* 1975). The marked change since European settlement probably results from direct and indirect anthropogenic factors (Shortridge 1909, 1936, Carter, 1923, Kitchener *et al.* 1978) such as changed fire regime, land alteration for agriculture, exotic diseases and introduced predators and competitors.

Birds

Zoogeographically south-western Australia is an area where Eyrean and Bassian faunas mingle (Serventy and Whittel 1954). The coastal areas dealt with in this study contain a number of Bassian endemics or species with disjunct populations in south-western and south-eastern Australia. In general these species have extremely curtailed distributions and have attracted considerable comment (Smith 1977). All have been affected markedly by the activities of European man in the last 100 years.

The first bird collections were made in the south-west coastal regions within a few years of the establishment of colonies around the Avon River and King George Sound. John Gilbert made three collecting trips to the region: in February 1840 he collected at King George Sound and inland to Cranbrook; in November 1842 with the botanist James Drummond he collected between Perth and Augusta; and in June 1843 he made an overland collecting trip from Perth to King George

Sound via Kojonup. Specimens collected by Gilbert were often new to science and provided the main source of material for Gould. Gilbert's collecting trips are documented by Whittell (1941, 1954a).

The next major ornithological work was by Milligan (1902) who in 1901 collected and made numerous field notes in the area immediately north of Margaret River. A notable feature of this work was the first collection of the Rufous Bristlebird *Dasyornis broadbenti*. Milligan commented on the abundance of birds in the coastal hills where he encountered "tens of thousands" of Grey Currawongs *Strepera versicolor* and Ring-necked Parrots *Platycercus zonarius* and provided notes on a total of 57 species in the area. Most of the species recorded by Milligan are still relatively abundant. However the Whipbird *Psophodes nigrogularis,* Rufous Bristlebird, and Mallee Fowl *Leipoa ocellata* and probably the Stone Plover *Burhinus grallarius* are now locally extinct.

Carter (1923) presented an annotated list of 197 species of birds that he had encountered within a radius of 250 km of Broomehill. He provided data on 131 species that he recorded in coastal areas such as Busselton, Cape Naturaliste, Cape Mentelle, Cape Leeuwin, Augusta, Warren River, Denmark and Albany. Carter's paper was the first attempt to appraise the distribution, status, and habitat of all the known birds of the south-west. He was also aware of changes in abundance resulting from activities of European man:- he stated that in 1902 Mallee Fowl were not uncommon in the coastal scrubs between Cape Naturaliste and the mouth of the Warren River but by *c.* 1920 had diminished because of burning off the coastal vegetation to improve grazing for cattle. This population was extinct by 1950 (Storr 1954).

Similarly Carter identified the decline in Western Bristlebird and Rufous Bristlebird; "I revisited the same locality in March, 1916, 1919 and 1922 and found that where there had been dense impenetrable scrub, was mostly bare sand drifts caused by fires made to improve the country for cattle". He considered also that feral cats were hastening this extinction.

Further data on coastal avifauna were provided by Ashby and LeSouef (1928), Whitlock (1939), Whittell (1933, 1938) Lane (1975) and Abbott (1976). Information on coastal islands was provided by Storr (1965), Abbott (1978a, b, c, d, e, f, 1980), Fullagar (1978), Kolichis and Abbott (1978) and Lane (1978). These studies and the summary distributions in Blakers *et al.* (1984) provide the background for the avifauna of the region.

Herpetofauna

There has been a marked change in our understanding of the herpetofauna of Western Australia in the last 20 years with a significant increase in the information published (Daze 1984), a vast increase in collections and surveys and a doubling of the number of species described or recognised. The principal systematic revisions have occurred in the lizards (Lacertilia), although several new species of frogs (Batrachia) and snakes (Serpentes) have also been described (Figure 2). Many of

these new species have resulted from a re-evaulation of previously known taxa, but most have been collected in remote areas. It has consequently been difficult to evaluate historical changes in this group; this difficulty is further compounded by a general disinterest in reptiles by early collectors, and a poorly documented and researched sub-fossil fauna.
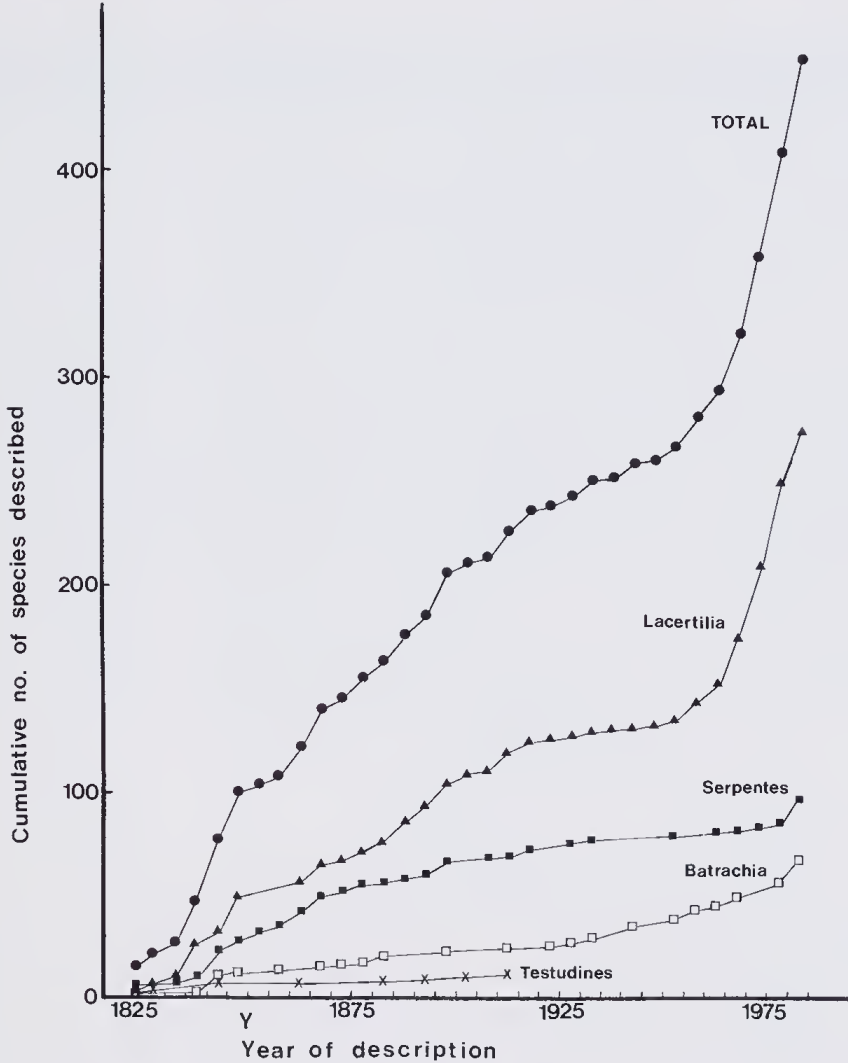

Figure 2   Species of Reptilia and Amphibia described in Western Australia accumulated for five-year intervals. (Both species of Crocodylidae were described before 1873).

Few new frog locality records resulted from our study, principally because sampling was undertaken in the late spring-late summer period when most frogs are inactive. The record of *Ranidella subinsignifera* in the Point D'Entrecasteaux area is a southwestward extension of its known range (Tyler *et al.* 1984) while

Heleioporus psammophilus has now been shown to occur along the Scott River Plains, and *H. inornatus* has been recorded from the Cape Naturaliste area. The two species of *Litoria* were infrequently collected in the Busselton-Dunsborough area but recent revision of the *Geocrinea rosea-lutea* complex has shown that two undescribed species also occur in the study region (Roberts and Wardell-Johnstone pers. comm.).

The Loggerhead Turtle *Caretta caretta* and the four species of marine snakes in the families Homalopsidae and Hydrophiidae, stranded on beaches, were presumably swept down and around the south coast by the Leeuwin Current. The Oblong Turtle *Chelodina oblonga* is present in many of the freshwater streams and swamps of the study region.

Many families of oviparous terrestrial squamate reptiles are represented in the study region by single species, e.g. Agamidae, Varanidae, Typhlopidae and Boidae, and except in the extreme south-east of the region only one species of gecko occurs.

This study has added little to the knowledge of distribution of reptiles occupying the coastal fringe, an impoverished assemblage when compared to those further north (Storr *et al.* 1978) and east (Chapman pers. comm.). However, it contains many elements of the southern forest assemblages (Christensen *et al.* 1985). Only 29 species were recorded during this study. The only species added to the regional assemblage was the cryptic *Lerista elegans*, previously known from the west-coastal sands (Storr *et al.* 1981) but now known to extend as far south as the Scott River Plains, east of the Blackwood River. *Ctenotus catenifer* has now been collected at a number of localities west to Augusta. The capture of *C. impar* from the Margaret River subregion and *Ramphotyphlops australis* from Denmark represents their most south-westerly or southerly distribution. All other reptiles observed or collected were within their previously determined distributions.

Gaps apparent in near-coastal distributions (Appendix II) may well be changed by future surveys that record the more cryptic and less abundant species, particularly from areas between Augusta and Denmark that have received little attention and remain poorly documented. The southern forest surveys (Christensen *et al.* 1985) examined four areas which are encompassed by the present study region viz. Boranup in Augusta subregion (4), Yeagerup and Dombakup in D'Entrecasteaux subregion (6) and Woolbales in Walpole subregion (7). All representative specimens collected by those surveys are lodged in the Western Australian Museum and consequently appear in Appendix II. However, they made the following observations that are new for the subregions, or in two cases, the region: the skinks *Cryptoblepharus plagiocephalus, Ctenotus impar, Lerista distinguenda* and *Menetia greyi* in the Boranup survey; *Egernia luctuosa, Morethia lineoocellata, M. obscura, Hemiergis initialis, Tiliqua rugosa,* the legless lizard *Delma fraseri,* the snake *Rhinoplocephalus bicolor* and monitor *Varanus gouldii* at Woolbales. It is unlikely that the distributions of *V. gouldii, M. obscura, H. initialis* and *D. fraseri* extend to the southern coast (Storr *et al.* 1981, 1983), hence these may have been

misidentified by Christensen *et al.* (1985); all other observations represent plausible new distribution records for the coastal region.

Species such as *Pygopus lepidopodus, Egernia kingii, E. luctuosa, E. pulchra, Sphenomorphus australis, Varanus rosenbergi, Notechis curtus, N. minor* and *Rhinoplocephalus bicolor* probably occur throughout near-coastal areas, although the abundant litter skinks *Menetia greyii* and *Lerista distinguenda* and the dragon *Pogona minor* do not occur in the higher rainfall areas of the south coast or adjacent forests (Chapman and Dell 1985, Christensen *et al.* 1985) but re-occur in the drier south-east of the region.
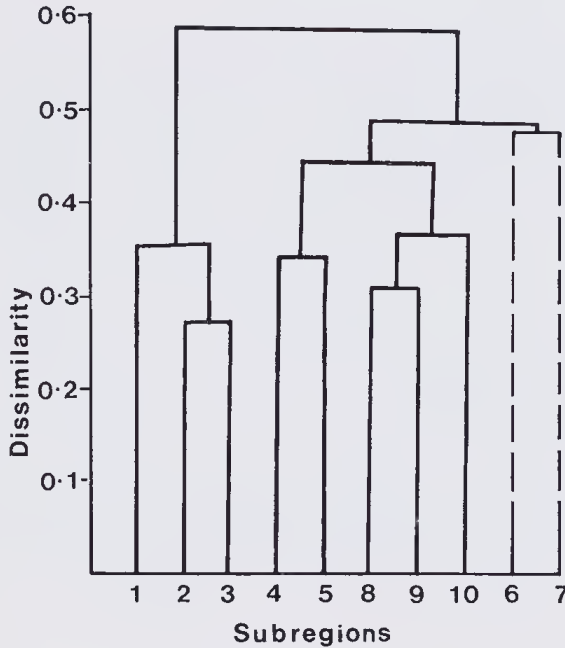

Figure 3   Dendrograms of faunal dissimilarity of subregions for the terrestrial reptile assemblage. Bold lines link significant groupings (see Methods).

Comparison of assemblage similarity indices for the subregions (from Appendix II) shows that for terrestrial snakes and lizards there is a marked dichotomy between the Busselton, Cape Naturaliste, Margaret River subregions and all other subregions (Figure 3). This suggests a zoogeographic boundary in the area between Margaret River and Augusta with the northward range termination here of *Ctenotus catenifer* and *Sphenomorphus australis* and a southward range termination of *Aprasia repens, Lialis burtonis, C. impar, Lerista distinguenda* and *Menetia greyi.*

Examination of the assemblages of terrestrial squamate reptiles in the 10 subregions and adjacent regions (Table 3) indicates a major change in the percentage occurrence of viviparous species. The highest percentage of viviparous species occurs in the Walpole subregion (61%) and the lowest in Cape Naturaliste

(33%). The inference from Table 3 is that the more southerly, higher rainfall subregions have a higher percentage of live-bearing species.

Table 3   Percentage of viviparous species in the terrestrial squamate reptile assemblage of near-coastal subregions and adjacent areas. The mean annual rainfall and mean rain days are presented for the nearest recording station.

AREA	Rainfall	Rain Days	Squamate Reptiles	Viviparous Species	Viviparity (%)
Busselton	838	137	26	10	39
Cape Naturaliste	838	156	27	9	33
Margaret River	1192	147	23	9	39
Augusta	994	183	22	10	46
Scott River	994	183	21	10	48
Point D'Entrecasteaux	1387	178	14	7	50
Walpole	1369	185	18	11	61
Denmark	1012	192	24	12	50
Albany	815	179	26	12	46
Two Peoples Bay	815	179	27	14	52
Fitzgerald N. Pk[1]	628	118	40	12	30
Southern Forests[2]	1055	153	25	12	48
Northern Swan Plain[3]	849	102	55	11	20

Data from   1. Chapman (pers. comm.)
                    2. Christensen *et al.* (1985)
                    3. Storr *et al.* (1978)

The proportion of viviparous species within the 10 subregions is not related to rainfall (Spearman's rank correlation = 0.324, $t_8 = 0.969$, N.S.) but is strongly correlated with the number of rainy days (Spearman's rank correlaton = 0.694, $t_8 = 2.726$, $p = 0.026$) and this relationship is enhanced when data from adjacent areas (Table 3) are included (Spearman's rank correlation = 0.762, $t_{11} = 4.156$, $p = 0.0016$) which yields the relationship $y = 3.869x + 2.352$ (N = 13, $r = 0.884$, $p < 0.001$), where $y = \sin^{-1}\sqrt{}$ proportion viviparous and $x =$ number of rainy days.

These findings are in close agreement with those of Shine and Berry (1978), who concluded, from a detailed examination of climatic correlates of viviparous species, that live-bearing is as closely correlated with measures of precipitation, evaporation and humidity as it is with environmental temperatures and irradiance measures and that viviparity essentially conferred a selective advantage for reproduction in cold-moist climates.

Conclusion

". . . and I declare that neither in Victoria nor Queensland have I seen so many species and individuals within a similar area to that traversed." (Milligan 1902).

The above quotation refers to the avifauna of the Cowaramup-Margaret River area which at that time included Stone Plovers, Western Whipbirds, Rufous

Bristle-birds and Mallee Fowl. These species were greatly reduced only 20 years later, a fact attributed to the alteration of habitat by fire (Carter 1923); they are now extinct in the area.

The destructive impact of fires on fauna is a recurring theme in Western Australia. Fire is blamed for the decline of marsupials in the Leeuwin-Naturaliste area (Shortridge 1909), and of the mammals of the south-west of the State (Shortridge 1936), Swan Coastal Plain (Kitchener *et al.* 1978) and deserts (Burbidge and MacKenzie pers. comm.). In coastal habitats of southern New South Wales, it has been shown that wildfires markedly change faunal assemblages and that post-fire recovery is variable (Newsome *et al.* 1975).

The Leeuwin-Naturaliste area was one of the first settled in the State, and as population increased so did clearing of land for agriculture, forest plantations and, more recently, viticulture, hobby farms and holiday homes. The fragmentation of native vegetation through clearing has probably had the most pronounced effect of all man-made changes on the fauna. This is exacerbating the impacts of most other changes and promoting the competition between introduced herbivores (such as ungulates, rabbits and rodents) and carnivores (cats and foxes) and their native counterparts.

Disease has been blamed for the sudden reduction in range and abundance and possibly even disappearance of several mammal species between the 1880s and the turn of the century (Shortridge 1909) and even later in the 1920s (White 1952). George Gardner (pers. comm.) stated that the swamps around Northcliffe were full of Quokka bodies in the early 1920s, presumably the result of a major epizootic. The influence of disease on changing assemblages will remain anecdotal.

The first record of foxes in Western Australia was in 1911-12 (King and Smith 1985), and after their arrival they are believed to have had a significant impact on the medium-sized mammals through predation (King *et al.* 1981). The decline in the mammal fauna of the Perup forest in 1973-74 has also been attributed to the high incidence of predation by foxes (Christensen 1980). Feral cats have similarly been destructive of native mammals and reptiles. Predation by 'cats gone wild' was believed to be an important factor in species reduction in the early 1900s (Shortridge 1909), and numerous species of native vertebrate are represented in museum collections that were 'brought in by cats'.

Nearly all known mammal species, including widespread ones, occur in low densities in the study region, thus requiring considerable effort to adequately document the assemblages of subregions. The marked decline in abundance and distribution of the Brushtail *Trichosurus vulpecula* and Ringtail Possums *Pseudocheirus occidentalis* in near-coastal localities is of particular concern. The Brushtail Possum was once widespread through the mesic and semi-arid southwest of the State and abundant in the lower south-west where it was hunted for its skin (Serventy 1954); the Ringtail Possum is confined to the lower south-west. Recent work has shown that the numbers of both species, although fluctuating,

are considerably reduced and that some range contraction is still occuring (Christensen *et al.* 1985).

The impact of environmental changes on lizards has been evaluated in a survey of nature reserves in the semi-arid wheatbelt of Western Australia (Kitchener *et al.* 1980). Despite the major fragmentation of native vegetation with increasing demand for agricultural land, it appears that there has been no large-scale loss of lizard species from that region (unlike the situation for mammals), and their assemblages probably remain little altered. Kitchener *et al.* (1980) concluded also that the richness of lizard species correlated with vegetation associations which in turn correlated with edaphic factors.

The predominantly sandy soils of south-western near-coastal areas, together with the cool, moist environment, results in a considerably reduced assemblage of ectothermic vertebrates. The prolonged winter, lower temperatures and higher rainfall have been advanced as factors explaining the lower number (32) of reptile species present in southern forests compared with the rich (55) assemblage of the northern Swan Coastal Plain (Christensen *et al.* 1985). The significant positive correlation between the percentage of viviparous squamate species and the mean annual number of rainy days suggests a reproductive advantage for live-bearing species in these cool-moist climates.

Reptile species richness is greatest at each end of the study region and decreases centrally. This may be partly accounted for by reduced sampling in the less accessible high rainfall areas of the central subregions, although some coastal species near Margaret River and Augusta are apparently absent from the wetter south coast subregions but appear further east. Several west coast species only extend south to Busselton and on to the Leeuwin-Naturaliste ridge. These two factors combine to differentiate the reptile assemblage of the Busselton-Margaret River area from the other near coastal subregions.

The mammal and bird faunas of coastal and near-coastal areas between Busselton and Albany have considerably changed since European settlement, resulting in the disappearance of several species and a contraction of range in others. It is unlikely that any single factor has been responsible, more probably the accumulated effects of changed fire regimes, land clearance for agriculture, predation, competition and disease have acted in concert.

Acknowledgements

Appendix I List of the mammal species represented in the collection of the Western Australian Museum from ten subregions in the near-coastal region of the lower south-west. Horizontal lines represent specimens collected before 1950, vertical lines between 1950-1975 and circles after 1975. Materal from cave deposits has been excluded.

Family/Species	Subregions									
	1	2	3	4	5	6	7	8	9	10
MARSUPIALIA										
BURRAMYIDAE										
Cercartetus concinnus	−	+	−	⊕						−	−		
DASYURIDAE										
Antechinus flavipes											
Dasyurus geoffroii	−	−		−								
Phascogale tapoatafa	⊕	+	+	⊕			○	−	−	○	
Sminthopsis griseoventer					−	⊕	①		①	⊕	⊕	○
MACROPODIDAE										
Macropus eugenii		−		−						
Macropus fuliginosus		①		⊕	①							①		
Macropus irma		①			+	−				−	
Setonix brachyurus		⊖	⊕	−	①			①	①	−	①
MYRMECOBIIDAE										
Myrmecobius fasciatus									−	
PERAMELIDAE										
Isoodon obesulus	+			+	○	①		○	①	⊕	①
PETAURIDAE										
Pseudocheirus occidentalis	①	①			①				⊕	①
PHALANGERIDAE										
Trichosurus vulpecula			○	−						○	
POTOROIDAE										
Bettongia penicillata				−					−	
TARSIPEDIDAE										
Tarsipes rostratus	+	○		−		○	○	+	⊕	○
RODENTIA										
MURIDAE										
Hydromys chrysogaster	⊕			−	⊖	○			+	+	⊖
Mus musculus	⊕	○		+					①	+	⊖
Pseudomys albocinereus										○
Rattus fuscipes	−	○	○	①	○	①	①	①	+	①
Rattus rattus	⊕	⊕		+	○		①	①	⊖	⊕
CHIROPTERA										
VESPERTILIONIDAE										
Chalinolobus gouldii		○		○	○					
Chalinolobus morio			○	①	○			○	○		
Eptesicus regulus	⊕	○	−				○	○	①	①
Falsistrellus mackenziei						①				

Family/Species	Subregions									
	1	2	3	4	5	6	7	8	9	10
Nyctophilus geoffroyi				⊕	○				1	
Nyctophilus gouldii				1						
Nyctophilus major	+	1	−	○	1		○		1	
ARTIODACTYLA										
CERVIDAE										
Capreolus capreolus				1						
SUIDAE										
Sus scrofa				1						
CARNIVORA										
CANIDAE										
Canis familiaris			1	1			1	−		
Vulpes vulpes					1			1		
FELIDAE										
Felis catus	1									
LAGOMORPHA										
LEPORIDAE										
Oryctolagus cuniculus									1	○
CETACEA										
BALAENIDAE										
Eubalaena glacialis								○		
BALAENOPTERIDAE										
Balaenoptera acutorostrata							1			
Balaenoptera borealis	−									
DELPHINIDAE										
Delphinus delphis	−								⊕	
Grampus griseus	1									
Orcinus orca									○	
Pseudorca crassidens			○	○						1
Stenella coeruleoalba					○	−				
Tursiops truncatus		+		+				1		
PHYSETERIDAE										
Physeter catodon		−		−	−				+	
ZIPHIIDAE										
Mesoplodon bowdoini				1						
Mesoplodon grayi	○				1				1	
PINNIPEDIA										
OTARIIDAE										
Neophoca cinerea								○	−	
PHOCIDAE										
Hydrurga leptonyx									1	

Appendix II   List of herpetofauna species represented in the collection of the Western Australian Museum from ten subregions in the near-coastal region of the lower Southwest. Crosses represent collections prior to the present study and circles those made during the present study.

Family/Species	Subregions									
	1	2	3	4	5	6	7	8	9	10
ANURA										
LEPTODACTYLIDAE										
Crinia georgiana		×	×	×	⊗	⊗	⊗	×	×	×
Geocrinia leai			×	×	⊗	⊗	⊗	×		×
Geocrinia rosea						×	×			
Heleioporus eyrei	⊗	⊗	⊗	⊗	⊗	⊗	×	⊗	×	⊗
Heleioporus inornatus		⊗						×		
Heleioporus psammophilus	×	×			○	⊗	×			
Limnodynastes dorsalis	×	×	⊗	○	○			⊗	×	⊗
Pseudophryne guentheri	⊗	⊗			○	×		×	×	⊗
Pseudophryne nichollsi		⊗		×	×		⊗		×	
Ranidella glauerti						×	⊗		×	×
Ranidella insignifera	⊗									
Ranidella subinsignifera						⊗		×		×
HYLIDAE										
Litoria adelaidensis		○	×	×	⊗	⊗	×	⊗	×	⊗
Litoria moorei		○	×	⊗	⊗	⊗	×	⊗	×	⊗
TESTUDINES										
CHELONIIDAE										
Caretta caretta gigas	×		×	×	×	×	×			
CHELUIDAE										
Chelodina oblonga	×				×		×		×	×
LACERTILIA										
GEKKONIDAE										
Phyllodactylus marmoratus marmoratus	⊗	×	⊗	×	⊗	⊗	○	⊗	×	×
Phyllurus milii								×		
Diplodactylus granariensis										×
PYGOPODIDAE										
Aprasia pulchella	×	×	○		×					
Aprasia repens	×	×							×	
Aprasia striolata									×	×
Delma australis										×
Lialis burtonis			×	×				×		
Pygopus lepidopodus	×	×	×	⊗			×	×	×	×
AGAMIDAE										
Pogona minor minor	○	○	⊗	×				×	×	
SCINCIDAE										
Cryptoblepharus plagiocephalus	⊗	×					×			
Ctenotus catenifer				×	○	⊗		⊗	×	⊗
Ctenotus impar	⊗	⊗	○							

Family/Species	Subregions									
	1	2	3	4	5	6	7	8	9	10
Ctenotus labillardieri		⊗	⊗	⊗	⊗	⊗	⊗	⊗	×	×
Egernia kingii	×		×	×	×	×	×	⊗	×	⊗
Egernia luctuosa					○			×	×	×
Egernia multiscutata bos										×
Egernia napoleonis	×	⊗	○	×	⊗	⊗	⊗	×	×	⊗
Egernia pulchra pulchra			×			×	×	×	×	×
Hemiergis peronii	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	×	×
Hemiergis quadrilineata	⊗									
Leiolopisma trilineatum	○	○	⊗	⊗	○	⊗		⊗	×	⊗
Lerista distinguenda	×	⊗	×						×	
Lerista elegans	○	○	○	○	○					
Lerista lineata	×									
Lerista microtis microtis					⊗	×	×	⊗	×	⊗
Menetia greyii	⊗	⊗						×	×	
Morethia lineoocellata	○	⊗	⊗	⊗	⊗					
Morethia obscura										×
Sphenomorphus australis				×	○		×	×	×	×
Tiliqua occipitalis								×		×
Tiliqua rugosa rugosa	○	⊗	⊗	○	⊗		×	○	×	⊗
VARANIDAE										
Varanus rosenbergi	○	⊗	×	⊗	○			⊗	×	×

SERPENTES

TYPHLOPIDAE

Ramphotyphlops australis	⊗	×		×	⊗	⊗		○		

BOIDAE

Morelia spilota imbricata		×	×	×						×

HOMALOPSIDAE

Fordonia leucobalia	×									

ELAPIDAE

Notechis coronatus	×	×		⊗	⊗	⊗	⊗	×	×	×
Notechis curtus	×	×	⊗	×	×		⊗	×	×	×
Notechis minor	×			×		×	⊗	×	×	×
Notechis scutatus occidentalis	×	⊗	×	×	⊗	⊗	×	⊗	×	×
Pseudonaja affinis affinis	⊗	⊗	⊗	⊗	⊗	⊗	×	×	×	×
Rhinoplocephalus bicolor		×	×	×			×		×	×
Rhinoplocephalus gouldii		⊗								
Rhinoplocephalus nigriceps	⊗	×	×		×					
Vermicella semifasciata							×			

HYDROPHIIDAE

Hydrophis elegans	×	×								
Hydrophis ocellatus	×									
Pelamis platura	×	×	×					×	×	×

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SHORT COMMUNICATIONS

Range extensions of *Metapenaeopsis lamellata* (de Haan) and *Trachypenaeus curvirostris* (Stimpson)(Crustacea: Decapoda) off south Western Australia

R.J.G. Manning*

Introduction

Two widespread species of Indo-west Pacific penaeid prawns, *Metapenaeopsis lamellata* (de Haan) and *Trachypenaeus curvirostris* (Stimpson) have previously been recorded on the West Australian coast as far south as Shark Bay. They are now recorded about 750 km further south. Specimens are all lodged in the Western Australian Museum and registration numbers are prefixed by WAM. Carapace length of specimens are abbreviated as CL.

Metapenaeopsis lamellata (de Haan, 1850)

A single female specimen (WAM 98-87), 17 mm CL, was collected in February 1986 by a commercial prawn fisherman from the entrance channel of the Peel-Harvey Estuary, Mandurah (32°31'S, 115°43'E), Western Australia. The specimen was caught on a medium to strong outgoing tide, using beam-tide nets within 1.2 m of the surface in 4 m of water over a sandy substrate. The diagnostic features are detailed by Racek and Dall (1965). The coloration of this specimen in life was reddish pink with bright red on the legs, pleopods and dorsal ridges of the carapace. The posterior segments, telson and uropods were cream-white. This record of *M. lamellata* from Mandurah extends the range of this species approximately 760 km south of its previously known southern limit, Shark Bay, Western Australia (Grey *et al.* 1983). The species occurs throughout tropical Australia, New Guinea, South East Asia, China and Japan (Grey *et al.* 1983).

Trachypenaeus curvirostris (Stimpson, 1860)

Four specimens (WAM 97-87) two males, 13 mm and 14 mm CL (petasma missing from the latter) and two females, both 20 mm CL were collected in commercial trawls from Singleton (32°27'S, 115°44'E), Western Australia. A further series was collected north-west of Rottnest Island (31°59'S, 115°34'E). This species is commonly taken in commercial catches of *P. latisulcatus* from sandy substrate between limestone reefs at 12 m. The diagnostic features of this species are detailed by Dall (1957). The coloration in life was a light, reddish pink, with darker reddish banding in the posterior dorsal edge of the body segments which tapered into the basic body colour laterally. The legs were white to

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pink, turning light brown towards the body. The records of *T. curvirostris* from Singleton and north-west of Rottnest Island extend the range 750 km and 690 km respectively south of its previous known southern limit Shark Bay (Grey *et al.* 1983). This widespread species occurs from East Africa, Egypt, Mediterranean Sea, Israel, Turkey, China, Japan, South-East Asia and New Guinea (Grey *et al.* 1983).

Acknowledgements

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