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Cover: The Numbat (*Myrmecobius fasciatus*), drawn by Martin Thompson, Western Australian Museum. The Numbat, State emblem of Western Australia, is a medium-sized marsupial, unusual in that it is active during daylight: as a consequence, it is perhaps the most strikingly camouflaged of all the Australian marsupials.

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A REVISION OF THE AUSTRALIAN FROGFISHES (BATRACHOIDIDAE)

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ABSTRACT

Two genera of batrachoidid fishes, *Halophryne* Gill and *Batrachomoeus* Ogilby, are recognized from Australia. The main generic characters for *Halophryne* are the absence of a pore in the pectoral axilla, mandible and palate with bands of small cardiform teeth, gill slit present on the upper half to two-thirds of the pectoral base and ten precaudal vertebrae. The features which distinguish *Batrachomoeus* include a pectoral axillary pore, mandible and palate usually with one series of strong conical teeth, gill slit encompassing the entire pectoral base and nine precaudal vertebrae. Three species of *Halophryne* are recognized: *ocellatus* Hutchins, *diemensis* (Lesueur) and *queenslandiae* (De Vis). Five species of *Batrachomoeus* are recognized: *dubius* (Shaw), *trispinosus* (Günther), *dahli* (Rendahl), *occidentalis* n. sp. and *rubricephalus* n. sp. Two species of *Halophryne* and four of *Batrachomoeus* are considered to be endemic to Australia. The type locality of *Halophryne diemensis* is apparently the north-western corner of the Northern Territory, near Darwin, rather than Tasmania as previously thought. Shaw is recognized as the author of *Batrachomoeus dubius* and the distribution of this species is considerably reduced. *Batrachomoeus broadbenti* Ogilby is placed in the synonymy of *B. trispinosus* and *B. striatus* (Castelnau) is provisionally included with *B. dubius*.

INTRODUCTION

The family Batrachoididae is made up of eighteen genera and approximately forty-six species (Norman, 1966: 583; Smith, 1952: 314; Collette, 1966: 848). The distribution generally is along the coasts of most continents and nearby islands in areas of warm water, from the shoreline to the vicinity of the continental shelf.

In Australia, the family is represented by two genera, *Halophryne* and *Batrachomoeus*. Previously only Ogilby (1908), De Beaufort (1962) and Taylor (1964) reviewed the Australian genera. Ogilby's work was the most

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comprehensive, but only dealt with four Queensland species. The other two works each involved two species from northern Australia. Whitley (1957) discussed generally five species from Australia, which he also listed in a later paper (1964: 54). In this review, three species of *Halophryne* and five species of *Batrachomoeus* are recognized; two members of the latter genus are herein described as new.

Australian batrachoidids represent a diverse group found at depths exceeding 180 metres, on coral reefs, and in estuaries. They are bottom dwellers and usually shelter under rocks, in caves or bury themselves in sand or mud. They are possibly nocturnal. At least one species, *Batrachomoeus occidentalis*, may migrate from deep water to shallower areas, possibly for reproductive purposes. The spines of the gill covers and dorsal fin are solid and non-venomous. Although the dentition of the two genera differs considerably, their diet is similar consisting of crustaceans (crabs and prawns), molluscs (bivalves, gastropods, chitons and octopuses), echinoderms (sand dollars) and fishes. Food is generally ingested whole. The stomach is capable of great expansion and can occupy the whole abdominal cavity.

Methods

The following abbreviations are used in the text to denote the institutions where the specimens examined are deposited: AM — Australian Museum, Sydney; BM(NH) — British Museum (Natural History), London; KFRS — Kanudi Fisheries Research Station, Papua New Guinea; QM — Queensland Museum, Brisbane; WAM — Western Australian Museum, Perth.

Type specimens have been lodged at AM, BM(NH) and WAM.

Specimens were measured with needle-point dial calipers to the nearest mm (to the nearest tenth of a mm for measurements less than 10 mm). The range for proportional measurements which appears in the species accounts is based on specimens in excess of 40 mm standard length (SL). The peculiar morphology of batrachoidid fishes necessitates the following definitions: Head length — from the anteriormost point of the upper jaw to the midpoint on the nape in line with both upper ends of the gill openings. Head depth — vertical distance from the midpoint between the ventral fin bases to the midline of the nape. Head width — greatest horizontal distance between the preopercular borders of each side. Eye — horizontal diameter of bony orbit. Interorbital — least width of bony interorbital. Snout length — from the anteriormost point of the upper jaw to the midpoint of a line joining the front borders of the eyes. Length of soft dorsal and anal fin bases — from the anterior base of the first ray to the point where the fin membrane meets the caudal peduncle. Lateral line count — this is expressed as the number of bifid tentacles in the upper series on the body, from the mucous pore above the base of the uppermost opercular spine to below the rear edge of the dorsal fin (only those tentacles with their bases arranged vertically, as opposed to

horizontally, are counted). Mucous pore size — the diameter of the largest pore in the preoperculo-mandibular series, usually second or third from tip of lower jaw (see Fig 1). Skin ridge — a raised, narrow fold of skin. When the last two rays of the soft dorsal and anal fins are joined at their bases, they are counted as a single ray (this condition occurs only rarely in *Batrachomoeus*).

Several skeletons of each species except *Halophryne queenslandiae* were studied, thus facilitating a comparison of skull and vertebral features. Where possible, the grooves in the transverse processes of the frontal bone were examined.

Morphology

The general shape of preserved specimens of the same species varies greatly, especially in the genus *Batrachomoeus*. Expanded gill cavities, arched napes, reduced tentacles and looseness of the skin are primarily responsible for this variability. Dentition is also variable due to the nature of the diet; many teeth may be lost, damaged or irregularly arranged, particularly on the vomer.

The sex in *Batrachomoeus* and *Halophryne* can be determined in most cases by examining the first two rays of the anal fin. In females, these rays are considerably differentiated from the rays following them, generally being prominent and the integument unpigmented (see Figs 7 and 12). In males, these rays are identical to those following, hidden by the integument of the fin (see Fig 13).

A slender, flexible spine is present in the angle made by the upper subopercular spine and the ventral limb of the opercular bone. This spine extends in the skin of the gill cover to a point just posterior to the uppermost spine. It possibly has a support function similar to that of the branchiostegal rays. This spine is relatively prominent in *Batrachomoeus* but may be difficult to detect in *Halophryne*. A bony swelling may form at the base of this spine in large specimens, giving the appearance of a further strong spine on the suboperculum.

The pores of these two genera fall into two categories:

Mucous pores — generally open round holes found only on the head, which may have a slender tentacle on the rim. Beneath the pores is a canal which runs along a groove in the underlying bone. There are five pairs of these canals and a single transverse one, supplying 30 or 32 pores. Fig. 1a-b shows the position of these pores in *Halophryne*. There is a series of nine pores along the lower surface of each half of the mandible continued along the preopercular border (preoperculo-mandibular pores). Two canals supply these pores, one in each bone. Three pores are located above the upper lip on each side of the snout, served by a canal in the supramaxilla. Two canals run along the interorbital space and join posteriorly a transverse canal at its midpoint

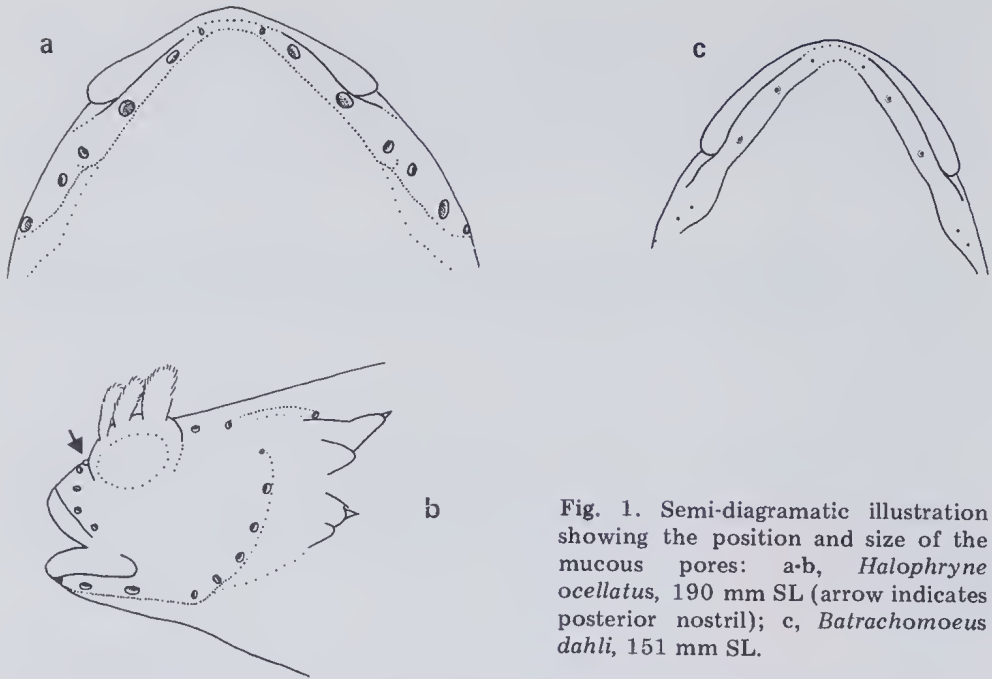


Fig. 1. Semi-diagrammatic illustration showing the position and size of the mucous pores: a-b, *Halophryne ocellatus*, 190 mm SL (arrow indicates posterior nostril); c, *Batrachomoeus dahli*, 151 mm SL.

(see grooves in frontal bone, Fig. 14). This canal system serves four pores, two on each side of the head. The anterior pore is located just anterior to the posterior nostril and the posterior one is found immediately behind the eye on the nape. The last pair of canals do not run in a bony groove but are contained in the skin of the nape. Each canal supplies two pores, one at each end, the anterior pore being located just posterior to the above mentioned pore behind the eye, and the posterior one is found above the base of the upper opercular spine (this canal can usually be seen in the skin). This arrangement is the same for *Batrachomoeus*, except that there is one less pore on the preopercular border. These pores vary in size considerably among the species of the two genera (see Figs. 1 and 2, Table 1).

Sensory pores — these are much smaller than the mucous pores and always surrounded by a bifid tentacle, generally occurring in series on the head and body. There is a single series below each eye, four series along the nape to the dorsal fin, and more or less scattered pores on the lower surface of the mandible, above the upper lip and on the gill covers. The sensory pores of the body are in three series with some scattered ones below the spinous dorsal. The first series commences above the upper opercular spine base and runs below the soft dorsal base to the upper caudal peduncle. The second series branches down from the first row, passes beneath the pectoral fin and continues intermittently along the middle of the side to the caudal peduncle. The last series commences either above the ventral fin base or below the pectoral base and extends along the anal base to the lower caudal peduncle

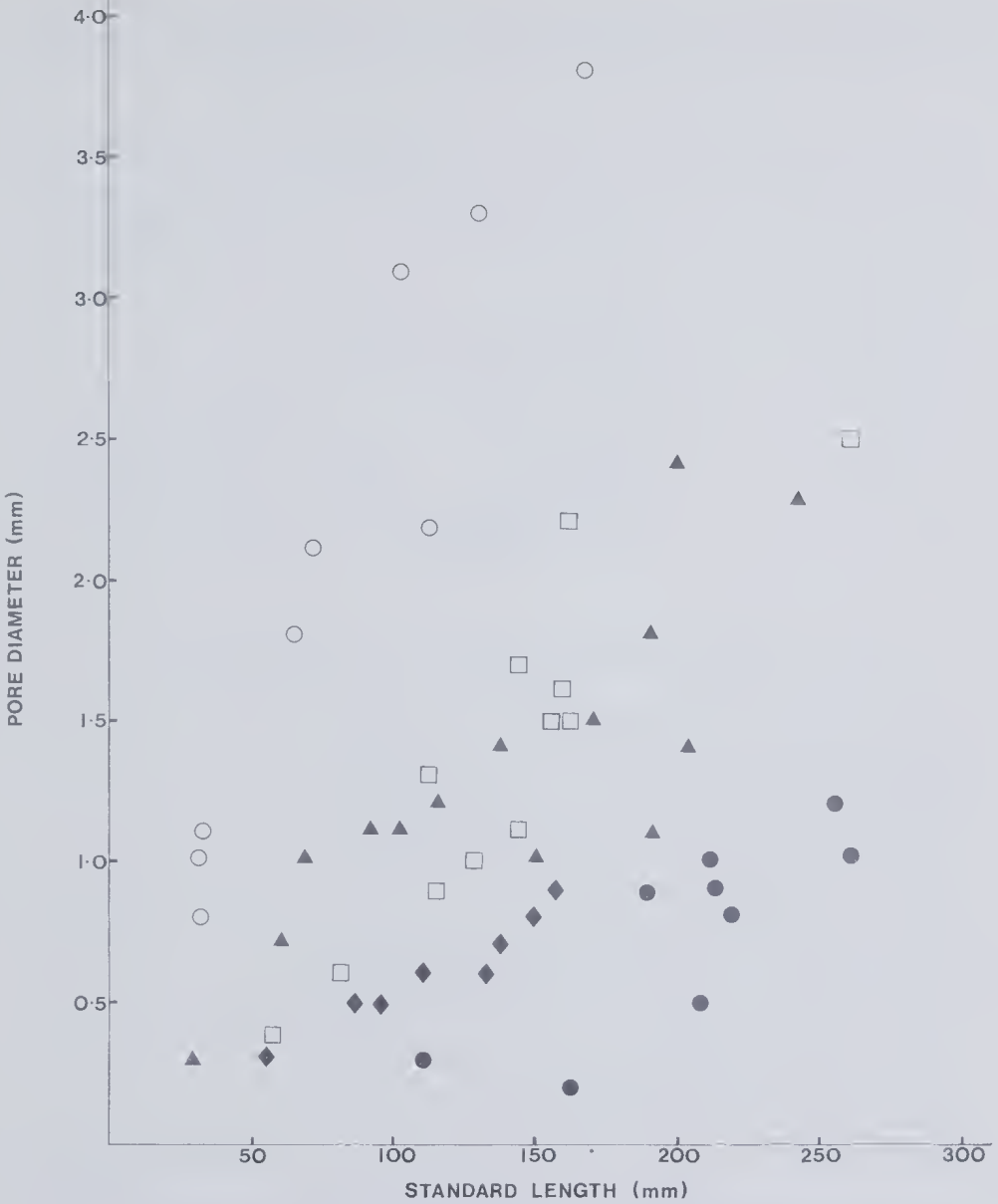


Fig. 2. Mucous pore diameters in *Batrachomoeus occidentalis* (empty circles), *B. dubius* (solid triangles), *B. rubricephalus* (solid circles), *B. trispinosus* (empty squares) and *B. dahl* (solid diamonds).

(see generic descriptions for variations in first and third series). Two series of pores extend a short distance onto the caudal fin.

An axillary pore is found in all species of the genus *Batrachomoeus*. It is located just below the upper termination of the gill opening which curves

back over the top of the pectoral fin base. The internal structure of this organ consists of many invaginated folds which suggests a secretory function. It varies in size among the species of the genus (see Table 1).

TABLE 1. Comparative pore sizes among the species of *Halophryne* and *Batrachomoeus*

Species	Mucous pore size	Axillary pore size
<i>H. ocellatus</i>	Large	—
<i>H. diemensis</i>	Small to medium	—
<i>H. queenslandiae</i>	Large	—
<i>B. occidentalis</i>	Large to very large	Medium
<i>B. dubius</i>	Small to large	Medium to large
<i>B. rubricephalus</i>	Minute to small	Large to very large
<i>B. trispinosus</i>	Medium to large	Small to medium
<i>B. dahli</i>	Small	Small

KEY TO THE AUSTRALIAN GENERA OF BATRACHOIDIDAE

- Gill slit present on upper $\frac{1}{2}$ to $\frac{2}{3}$ of pectoral base; mandible and palate with bands of small cardiform teeth (Fig. 3a); pore absent from pectoral axilla; 3 or 4 (nearly always 4) spines on gill cover; orbital tentacles nearly equal in size, middle one longest; 9 preoperculo-mandibular pores; vertebrae 10 + 18 — 19 *Halophryne*
- Gill slit embraces entire pectoral base, mandible and palate with strong conical teeth, mostly in one series (Fig. 3b); pore present in pectoral axilla; 3 spines on gill cover; orbital tentacles never nearly equal, middle one generally much smaller; 8 preoperculo-mandibular pores; vertebrae 9 + 17 — 21 *Batrachomoeus*

Genus *Halophryne* Gill 1863

Halophryne Gill, 1863: 170 (Type species: *Batrachoides diemensis* Lesueur, 1824, by monotypy).

Coryzichthys Ogilby, 1908: 50 (Type species: *Batrachoides diemensis* Lesueur, 1824, by original designation).

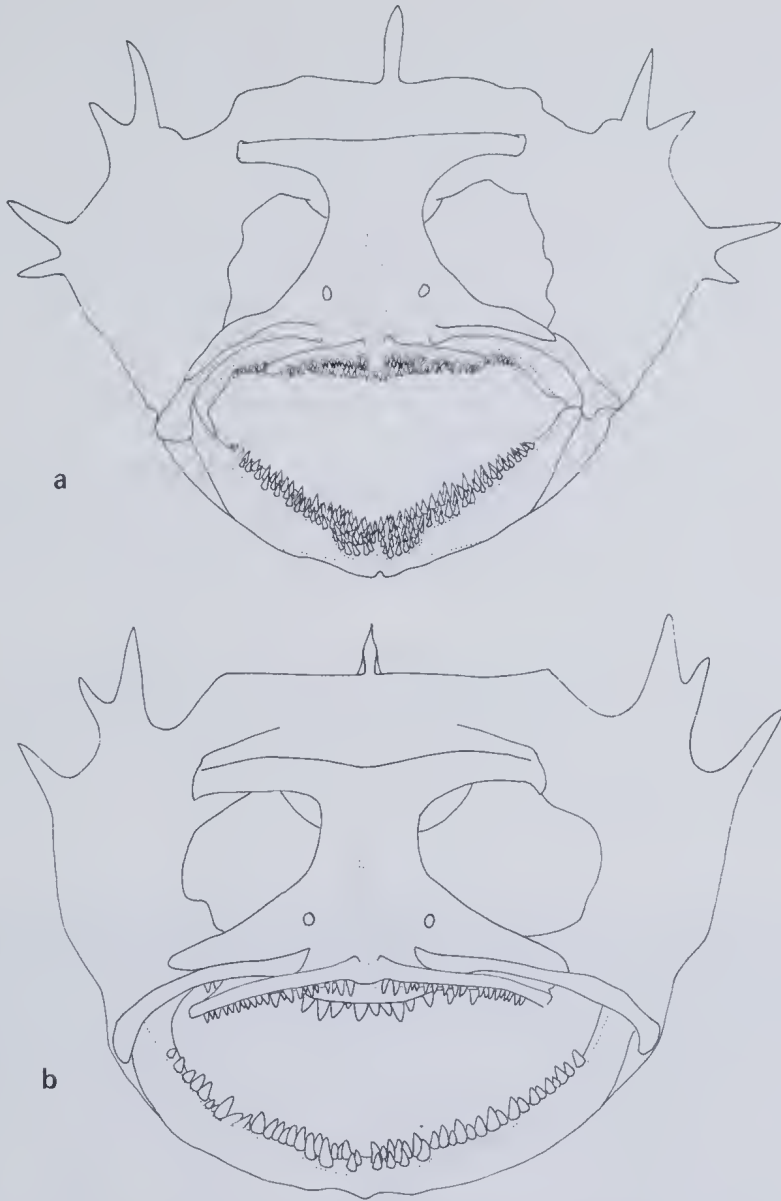


Fig. 3. Semi-diagrammatic illustration showing the dentition of a. *Halophryne ocellatus*, 170 mm SL; and b, *Batrachomoeus occidentalis*, 131 mm SL.

Description

Dorsal rays III, 19-21; anal rays 16-18; pectoral rays 22-24; segmented caudal rays 14-16; pores in lateral line 25-39; vertebrae 10 + 18 - 19.

Body cylindrical, compressed posteriorly; head somewhat depressed; snout short, rather blunt, rounded in profile; jaws equal, gape horizontal,

maxilla reaching to below centre of eye or slightly farther; eyes elevated, interorbital space concave; operculum with 2 divergent spines joined at their bases, upper about equal to eye, $\frac{1}{3}$ longer than lower spine; suboperculum with 1 or 2 spines, similar to above but relatively shorter; gill opening a vertical slit on upper $\frac{1}{2}$ to $\frac{2}{3}$ of pectoral fin base.

Skin smooth or with ridges, scaleless and loosely attached to head, body and fins; 3 tentacles above eye, either simple or multifid, the middle one slightly longer; simple and multifid tentacles on snout, arranged around mouth, along preopercular border and on gill cover; series of bifid tentacles on head and body (see preceding section on morphology); upper series of lateral-line pores commences above opercular spines, approaches spinous dorsal base and continues to upper caudal peduncle; lower series of pores commences just superior and anterior to ventral fin, runs along side of abdomen, above anal base to lower caudal peduncle; open mucous pores on head small to large (see morphology section); 9 preoperculo-mandibular pores; pectoral axillary pore absent; anterior nostril tubular, projecting forwards on each side of snout tip; posterior nostril near inner front border of eye, without an elongate rim.

Jaws, palate and pharyngeals with bands of sharp, cardiform teeth (villiform in small specimens); premaxilla with 1-3 series of small teeth, widening near symphysis to form 2-4 series; teeth on vomer and palatines larger and in 3-5 series (a few slightly larger teeth may be present posteriorly on palatines); mandibular teeth similar in size to those on palate, in 2-4 series expanding near symphysis forming 2 round or rectangular patches; teeth on lower pharyngeals canine-like, larger than those on palate, in 3-5 series, the bands



Fig. 4. The hyoid and branchial arches structure of left, *Halophryne ocellatus*, 170 mm SL; and right, *Batrachomoeus dahli*, 151 mm SL.

of teeth on each side meeting in the form of a V (Fig. 4); those on upper pharyngeals separated into anterior and posterior bands, the anterior teeth small, villiform, and posterior teeth larger, especially near symphysis and posteriorly; 3-5 knob-like gill rakers on lower limb of each gill arch (those on first arch elongated), terminating in small patches of divergent teeth.

Origin of dorsal fin at or just behind rear border of head; spinous dorsal covered by thick skin, joined to soft dorsal by a low fold of skin; rays of soft dorsal, except last 2-3, about equal in length; rays of anal, except first 2-3 and last 2-3, about equal but shorter than those of soft dorsal; pectoral and caudal rounded, about equal in length; ventral fin consists of one hidden spin and 2 rays, the first much longer and fleshier, equal to pectoral.

KEY TO THE SPECIES OF *HALOPHRYNE*

- | | | |
|----|--|----------------------|
| 1a | Body with numerous small ocelli; last 2 body bars not joined medially; skin ridges absent from head and anterior portion of body; preoperculo-mandibular pores always large (Fig. 1a) (Western Australia) | <i>ocellatus</i> |
| 1b | Body without ocelli; last 2 body bars joined medially; skin ridges generally present on head and anterior portion of body; preoperculo-mandibular pores small to large (Fig. 1) | 2 |
| 2a | Four spines on gill cover; skin ridges always on head, arranged longitudinally; preoperculo-mandibular pores small to medium (Western Australia, Northern Territory and Queensland) | <i>diemensis</i> |
| 2b | Three spines on gill cover; skin ridges on head, if present, forming intersecting network; preoperculo-mandibular pores medium to large (Queensland) | <i>queenslandiae</i> |

Halophryne ocellatus Hutchins 1974

Figs. 1a-b, 3a, 4 and 5

Halophryne ocellatus Hutchins, 1974: 115, figs. 1, 2a and 3a. (Type locality: Houtman Abrolhos, Western Australia).

Diagnosis

Dorsal rays III, 20-21; anal rays 17-18; pectoral rays 22-23; segmented caudal rays 14-15; pores in lateral line 26-30.

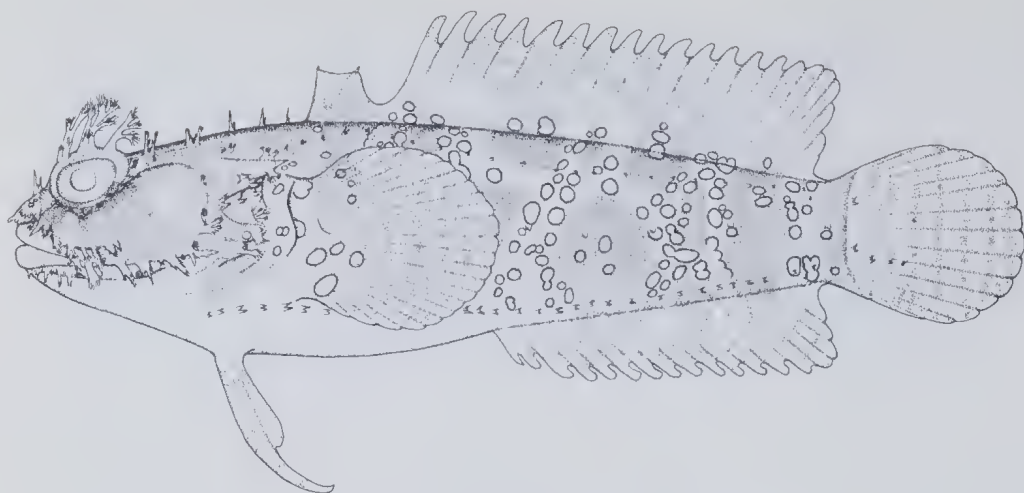


Fig. 5. *Halophryne ocellatus*, WAM P.3364, 138 mm SL.

Head length 2.6-3.1, head depth 3.5-3.8, both in SL; eye 3.0-4.2, snout 4.9-9.0, head depth 1.2-1.5, head width 1.0-1.2, anal base 0.8-0.9, pectoral 1.3-1.5, all in head length; interorbital 1.5-3.6, first dorsal spine 1.0-1.7, both in eye.

Operculum and suboperculum each with 2 prominent spines; preoperculo-mandibular pores large (1.2-3.4 mm in diameter for specimens larger than 100 mm SL); skin ridges absent from head and beneath pectoral fins; orbital tentacles large, about equal to eye, multifid and fringed at extremities; 4 prominent bifid tentacles across occiput immediately behind orbital region nearly in a straight line; grooves in frontal bone of skull wide and deep (see Hutchins, 1974, Fig. 2a); lateral processes of frontal are only slightly directed posteriorly.

Colour in alcohol — Pale brown with dark brown blotches forming 8-9 irregular transverse bars, first across interorbital and last on caudal peduncle, never joined to the preceding bar; sides and head with scattered white ocelli outlined by prominent blackish-brown margins, may be small or great in number and may merge to form blotches; ocelli generally absent or scarce on fins and ventral surface; fins with series of transverse bars, those on soft dorsal and anal forming a continuation of body bars, angled obliquely forward, becoming more numerous and breaking up into small blotches with increasing size (see Hutchins, 1974, fig. 1); the presence of a mucous coating imparts a yellowish-brown colour.

Distribution

H. ocellatus is found only in Western Australia (Fig. 8). Only three specimens have been collected north of Exmouth Gulf and one south of the Houtman Abrolhos. Unlike *H. diemensis*, this species does not appear to

frequent intertidal and shallow water areas. It has been collected by trawl net and craypot in 20-40 metres.

Material examined

30 specimens, 20-231 mm SL. (Unless otherwise designated, all specimens at WAM). Fremantle — AM I.7029, 120 mm SL. Houtman Abrolhos area — P.3364, 138 mm SL; P.5956, holotype, 190 mm SL; P.24829, 231 mm SL; P.24991, 71 mm SL. Shark Bay — P.5851, 2 specimens, 109-127 mm SL; P.5955, 102 mm SL; P.6149, 136 mm SL; P. 6260, 130 mm SL; P.8169; skeleton, 152 mm SL; P.13767-9, 3 specimens, 75-98 mm SL; P.14653, 101 mm SL; P.14702, 79 mm SL; P.14883, 125 mm SL; P.23604, 99 mm SL; P.24830, 23 mm SL; P.24990, 65 mm SL; P.24993, 2 specimens, 52 mm SL; P.25045-001, 52 mm SL. Exmouth Gulf — P.9393-4, 2 specimens, 43-45 mm SL; P.12073, 38 mm SL; P.16296, 102 mm SL. Onslow — P.24562, 101 mm SL. Dampier Archipelago — P.7148, 47 mm SL. Broome — P. 16483, 88 mm SL. Unknown locality — P.25046-001, 20 mm SL; P.25058-001, skeleton, 170 mm SL.

Halophryne diemensis (Lesueur) 1824

Fig. 6

Batrachoides diemensis Lesueur, 1824: 402 (Type locality: Coasts of Van Diemens Land) (apparently near Darwin, Northern Territory — see discussion under Remarks).

Batrachus quadrispinis Valenciennes, 1837: 487 (Type locality: Indian Ocean).

Batrachus diemensis Richardson, 1843: 352; Richardson, 1844-48: 17, pl. 8; Günther, 1861: 170; Günther, 1867: 61; Macleay, 1878: 355; Macleay, 1881: 573; Weber, 1913: 556.

Batrachus mulleri Klunzinger, 1879: 387 (Type locality: Darwin); Macleay, 1884: 29.

Batrachus grunniens (non Linnaeus) Macleay, 1882: 360.

Marcgravia diemensis Jordan & Richardson, 1908: 282.

Coryzichthys diemensis Ogilby, 1908: 51; McCulloch, 1926: 39; Whitley, 1927: 30; Paradise & Whitley, 1927: 94, 96; Fowler, 1928: 447; McCulloch, 1929: 359; Whitley, 1932: 300.

Coryzichthys guttulatus Ogilby, 1910: 42 (Type locality: Aru Islands, south of New Guinea).

Halophryne diemensis Whitley, 1937: 144; Whitley, 1948: 28; De Beaufort, 1962: 189; Taylor, 1964: 299, pl. 67; Marshall, 1964: 508, pl. 63; Munro, 1967: 575, pl. 77; Grant, 1972: 358, pl. 85; Hutchins, 1974: 120, figs. 2b, 3b.



Fig. 6. *Halophryne diemensis*, AM I.15641-002, 111 mm SL.

Diagnosis

Dorsal rays III, 19-21; anal rays 16-18; pectoral rays 22-24; segmented caudal rays 14; pores in lateral line 30-39.

Head length 2.5-2.9, head depth 3.4-4.8, both in SL; eye 3.3-5.1, snout 6.2-8.0, head depth 1.4-1.9, head width 1.0-1.3, anal base 0.8-1.1, pectoral 1.4-2.0, all in head length; interorbital 1.5-5.0, first dorsal spine 1.4-2.0, both in eye.

Operculum and suboperculum each with 2 spines, upper 3 prominent, lowest small to medium but always present; preoperculo-mandibular pores small to medium (0.5-1.8 mm in diameter for specimens larger than 100 mm SL); many longitudinal skin ridges on head becoming thicker and more reticulated beneath pectoral fin; orbital tentacles either small and simple or medium and multifid; 4 prominent bifid tentacles across occiput immediately behind orbital region not in a straight line, central 2 more advanced; grooves in frontal bone generally narrow and shallow (see Hutchins, 1974, fig. 2b); lateral processes of frontal are prominently directed posteriorly.

Colour in alcohol — Australian specimens of *H. diemensis* can be generally divided into three colour varieties: spotted (Western Australia and Northern Territory), non-spotted ornate (Northern Territory and Queensland) and non-spotted plain (Western Australia). These are all variations of a basic colour pattern which consists of about 8 brown to dark brown transverse bars on a pale brown ground. The last 2 body bars are joined medially.

Spotted variety (see Hutchins, 1974, fig. 3b): head and body spotted with black dots and small blotches; fins either pale with narrow dark transverse bars, sloping obliquely forward on soft dorsal and anal, or pale and covered with black spots and blotches (type description was based on a specimen with this colour pattern).

Non-spotted ornate variety (see Fig. 6): brown bars on head and body

generally broken up into a few or many irregular blotches; fins mostly covered with irregular sized blotches in a reticulated pattern and pale narrow transverse bars may be present; a prominent reticulated pattern of brown blotches on lower surface of abdomen, throat and lower jaw, increasing in number with size; a combination of this colour pattern and the above (i.e. spotted ornate) may occur rarely.

Non-spotted plain variety: transverse bars paler, sometimes hard to distinguish from ground colour, especially in large specimens; fins usually immaculate, but bars on median fins sometimes discernible.

Colour in life — Spotted variety (from a colour transparency of an aquarium specimen collected at Point Samson, Western Australia): transverse body bars generally dark brown but those near pectoral fin blackish; 2 black blotches readily discernible, one on spinous dorsal, the other at base of 6th to 9th soft dorsal rays; ground colour pale brown becoming whitish on soft dorsal and anal; bars on these fins honey-brown, greyish-brown on others; spots black with obscure brown margins; all tentacles tipped with white; lips dark brown.

Non-spotted ornate variety (see Grant, 1972: 359, colour-plate 85): background generally yellow, bars dark brown; lips blackish-brown.

Non-spotted plain variety (from observations of an aquarium specimen at Shark Bay, Western Australia): ground colour pale olive-brown, transverse bars darker; tips of tentacles white.

Distribution

The range of *H. diemensis* extends from Shark Bay in Western Australia, across the northern half of Australia to Heron Island, off the southern Queensland coast (Fig. 8). It has been widely recorded throughout the Indo-Malay Archipelago (see De Beaufort, 1962: 190). It is found intertidally as well as trawled in depths up to at least 20 metres. Specimens have been collected from inshore rock pools and caves on the outer reef slope.

Remarks

Lesueur (1824) gave the distribution of *Batrachoides diemensis* as the 'Coasts of Van Diemens Land'. Richardson (1842: 352) interpreted this as Tasmania. In 1908, Ogilby noted that this species had not been found in Tasmania since it was supposedly described from there. McCulloch (1929: 359) recorded the type locality as Shark's Bay, Western Australia, but gave no reason for this.

Lesueur (1824) described *Batrachoides diemensis* from a drawing of a fish collected by Péron during the explorations of Nicholas Baudin in 1800-1804. As well as visiting Tasmania (then known as Van Diemen's Land), the expedition explored along the Western Australian-Northern Territory coast as far north as the area now known as Darwin (see Péron & Freycinet, 1807-16, 2: 287-8). Early Dutch and French maps refer to the north-west

corner of the Northern Territory as Van Diemen's Land, and Arnhem Land is used for the north-east corner (see Skelton, 1970: 221 and Tooley, 1970: 121). Van Diemen's Land of the north, as it was often referred to, was named in 1636 by Pieter Pieterszoon, six years before Tasman discovered Tasmania. It is therefore reasonable to assume that the type locality designation referred to the north-west corner of the Northern Territory rather than Tasmania.

Specimens of *Halophryne diemensis* either have moderate-sized multifid orbital tentacles (Fig. 6) or small simple ones (see Taylor, 1964: 300, pl. 67). Specimens examined from Queensland have moderate orbital tentacles, all but one from the Northern Territory have small tentacles and one-third of those from Western Australia possess small tentacles. Specimens from New Guinea and Christmas Island possess moderate orbital tentacles.

Material examined

62 specimens, 45-233 mm SL. Western Australia (WAM specimens): Shark Bay — P.4346, 233 mm SL; P.5954, 207 mm SL. Exmouth Gulf & North West Cape — P.4344, 138 mm SL; P.23408-9, 2 specimens, 134-160 mm SL; P.23769, 218 mm SL; P.25052-001, 204 mm SL; P.25054-001, 2 specimens, 45-67 mm SL; P.25055-001, 66 mm SL; P.25057-001, 162 mm SL. Onslow — P.15578, 144 mm SL; P.25050-001, 170 mm SL. Barrow Island — P.25047-001, 99 mm SL; P.25053-001, 2 specimens, 106-142 mm SL. Dampier Archipelago — P.4323, 170 mm SL; P.7615, 161 mm SL; P.25051-001, 154 mm SL; P.25056-001, 2 specimens, 99-109 mm SL. Port Hedland — P.3567, skeleton, 204 mm SL; P.3588, 192 mm SL; P.4324, 175 mm SL; P.15289-90, 2 specimens, 140-164 mm SL. Broome — P.13696, skeleton, 136 mm SL; P.13697, 98 mm SL; P.13703, 178 mm SL; P.16489, 94 mm SL; P.25048-001, 77 mm SL; P.25049-001, 159 mm SL. Yampi Sound — P.6156-7, 2 specimens, 99-124 mm SL; P.16485, 61 mm SL. 'North West Coast' — P.577, 2 specimens, 105-108 mm SL. Northern Territory (AM specimens): Darwin — I.10441, 136 mm SL. IA.1715-6, 2 specimens 48-78 mm SL; IA.7749, 155 mm SL. Cape Don — IB.7641, 2 specimens, 113-123 mm SL. Queensland: Thursday Island — QM I.8221, 172 mm SL. Esk Island, Palm Group — QM I.12486, 120 mm SL. Swain Reefs — AM IB.6043, 160 mm SL. Tryon Island, Capricorn Group — AM I.15610-006, 149 mm SL. One Tree Island, Capricorn Group — AM I.15641-002, 111 mm SL; AM I.15680-002, 164 mm SL; AM I.15683-001, 159 mm SL. Heron Island, Capricorn Group — QM I.9547, 170 mm SL; QM I.11417, 203 mm SL; AM IB.5241, 72 mm SL; AM IB.5376, 167 mm SL. New Guinea (unless otherwise designated, all specimens at KFRS): Taurama Beach, Bootless Bay — FO.752, 167 mm SL; FO.786, 2 specimens, 84-110 mm SL. Port Moresby — FO.1250, 166 mm SL. Tuma Island, Louisiade Archipelago — FO.1701, 178 mm SL. Bristow Island, Western Papua — FO.1975, 112 mm SL. 'South coast of New Guinea' — AM I.13402, 180 mm SL. Christmas Island, Indian Ocean: WAM P.21803, 121 mm SL.

Halophryne queenslandiae (De Vis) 1882

Fig. 7

Batrachus dussumieri (non Valenciennes) Klunzinger, 1879: 386.

Porichthys queenslandiae De Vis, 1882: 370 (Type locality: Dunk Island, Queensland).

Coryzichthys diemensis Ogilby, 1908: 51 (in part).

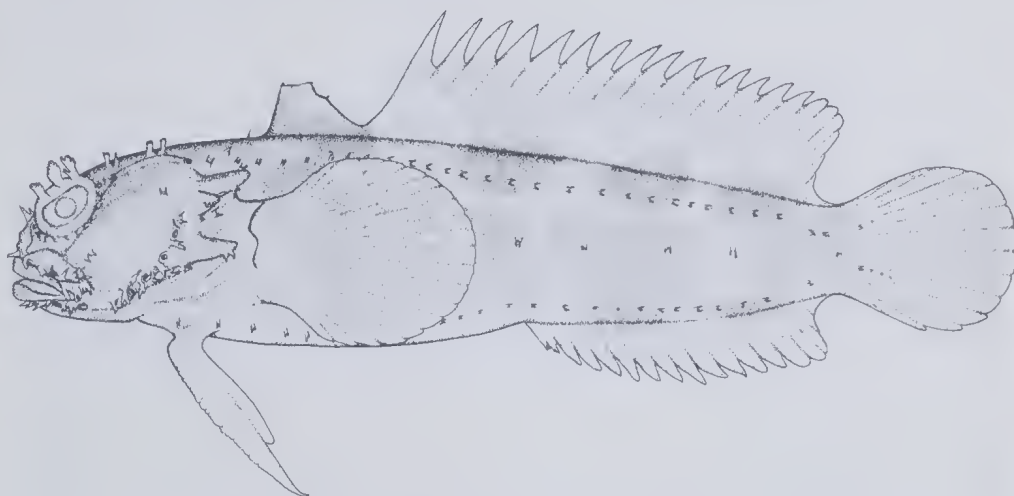


Fig. 7. *Halophryne queenslandiae*, QM I.6628, 212 mm SL.

Diagnosis

Dorsal rays III, 20; anal rays 16-17; pectoral rays 22-23; segmented caudal rays 14; pores in lateral line 25-29.

Head length 2.8-2.9, head depth 4.1-4.4, both in SL; eye 3.6-4.4, snout 6.6-7.4, head depth 1.4-1.5, head width 1.1-1.3, anal base 0.8-0.9, pectoral 1.4-1.7, all in head length; interorbital 1.5-3.7, first dorsal spine 1.2-1.5, both in eye.

Operculum with 2 spines, suboperculum with 1; preoperculo-mandibular pores medium to large (1.1-3.0 mm in diameter for specimens larger than 100 mm SL); skin ridges on head, when present, in the form of intersecting network, not prominently longitudinal, tend to form concentric semi-circles beneath pectoral fin; orbital tentacles medium to large, multifid; grooves in frontal bone moderately wide and deep.

Colour in alcohol — Head and body dark brown with darker ill defined transverse bars, the last 2 body bars joined medially; lower surface of abdomen and breast pale, no prominent small blotches; body bars continued



Fig. 8. Map of Australia showing distribution of the species of *Halophryne*.

on soft dorsal and anal, ill defined and angled obliquely forward; caudal and pectoral fins immaculate or with a series of pale transverse bars, thin and irregular (all specimens examined have very poor colour patterns due to long preservation).

Distribution

H. queenslandiae appears to be restricted to Queensland, from the Brisbane River to Dunk Island in the north (Fig. 8). It has been collected from islands close to the coast, and also from the Brisbane River estuary.

Remarks

Previous authors have usually included this species in the synonymy of *H. diemensis* on the assumption that the lower subopercular spine of the latter species may be small and therefore difficult to detect. Ogilby, in his revision of the batrachoidid fishes of Queensland (1908), noted that in twelve specimens of *H. diemensis* he examined, the lower subopercular spine was absent in four, but no other differences were evident; however, he was unable to examine the types of *Porichthys queenslandiae* as, according to him, they were missing. Examination of four specimens lacking the lower subopercular spine by the present author revealed morphological distinctions indicated in the above diagnosis.

De Vis's description is poor, giving little indication as to what genus or species he was describing. He placed his new species in the genus *Porichthys* as he recorded only two spines in the spinous dorsal and small canines on the vomer. Examination of the type (QM I.3735) showed that there are three dorsal spines (the third can be difficult to detect in some specimens of *Halophryne* and *Batrachomoeus*). In addition, enlarged teeth on the palate is a relatively common occurrence in all species of *Halophryne*.

Material examined

4 specimens, 94-212 mm SL. (Unless otherwise designated, all specimens at QM). Dunk Island — I.3735, type, 94 mm SL. Moreton Island — I.6628, 212 mm SL. Brisbane River — AM I.9500, 116 mm SL. South-east Queensland — I.8256, 138 mm SL.

Genus *Batrachomoeus* Ogilby 1908

Pseudobatrachus Castelnau, 1875: 24 (Type species: *Pseudobatrachus striatus* Castelnau, 1875, by monotypy; preoccupied by *Pseudobatrachus* Peters, 1873, an amphibian).

Pelophiletor Ogilby, 1906: 9 (Type species: *Pelophiletor caloundrae* Ogilby, 1906, by monotypy). Nomen nudum, no description given.

Batrachomoeus Ogilby, 1907: 10 (Type species: *Thalassophryne coecus* De Vis, 1884, by original designation). Nomen nudum, no description given.

Batrachomoeus Ogilby, 1908: 45 (Type species: *Batrachomoeus minor* Ogilby, 1908, by subsequent designation of McCulloch, 1929: 358).

Description

Dorsal rays III, 19-24; anal rays 15-20; pectoral rays 21-23; segmented caudal rays 13-16; pores in lateral line 22-38; vertebrae 9 + 17 - 21.

Body cylindrical, compressed posteriorly; head considerably depressed; snout moderate, flat or slightly arched; lower jaw protruding, gape generally horizontal; maxilla reaching to below posterior half of eye or further; eyes large, elevated or only slightly; interorbital space concave to flat, increasing noticeably in width with size; operculum with 2 divergent spines joined at their bases, upper about equal to eye, $\frac{1}{3}$ longer than lower; suboperculum with one spine, either equal to or somewhat shorter than upper opercular one; a flexible spine always present on upper base of subopercular spine, extending to near tip of upper opercular spine (base of this spine may become enlarged and bonelike with age); gill opening moderate, encompassing base of pectoral fin.

Skin smooth and scaleless, loosely attached to head, body and fins; 3-4 tentacles above each eye, posterior one largest, middle smallest, all may be very reduced; small or medium frontonasal tentacle present; simple and multifid tentacles arranged around mouth, along preopercular border and on gill cover; series of bifid tentacles on head and body (see preceding section on morphology); upper series of lateral line pores commences above opercular spines, runs back along upper side, generally rising to near soft dorsal base at middle of fin, and continues to upper caudal peduncle; lower series of pores commences below or just anterior to pectoral fin base, runs along side of abdomen, above anal base to lower caudal peduncle; open mucous pores small to large, 8 in preoperculo-mandibular series (see morphology section); anterior nostril tubular, projecting forwards and upwards from each side of snout tip; posterior nostril near inner front border of eye, without an elongated rim; a small to large pore present in upper portion of pectoral axilla.

Teeth on mandible, vomer and palatines strong and conical, generally in one series except near symphysis of mandible where they are in 2-3 series (teeth on vomer sometimes in several irregular series, which could be due to damage caused by feeding); premaxillary teeth smaller, more acute, in 1-2 series posteriorly, 2-3 series near symphysis; upper and lower pharyngeal teeth cardiform, in 3 series, the posterior row consisting of the largest teeth; lower pharyngeal teeth generally in irregular rows, the bands on each side meeting in the form of a U (Fig. 4); 5-7 low knob-like gill rakers on lower limb of each gill arch, terminating in prominent patches of divergent teeth.

Origin of dorsal fin at or just before rear border of head; spinous dorsal covered by thick skin, joined to soft dorsal by a low fold of skin; soft dorsal rays, except last 2-3, about equal in length; anal rays, except first 2-3 and last 2-3 about equal in length, shorter than those of soft dorsal; pectoral and caudal rounded, about equal in length; ventral fin consists of one hidden spine and 2 rays, first somewhat longer and fleshier, second with 3-4 branches, former equal to or less than length of pectoral.

Remarks

Ogilby introduced his new genus *Pelophiletor* in 1906 to accommodate a single species, *caloundrae*, also new. Both the genus and species were included in a list without an accompanying description. The following year he withdrew both names and replaced them with another new genus and species, *Batrachomoeus minor* (1907: 10 and 13). Besides indicating that a description of *Batrachomoeus minor* had been published earlier that year (misprint?), this name was also listed without description, and he gave no reason for withdrawing *Pelophiletor caloundrae*. It was not until the following year, 1908, that a generic and specific description for *Batrachomoeus minor* was published. Therefore, Ogilby's generic names prior to 1908 are not valid.

De Beaufort (1962), followed by Nagabhushanam & Rama Rao (1970), placed *Batrachomoeus* in the synonymy of *Halophryne*. On the basis of the characters already mentioned in the key to the genera, this is considered incorrect.

KEY TO THE SPECIES OF *BATRACHOMOEUS*

- 1a Dorsal fin rays III, 19-20; anal fin rays 15-17; colour pattern not marbled, consisting of separate transverse bars on body, with or without blotching; vertebrae 9 + 17 - 18 2
- 1b Dorsal fin rays III, 21-24; anal fin rays 17-20 (rarely 17); colour pattern generally marbled, the transverse body bars either joined medially (Fig. 16) or the last 3 separate (Fig. 13); vertebrae 9 + 19 - 21 3
- 2a Usually 3 sets of double transverse bars on body, posterior to pectoral fin (Fig. 9); small dark blotches on body absent; pectoral and caudal fins pale, with narrow transverse bars; preoperculo-mandibular pores large to very

- large (Fig. 2); head length 2.1-2.4 in SL, greater than length of anal fin base (Western Australia) *occidentalis* n. sp.
- 2b Two wide transverse bars on body, with scattered small dark and pale blotches (Fig.11); pectoral and caudal fins dark, with scattered pale blotches, round and in irregular rows on pectoral, few in number on caudal; preoperculo-mandibular pores small to large (Fig. 2); head length 2.5-3.0 in SL, less than length of anal fin base (New South Wales and Queensland) *dubius*
- 3a Prominent depression on head behind orbital region; maxilla extends to below pupil or slightly farther; pink bars and blotches may be present on head; pectoral and caudal fins dark with large scattered white blotches (Fig. 12); oblique bars on anal fin absent; preoperculo-mandibular pores minute to small (Fig. 2); pore in pectoral axilla large to very large (Western Australia) *rubricephalus* n. sp.
- 3b Depression on nape absent; maxilla extends to below posterior border of eye or further; pectoral and caudal fins with series of dark transverse bars (Figs. 13 and 16); oblique bars on anal fin; preoperculo-mandibular pores small to large; pore in pectoral axilla small to medium 4
- 4a Head length 0.9-1.0 in length of anal fin base; interorbital relatively wide (Fig. 15); preoperculo-mandibular pores medium to large (Fig. 2); dorsal surface of head usually with well contrasted bars and blotches (Western Australia, Northern Territory and Queensland) *trispinosus*
- 4b Head length 0.7-0.8 in length of anal fin base; interorbital relatively narrow (Fig. 15); preoperculo-mandibular pores small (Figs. 1c and 2); dorsal surface of head uniform brown or with poorly contrasting bars and blotches (Western Australia) *dahli*

Batrachomoeus occidentalis n. sp.

Figs. 3b, 9 and 10; Table 2

Holotype

WAM P.23702, 169 mm SL, male, collected near Sunday Island, Exmouth Gulf, Western Australia, by prawn trawl in 14-20 metres, R. Rowe, August 1973.



Fig. 9. *Batrachomoeus occidentalis*, n. sp., holotype, WAM P.23702, 169 mm SL.

Paratypes

9 specimens, 32-169 mm SL (unless otherwise designated, all specimens at WAM). P.23876-7, 2 specimens, the larger a skeleton, 113-131 mm SL, 11 kilometres W of North West Cape, trawled in 150 metres, R. Rowe, August 1973; P.9343, 32 mm SL, DM1/24/64, HMAS *Diamantina*, 1 February 1964, no other data; AM I.18472-001, 62 mm SL, SW of Dongara, station 214 (29° 49'S, 114° 22'E), 140-144 metres, HMAS *Diamantina*, 11 October 1963; BM(NH). 1975. 10.10.1, 66 mm SL, W of Dongara, station 56 (29° 18'S, 114° 04'E), 170-174 metres, HMAS *Diamantina*, 20 March 1972; P.25091-001, 32 mm SL, NW of Green Head, station 66 (29° 59'S, 114° 25'E), 146 metres, HMAS *Diamantina*, 22 March 1972; P.25092-001, 33 mm SL, W of Rottnest Island, station 78 (32° 00'S, 115° 15'E), 146-150 metres, HMAS *Diamantina*, 23 March 1972; P.25093-001, 2 specimens, 73-104 mm SL, NW Rottnest Island, 160 metres, W. & W. Poole on *Bluefin*, 15 September 1965.

Diagnosis

A species of *Batrachomoeus* characterized by the following combination of characters: low dorsal and anal fin ray counts (D.III, 19-20; A.15-16); large puggish head (2.1-2.4 in SL); large preoperculo-mandibular pores (2.2-3.8 mm in diameter); colour pattern generally consisting of 3 double transverse bars on body behind pectoral fin and transverse bars on pectoral and caudal fins.

TABLE 2. Measurements in mm and fin ray counts of selected type specimens of *Batrachomoeus occidentalis*

	Holotype		Paratypes		WAM	
	WAM P.23702	WAM P.23877	WAM P.25093-001	BM(NH) 1975.10.10.1	WAM P.9343	WAM P.25091-001
Total length	216	143	128	84	43	42
Standard length	169	113	104	66	32	33
Soft dorsal fin base	93	56	55	34	15	17
Anal fin base	66	44	37	25	13	13
Head length	72	50	46	29	15	15
Head depth	42	28	28	19	8.0	7.2
Head width	65	41	41	26	13	12
Eye diameter	17	11	12	8.8	4.0	4.7
Interorbital width	9.2	5.5	4.3	3.5	0.8	0.8
Snout length	10	7.0	7.3	5.0	2.6	2.4
Pectoral fin length	38	25	21	14	8.0	8.0
Ventral fin length	32	22	23	13	9.0	8.0
1st dorsal spine length	10	7.5	6.0	5.5	1.8	*
2nd dorsal spine length	11	7.7	7.0	*	2.3	*
Longest dorsal ray	23	*	15	*	*	*
Longest anal ray	20	*	12	*	*	*
Mucous pore diameter	3.8	2.2	3.1	1.8	1.0	0.8
Axillary pore diameter	2.0	1.5	0.9	0.9	*	0.6
Soft dorsal ray count	20	20	19	19	19	20
Anal ray count	16	16	16	15	15	16
Pectoral ray count	22	23	21	22	21	22
Caudal ray count	15	15	15	15	14	*
Lateral line count	30	28	22	24	24	*
Sex	Male	Female	Male	Male	Juvenile	Juvenile

* Some measurements and counts were not taken due to distortion and small size.

Description

Measurements and counts of the holotype and selected paratypes are presented in Table 2. Counts and proportions are given below for the holotype, followed by the range for the paratypes in parentheses.

Dorsal rays III, 20 (III, 19-20); anal rays 16 (15-16); pectoral rays 22 (21-23); segmented caudal rays 15 (13-15); pores in lateral line 30 (22-30); vertebrae (9 + 17 - 18).

Head length 2.3 (2.1-2.4), head depth 4.0 (3.5-4.0), pectoral 4.4 (4.0-5.0), all in SL; eye 4.2 (3.0-4.5), snout 7.2 (5.4-7.2), anal base, 1.1 (1.1-1.3), head depth 1.7 (1.5-1.9), head width 1.1 (1.1-1.2), all in head length; interorbital 1.7 (1.7-5.0), first dorsal spine 1.7 (1.6-2.3), both in eye.

In addition to the characters given for the genus, the following features are distinctive: eyes large, elevated; mouth wide, giving the head a distinctive pug-like appearance (Fig. 10); maxilla extends to below posterior border of eye or slightly farther; orbital tentacles usually flaps of skin with a fringed margin, considerably reduced in specimens over 100 mm SL; small fronto-nasal tentacle; upper series of lateral line pores generally do not rise noticeably below middle of soft dorsal fin base; mucous pores on head large to very large, preoperculo-mandibular series 2.2-3.8 mm in diameter for specimens over 100 mm SL (Fig. 2); premaxillary teeth in 1-2 series posteriorly, 2 series near symphysis; grooves in frontal bone relatively wide and deep; pore in pectoral axilla medium (0.9-2.0 mm in diameter for specimens over 100 mm SL).

Colour of holotype in 70% ethanol: head and body pale brown with 9-10 dark brown irregular transverse bars, those occurring behind pectoral fin tending to form 3 pairs; first bar joins anterior portion of eyes across interorbital, passes through eye and divides into 2 sections, one bar anteriorly to maxilla and the other sloping posteriorly across cheek to preopercular border; second bar always separated dorsally along its midline (Fig. 10); fins pale with series of dark transverse bars, those on soft dorsal and anal forming continuation of body bars, angled obliquely forward; bars on pectoral and caudal narrow with darker margins, increasing in number with size; occasionally bars on pectoral in a somewhat reticulated pattern.

Colour when fresh (frozen specimen): ground colour pale yellowish-green, paler on ventral surface of abdomen, breast and throat; bars on head and body dark brownish-green, those on fins lighter with dark brown margins; iris yellow.

Comparisons

B. occidentalis is easily distinguished from its closest relative *B. dubius* by the combination of characters indicated in the diagnosis. The most conspicuous of these are the large puggish head and colour pattern. Furthermore, *B. occidentalis* differs from *B. dubius* by having more prominent bars

on the dorsal surface of the head (Fig. 10), the second bar separated medially rather than being continuous, less prominent tentacles on head and body, orbital tentacles which are conspicuously fringed rather than smooth edged, larger mucous pores, enlarged elongated rims on the anterior nostrils, and by having grooves in the frontal which are relatively wider and deeper.



Fig. 10. Dorsal colour patterns of left, *Batrachomoeus occidentalis*, holotype, WAM P.23702, 169 mm SL; and right, *Batrachomoeus dubius*, WAM P.25087-001, 152 mm SL.

Distribution

B. occidentalis has been found only in Western Australia, from off Rottnest Island north to Exmouth Gulf (Fig. 17). Except for one specimen taken in 14-20 metres, it has only been collected by deepwater trawling and dredging in 140-174 metres.

Remarks

Named *occidentalis* with reference to the geographical distribution.

Batrachomoeus dubius (Shaw) 1790

Figs. 10 and 11

Lophius dubius Shaw in White, 1790: 265, figure (Type locality: near Sydney, New South Wales).

Batrachus dubius Richardson, 1844-48: 16, pl. 10; Günther, 1861: 169; Günther, 1867: 61; Castelnau, 1879: 353; Macleay, 1881: 572; Ogilby, 1886: 31.

Batrachus trispinosus (non Günther) Kner, 1865: 189.

?*Pseudobatrachus striatus* Castelnau, 1875: 24 (Type locality: Cape York, Queensland).

Thalassophryne coeca De Vis, 1884: 547 (Type locality: Queensland).

Pelophiletor caloundrae Ogilby, 1906: 9. Nomen nudum (see remarks in preceding section on genus).

Batrachomoeus coecus Ogilby, 1907: 10; Ogilby, 1908: 49.

Batrachomoeus minor Ogilby, 1907: 13. Nomen nudum (see remarks in preceding section on genus).

Batrachomoeus minor Ogilby, 1908: 47 (Type locality: Moreton Bay, Queensland).

Pseudobatrachus dubius McCulloch, 1914: 224; McCulloch, 1922: 122, pl. 41; McCulloch, 1929: 358; Whitley, 1937: 144.

Batrachomoeus dubius Whitley, 1957: 139; Marshall, 1964: 507, pl. 63; Grant, 1972: 358.

Diagnosis

Dorsal rays III, 19-20; anal rays 16-17; pectoral rays 22-23; segmented caudal rays 13-15; pores in lateral line 25-32; vertebrae 9 + 17 - 18.

Head length 2.5-3.0, head depth 4.1-6.4, pectoral 3.3-4.6, all in SL; eye 3.1-5.3, snout 5.6-6.8, anal base 0.8-0.9, head depth 1.6-2.3, head width 0.9-1.3, all in head length; interorbital 1.6-6.5, first dorsal spine 1.2-2.6, both in eye.

Preoperculo-mandibular pores small to large, 1.0-2.4 mm in diameter for specimens larger than 100 mm SL (Fig. 2) (see section on comparisons below); maxilla extends to below posterior portion of eye, or to hindborder; pore in pectoral axilla medium to large (1.7-2.8 mm in diameter for specimens greater than 100 mm SL); tentacles on head simple, multifid or flaps of skin; orbital tentacles small to medium flaps of skin, smooth edged or minutely fringed, 3 or 4 above each eye (2 small middle tentacles sometimes present); eyes usually elevated, interorbital space concave or flat; grooves in frontal bone relatively shallow and narrow.

Colour in alcohol — Head greyish-black to uniform black, speckled with obscure small paler blotches, a paler diffuse V-shaped bar across occiput, ventral surface grey; sides of body greyish with 2 darker wide transverse bars, profusely covered with pale blotches, some of which may be larger; small dark blotches scattered between body bars; body bars continued onto soft dorsal fin, angled obliquely forward; anal fin dark grey with scattered pale blotches; pectorals and caudal dark grey, with scattered pale blotches, round and in irregular rows on pectorals, few in number on caudal; tips of all fin rays may be white; long preservation usually imparts a much browner colouration.

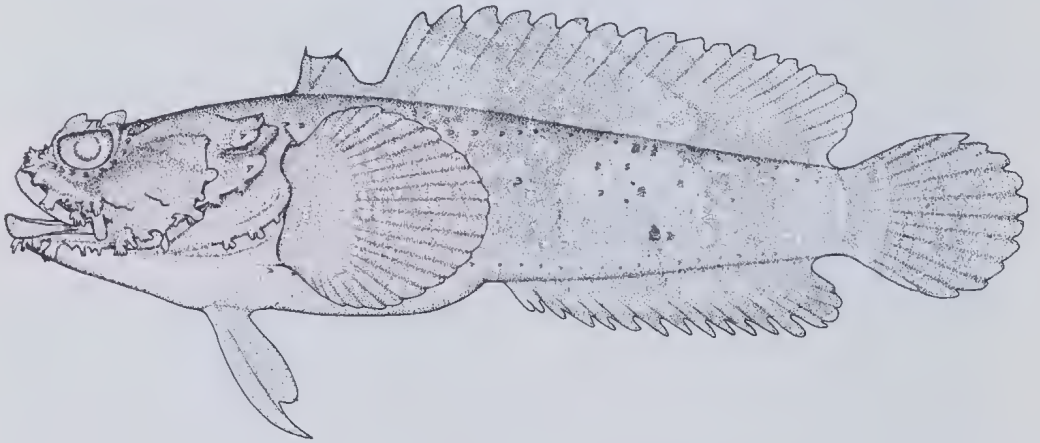


Fig. 11. *Batrachomoeus dubius*, WAM P.25087-001, 152 mm SL.

Comparisons

B. dubius has been confused with *B. trispinosus*, but it is distinguished from this species by fin ray counts and colour pattern, especially the absence of dark transverse bars on the pectoral and caudal fins. For a comparison with the closely related *B. occidentalis* see the discussion under that species.

B. dubius exhibits geographical variation in the mucous pores and orbital tentacles. These are relatively larger in Sydney specimens compared with those from Moreton Bay, Queensland. Also, some specimens from Queensland have many simple tentacles spread over the nape and cheeks, absent on those from Sydney.

Distribution

B. dubius is found from Sydney, New South Wales northwards to Mooloolabar in Queensland (Fig. 17). It frequents estuaries, inshore reefs and has been trawled off the coast in 140 metres.

Remarks

B. dubius was described as *Lophius dubius* in the appendix to White (1790) but the actual author of this description has been in doubt. In a preface to the narrative of this paper, the editor mentions that the naturalists Shaw, Smith and Hunter assisted with the descriptions. Shaw is considered the author of the birds described in the appendix (Cleland, 1950: 553) and Hunter's contribution is introduced as such. There is no information as to the author of the fishes described and most workers have attributed the descriptions to White. McCulloch (1914) considered Shaw as the author of *B. dubius*, apparently attributing the appendix to him, but reverted back to White in his 1929 paper. However, he gave no reason for this change. Shaw, in his 1803 paper, says of *Cottus australis* (= *Centropogon australis*): 'A doubtful species, described by myself in Mr Whites Voyage to Botany Bay.' This description is found on page 266 and the description of *Lophius dubius* occurs on the previous page. Therefore it seems likely that Shaw is the author of the new fishes described in White.

Pseudobatrachus striatus was described by Castelnau from Cape York, Queensland in 1875 and since then has either been placed in the synonymy of *Batrachomoeus dubius* (McCulloch, 1929: 358) or recognized as a valid species (Whitley, 1957: 141 and 1964: 54). However, no additional specimens have been reported since the original description. Castelnau's description indicates that this species belongs to the genus *Batrachomoeus*, but the only member of this genus occurring in the Cape York area is *B. trispinosus* which has much higher fin ray counts (Castelnau's counts of D. II, 17; A.14 could easily be incorrect if his specimens were in poor condition). Castelnau noted that his specimen appeared to resemble Richardson's figure (1844-48, pl. 10) of *Batrachomoeus dubius*, however, the 'strong longitudinal striae' on the head and body are characteristic of *Halophryne diemensis*. Because no recent specimens have been collected and the original description is inadequate, this species is provisionally relegated to the synonymy of *Batrachomoeus dubius*.

Batrachomoeus minor Ogilby, 1908 was described from a specimen collected in Moreton Bay, Queensland. McCulloch (1914) compared this species with specimens of *B. dubius* from Sydney and concluded that they were identical. I concur with this opinion. However, there are slight variations between the Sydney and Moreton Bay populations (see discussion above). The specimen registered as holotype for *B. minor* (QM I.1564) was apparently selected by McCulloch when he designated this species as the type for the genus *Batrachomoeus* (1929: 358). However, this specimen is definitely not one of those that Ogilby used for his description. Examination showed that it has two irregular rows of teeth on the vomer instead of one row (see Ogilby, 1908: 49). This specimen is probably the basis of Ogilby's redescription of *Batrachomoeus coecus* (De Vis) 1884 in his 1908 paper. This

discrepancy is puzzling as McCulloch had earlier (1914) recognized *B. coecus* as the large adult of *B. minor*.

Records of *B. dubius* from north Queensland, Gulf of Carpentaria, New Guinea and Western Australia are in error, being attributable to either *B. trispinosus*, *B. dahli*, *B. rubricephalus* or *Halophryne diemensis*.

Material examined

25 specimens, 30-244 mm SL. New South Wales (unless otherwise designated, all specimens at AM): Sydney Harbour — IB.8254, 206 mm SL; I.15895-016, 2 specimens, 30 mm SL; I.16249-008, 2 specimens, 92-171 mm SL; I.17759-001, 60 mm SL; I.17760-006, 61 mm SL; I.17793-002, 3 specimens, 70-155 mm SL; WAM P.25086-001, 31 mm SL; WAM P.25087-001, 152 mm SL; WAM P.25088-001, skeleton, 138 mm SL. Minnie Waters (south of Grafton) — IB.8248, 2 specimens, 122-146 mm SL. North Solitary Island — IB.8186, 244 mm SL. Queensland (unless otherwise designated, all specimens at QM): Brisbane River — AM I.12547, 171 mm SL. Moreton Bay — I.343, 145 mm SL; I.1564, not type of *Batrachomoeus minor*, 198 mm SL; I.5236, 159 mm SL; I.7943, 192 mm SL; I.7723, 205 mm SL; AM I.9503, 194 mm SL. Moreton Island — I.4941, 152 mm SL. Mooloolabar — I.9734-5, 2 specimens, 110-120 mm SL.

Batrachomoeus rubricephalus n. sp.

Figs. 12 and 14b; Table 3

Pseudobatrachus dubius McCulloch, 1914: 226 (in part); Whitley, 1948: 28.

Holotype

WAM P.25082-001, 211 mm SL, female, collected west of Garden Island, Western Australia, T.K. MacFarlans, 7 August 1960.

Paratypes

14 specimens, 111-262 mm SL (unless otherwise designated, all specimens at WAM). P.159, skeleton, 196 mm SL, Eucla, W.B. Alexander, July 1914; P.1195, 232 mm SL, Point Peron, J.S. Gary, November 1931; P.4003, 262 mm SL, Rottnest Island, V. Glauert, December 1956; P.4292, 203 mm SL, near Perth, W. David, July 1958; P.5792, 191 mm SL, Safety Bay, August 1962; P.6092, 214 mm SL, Cervantes, N. Beissell, 26 January 1963; AM I.18473-001, 219 mm SL, Garden Island, May 1959; P.7120, 256 mm SL, Lancelin, J. Oliver, 10 May 1964; P.7122, 236 mm SL, Shoalwater Bay, R.W. Clifton, 16 April 1964; P.7198, 256 mm SL, Marmion Beach, J. Blakey, 11 May 1964; P.14788, 193 mm SL, Pelsart Group, Houtman Abrolhos, R.J. McKay, 10 May 1963; BM(NH).1975.10.10.2, 162 mm SL, Snag Island, in craypot, J. Bario, June 1972; P.25083-001, skeleton, 222 mm SL, Recherche Archipelago, W. & W. Poole, 1959; P.25123-001, 111 mm SL, Cliffhead, 13 metres in craypot, D. Wright, 13 December 1974.

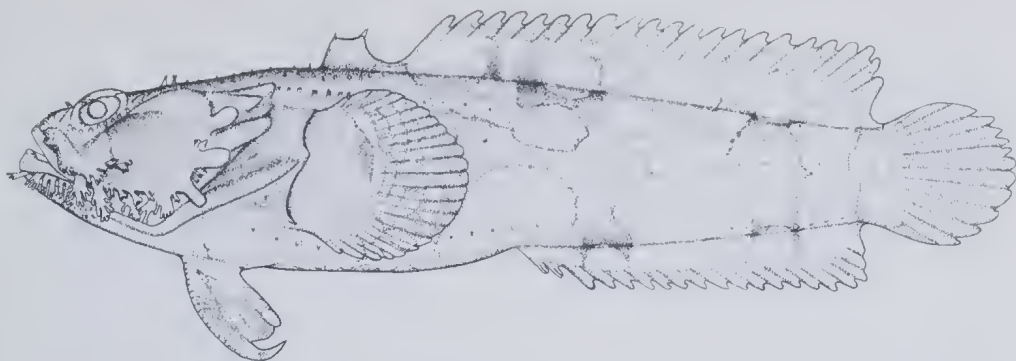


Fig. 12. *Batrachomoeus rubricephalus* n.sp., holotype, WAM P.25082-001, 211 mm SL.

Diagnosis

A species of *Batrachomoeus* characterized by the following combination of characters: higher dorsal and anal fin ray counts (D.III, 21-23; A.18-20); prominent depression on nape; shorter maxilla; large pore in pectoral axilla (2.0-5.0 mm in diameter); minute to small preoperculo-mandibular pores (0.2-1.2 mm in diameter); blotched colour pattern of the pectoral and caudal fins; pink bars and blotches may be present on head.

Description

Measurements and counts of the holotype and selected paratypes are presented in Table 3. Counts and proportions are given below for the holotype, followed by the range for the paratypes in parentheses.

Dorsal rays III, 23 (III, 21-23); anal rays 20 (18-20); pectoral rays 23 (22-23); segmented caudal rays 14 (14-16); pores in lateral line 29 (24-29); vertebrae (9 + 20 - 21).

Head length 2.8 (2.5-2.8), head depth 4.5 (4.2-4.9), pectoral 5.0 (4.1-5.5), all in SL; eye 4.5 (3.9-5.2), snout 6.4 (5.2-6.9), anal base 0.8 (0.8-0.9), head depth 1.6 (1.6-1.9), head width 1.0 (1.0-1.3), all in head length; interorbital 1.5(1.1-2.1), first dorsal spine, 1.5 (1.3-2.1), both in eye.

In addition to the characters given for the genus, the following features are distinctive: eyes slightly elevated, interorbital space somewhat concave; maxilla extends to below posterior half of eye or, at most, rear border of eye; 3 tentacles above each eye but usually prominently reduced or absent; small fronto-nasal tentacle; tentacles on posterior border of preoperculum large fleshy flaps, occasionally reduced; mucous pores on head minute to small, difficult to detect, preoperculo-mandibular series 0.2-1.2 mm in diameter for specimens over 100 mm SL (Fig. 2), teeth on premaxilla nearly always in one series posteriorly, 2 series near symphysis; grooves in frontal bone relatively narrow (Fig. 14b); interorbital width relatively wide (Fig. 15);

TABLE 3. Measurements in mm and fin ray counts of selected type specimens of *Batrachomoeus rubricephalus*

	Holotype		Paratypes		BM(NH) 1975.10.10.2	WAM	
	WAM P.25082-001	WAM P.7198	WAM P.4003	AM L18473-001		Female P.25123-001	Male
Total length	25.4	32.0	31.0	26.6	19.3	13.7	
Standard length	21.1	25.6	26.2	21.9	16.2	11.1	
Soft dorsal fin base	1.22	1.62	1.72	1.21	0.91	0.68	
Anal fin base	0.92	1.18	1.16	0.98	0.75	0.51	
Head length	7.6	9.1	9.7	8.3	6.4	4.3	
Head depth	4.7	5.8	5.6	5.2	3.3	2.3	
Head width	7.5	8.5	7.9	7.3	5.3	3.3	
Eye diameter	1.7	1.9	1.8	1.6	1.3	1.1	
Interorbital width	1.1	1.5	1.6	1.2	0.8	0.52	
Snout length	1.2	1.6	1.4	1.6	1.2	0.67	
Pectoral fin length	4.2	5.8	5.7	4.7	2.9	2.7	
Ventral fin length	4.0	5.0	4.3	4.2	2.8	2.4	
Longest dorsal ray	2.8	4.1	3.4	3.1	*	1.9	
Longest anal ray	2.6	3.8	2.9	2.7	*	1.6	
1st dorsal spine length	1.1	9.6	1.2	9.4	8.3	7.1	
2nd dorsal spine length	1.4	1.4	1.4	1.3	1.0	7.7	
Mucous pore diameter	1.0	1.2	1.0	0.8	0.2	0.3	
Axillary pore diameter	4.1	5.0	2.8	2.5	3.5	2.1	
Soft dorsal ray count	22	22	22	22	21	22	
Anal ray count	19	19	18	18	19	19	
Pectoral ray count	23	22	23	23	*	22	
Caudal ray count	14	14	15	15	16	15	
Lateral line count	29	*	27	26	28	29	
Sex	Female	Male	Female	Male	Female	Male	

*Some measurements and counts were not taken due to damage and distortion.

pore in pectoral axilla large to very large (2.0-5.0 mm in diameter for specimens over 100 mm SL).

Colour of holotype in 70% ethanol: body a pale greenish-grey with irregular dark brown transverse bars and mottlings, bars with darker borders (Fig. 12); numerous round pale blotches on sides, more noticeable ventrally and on abdomen; head greenish-grey with faint brownish blotches on dorsal surface; ventral surface of head greyish with brown mottlings; body bars continued irregularly on soft dorsal and anal fins, sloping obliquely forward on former; outer half of anal fin dark brown; pectoral and caudal fins dark brown with numerous round pale blotches, those on pectoral tending to form transverse series (similar blotches on outer portion of soft dorsal); ventrals dark with several pale blotches.

Paratypes are similar to the holotype except the general coloration of some tends to be brownish rather than greenish, and many have retained pink bars and blotches on the head.

Colour when fresh (frozen specimen, P.25123-001): ground colour pale greenish-brown with white to yellowish-white ventral surface; bars on body dark brown, on head dark brown with reddish-pink margins and tinges, the bar across interorbital a prominent reddish-pink; pectoral and caudal fins prominent dark brown with large green blotches on former and obscure white blotches on latter; ground colour of soft dorsal pale brown, bars dark brown, green blotches on outer portion of fin; anal fin with pale brown basal half, outer half a prominent dark brown; ventral fin yellowish-brown with outer portion dark brown; membrane at base of mandibular teeth yellow; iris pink with reddish-brown radiating bars.

Comparisons

B. rubricephalus differs from its closest relatives *B. trispinosus* and *B. dahli* in having a prominent depression on the nape, the pinkish colouration of the head, the blotched nature of the pectoral and caudal fins rather than barred, the outer portion of the anal being prominently darker, and by having grooves in the frontal which are relatively narrower (Fig. 14b). Furthermore, the relative sizes of the mucous pores and pectoral axillary pores among these species are significant (Table 1, Fig. 2).

Distribution

B. rubricephalus is known only from Western Australia, from Eucla in the south-east to the Houtman Abrolhos on the west coast (Fig. 17). Most specimens have been taken by handline and craypot.

Remarks

Named *rubricephalus* in reference to the pinkish colour of the head when fresh.

Batrachomoeus trispinosus (Günther) 1861

Figs. 13 and 14a

Batrachus trispinosus Günther, 1861: 169 (Type locality: Singapore and Penang, Malaysia); Weber, 1913: 557.

Batrachus dubius (non White) Alleyne and Macleay, 1877: 335; Macleay, 1883: 267.

Batrachomoeus trispinosus Bean & Weed, 1912: 609; Taylor, 1964: 299, pl. 68.

Batrachomoeus broadbenti Ogilby, 1908: 49 (Type locality: Cardwell and Bundaberg, Queensland); McCulloch, 1929: 358; Whitley, 1952: 311 (fig. only); Whitley, 1957: 141; Marshall, 1964: 508; Grant, 1972: 358.

Pseudobatrachus eugeneius Fowler, 1937: 260, fig. 288 (Type locality: Rayong, Thailand).

Batrachomoeus dahli Whitley, 1957: 140, figure.

Batrachonemus trispinus (mis-spelling) Gillis, 1961: 5.

Halophryne trispinosus De Beaufort, 1962: 186.

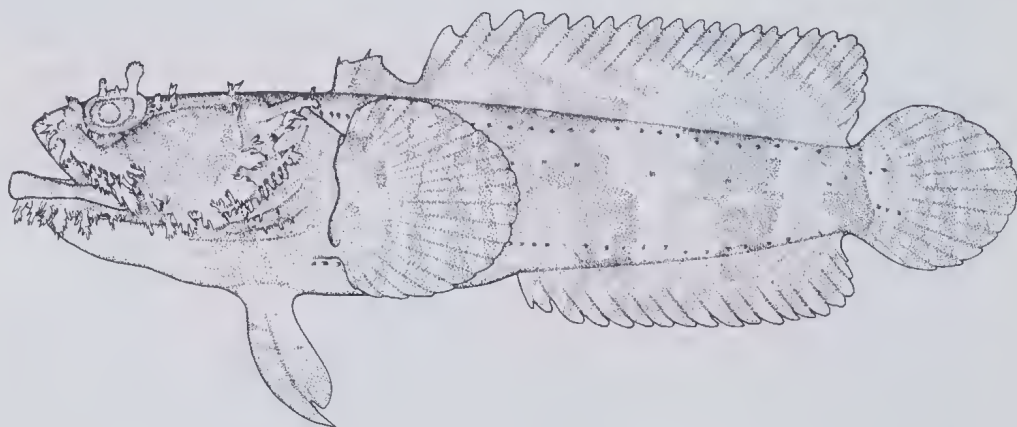


Fig. 13. *Batrachomoeus trispinosus*, AM I.15557-280, 163 mm SL.

Diagnosis

Dorsal rays III, 21-23; anal rays 17-20; pectoral rays 22-23; segmented caudal rays 14-16; pores in lateral line 28-38; vertebrae-9 + 19 - 20.

Head length 2.4-2.7, head depth 3.9-5.4, pectoral 4.2-4.7, all in SL; eye 4.0-7.2, snout 5.9-8.4, anal base 0.9-1.0, head depth 1.6-2.0, head width 1.1-1.4, all in head length; interorbital 0.9-2.6, first dorsal spine 1.3-2.1, both in eye.

Preoperculo-mandibular pores medium to large, 0.9-2.5 mm in diameter for specimens above 100 mm SL (Fig. 2); maxilla extends to below hind-border of eye or farther; pore in pectoral axilla small to medium (0.6-2.0 mm in diameter for specimens over 100 mm SL); tentacles on head either medium to large or considerably reduced; head generally large and broad; eyes elevated or not, interorbital space concave or flat; grooves in frontal bone wide and deep (Fig. 14a).

Colour in alcohol — Head and body pale brown with irregular dark brown transverse bars and blotches, those bars on posterior part of body usually well separated (Fig. 13); bars and blotches always with sharply defined borders, well contrasted from ground colour; lower surface of head and abdomen uniform creamy to pale brown or spotted and blotched with darker brown; fins pale brown with series of dark brown irregular transverse bars, those on soft dorsal and anal continuous with body bars, sloping obliquely forward; prominent bars on pectoral and caudal fins.

Comparisons

B. trispinosus is easily confused with *B. dahli* but the combination of characters indicated in the key will distinguish them. Furthermore, *B. trispinosus* has the last three body bars usually well separated rather than joined medially, a relatively longer first dorsal spine (1.3-2.1 in eye versus 2.1-2.9 for *B. dahli*) and wider grooves in the frontal (Fig. 14). The largest *B. dahli* known is 158 mm SL while specimens of *B. trispinosus* in excess of this are frequently taken. For comparison with *B. dubius* see section under that species.

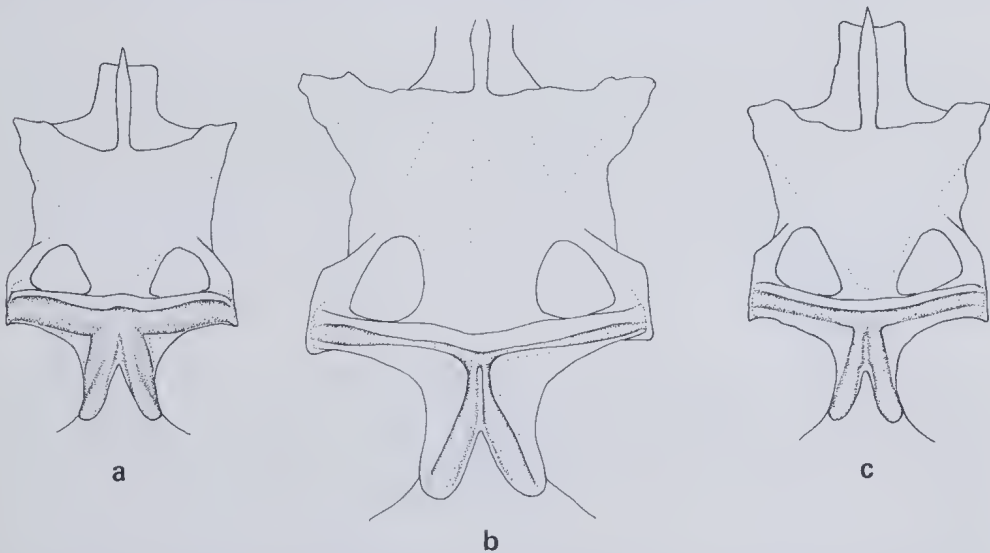


Fig. 14. Semi-diagrammatic illustration showing the frontal grooves (dorsal view) in skulls of a, *Batrachomoeus trispinosus*, 125 mm SL; b, *B. rubricephalus*, 196 mm SL; c, *B. dahli*, 158 mm SL.

Distribution

B. trispinosus is found in northern Australia, from Barrow Island, off Western Australia to Maroochydore in southern Queensland (Fig. 17). It appears to favour more northern waters and is found only rarely below 18° south. It has been trawled in depths to 36 metres, and has been taken intertidally amongst mangroves, on reefs, and in estuaries on the east coast of Queensland.

B. trispinosus is also found in New Guinea and most likely distributed throughout the East Indies to Thailand (see De Beaufort, 1962: 188).

Remarks

Günther described *Batrachus trispinosus* from two specimens, a half grown individual from Singapore and the dried skin of an adult from Penang. The vertebral count that he gave (12 + 17) has caused confusion (Ogilby, 1908: 47), as all Australian species of *Batrachomoeus* only have nine precaudal vertebrae. Günther perhaps copied this count from Valenciennes's description (1837: 472) of *Batrachus grunniens* (Linnaeus) which he believed was identical with *Batrachus trispinosus*. A radiograph of Günther's Singapore specimen (83 mm SL) was kindly sent to me by Mr A. Wheeler of the British Museum (Natural History). This clearly shows nine precaudal and nineteen caudal vertebrae, which proves that Günther's count was incorrect.

In their review of the Indian frogfishes, Nagabhushanam & Rama Rao (1970: 340) placed *Batrachomoeus trispinosus* in the synonymy of *Batrachus dussumieri* Valenciennes (1837: 477). As the specimens they examined all had four spines on the gill cover (above radiograph of the type of *Batrachus trispinosus* shows three spines), *Batrachomoeus trispinosus* is retained here.

Batrachomoeus broadbenti was described by Ogilby in his 1908 revision. In the description his mention of a small second subopercular spine on the upper base of the normal long subopercular spine has created some confusion (Taylor, 1964: 299). This spine is actually a bony swelling which forms at the base of the flexible spine which is found in the above position on all species of *Batrachomoeus* (see preceding section on morphology). This swelling can usually only be detected in large specimens.

Material examined

32 specimens, 19-262 mm SL. Western Australia (WAM specimens): Barrow Island — P.24572, 176 mm SL. Admiralty Gulf — P.25070, 2 specimens, the larger a skeleton, 93- 125 mm SL. 'North-west coast' — P.577, 120 mm SL. Northern Territory: Darwin area — WAM P.14221, 129 mm SL; WAM P.16482, 145 mm SL; AM IA. 1714, 2 specimens, 31-82 mm SL; AM IA. 7770, 143 mm SL. Melville Island — AM IA. 7858, 30 mm SL. Cobourg Peninsula — AM IA. 7847, 19 mm SL. Queensland: Gulf of Carpentaria — WAM P.25071-001, 116 mm SL; QM I.7929, 151 mm SL; AM IB.6937-8, 2 specimens, 24-73 mm SL; AM I.15557-280, 4 specimens,

57-163 mm SL. Cairns — AM I.16530, 262 mm SL. Cardwell — QM I.874, type of *Batrachomoeus broadbenti*, 198 mm SL. Proserpine — QM I.8303, 157 mm SL. Maroochydore — QM I.8128, 138 mm SL. No locality, unregistered, in jar with QM I.874, 179 mm SL. New Guinea (KFRS specimens): Marshall Lagoon, eastern Papua — FO.341, 142 mm SL. Yule Island — FO.2060, 162 mm SL. Orokolo Bay, Gulf of Papua — FO.2070, 160 mm SL. Bahoture River, western Papua — FO.2984, 2 specimens, 56-65 mm SL; FO.2986, 85 mm SL. Kerema, Gulf of Papua — FO.4121, 121mm SL.

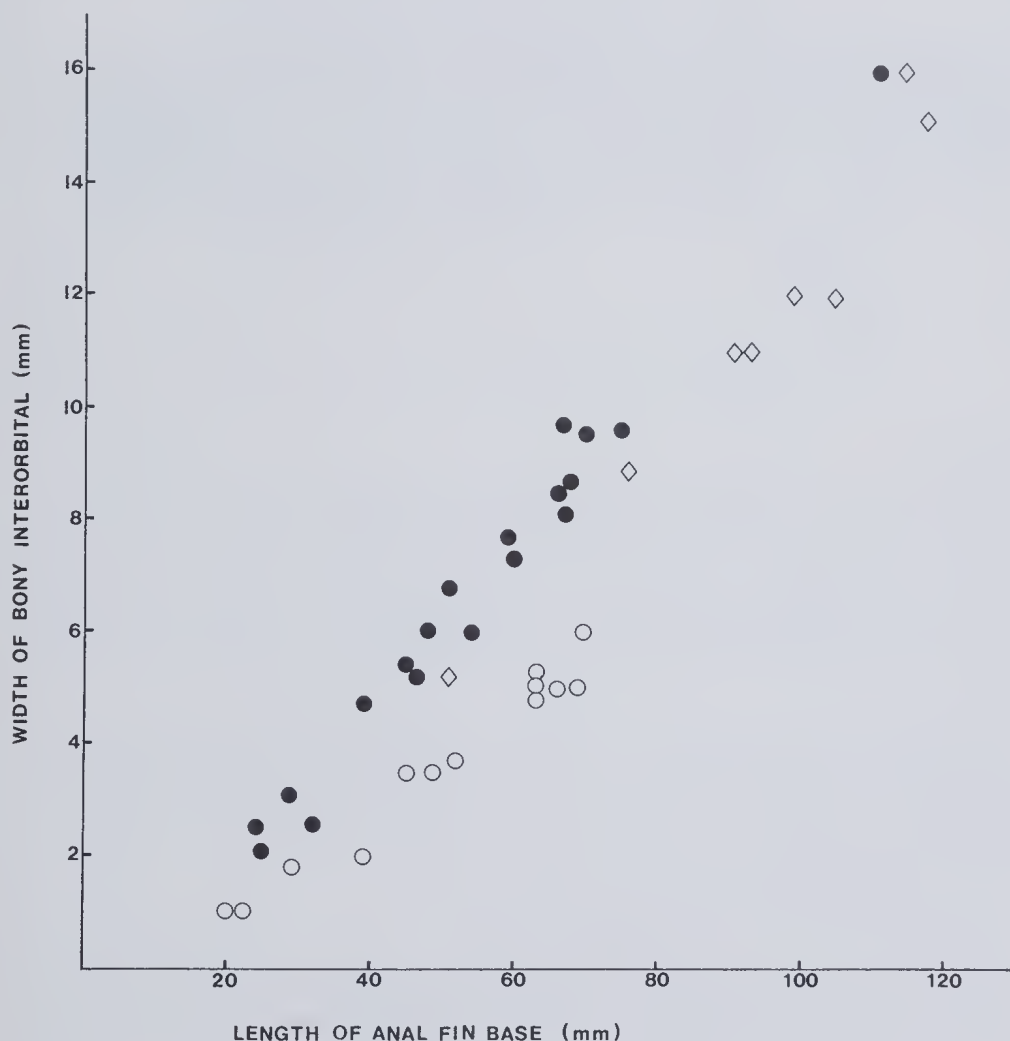


Fig. 15. Bony interorbital widths in *Batrachomoeus trispinosus* (solid circles), *B. dahli* (empty circles) and *B. rubricephalus* (diamonds).

Batrachomoeus dahli (Rendahl) 1922

Figs. 1c, 4b, 14c and 16

Pseudobatrachus dahli Rendahl, 1922: 195 (Type locality: Roebuck Bay, Western Australia); Whitley, 1937: 145; Whitley, 1948: 28.

Batrachomoeus dahli Whitley, 1957: 141; Whitley, 1964: 54.



Fig. 16. *Batrachomoeus dahli*, WAM P.13698, 151 mm SL.

Diagnosis

Dorsal rays III, 21-24; anal rays 18-20; pectoral rays 22-23; segmented caudal rays 15-16; pores in lateral line 30-35; vertebrae 9 + 20.

Head length 2.6-3.1, head depth 4.3-5.4, pectoral 4.1-5.2, all in SL; eye 3.3-4.9, snout 5.6-7.0, anal base 0.7-0.8, head depth 1.5-2.0, head width 1.0-1.4, all in head length; interorbital 1.8-3.5, first dorsal spine 2.1-2.9, both in eye.

Preoperculo-mandibular pores small, 0.5-0.8 mm in diameter for specimens over 100 mm SL (Figs. 1c and 2); maxilla extends to below posterior border of eye or slightly farther; pore in pectoral axilla small (0.5-1.0 mm in diameter for specimens over 100 mm SL); tentacles on head never reduced in size; eyes elevated, interorbital space concave, rather narrow; grooves in frontal relatively narrow and shallow (Fig. 14c).

Colour in alcohol — sides of body pale brown with darker blotches tending to form irregular transverse bars, usually joined along midline of side giving a marbled appearance (Fig. 16); head is generally dark brown dorsally or with poorly contrasted bars and blotches, the ventral surface cream; dark brown bar connects anterior half of each eye; fins pale with series of irregular transverse bars, those on soft dorsal and anal continuous with body bars, sloping obliquely forward; bars on pectoral and caudal may be indistinct or joined in a reticulated pattern.



Fig. 17. Map of Australia showing the distribution of the species of *Batrachomoeus*.

Comparisons

For comparisons with *B. trispinosus* and *B. rubricephalus* see the relevant section under each species account.

Distribution

B. dahli is restricted to Western Australia, occurring from Shark Bay northwards to Broome. It has been collected from intertidal areas on offshore islands and trawled in relatively shallow water.

Material examined

24 specimens, 41-158 mm SL. (Unless otherwise designated, all specimens at WAM). Shark Bay — AM I.13282, 48 mm SL; P.14659, 102 mm SL. Barrow Island — P.25066-001, 2 specimens, 106-110 mm SL. Dampier Archipelago — P.20244, 123 mm SL; P.22250, 138 mm SL; P.23975, 57 mm SL; P.25065-001, 41 mm SL. Port Hedland — P.3589, 140 mm SL; P.16484, 155 mm SL. Broome & Roebuck Bay — P.6306, 108 mm SL; P.13690-1, 6 specimens, 82-143 mm SL; P.13698-9, 2 specimens, 111-151 mm SL; P.13700, skeleton, 158 mm SL; P.13701-2, 2 specimens, 87-116 mm SL.

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A NEW GENUS AND TWO NEW SPECIES OF LEPTODACTYLID FROGS FROM WESTERN AUSTRALIA

MICHAEL J. TYLER*

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INTRODUCTION

The frog fauna of the south-western portion of Western Australia is well known and has been the subject of a field guide by Main (1965). In contrast, there are elements of the fauna of the northern part of the State still being discovered, whilst other components remain known from a few preserved specimens in museum collections.

In recent years the Western Australian Museum has devoted a considerable proportion of its efforts to gathering specimens and data in the northern districts, and the present paper reports a new genus and two new species of leptodactylid frogs obtained in this way.

Material and methods

With the exception of one paratype now in the South Australian Museum, all of the specimens reported here are deposited in the Western Australian Museum. The abbreviations preceding the registration numbers of the specimens are SAM and WAM respectively.

Because one of the species reported here is known from a single specimen, numerous radiographs were prepared from a variety of aspects to establish data about skeletal anatomy, and so minimise the need for dissection. Essential dissections were performed using a low-power stereoscopic microscope, and measurements were obtained on this and the other specimens using a pair of dial callipers.

Methods of measurement follow those of Tyler (1968), whilst the abbreviations used in referring to various features employed in morphometric investigations are: S-V snout to vent length; TL tibia length; HL head length; HW head width; E-N eye to naris distance; IN internarial span.

Arenophryne new genus

Type species

Arenophryne rotunda sp. nov.

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Diagnostic definition

1. Skull distinctly broader than long.
2. Frontoparietal foramen very large.
3. Mandibles well developed, with pronounced post-articular extremities.
4. Maxilla and premaxillae dentigerous.
5. Tongue long, slender and free behind.
6. Tympanum entirely absent.
7. Omosternum absent.
8. Clavicles broad and fused medially.
9. Coracoids broad and posteromedially directed.
10. Epicoracoids and mesosternum calcified or ossified in adults.
11. Sacral diapophyses broadly dilated.
12. Musculus intermandibularis with elongate median aponeurosis.
13. M. intermandibularis not differentiated and not attached upon ventral surface of M. submentalis.
14. M. depressor mandibulae with two bodies.
15. Fingers and toes short.
16. Fingers of males lacking nuptial pads.
17. Liver large: extending for entire length of body cavity.
18. Parotoid and flank glands present.
19. Skin surrounding body forming loose sac extending to knee and elbow.
20. Eggs large and unpigmented.
21. Development probably direct.

A discussion of the diagnostic characters and phylogenetic affinities of the new genus are given below in the remarks on *A. rotunda*.

Arenophryne rotunda new species

Holotype

WAM R.39120. An adult male collected approximately 100 m from False Entrance Well Tank (26°23'S; 113°18'E), Carrarang Station, 320 km NNW of Geraldton, Western Australia, on 24 August 1970 by A. Baynes and Tom A. Smith.

Description

Habitus stout and head considerably broader than long (Fig. 1a). Eye large but not particularly prominent, its diameter equivalent to distance separating it from tip of snout. Snout blunt and evenly rounded when viewed from above and in profile (Fig. 1b). Nostrils small and inconspicuous and directed dorsolaterally. Distance between eye and nostril considerably less than internarial span (E-N/IN 0.769). Canthus rostralis inconspicuous and very gently rounded. No tympanum. Pupil horizontal. No vomerine teeth. Tongue long and half free.

Fingers very short, fourth very broad and reduced to a single phalanx (Fig. 1c). Fingers in decreasing order of length $3 > 2 > 1 > 4$. Hindlimbs particularly short and enveloped in a loose-fitting patagium. TL/S-V ratio 0.167. Toes rather short (Fig. 1d), in decreasing order of length $4 > 3 > 2 = 5 > 1$. A very weak inner but no outer metatarsal tubercle.

Skin of dorsal surface thick and smooth. A prominent postocular ('supratympanic') gland. Skin on tip of snout highly modified to produce a

colourless and almost translucent appearance. Ventral surfaces of body smooth except for sparse folding on abdomen.

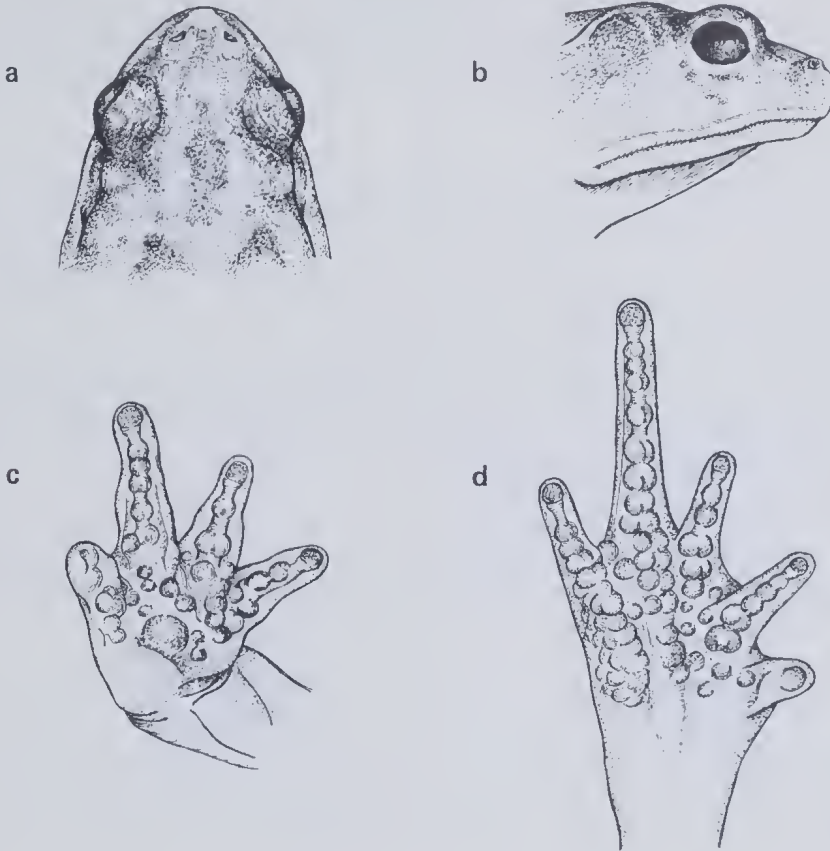


Fig. 1. *Arenophryne rotunda* new species: WAM R39119 (paratype) (a) dorsal view of head; (b) lateral view of head; (c) palmar view of hand; (d) plantar view of foot.

Vocal sac a submandibular structure with a single aperture in floor of mouth on left side of tongue. No nuptial pads.

Dorsal surface of body and limbs dull cream with brown stippling. Stippling concentrated on and between upper eyelids and on dorsolateral surfaces of body, flanks and each side of posterior half of midline. Ventral surface a paler shade of cream with small isolated clusters of dark stippling.

Dimensions

Snout to vent length 30.4 mm; tibia length 5.1 mm; eye to naris distance 2.0 mm; internarial span 2.6 mm; eye diameter 4.6 mm.

Variation

There are nine paratypes all of which were collected at the type locality. Five adult paratypes (WAM R39115-17, 39119, 39123) were taken with the holotype on 24 August 1970, and the four juveniles (WAM R39118, 39121-22, SAM R14521) were collected on 20 August 1970. The adults consist of two gravid females 30.2-31.4 mm S-V, two males 26.4-27.7 mm, one eviscerated unsexed specimen 23.8 mm. The juveniles range in size from 13.3 to 17.8 mm.

All of the paratypes are squat, short-legged frogs. The gravid females have large unpigmented eggs, and the juveniles are all very much darker coloured than the holotype and other adults. There is evidence of ontogenetic retrogression in digital subarticular tubercles, for these are most pronounced in juveniles and scarcely detectable in adults.

At Carrarang Station the mean annual rainfall over a 61-year period up to 1970 was 27.4 cm. On average 87% fell during the period April-September. The type locality may have a slightly higher rainfall but will nevertheless be exposed to long periods of drought.

The False Entrance Well Tank at the type locality is fed by a mill and is reported by Mr Baynes to be the only source of permanent fresh water in the district. The tank was not accessible to the frogs, and only the flooding spillway could provide a source of reasonably fresh water.

It is situated on the edge of coastal sand dunes and it was amongst these dunes that all of the frogs were found. Whether or not the frogs require fresh water for breeding purposes is uncertain, but the spillway would appear to be the only possible site. However, the ovarian eggs are large (up to 3 mm in diameter), and direct development is strongly indicated. Baynes and Smith found all of the type specimens following showers of rain.

Phylogenetic affinities

At first glance *Arenophryne* could be mistaken for a short-legged *Pseudophryne* species. Its phylogenetic affinities seem to lie with that genus and with *Myobatrachus*.

As currently defined, *Pseudophryne* includes eleven species (if Blake's (1972) proposals to suppress the monotypic Western Australian genus *Metacrinia*, and to refer *M. nichollsi* to *Pseudophryne* are supported). The vast majority of these species are diminutive creatures with warty skins, short limbs and moderate to long cylindrical digits. Parotoid, inguinal and femoral cutaneous glands occur commonly in the members of this genus.

Arenophryne differs from *Pseudophryne* in the following respects:

1. Gross enlargement, reinforcement and spreading of the component portions of the pectoral girdle (Fig. 2);

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Page 49, caption to figure 2a,

(a) *Arenophryne robusta* SHOULD READ

(b) *Arenophryne rotunda*

2. Reduction of the length of the digits by a process of loss of various phalanges;
3. Adaptation of the dermis on the tip of the snout;
4. Enlargement and elongation of the liver;
5. A loose, voluminous skin;
6. Increased size of ova;
7. Probably direct development (possibly shared by *P. nicholli*);
8. Absence of extensive areas of dark pigmentation on the ventral surface of the body.

Judging from the listed generic criteria of Lynch (1971), the presence of two bodies to the Musculus depressor mandibulae would also appear to distinguish *Arenophryne* from *Pseudophryne*, for the latter is stated to have only one. However, I have examined the M. depressor mandibulae in six species of *Pseudophryne*, and found a bipartite muscle in each one. A second point of variance with Lynch's definition of *Pseudophryne* involves the nature of the palatine bones, which he states are reduced to splinter-like bones lacking contact with the maxillae. This is certainly descriptive of the majority of *Pseudophryne* species, including the two examined by Lynch, but it will not embrace *P. guentheri*, because maxillary contact persists in that species, and the palatines are much more substantial features.

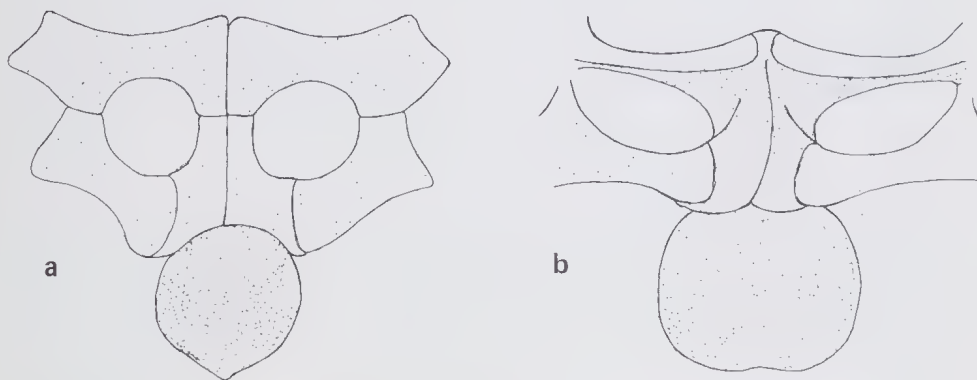


Fig. 2. Pectoral girdles. (a) *Arenophryne robusta*; (b) *Pseudophryne guentheri*. Light stippling = bone and dense stippling = cartilage.

The reinforced pectoral girdle of *Arenophryne* (Fig. 2) is reminiscent of the condition in *Myobatrachus* (Parker, 1940, Fig. 20). However, the monotypic *Myobatrachus* is a more substantial form, structurally even more highly-adapted to a fossorial life. For example, the vast musculature of the hind limbs of *Myobatrachus* creates a demand for an increase in the surface

area of ischium and pubis for their attachment. Hence comparison of radiographs of the pelvic regions of *Myobatrachus* and *Arenophryne* shows a large post-acetabular, ischial zone in *Myobatrachus*.

Myobatrachus has a much smaller head than *Arenophryne*, possesses a tympanum (although hidden), has a greatly reduced maxilla and lacks teeth. Despite the number of differences between *Pseudophryne* and *Myobatrachus*, the existence of this new genus suggests that a reasonably close relationship may exist between them.

Limnodynastes depressus new species

Holotype

WAM R43896. An adult male collected near the former Argyle Downs homestead, Ord River, Western Australia (now submerged by Lake Argyle), by a survey party from the Western Australian Museum on 12 January 1972.

Description of holotype

A moderately-sized frog of rather elongate habitus with a flattened head (Fig. 3a). Head approximately as long as broad (HL/HW 0.979). Eye small and rather depressed, with an exceptionally prominent upper eyelid jutting horizontally outwards like a shelf. Snout bluntly rounded when viewed from above and more gently rounded in profile (Fig. 3b). Nostrils small and directed superiorly. Distance between eye and naris less than internarial span (E-N/IN 0.892). Canthus rostralis quite straight and inconspicuous. Tympanum completely covered with skin. Vomerine teeth situated between and completely posterior to choanae. Tongue broad and partly free behind.

Fingers rather long and without terminal discs, lateral fringes and webs (Fig. 3c). Fingers in decreasing order of length $3 > 4 = 2 > 1$. Hindlimbs muscular and relatively short. TL/S-V 0.410. Toes elongate, unfringed and unwebbed (Fig. 3d), in decreasing order of length $4 > 3 > 5 > 2 > 1$. A small but prominent inner but no outer metatarsal tubercle; prominent subarticular tubercles present. Palmar tubercles large; digital subarticular tubercles rounded and prominent.

Skin of dorsal and ventral surfaces of body and limbs quite smooth. No supratympanic fold.

Vocal sac a submandibular and apparently unilobular structure. No nuptial pads.

Dimensions

Snout to vent length 38.5 mm; tibia length 15.8 mm; head length 14.0 mm; head width 14.3 mm; eye to naris distance 3.3 mm; internarial span 3.7 mm; eye diameter 3.4 mm; tympanum diameter 2.4 mm.

Dorsal surface a very pale grey liberally marked with small brown vermiculations. Ventral surface of body and limbs uniformly immaculate cream.

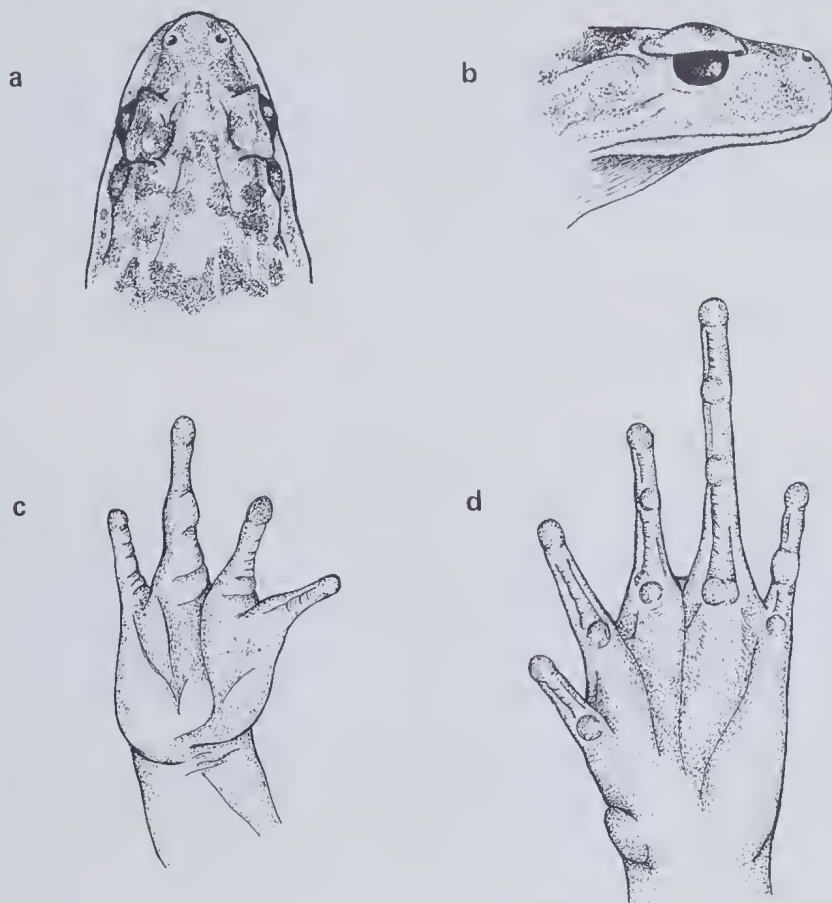


Fig. 3. *Limnodynastes depressus* new species: WAM R43896 (holotype) (a) dorsal view of head; (b) lateral view of head; (c) palmar view of hand; (d) plantar view of foot.

Comparison with other species

The most conspicuous morphological features unique to *L. depressus* and distinguishing it from all congeners are: 1. the short vomerine teeth rows; 2. the fact that these rows are medially separated from one another, and 3. the shelf-like nature of the upper eyelid.

The majority of *Limnodynastes* species occur thousands of kilometres distant in southeastern Australia, and in fact the only species known to be

sympatric with *L. depressus* is *L. ornatus*. The latter species is a distinctly robust-bodied animal with a shovel-shaped inner metatarsal tubercle. *Limnodynastes convexiusculus* could conceivably be sympatric, but this is a larger animal that has a high instead of a flattened head and invariably a sub-aural glandular fold, and adult males have dense submandibular dermal pigmentation.

The extent of morphological divergence renders the generic disposition of this solitary specimen suspect. Additional specimens are required to confirm the matter, and for the present it is expedient to consider it a member of the genus *Limnodynastes*. It is at least possible that the collection of additional material will cause a new genus to be erected for this unique frog.

ACKNOWLEDGEMENTS

The opportunity to visit the Western Australian Museum in 1973 and provisionally examine the specimens reported was provided by the Science and Industry Endowment Fund. I am indebted to the Trustees for making that visit possible.

My studies at the Western Australian Museum were aided considerably by the enthusiastic co-operation of Dr G.M. Storr, Mr L.A. Smith and Mr R. E. Johnstone. Mr A. Baynes gave freely of his time providing detailed information about Carrarang Station and the collection of frogs there.

I am also greatly indebted to Miss Adrienne Edwards of the South Australian Museum for the preparation of the illustrations, and to the Interim Council of the Australian Biological Resources Study for supporting the comparative anatomical studies.

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THE GENUS *CRYPTOBLEPHARUS* (LACERTILIA, SCINCIDAE) IN WESTERN AUSTRALIA

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ABSTRACT

Four taxa are recognized: *C. virgatus clarus* (Storr), *C. carnabyi* nov., *C. plagiocephalus* (Cocteau) and *C. megastictus* nov.

INTRODUCTION

It has become clear in recent years that the *Ablepharus boutonii* of authors, especially Mertens (1931, 1964), far from being a single wide-ranging polytypic species, comprises a genus of many species. The oldest name for this genus is *Cryptoblepharus*. For the osteology of *Cryptoblepharus*, see Fuhn (1969); and for its relationship to other lygosomatine skinks, see Greer (1974).

A big task for future workers is to arrange the numerous 'races of *Ablepharus boutonii*' into species. It is unlikely that any of the four Western Australian members of *Cryptoblepharus* are conspecific with *boutonii* of Mauritius; the two species most like *boutonii* (*plagiocephalus* and *carnabyi*) are still closer to each other.

All the material used in this revision is lodged in the Western Australian Museum. I am grateful to Mrs Ariadna Neumann for translating much of Professor Mertens' work.

Genus *Cryptoblepharus* Wiegmann

Diagnosis (based on Australian species).

Small arboreal or rock-climbing pentadactyl skinks with lower eyelid immovable and bearing a large circular transparent disc, and interparietal and frontoparietals fused into a large quadrilateral shield. Distinguishable from *Morethia* by frontal not much larger than prefrontals, enlargement of uppermost pericocular granules, and absence of supranasal.

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Distribution

From east coast of Africa through the Indian Ocean and Australia to the east Pacific.

Description (based on Australian species)

Nasals widely separated, usually bearing a groove behind nostril. Pre-frontals normally forming a long median suture. Frontal usually in narrow contact with frontoparietal-interparietal, sometimes separated. Loreals two, in horizontal series. Supraoculars 4, second largest, first two in contact with frontal. Supraciliaries normally 5 or 6 with respectively second or third widest. Enlarged periocular granules (ciliaries) usually 3, occasionally 4, rarely 2 or 5. Labials normally 7, fourth subocular and much the widest. Temporals normally 3, uppermost much the largest. A pair of very large nuchals, sometimes followed by one or more smaller nuchals. Scales smooth, 20-30 rows at midbody. Subdigital lamellae smooth, callose or finely keeled.

KEY

1. Straight-edged black laterodorsal stripe, bordered below by conspicuous white dorso-lateral stripe; supraciliaries normally 5 *virgatus clarus*
 No laterodorsal stripe — at most a laterodorsal series of black or dark brown spots; with or without a pale ragged-edged dorsolateral stripe; supraciliaries 5 or 6 2
2. Subdigital lamellae finely keeled and mucronate; plantar scales with sharp white apices; supraciliaries normally 5 *carnabyi*
 Subdigital lamellae smooth or callose; plantar scales with rounded brown apices; supraciliaries usually 6 3
3. Dark dorsal spots (if present) much smaller than dorsal scales and largely confined to laterodorsal series; dark upper lateral spots tending to coalesce, forming an irregular blackish stripe; lower labials and lower half of upper labials pale (except in far south of W.A.); abdomen whitish in alcohol; occurring throughout most of W.A. and N.T. *plagiocephalus*
 Dark dorsal spots often occupying whole of scale and as often present on two median series as on outer dorsals; no black upper

lateral stripe, lateral pattern tending to be reticulate, i.e. scales dark-edged and pale-centred; upper and lower labials dark; abdomen bluish in alcohol; confined to N.W.

Kimberley *megastictus*

Cryptoblepharus virgatus clarus

Ablepharus boutonii clarus Storr, 1961, W. Aust. Nat. 7: 176. Dalyup River, W.A. (G.M. Storr).

Diagnosis

A small *Cryptoblepharus* with straight-edged black laterodorsal stripe, conspicuous bluish white dorsolateral stripe and 5 supraciliaries.

Distribution

South and south-east coasts of Western Australia from the Pallinup River to Eucla, thence east through the west coast of South Australia presumably to south-east Queensland.

Description

Snout-vent length (mm): 18-40 (N 46, mean 33.8). Tail up to 156% of SVL.

Supraciliaries 5, second usually much the widest. Ciliaries usually 3 (93%), rarely 2 or 4. Upper labials 7 (95%), rarely 6. Nuchals 1-4, mostly 1 or 2 (N 42, mean 1.7). Midbody scale rows 22-28 (N 38, mean 25.3). Subdigital lamellae smooth, 16-21 (N 36, mean 18.8) under fourth toe.

Usually a black vertebral line on anterior quarter of body. Black laterodorsal stripe usually wide, leaving only a narrow median strip of grey ground colour. Narrow whitish dorsolateral stripe. Flanks grey spotted with black and dotted with white, black markings concentrating in upper lateral zone.

Remarks

Until more east Australian material is examined, it will remain uncertain whether *clarus* is conspecific with *C. virgatus* (Garman). Our two south-east Queensland specimens (18270 from Amiens and 18283 from Enoggera) are discoloured with formalin but appear to have much the same colour pattern as in western *clarus*; they also agree in their small size and low number of supraciliaries (5). Our specimens from further north and west in Queensland, viz. 21476-81 and 21489 from Charters Towers and 18269 from Cunnamulla are larger (SVL in 7 of 8 specimens exceeds 40 mm) and 6 of 8 specimens have 6 supraciliaries of which the fourth is considerably higher than adjacent scales; they have 24 or 26 rows of midbody scales; the

snout is relatively short and the head relatively high; though distinct from *clarus*, they do not agree with descriptions of typical *virgatus*.

Material

South-west Division (W.A.): Pallinup River, 16 km NE of Bluff Knoll (47732); Hunter River, 8 km E of Bremer Bay (36200); Fitzgerald River (36782, 36851-2, 36864-5, 36879-80, 36945, 36992-3); Middle Mt Barren (36905-7).

Eucla Division (W.A.): Oldfield River (30145); Munglinup River (36231-3); Jonegatup, Young River (36286); Dalyup River (18228-31); 8 km E of Gibsons Soak (21992); Esperance (13370, 18232); 23 km E of Esperance (18225); Mondrain Island, Archipelago of the Recherche (18226-7); Middle Island, Archipelago of the Recherche (47626); Pine Hill (36214-9); Junana Rock (22523); Toolinna Rock-hole (32° 42'S, 124° 57'E) (45347); Caiguna (31893); Billolee Rock-hole (32° 33'S, 125° 33'E) (45353); 24 km SE of Cocklebidy (34476); 43 km E of Madura (24646-7); Eucla (294).

South Australia: 6 km E of Wilsons Bluff (28132); 14 km E of Smoky Bay (24537).

Cryptoblepharus plagiocephalus

Scincus plagiocephalus Cocteau, 1836, Etudes sur les Scincoides, p. 7. Tasmania and Shark Bay (Péron) [= Swan River, W.A., *vide* Storr 1961: 176].

Ablepharus peronii Duméril & Bibron, 1839, Erpétologie générale 5: 813. [Swan River, W.A., *vide* Storr 1961: 176].

Tiliqua Buchananii Gray, 1839, Ann. Nat. Hist. 2: 291. New Holland [= Western Australia, *vide* Boulenger 1887: 347].

Ablepharus boutonii var. *metallicus* Boulenger, 1887: 347. North Australian Expedition, J.R. Eley [presumably Victoria River, N.T.].

Ablepharus boutoni australis Sternfeld, 1918, Abh. Senckb. Naturf. Ges. 36: 424. West Central Australia [= Hermannsburg, N.T.].

Ablepharus boutoni punctatus Sternfeld, 1918, *ibid.* Western Australia.

Diagnosis

A moderately large *Cryptoblepharus* with no black laterodorsal stripe (at most only a laterodorsal series of dark spots, each much smaller than a dorsal scale); pale dorsolateral stripe (when present) never sharp-edged; supraciliaries 6 (occasionally 5); subdigital lamellae smooth or callose; plantars with flattened, smooth, brown apices.

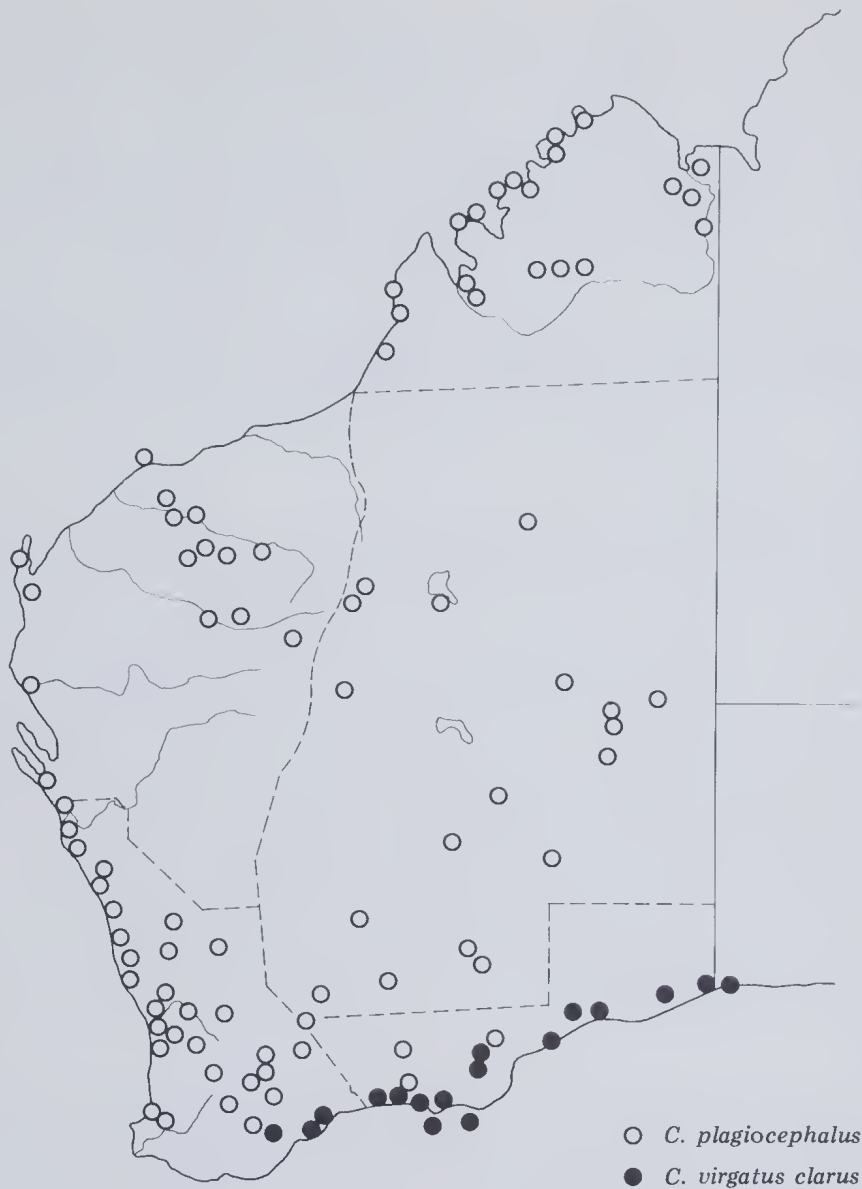


Fig. 1: Map of Western Australia showing location of specimens of *Cryptoblepharus virgatus clarus* and *C. plagiocephalus*.

Distribution

Greater part of Western Australia south to Busselton, Jarrahwod, Gnowangerup, Scaddan and Balladonia. Extralimital in Northern Territory and western South Australia.

Description

Snout-vent length (mm): 16-47 (N 388, mean 36.6). Tail up to 177% of SVL.

Supraciliaries usually 6 with third widest; occasionally 5 with second widest. Ciliaries 3 (94%), occasionally 4, rarely 1, 2 or 5. Upper labials 7 (94%), occasionally 8. Nuchals 1-4 (N 363, mean 1.1). Midbody scale rows 22-30 (N 292, mean 25.2). Subdigital lamellae smooth or with broad to moderately narrow brown calli; 14-22 (N 304, mean 17.9) under fourth toe.

Dorsally coppery or olive brown or olive grey, each scale with several dark brown or black striae; striae merging to form spots, especially on laterodorsal series. Flanks usually spotted with black and dotted with brownish white; black spots tending to coalesce and form an upper lateral stripe.

Geographic variation

Specimens from the South-west Division have more midbody scale rows than specimens from elsewhere (24-30, mean 25.8; *vs* 22-28, mean 24.7) and a smaller proportion of individuals with 8 (rather than 7) upper labials or 4 (rather than 3) ciliaries. They are also darker and less metallic in coloration. The trend towards melanism increases sharply in the southern interior of the Division (i.e. north to the Darling Range and the Narrogin and Lake Grace districts) and is possibly due to past introgression from *C. virgatus clarus*.

Pilbara specimens are the palest. Dark dorsal spots and striae are commonly sparse or absent; hence most specimens have little or no indication of a pale dorsolateral stripe (which is essentially a zone free of spots and striae).

In the Kimberley and Northern Territory almost all specimens have the subdigital lamellae callose, a condition that becomes increasingly uncommon further south. The frequency of 4 ciliaries is highest in the north of the Northern Territory (27%).

Material

Kimberley Division (W.A.): Kalumburu (27957-8, 40505, 43571-6, 47893-4); Borda Island (41489); Crystal Head, Admiralty Gulf (44285-7); Mitchell Plateau (43158-60, 43206, 43518, 44261); Boongaree Island (44091, 44104); Prince Regent River Reserve (46677, 46711-2, 46784, 46791, 46853, 46894, 46928, 46963, 46983-5); Augustus Island (41300); 17 km ESE of Kuri Bay (40393-5, 40398); Wood Islands (44169-73); Wotjulum (11218); Inglis Gap (27953-6); Mt Bell (32271); Lake Gladstone (32310-3); Ninbing (27948); Wyndham (32360-01); Parrys Creek (27949); 40 km ESE of Wyndham (23104); 50 km SE of Wyndham (23089); Lake Argyle (42758, 42774, 42785, 42905, 42915); Derby (20271, 45031-2); 24 km SE of Derby (32190); Coulomb Point (40264); Broome (14065, 14093); Injudinah Swamp (46494); Lagrange (27936-45).

North-west Division (W.A.): Dolphin Island (14289, 14296-7); Angel Island (37262); Mt Herbert (20023-4); Millstream (20025, 34735); Tambrey (20022); Hancock Gorge, 25 km S of Wittenoom (37075, 37485); Hamersley Gorge (34730); Yampire Gorge (18539); Weeli Wolli Creek, W of Marrillana (22640); near Tom Price (31015); Yardie Creek (47773); 13 km NE of Cardabia (16967); 'Bernier Island' [probably in error for Carnarvon] (11251-2); Tunnel Creek, 40 km N of Mt Vernon (22807-14); gorge *ca* 30 km W of Mt Vernon (22815-8); 37 km NW of Mt Vernon (25242); Kumarina (23979-81); 8 km S of Tamala (23854).

Eastern Division (W.A.): Well 37, Canning Stock Route (3974); 32 km E of Jiggalong (25202); 19 km SE of Jiggalong (42294); Durba Hills, S of Lake Disappointment (40350-3); Windich Spring, Canning Stock Route (27951-2); dunes N of Lake Breaden (21038); Walter James Range (34223); Warburton Range (22109); Ainslie Gorge, 18 km S of Warburton Range (18284-5); Skipper Knob, 116 km S of Warburton Range (22116); Lake Throssell (18238); White Cliffs (20664); 220 km N of Seemore Downs (24864); Zanthus (26521); 24 km N of Coonana (30264); 5 km NW of Callion (22535); Higginsville (7088); 24 km S of Yellowdine (37931, 37938); Split Rocks (37828).

South-west Division (W.A.): 48 km NNW of Murchison House (33925); 26 km NE of Kalbarri (33491-3); Murchison House (29927); Kalbarri (9615, 18262, 29628) and 8 km SE (33881) and 42 km ESE (33809); Hutt River (11133-4); 32 km E of Geraldton (18261); Ellendale Pool (18268); Greenough River (11137); Lake Arrowsmith (22250-1); Lake Arramel (22254); 40 km SW of Enneabba (25289-92); Buntine Reserve (43601-5, 44905); 3 km N of Mt Lesueur (25288); Cockleshell Gully (22232); mouth of Moore River (18254); 47 km NNE of Beacon (44243-4); 23 km NE of Wialki (18237); Miling (47767); Bindi Bindi (22839); Yewadabby Spring (18271-6); Wookawooka (18255-7); 11 km SE of Bindoon Hill (18258-60); Culham (22459); Toodyay (29291-6); Chittering East (12833); Muchea (461); Bullsbrook (13121); Gngangara East (34369); Noble Falls (21803, 31130); Northam (31448); 32 km SE of Kellerberrin (18235); 16 km SE of Sawyers Valley (22673); Mundaring Weir (15204, 19249, 19747); Zamia (21342-4); Darlington (2806); Boya (21747); Middle Swan (4935); Perth and suburbs (4184, 18247-53, 21607, 21882, 22999, 25367, 26440, 26583, 28933, 32372, 33379, 34119, 40012-3, 47361); Gooseberry Hill (4678); 10 km E of Kalamunda (16915); Lesmurdie (18242-6); Karragullen (18236); Kenwick (18241); Kelmscott (12898-9); Jandakot (28313-4, 36560); Garden Island (28478-9); W of Byford (15821); Bedfordale (18240); York (39104, 43818-20); Boyagin Reserve (41008-11, 43991); Pingelly (1937) and 26 km E (18234); Bending Flora Reserve (43677-8); East Kulin (8108); Dragon Rocks (42978-9, 42981); North Bannister (36322); Narrogin (5968); Lake Grace (42601-3, 43822, 44204, 44208-11, 44227-8); Lake Varley (19805); North Tarin Rock Reserve (40074-5, 40085, 44418); Tarin Rock Reserve

(40037-8, 40058, 44397-8, 44454); Chinocup Reserve (41099); Cairlocup Reserve (41116-8); 10 km E of Woodanilling (23351-2); Busselton (42592); Jarrahwood (45748); Gnowangerup (33411-2).

Eucla Division (W.A.): 32 km N of Salmon Gums (18233); 51 km N of Esperance (19922); 19 km SW of Balladonia (17423).

Northern Territory: Yirrkala (13510); near Oenpelli (32247-8, 37165-70); Port Essington (31178); near Darwin (23500, 32239-41); ca 30 km NW of Mt Roper (32058); Red Lily Lagoon, Daly River (34605-11); 26 km NE of Pine Creek (23206); Edith River, 51 km NW of Katherine (23175); Katherine (13948-9, 13957, 19894-5, 23173); 35 km N of Daly Waters (24148); Elliott (24189); near Tennant Creek (21471-3, 21475); 35 km NNE of Wauchope (24274); Owen Springs (20850); 32 km W of Hermannsburg (37085); Mt Olga (34159-60).

South Australia: 11 km NE of Musgrave Park (20947); Pidinga (25425-7).

Cryptoblepharus carnabyi nov. sp.

Holotype

R21182 in Western Australian Museum, collected by D.L. Serventy and G.M. Storr on evening of 29 July 1963 under bark of dead standing mulga (*Acacia aneura*) at 11 km WSW of Youanmi, Western Australia, in 28° 37' S, 118° 43' E.

Diagnosis

A small *Cryptoblepharus* much the same as *C. plagiocephalus* in coloration but with each subdigital lamella bearing a fine weak keel terminating in a mucron, palmar and plantar scales white and sharp-pointed, and supraciliaries normally 5.

Distribution

Sporadically in Western Australia from southern Kimberley south to the Houtman Abrolhos, northern Wheat Belt and Eastern Goldfields. Extralimital in Northern Territory (Sir Edward Pellew Group in Gulf of Carpentaria).

Description

Snout-vent length (mm): 18-40 (N 91, mean 32.7). Tail up to 186% of SVL.

Supraciliaries normally 5, second much the widest. Ciliaries usually 3 (87%), occasionally 4. Upper labials usually 7 (87%), occasionally 8, rarely 6. Nuchals 0-3, mostly 1 (N 82, mean 1.1). Midbody scale rows 22-28 (N 82, mean 25.1). Lamellae under fourth toe 14-22 (N 85, mean 18.6).

Coloration varying as in *plagiocephalus*, i.e. more coppery in north, more spotted in south; where they are sympatric *carnabyi* is usually the more strongly spotted and striate.

Remarks

This species is dedicated to the memory of naturalist Ivan C. Carnaby (1908-1974), who donated many specimens of reptiles and birds to the Western Australian Museum.

It seems that *C. carnabyi* is being replaced by its slightly larger sibling, *C. plagiocephalus*. *C. carnabyi* survives mainly on islands and peninsulas.

Paratypes

Kimberley Division (W.A.): Derby (20267-70, 20272-3, 20338-41, 22331, 23004, 45033-4); 8 km S of Derby (23006-8); Beagle Bay Mission (46481); Coulomb Point (40258-9, 40261-3); 24 km SSW of Christmas Creek HS (46117).

North-west Division (W.A.): 24 km E of Mundabullangana (17070); Depuch Island (14563); Barrow Island (27946-7, 28458-9, 47666-9); 27 km NE of Marrillana (18277-9); Bernier Island (13182*a-b*, 20512-5); Dorre Island (13194*a-b*); Dirk Hartog Island (12471-3, 42368-70, 44545); Wilds Island, Freycinet Estuary (25778); Three Bays Island, Freycinet Estuary (25749); south end of Bellefin Prong (39031); Hamelin Pool (18263-7); Mullewa-Gascoyne Junction road, near Tallering Peak (47711).

Eastern Division (W.A.): Coondra Coondra Spring, 40 km NE of Jiggalong (42291); 11 km WSW of Youanmi (21183-4); Cowarna Downs (14239).

South-west Division (W.A.): Lockwood Spring, Kalbarri National Park (37563, 37568); East Wallabi Island (18283, 22781, 25833-4); West Wallabi Island (18280-1); Rat Island (30440-3, 37534-6); Gun Island (27193-4, 30437); Shark Island (37507); 35 km NE of Mingenew (31386); Koorda (22836).

Northern Territory: islet east of Centre Island, Sir Edward Pellew Group (40311).

Cryptoblepharus megastictus sp. nov.

Holotype

R43245 in Western Australian Museum, collected on 24 January 1973 by L.A. Smith and R.E. Johnstone on the Mitchell Plateau, Western Australia, in 14°52'S, 125°50'E.

Diagnosis

A *Cryptoblepharus* with low head and long snout, large dark dorsal spots, and no pale dorsolateral stripe. Further distinguishable from sympatric

plagiocephalus by dark lips, smooth (rather than callose) subdigital lamellae, and bluish abdomen in alcohol.

Distribution

North-west Kimberley, including the Osborne Islands.



Fig. 2: Map of Western Australia showing location of specimens of *Cryptoblepharus carnabyi* and *C. megastictus*.

Description

Snout-vent length (mm): 26-38 (N 9, mean 34.6).

Supraciliaries usually 6, occasionally 5. Ciliaries 3. Upper labials usually 7, occasionally 8. Nuchal 1. Midbody scale rows 24-28 (N 6, mean 26.2). Lamellae under fourth toe 17-20 (N 8, mean 18.4).

Dorsally coppery brown in life (*vide* L.A. Smith), becoming olive green, olive brown, olive grey or bluish grey in alcohol, spotted and striated with black or dark brown. Lateral scales dark-edged, pale-centred. Limbs coppery brown in life, variegated with black.

Remarks

These skinks are confined to black basalt rocks on the coast or on near-coastal plateaux and, unlike sympatric *plagiocephalus*, were never found in trees (L.A. Smith, pers. comm.). On the coast of Middle Osborne Island they actually live in the splash zone. *C. megastictus* is thus ecologically similar to *C. litoralis* (Mertens) of north-east Queensland.

This is yet another lizard endemic to the sub-humid zone of north-west Kimberley.

Paratypes

Kimberley Division (W.A.): Mitchell Plateau (43246); Middle Osborne Island (41493-8); South-west Osborne Island (44114).

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A REVIEW OF TWO WESTERN AUSTRALIAN SHRIMPS
OF THE GENUS *PALAEEMONETES*, *P. AUSTRALIS* DAKIN 1915
AND *P. ATRINUBES* SP. NOV. (DECAPODA, PALAEMONIDAE)

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ABSTRACT

Palaemonetes atrinubes sp. nov. from marine and estuarine habitats of north and west Australia is described. *Palaemonetes australis* Dakin from fresh-water and estuarine habitats of south and west Australia is redescribed and data on the variation in the mandibular palp is included. The use of the mandibular palp as a single character to form generic groupings within the Palaemoninae of the world is only partially successful. The affinities of *P. australis* and *P. atrinubes* with other Australian Palaemoninae are discussed and a key to the Australian species of *Palaemon* and *Palaemonetes* is given.

INTRODUCTION

In his major revisions of the Indo-Pacific and American Palaemonidae, Holthuis (1950, 1952) regarded the mandibular palp as a character of generic importance. After grouping species with branchiostegal spines and without supraorbital spines he classified species with mandibular palps into the genera *Creasaria*, *Leander* and *Palaemon* while species without mandibular palps were classified into the genera *Leandrites* and *Palaemonetes*. Despite these groupings he considered *Palaemonetes* to closely resemble *Palaemon* stating that the 'only difference of importance is that in *Palaemon* the mandible possesses a palp, while this palp is absent in *Palaemonetes*'.

In the same revisions Holthuis used the number of segments in the mandibular palp as a character of subgeneric importance. Within the genus *Palaemon* he grouped species with branchio-stegal groove present, pleura of fifth abdominal segment pointed and rostrum without elevated basal crest. In this group species with mandibular palps of two segments were classified as subgenus *Paleander* while species with mandibular palps of three segments were classified as subgenus *Palaemon*.

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More recently Fujino and Miyake (1968) found intraspecific variation in the number of segments of the mandibular palp in five of the species included by Holthuis in the genus *Palaemon*. In each species a palp with three segments was the most common form and the number of segments varied between the following values: *Palaemon paucidens*, 1-3; *Palaemon serrifer*, 2-3; *Palaemon macro-dactylus*, 2-4; *Palaemon pacificus*, 2-3; and *Palaemon debilis*, 2-3.

In a further study of *Palaemon debilis* Chace (1972) found that the mandibular palp was absent in each of 'nearly 100 specimens examined from several Hawaiian localities', in 12 of 25 specimens from Raroia Atoll and in 'a very small percentage' of specimens from the Palau Islands. He concluded that 'the form of the mandibular palp, or even its absence, is of minor importance in *P. debilis*' and drew attention to the doubtful status of the genus *Palaemonetes*.

In *Palaemonetes australis* from Western Australia, both Dakin (1915) and Serventy (1938) considered the mandibular palp to be absent. In 1969 Monzu (unpublished honours thesis, University of Western Australia) examined about 50 specimens of *P. australis* from the lower Swan River and found that about 20% of these did possess a mandibular palp with either one or two segments. In the present study of *P. australis* from many locations in south west Australia some specimens from each location did possess mandibular palps. These results cast further doubt on the validity of the current definition for the genus *Palaemonetes*, based simply on the absence of the mandibular palp.

During this study a new species of *Palaemonetes*, *P. atrinubes*, was found from the lower Swan River. This species lacks a mandibular palp and is the second species of the genus *Palaemonetes* to be recorded in Australia.

SUBFAMILY PALAEMONINAE

Shrimp with pleura of second abdominal somite overlapping those of first and third segments; first pereopod chelate and usually more slender than second pereopod; carpus of second pereopod not subdivided; third pereopod without chela; third maxilliped with pleurobranch at base; walking legs without exopods, epipods or arthrobranchs; rami of bifid antennular flagellum fused in basal portion; second pleopod of male with appendix masculina; posterior margin of telson with two pairs of spines and two or more setae.

GENUS PALAEMONETES HELLER

Shrimp with branchiostegal spine and branchiostegal groove but without supraorbital spine, appendix interna on first pleopod of male, or mandibular palp (except *P. australis* which often has a palp with one or two segments).

PALAEMONETES AUSTRALIS

Palaemonetes australis Dakin, 1915; Serventy (1938).

Diagnosis

A species of *Palaemonetes* usually without mandibular palp but sometimes with mandibular palp of either one or two segments; rostrum armed with

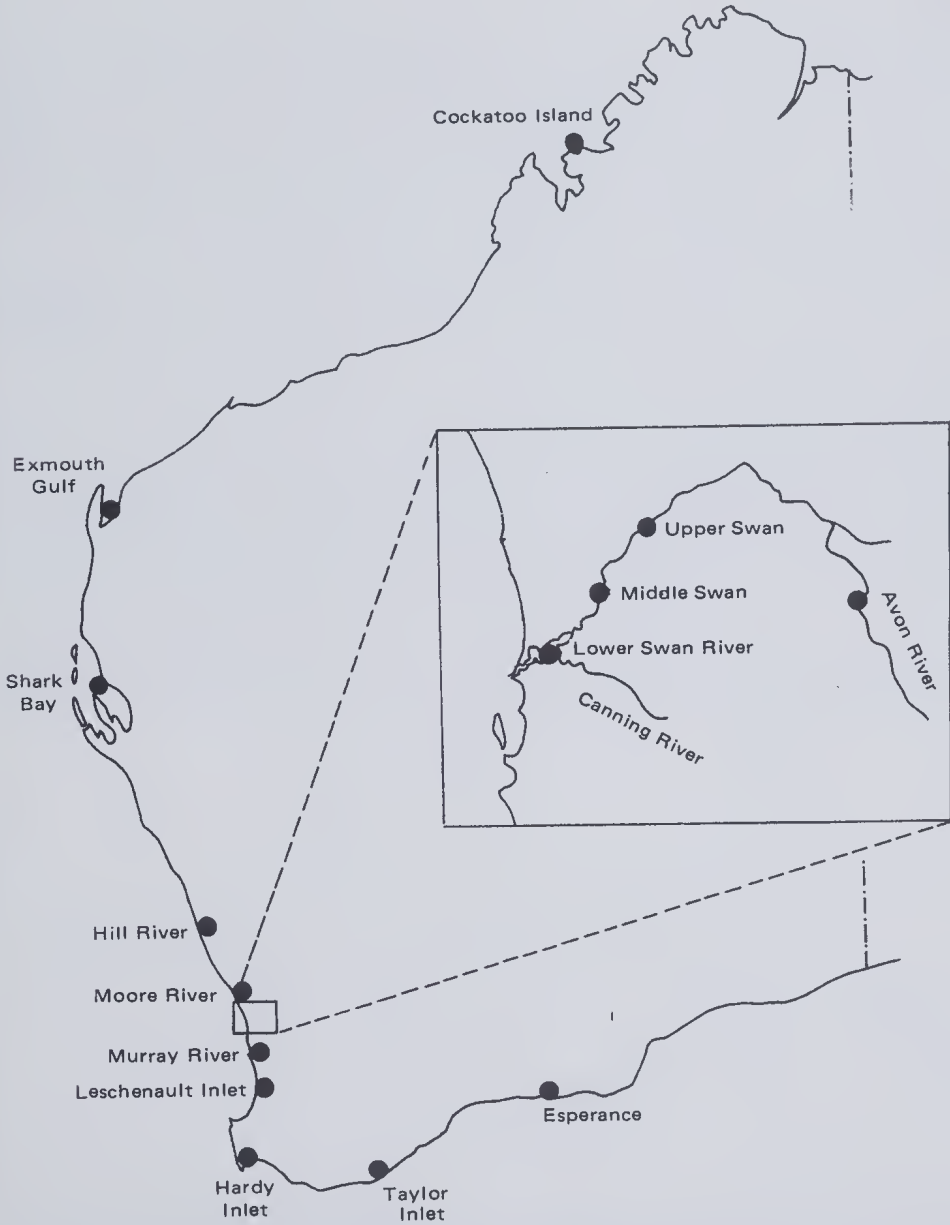


Fig. 1: Locations for samples in Western Australia.

regularly spaced dorsal teeth, bifid or trifid tip and rostral formula 4-7/2-4; branchiostegal spine distant from anterior margin of carapace; second pereopod reaching beyond scaphocerite by about half of chela; chela of second pereopod shorter than carpus; thickened ramus of bifid antennular flagellum up to twice as long as fused basal portion and eggs measuring about 1.1 x 1.6 mm.

Material examined

Neotype — Adult female, 36 mm total length, Upper Swan Bridge, 12.9.73, WAM 108-75.

Paratypes — 147 males (13-39 mm total length), 146 females (13-45 mm total length), 12 juveniles (6-12 mm total length) from Hill River; Swan River; York, Avon River; Murray River; Hardy Inlet; Taylor Inlet and Esperance (Fig. 1). WAM 36-74, 96-75, 102-75, 101-75, 92-75, 93-75, 107-75, 100-75, 109-75, 103-75, 110-75, 97-75.

Drawings are based on the neotype except for drawings of mouthparts and pleopods which were based on material dissected from paratypes as indicated in the descriptions.

Description of neotype

The depository of the type specimens was not given in Dakin's (1915) description and his specimens could not be located at either the Western Australian Museum or the Australian Museum (per. comm. D.J. Griffin 1974). An ovigerous female of 36 mm total length collected at the Upper Swan Bridge (12.9.73) is designated as neotype and is described as follows:

Rostrum (Fig. 2) curving up at tip; tip bifid, reaching to end of scaphocerite; dorsal margin with six regularly spaced teeth, sixth tooth located posterior to orbit; ventral margin with three teeth.

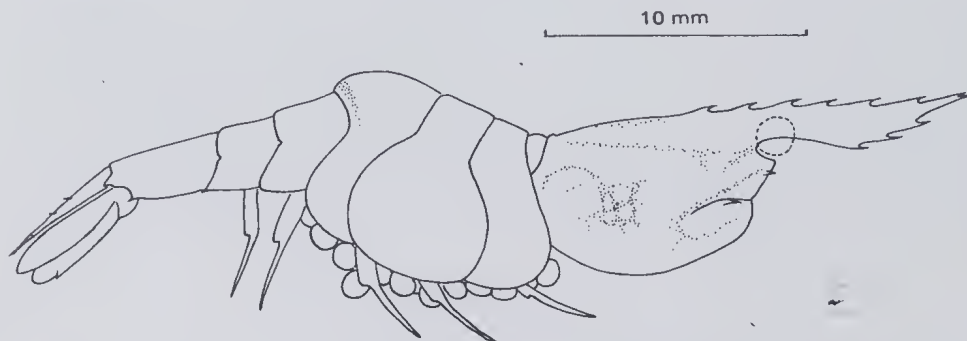


Fig. 2. General body shape of *Palaemonetes australis*. Stippled areas represent colour pattern on carapace and 3rd abdominal segment.

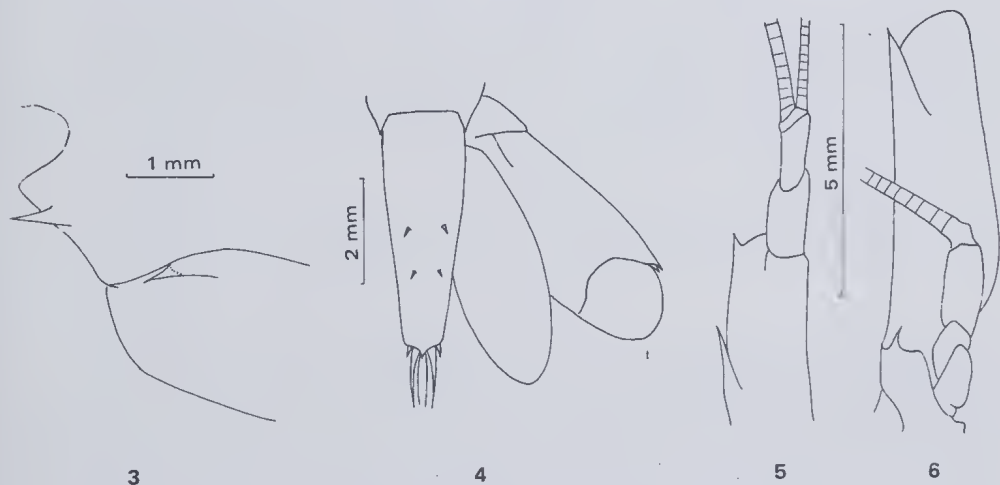
Carapace smooth; branchiostegal spine (Fig. 3) as large as antennal spine and distant by about its own length from anterior margin of carapace; base of branchiostegal spine visible as a line with dorsal side forming part of branchiostegal groove and ventral side commencing anteriorly at branchiostegal groove but not joining that groove posteriorly; branchiostegal groove rising dorsally from margin of carapace to dorsal side of branchiostegal spine then curving ventrally beyond that spine.

Pleura of three anterior abdominal somites rounded (Fig. 2), fourth pleuron bluntly acute, fifth pointed and acute. Third abdominal somite (Fig. 2) markedly recurved posteriorly, viewed laterally. Sixth abdominal somite one and three quarters length of fifth somite and about as long as telson.

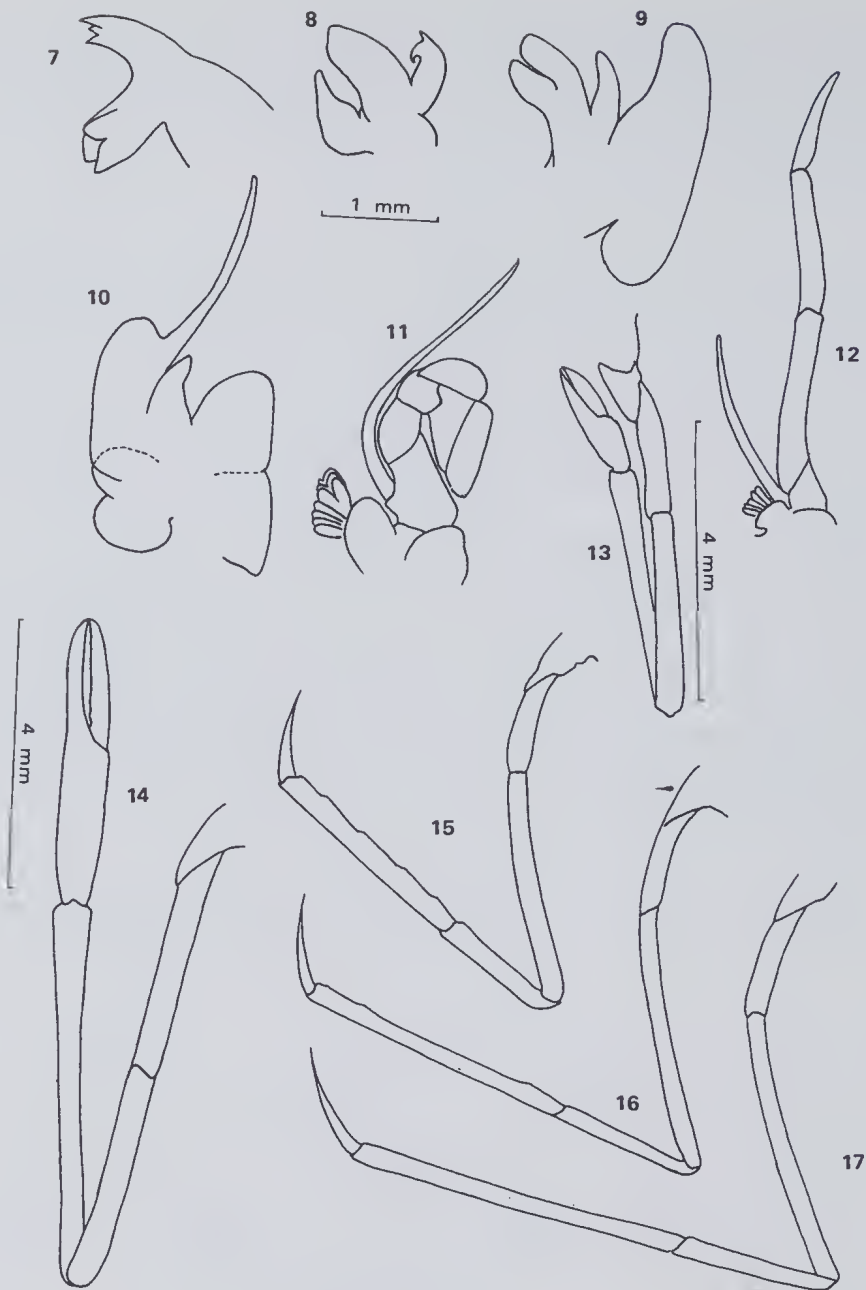
Telson (Fig. 4) with two pairs of dorsal spines arranged in a rectangle in posterior half. Posterior margin of telson pointed, with a pair of plumose setae and two pairs of stout spines, outer pair about one third length of inner pair.

Eyes stout, cornea pigmented, broader and shorter than stalk.

Antennular peduncle (Fig. 5) with stylocerite reaching midlength of basal segment; lateral margin of basal segment straight, with anterolateral spine not projecting beyond convex anterior margin; second segment about as long as distal segment, combined lengths of second and distal segments three quarters length of basal segment. External antennular flagellum bifurcate; fused portion of 10 segments, three fifths length of free portion of thickened ramus of three segments.



Figs 3-6, *Palaemonetes australis*: 3, anterior margin of carapace with antennal, branchiostegal spines and branchiostegal groove (x11); 4, telson and right uropod (x7); 5, left antennular peduncle (x7); 6, right scaphocerite (x7).



Figs 7-17, *P. australis*: 7, right mandible; 8, left first maxilla; 9, left second maxilla; 10, right first maxilliped; 11, right second maxilliped; 12, right third maxilliped; 13, left first pereopod; 14, left second pereopod; 15, left third pereopod; 16, left fourth pereopod; 17, left fifth pereopod; Magnifications: 7-12 (x15), 13-17 (x9). Figs 7-12: based on female paratype W.A.M. 93-75.

Scaphocerite (Fig. 6) four times as long as wide; lateral margin straight with distal tooth prominent but not reaching tip of scaphocerite.

Mandible (Fig. 7 figured female WAM 93-75) with incisor process toothed and molar section rectangular; mandibular palp absent. First maxilla (Fig. 8) with three stout lobes, endopodite with bifid tip. Second maxilla (Fig. 9) with three lobes, inner lobe bifid, endopodite tapers to a point, scaphognathite three times as long as wide. First maxilliped (Fig. 10) with five lobes, inner lobes broad with straight inner margins, endopodite tapered, exopodite long tapered extension of lateral lobe, epipodite bilobed with rounded margins. Second maxilliped (Fig. 11) hook shaped with long tapered exopodite and rounded epipodite bearing a bilobed podobranch. Third maxilliped (Fig. 12) reaching tip of antennal peduncle; exopod as long as ischiomerus; distal segment three quarters length of carpus; carpus four fifths length of ischiomerus.

First pereopod (Fig. 13) reaching anterolateral spine of scaphocerite; fingers as long as palm; chela half length of carpus; merus three quarters length of carpus.

Second pereopod (Fig. 14) reaching beyond scaphocerite by half of chela; fingers three quarters length of palm; chela four fifths length of carpus; merus three quarters length of carpus.

Third pereopod (Fig. 15) reaching short of tip of scaphocerite; dactylus two fifths length of propodus; carpus three fifths length of propodus and half length of merus.

Fourth pereopod (Fig. 16) reaching short of tip of scaphocerite; dactylus one third length of propodus; carpus half length of propodus and half length of merus.

Fifth pereopod (Fig. 17) reaching short of tip of scaphocerite; dactylus one third length of propodus; carpus four ninths length of propodus and half length of merus; propodus with five transverse rows of setae in posterodistal region.

First pleopod (Fig. 18) with endopod less than one third length of exopod.

Eggs in late stage of development attached to pleopods, measuring 1.6 x 1.1 mm.

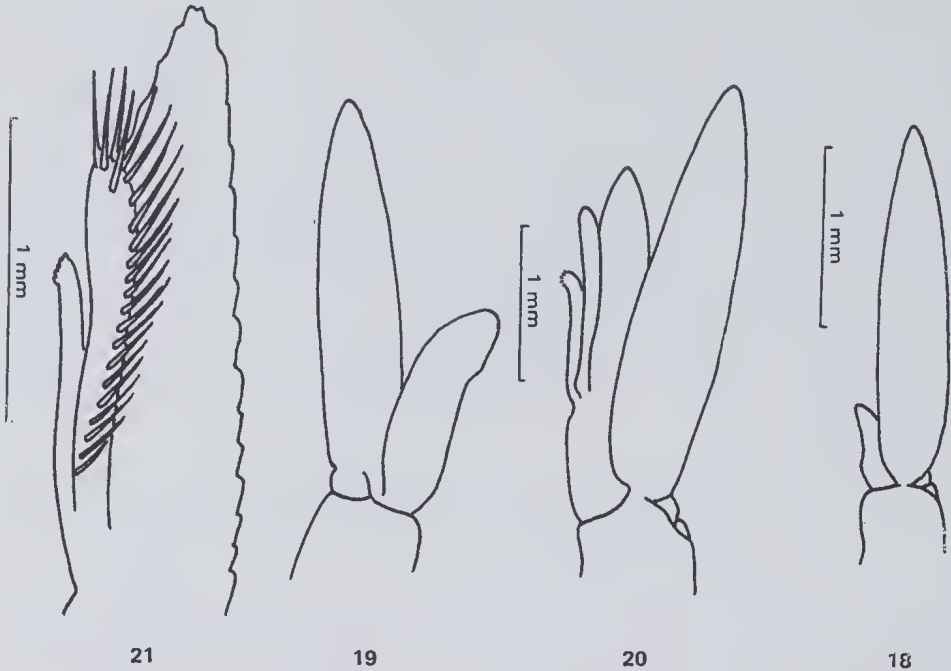
Figured male (WAM 92-75).

Endopod of first pleopod (Fig. 19) without appendix and reaching to midlength of exopod. Appendix masculina on endopod of second pleopod (Figs. 20, 21) reaching midway between appendix interna and tip of endopod; armed with outer apical row of three spines and inner row of 18 spines.

Variation in paratypical series

In the series of 290 specimens examined, variation was found in the rostrum, external antennular flagellum, first and second pereopods, appendix

masculina and mandible. In each character some of the variation was associated with growth.



Figs 18-21, *Palaemonetes australis*; 18, right first pleopod, female, W.A.M. 93-75 (x23); 19, right first pleopod, male (x20); 20, right second pleopod, male; 21, right appendix masculina (x40). Figs 19-21: mala paratype W.A.M. 92-75.

Rostrum — Dorsal margin armed with five to seven (occasionally four, rarely eight) teeth, one to two teeth posterior to orbit. Tip of rostrum usually bifid but may be trifid or single pointed (commonly single pointed for about three of the initial post-larval stages). Ventral margin with two to four teeth.

External antennular flagellum — Bifurcate, fused basal portion of five to ten segments, free portion of thickened ramus with one or more segments in juveniles and up to 15 segments in adults when it may be twice length of fused portion.

First pereiopod — Chela about nine tenths length of carpus in small juveniles and half length of carpus in adults.

Second pereiopod — Fingers as long as palm in juveniles but three quarters length of palm in adults. Chela as long as carpus in juveniles but about four fifths length of carpus in adults.

Appendix masculina — Not apparent in specimens less than 12 mm total length. Males between 12-14 mm total length bear a short appendix without spines. In mature males (greater than 24 mm total length) the appendix is

armed with an outer apical row of three to five spines and an inner row of 5-22 spines.

Mandible — Mandibular palps are present in some specimens from all samples studied. The structure of the mandibular palp is variable and palps were classified into four types: palp absent (A), small lump without setae (B), palp with single segment and with setae (C), and palp with two segments and with setae (D) (Fig. 22).

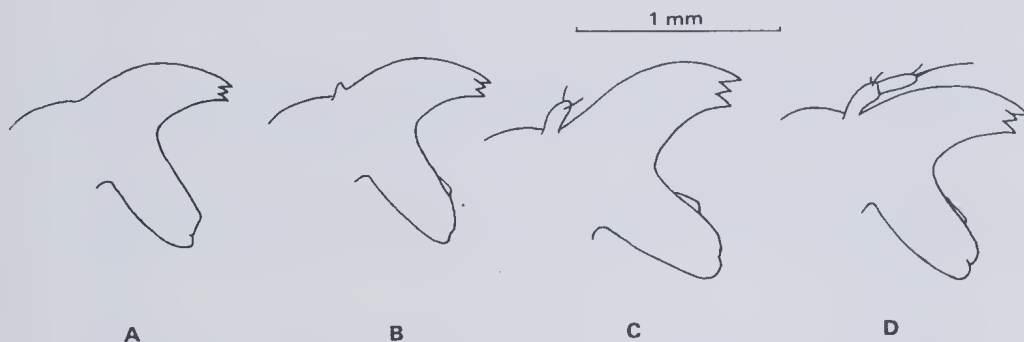


Fig. 22: Mandibles in *Palaemonetes australis*; A, without palp, B, with palp as small lump; C, palp with one segment and setae; D, palp with two segments and setae.

Table 1 gives the frequency of each variant in samples from south west locations. Although the frequencies at four locations within the Swan River were homogeneous ($X^2_{(3)} = 1.67, 0.9 > P > 0.5$) the frequencies varied between populations from different river systems ($X^2_{(3)} = 17.9, P < 0.001$). However, a pattern of variation indicating a latitudinal cline in frequency was not apparent.

Left and right mandibles sometimes differed in the structure of the mandibular palp (Table 2). The variation appeared to be random although Swan River specimens were more variable than those from other river systems. The presence of the palp was not related to sex and animals with and without palps were collected together at all locations. Mandibular palps were not present in shrimp less than 12 mm total length.

Observations were carried out in the laboratory to assess the natural variance in the form of the mandibular palp in controlled broods from single females of known mandibular palp type. The offspring from eight egg-bearing females without mandibular palps (type A) were reared to total lengths of 15-17 mm and their mandibles examined. Of the 21 surviving offspring, 9 possessed mandibular palps and 12 had no palp. A single female with mandibular palps (type C) gave rise to 3 offspring, 1 with palp and 2 without palps.

Table 1: Mandibular palps in *P. australis* from four south west Australian river systems. Palps were classed as: A without palp, B small lump without setae, C palp with one segment and setae, and D palp with two segments and setae, as shown in Fig. 22. The number of mandibles examined, 'n', is also listed.

CLASS OF PALP

LOCATION	A	B	C	D	n
Moore River	104	10	5	1	120
Lower Swan River	35	16	0	9	60
Middle Swan River	85	13	4	19	120
Upper Swan River	39	9	3	9	60
Avon (Swan) River, York	38	7	13	2	60
Combined Swan River	196	45	20	39	300
Murray River	44	7	1	8	60
Hardy Inlet	51	4	2	3	60
Taylor Inlet	5	0	0	1	6
Esperance	9	0	0	1	10

Table 2: Frequencies for the presence of similar palps, and combinations of different palps, on left and right mandibles. Palp classification as for text in Table 1.

LOCATION	FREQUENCIES OF PALP TYPES			
	AA or BB or CC or DD	AB or BC or CD	AC or BD	AD
Moore River	55	4	1	0
Lower Swan River	21	6	2	1
Middle Swan River	46	7	2	5
Upper Swan River	20	5	3	2
Avon (Swan) River, York	20	5	3	2
Combined Swan River	107	23	10	10
Murray River	22	5	1	2
Hardy Inlet	28	1	1	0

Colour pattern

Live specimens translucent. The overall colour is typically olive-green or brown and is produced by combinations of chromatophores with red, white,

yellow and blue pigments. The intensity of colour varies with the habitat and animals on pale substrates are almost transparent.

Carapace (Fig. 2) with diffuse dorsal and anterior bands of chromatophores and indistinct mottled pattern posteriorly. Thickened ramus of bifid antennular flagellum light red.

Mature ovaries green or brown in live specimens and usually orange when preserved. Live eggs green or brown in early stages of development and transparent with black eyes when mature. Preserved eggs usually orange.

Size

First stage juveniles 5-6 mm total length. Males mature at about 22 mm length and reach maximum lengths of about 30 mm; Females mature at about 24 mm and reach maximum lengths of about 34 mm.

Eggs large, measuring about 1.0 x 1.4 mm in early stages of development and about 1.4 x 1.9 mm when mature. Number of eggs rarely exceeding 70 per brood.

Reproduction

Females bearing eggs were collected between September and April and the peak of breeding is in November. Incubation period is about one month and an individual female appears to lay about 3-4 batches of eggs throughout the season.

Distribution

Rivers, lakes and estuaries of south west Australia from Esperance to Hill River. In regard to salinity tolerance, adult specimens were collected in Canning River (less than 1^o/oo) and in Leschenault Inlet (15-44^o/oo; no specimens have been found in habitats where the salinity is permanently higher than 25^o/oo).

Feeding and Habitat

The gut usually contains a brown gelatinous bolus which when teased apart is shown to contain sand grains and small pieces of shell; in addition complete or damaged copepods, amphipods, chironomid larvae, diatoms or foraminifera may occur.

In aquaria the activity pattern varies with time of day. Most shrimp remain inactive in shaded positions by day and become active at night, occasionally swimming clear of the substrate. In the field *P. australis* usually inhabits shallow water areas, shaded by reeds and other vegetation. Shrimp are rarely taken in areas of strong current flow or in still water which may become deoxygenated.

*PALAEMONETES ATRINUBES** sp. nov.

Remarks

*This name refers to the internal black spot visible at the posterior end of the sixth abdominal segment in live specimens.

Diagnosis

A species of *Palaemonetes* with rostral formula 4-7/2-4, bifid tip and dorsal margin without teeth for about one third of its length in distal region; branchiostegal spine located on anterior margin of carapace; fused basal portion of bifid antennular flagellum about twice as long as free portion of thickened ramus; first pereopod reaching short of tip of scaphocerite; chela of first pereopod about half length of carpus; second pereopod reaching by half of chela beyond tip of scaphocerite; second chela about three quarters length of carpus, and eggs measuring 0.5 x 0.9 mm.

Material examined

Holotype — Adult female, 34 mm total length, Canning Bridge, lower Swan River, 23.11.73, WAM 106-75.

Paratypes — 57 males (12-35 mm total length), 60 females (12-40 mm total length), 6 juveniles (8-11 mm total length) from Swan River estuary, Bay of Rest, Exmouth Gulf; Wapet Creek, Exmouth Gulf; Gladstone, Shark Bay, and Cockatoo Island, WAM 94-75, 95-75, 105-75, 104-75, 98-75, 515-73, 456-73, 519-73.

Drawings are based on the holotype except for drawings of mouthparts and pleopods which were based on material dissected from paratypes as indicated in the descriptions.

Description of holotype

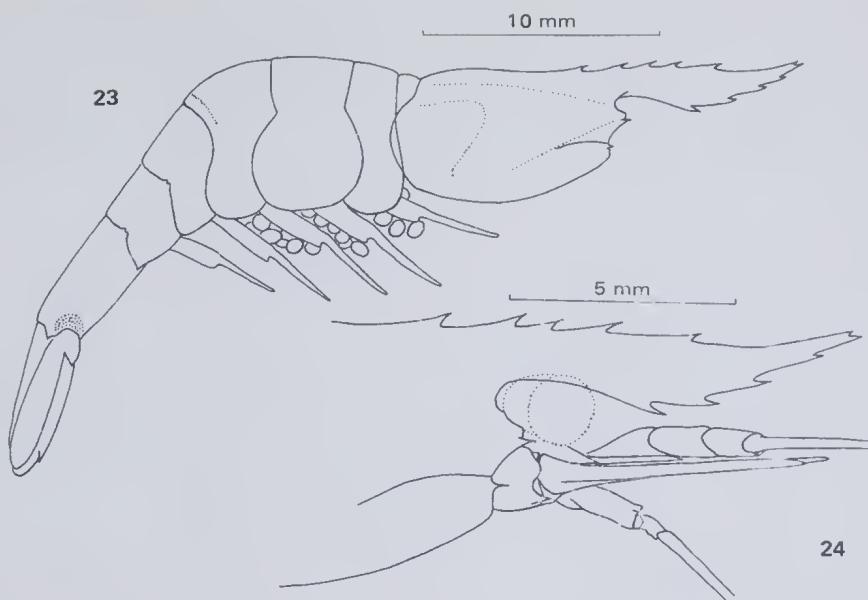
Rostrum (Figs. 23, 24) curving upward at tip, reaching slightly beyond scaphocerite; dorsal margin with five teeth, first tooth distant from bifid tip by about one third of rostral length, fifth tooth behind orbit and slightly distant from anterior teeth; ventral margin with four teeth.

Carapace smooth; branchiostegal spine (Fig. 24) located on anterior margin of carapace; branchiostegal groove commencing at anterior margin of carapace slightly above branchiostegal spine, curving ventrally beyond that spine.

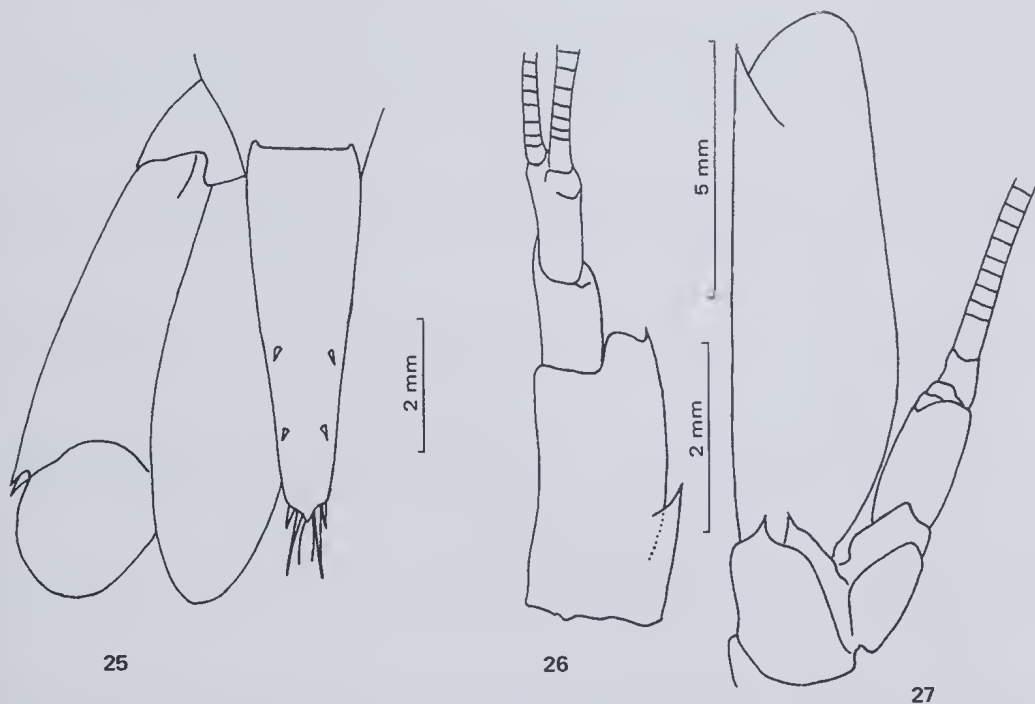
Pleura of three anterior abdominal segments rounded (Fig. 23), fourth pleura bluntly acute, fifth pointed and slightly acute. Sixth segment twice length of fifth and equal to telson. Third abdominal segment slightly recurved posteriorly if viewed laterally (Fig. 23).

Telson (Fig. 25) with two pairs of dorsal spines arranged in a rectangle, all in posterior half. Posterior margin of telson pointed, with a pair of plumose setae and two pairs of stout spines, outer pair about half length of inner pair.

Eyes stout; cornea pigmented, broader and shorter than stalk.



Figs 23, 24, *Palaemonetes atrinubes*: 23, overall body shape, colour pattern shown stippled (x3); 24, anterior region (x6).



Figs 25-27, *Palaemonetes atrinubes*: 25, telson (x8); 26, right antennular peduncle (x12); 27, right scaphocerite (x6).

Antennular peduncle (Fig. 26) with stylocerite reaching short of mid-length of basal segment; lateral margin of basal segment straight with anterolateral spine projecting slightly beyond convex anterior margin; combined length of second and distal segments two thirds length of basal segment. External antennular flagellum bifurcate, fused basal portion of 16 segments twice length of free portion of thickened ramus of 6 segments.

Scaphocerite length about four times width (Fig. 27); lateral margin straight with distal tooth prominent, reaching short of distal margin of blade.

Mandible (Fig. 28, female figured WAM 95-75) with incisor process toothed and molar process rectangular in section, mandibular palp absent. First maxilla (Fig. 29) with three lobes, endopodite with bifid tip. Second maxilla (Fig. 30) with three lobes, inner lobe bifid, endopodite tapers to a point, scaphognathite length three times width. First maxilliped (Fig. 31) with five lobes, inner lobes broad, endopodite tapered, exopodite long tapered extension of lateral lobe, epipodite bilobed with rounded margins. Second maxilliped (Fig. 32) hook-shaped with long tapered exopodite and rounded epipodite bearing a bilobed podobranch. Third maxilliped (Fig. 33) reaching tip of antennal peduncle; exopod equal to ischiomerus; distal segment three quarters length of carpus; carpus slightly shorter than ischiomerus.

First pereopod (Fig. 34) reaching tip of scaphocerite; fingers equal to palm; chela half length of carpus and three fifths length of merus.

Second pereopod (Fig. 35) with half of palm reaching beyond scaphocerite; fingers three fifths length of palm; chela four fifths length of carpus and equal to merus.

Third pereopod (Fig. 36) reaching short of scaphocerite tip; dactylus one third length of propodus; carpus half length of propodus and two fifths length of merus.

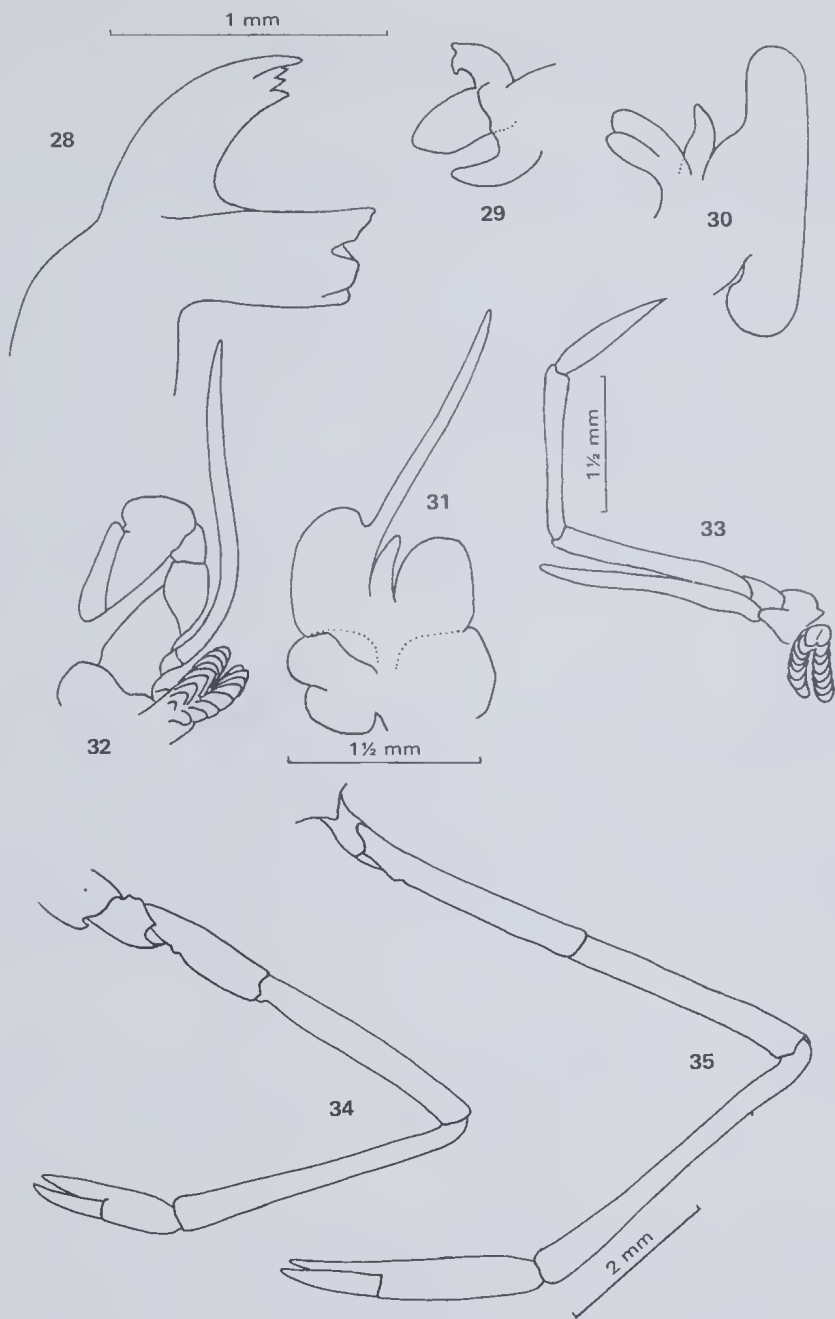
Fourth pereopod (Fig. 37) reaching almost to tip of scaphocerite; dactylus one quarter length of propodus; propodus twice length of carpus and equal to merus.

Fifth pereopod (Fig. 38) reaching tip of scaphocerite; dactylus one quarter length of propodus; propodus twice length of carpus and slightly longer than merus; postero-distal region of propodus with seven transverse rows of setae on left leg and five rows on right leg.

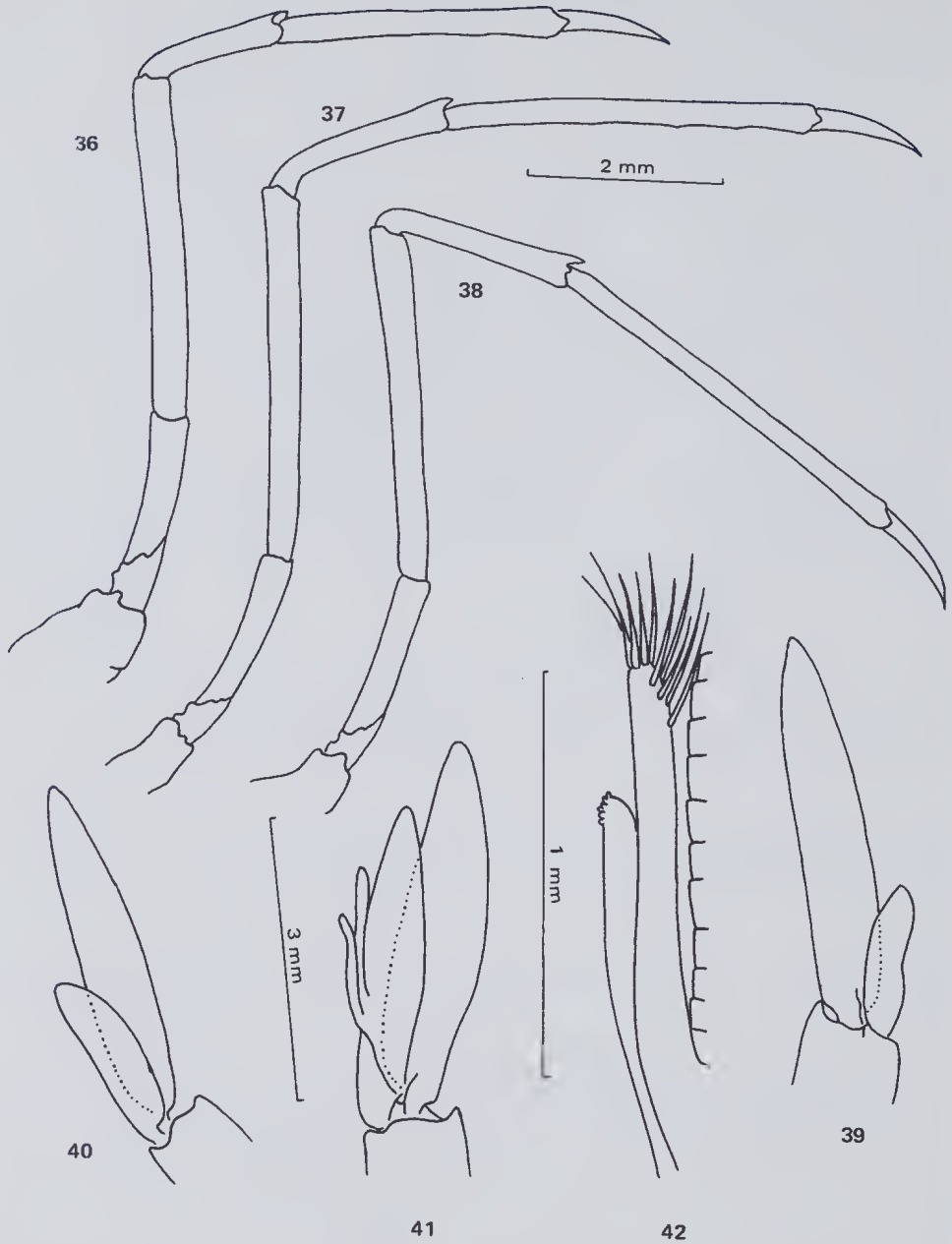
First pleopod (Fig. 39) with endopod about one third length of exopod; endopod with concave inner margin.

Figured Male (WAM 94-75).

Endopod of first pleopod (Fig. 40) without appendix and reaching mid-length of exopod. Appendix masculina on endopod of second pleopod (Fig. 41, 42) reaching midway between appendix interna and tip of endopod; armed with outer apical row of five spines and inner row of five spines.



Figs 28-35, *Palaemonetes atrinubes*: 28, left mandible; 29, right first maxilla; 30, left second maxilla; 31, right first maxilliped; 32, right second maxilliped; 33, left third maxilliped; 34, right first pereopod; 35, right second pereopod. Magnifications: 28, x35; 29-32, x16; 33-35, x10. Figs 28-33: female paratype WAM 95-75.



Figs 36-42, *Palaemonetes atrinubes*: 36, right third pereopod; 37, right fourth pereopod; 38, right fifth pereopod; 39, right first pleopod, female, W.A.M. 95-75; 40, left first pleopod, male; 41, left second pleopod, male; 42, right appendix masculina. Magnifications: 36-38 x12, 39-41 x12, 42 x52. Figures 40-42: male paratype W.A.M. 94-75.

Variation in paratypical series

In the series of 110 specimens examined, variation was found in the rostrum, external antennular flagellum, second pereopod and appendix masculina.

Rostrum — tip of rostrum usually bifid and rarely trifid. Dorsal margin armed with 4-7 teeth, usually 4-6 in juveniles and 5-6 in adults. Ventral margin usually with 3-4 teeth and occasionally 2 teeth. The location of teeth was constant and as described in the holotype.

External antennular flagellum — bifurcate, fused basal portion of 8-20 joints, free portion of thickened ramus with 1-3 joints in juveniles and up to 10 joints in adults when it is about half length of fused portion.

Second pereopod — reaching to tip of scaphocerite in juveniles and with most of chela beyond scaphocerite in adults. Fingers three fifths to four fifths length of palm. Chela two thirds to four fifths length of carpus.

Appendix masculina — appendix masculina in mature males overreaching appendix interna, armed with outer apical row of 3-5 spines and inner row of 4-16 spines.

Colour pattern

Live specimens transparent with distinct lines of red-blue chromatophores on the carapace (Fig. 23) and a single line on the posterior margin of the third abdominal segment; a black spot is clearly visible in the tissue at the posterior end of the sixth abdominal segment.

Mature ovaries green or brown in live specimens and often orange when preserved. Live eggs on abdomen green or brown in early stages of development; transparent with blue chromatophores and black eyes when mature. Preserved eggs usually orange.

Size

In the lower Swan River average total length was 31 mm for adult males and 36 mm for adult females. Eggs measured 0.5 by 0.9 mm and numbered between 90 and 200 per female.

Reproduction

In the lower Swan River females larger than 32 mm total length were found to bear eggs in summer between November and February. In the sample from Exmouth Gulf (WAM 515-73) females as small as 24 mm total length carried eggs. In the laboratory, groups of 6-10 females held at salinities of 15‰, 25‰, and 35‰ bred only at the higher salinities.

Distribution

Estuarine and marine habitats from Leschenault Inlet to Cockatoo Island.

Feeding and habitat

Gut contents consist largely of detritus and small crustaceans such as amphipods and ostracods.

Usually inhabits shallow water close to the shore over a substrate of mud or detritus. Unlike *P. australis*, which seeks shelter by day, *P. atrinubes* was often found swimming above the substrate during the day.

Discussion

Because variation in the morphology of the mandibular palp has been recorded for *Palaemon debilis* (Chace, 1972), for 4 other species of *Palaemon* (Fujino and Miyake, 1968) and for *Palaemonetes australis* (this work), the key proposed by Holthuis (1955) to separate the genera of Palaemoninae and the subgenera of *Palaemon* is not wholly satisfactory. For instance, those individuals of *P. australis* lacking a mandibular palp would be placed in the genus *Palaemonetes*, those with a palp of 2 segments would be placed in the genus *Palaemon* subgenus *Palaemon* and no classification exists for those specimens of *P. australis* with a palp of only 1 segment. Nevertheless, the key appears to be satisfactory for the majority of Palaemoninae, especially those in America and Europe, and both Chace (1972) and Holthuis (pers. comm. 1973) have suggested that it be retained pending a comprehensive review.

A satisfactory key for the Palaemoninae of a region can be constructed and the following key sets out the main characteristics distinguishing adults of those species in Australia: *Palaemonetes australis*, *Palaemonetes atrinubes*, *Palaemon serenus* and *Palaemon litoreus*. The key also provides distinguishing features for the genus *Macrobrachium**.

1. Branchiostegal spine present 2
Branchiostegal spine absent, hepatic spine present . . . genus *Macrobrachium* (freshwater and estuarine habitats in north and central Australia, except *M. intermedium* which occupies marine and estuarine habitats of southern half Australia).
2. Mandible with palp of three joints *Palaemon* 3
Mandible without palp or with palp of less than three joints . . . *Palaemonetes* 4
3. Second pereopod with carpus longer than palm of chela, fused basal portion of bifid antennular flagellum about half length of free part of thickened ramus . . . *Palaemon serenus* (marine)

*Riek (1951) has presented a key for the Australian freshwater species of *Macrobrachium* and Mr T. M. Walker (University of Tasmania) is currently revising this group.

and estuarine habitats of southern half of Australia).

Second pereopod with carpus shorter than palm of chela, fused basal portion of bifid antennular flagellum about one third length of free portion of thickened ramus . . . *Palaemon litoreus* (marine habitats of southern half of Australia)

4. Rostrum with dorsal margin unarmed for about one third its length in distal region, branchiostegal spine located on anterior margin of carapace . . . *Palaemonetes atrinubes* (marine and estuarine habitats of north-west Australia).

Rostrum with dorsal margin armed with regularly spaced teeth along its length, branchiostegal spine distant by about its own length from anterior margin of carapace . . . *Palaemonetes australis* (freshwater and estuarine habitats of south-west Australia).

The affinities of *Palaemonetes australis* with *Palaemonetes atrinubes* and with other Australian Palaemoninae are not clear. Groupings of these species based on characters such as general body shape, rostrum, carapace spines, external antennular flagellum, relative lengths of leg segments and egg size would link *Palaemon serenus* and *Palaemon litoreus* together, *Palaemonetes australis* and *Macrobrachium intermedium* form a second group while *Palaemonetes atrinubes* remains without close affinities to any other Australian species.

There is, however, a character that links *P. atrinubes* with *P. australis* and clearly distinguishes them from the other Australian species; this character is the absence of a transverse row of small setae on the anterior midline of the telson. The setae are small and not obvious unless closely examined. They were not mentioned by Yaldwyn (1954) in his description of *Palaemon affinis* but are shown in his drawing of the telson and they do occur in the specimens examined of *P. serenus* and *M. intermedium*.

ACKNOWLEDGEMENTS

I am grateful to Prof. W.D. Williams who provided collections of *P. australis* and to Prof. L.B. Holthuis who examined specimens of *P. atrinubes* and commented on the systematic status of *P. australis* and *P. atrinubes*.

I would like to thank Dr R.W. George for his helpful criticism of the manuscript.

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THE OCCURRENCE OF THE GENUS *HETERONARDOA*
(ASTEROIDEA: OPHIDIASTERIDAE) IN THE INDIAN OCEAN,
WITH THE DESCRIPTION OF A NEW SPECIES

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ABSTRACT

The distribution of the genus *Heteronardoa* Hayashi (1973a) is described. *Nardoa carinata* and *N. squamulosa* Koehler (1910) and *Narcissia mohamedi* Macan (1938) are considered conspecific and are referred to *Heteronardoa*. *H. carinata* has priority. *H. sagamina* Hayashi (1973a) is considered conspecific with *H. carinata*. A new species of *Heteronardoa* is described.

INTRODUCTION

The genus *Heteronardoa* was described by Hayashi (1973a), with the genotype *H. sagamina* Hayashi, from Sagami Bay, Japan. He considered the genus to be intermediate between *Certonardoa* H.L. Clark, 1921 and *Narcissia* Gray, 1841 in having groups of papulae restricted to the abactinal surface, the partial regularity of the abactinal plates and the presence of pedicellariae. Recently, 16 specimens from the Smithsonian Institution (U.S.N.M.) collections, including 14 specimens collected from the western parts of the Indian Ocean during the International Indian Ocean Expedition (I.I.O.E.) and 2 specimens from the Philippine Islands which had been identified by Fisher (1919) as *Nardoa squamulosa* Koehler, and 18 specimens from the Western Australian Museum collections, including 6 collected from off north-western Australia and 12 from off the Aru Islands in Indonesia, were examined. 14 of the U.S.N.M. specimens (including the 2 identified by Fisher) and 17 of the Western Australian Museum (W.A.M.) specimens are identified as *Nardoa carinata* Koehler, which is here transferred to the genus *Heteronardoa*. The other 3 specimens are described and considered to represent a new, nominal species of *Heteronardoa*. Also in this paper, *Nardoa squamulosa* Koehler, *Narcissia mohamedi* Macan and *H. sagamina* Hayashi

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are considered synonyms of *H. carinata* (Koehler). The extended distribution of *Heteronardoa* is described.

The author wishes to thank Drs F. Hotchkiss and D.L. Pawson, Smithsonian Institution, U.S.A. for the opportunity of examining the 2 Philippine specimens identified by Fisher (1919) and the I.I.O.E. material, and for 5 specimens of the latter donated to the Australian Museum; Miss M.E. Downey, Smithsonian Institution, U.S.A. for examining Fisher's (1919) specimen of *Nardoa semiregularis*; Mrs Loisetete Marsh, Western Australian Museum, for sending me the specimens from north-western Australia and the Aru Islands, of which one is now in the Australian Museum collections; Miss A.M. Clark, British Museum (Natural History), U.K., for allowing me to examine the type-specimens of *Narcissia mohamedi* and a specimen from Sri Lanka identified by Miss Clark (1967) as *Certonardoa carinata*.

I thank Mrs Loisetete Marsh for reading the manuscript and for her helpful comments. Mr G. Millen and Miss Heather McLennan, Photographic Department, The Australian Museum are thanked for photographing the specimens illustrated in this paper.

Heteronardoa carinata (Koehler)

(Figs 1-9.)

Nardoa carinata Koehler, 1910, p. 165, pl. XV fig. 6, pl. XVI figs 10-11.

N. squamulosa Koehler, 1910, p. 168, pl. I fig. 8, pl. XV figs 7-8; Fisher, 1919, p. 383, pl. 105 fig. 5, pl. 111 figs 7-8;

Certonardoa carinata, H.L. Clark, 1921, p. 56; A.M. Clark, 1967, p. 186.

C. squamulosa, H.L. Clark, 1921, pp. 56-57.

Narcissia mohamedi Macan, 1938, p. 408, pl. I figs 2 & 10.

Heteronardoa sagamina Hayashi, 1973a, p. 6; 1973b, p. 65, fig. 8, pl. 9 figs 4-5.

Material examined

One specimen, Mariel King Memorial Expedition (hereafter indicated by M.K.M.E.), stn AW I/5, west of Wasir I., western Wokam, Aru, 15.vi.70, Lat. 5° 30'S, Long. 134° 12'E, 55-58m; 1 specimen, M.K.M.E., stn AW IV/7, off west end of Udjir I., Wokam, Aru, 16.vi.70, Lat. 5° 37'S, 134° 10'E, 78-86m; 8 specimens, M.K.M.E., stn AM II/3, 8 mls south-west of Tg Ratoe, Maikoor, Aru, 18.vi.70, Lat. 6° 7'S, Long. 133° 57'E, 55-64m; 1 specimen, as above, stn AM II/4-6, 45m; 1 specimen, as above, stn AM II/8-11, 60-64m; 3 specimens, H.M.A.S. 'Diamantina', cruise 4, stn 187, west of Point Quobba, Western Australia, 24.vii.64, Lat. 24° 20'S, Long. 112° 46'E, 117m, W.A.M. Nos 1759-74, 1760-74(2), A.M. No. J9192(1); 2 specimens, R.W. Geroge, 50 mls north-east off Adele Island, northwestern Australia, Lat. 15° 31', Long. 123° 09'E, 20.x.62, 91.4m, W.A.M. Nos 1758-74, 1763-74; 2 speci-

mens, Philippine Islands (Albatross Expedition), U.S.N.M. Nos 40835, 40549 (these two specimens identified by Fisher (1919) as *Nardoa squamulosa*); 2 specimens 'Anton Bruun', cruise 9, stn 444, 16.xii.64, Lat. 9°36'N, Long. 51°01'E, 78-82m, U.S.N.M. No. E13779 (1), A.M. No. J9190 (1); 2 specimens, 'Anton Bruun', cruise 9, stn 445, 16.xii.64, Lat. 9°41'N, Long. 51°03'E, 60-70m, U.S.N.M. No. E13780 (1), A.M. No. J9189 (1); 4 specimens, 'Anton Bruun', cruise 9, stn 447, 16.xii.64, Lat. 10°00'N, Long. 51°15'E, 59-61m, U.S.N.M. No. E13781 (3), A.M. No. J9187 (1); 4 specimens, 'Anton Bruun', cruise 9, stn 449, 16.xii.64, Lat. 10°03'N, Long. 51°15'E, 31-39m, U.S.N.M. No. E13782 (3), A.M. No. J9191 (1).

Diagnosis

R/r 4 to 8.2; arms tapering to a narrow tip; abactinal surface with a carinal and up to 6 lateral rows of plates, dependant on arm length; carinal and first abactinal-lateral rows of plates extend (distally irregularly) to the arm tip; carinal plates transversely rectangular, larger than the abactinal-lateral plates, at least proximally on the arms; superomarginal and inferomarginal plates aligned along the arm; actinal-intermediate plates in 2-4 rows; adambulacral plates with 4-6 (usually 5-6) furrow spines, 4-5 subambulacral spines and 4-5 enlarged granules; surface with rounded to polygonal granules, those towards the centre of the plates and those around the papulae similar in size but larger than the granules towards the edge of and between the plates; papulae in groups, single only in juveniles, confined abactinally above the superomarginal plates; pedicellariae sometimes present.

Remarks

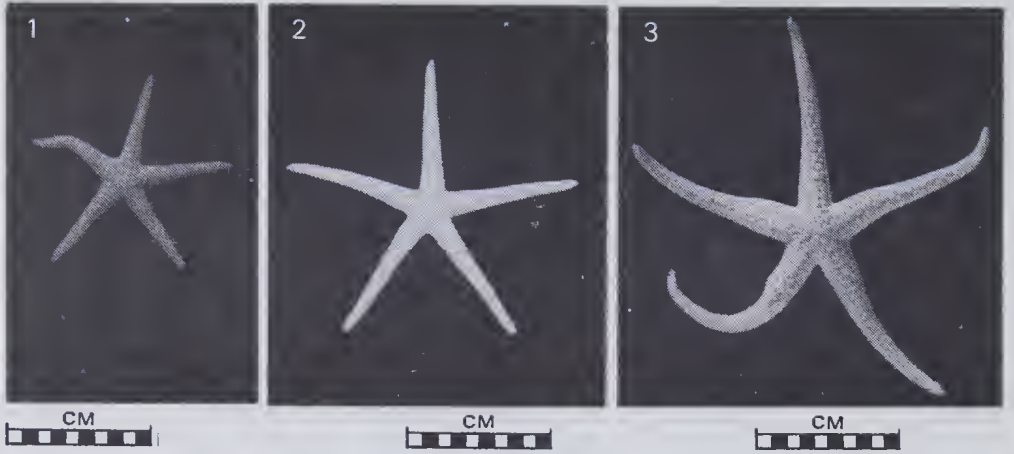
Koehler (1910) described this species from the Andaman Islands on the largest of seven small specimens ($R/r = 40\text{mm}/10\text{mm} = 4$). His smallest specimen had $R = 9\text{mm}$. He described a second species (*N. squamulosa*) on a single specimen, from the same area, which was smaller than the holotype of *carinata* ($R/r = 37\text{-}38\text{mm}/7\text{mm} = \text{c.}5.5$). Macan (1938) based his description of *Narcissia mohamedi* on the larger of 2 specimens ($R/r = 95\text{mm}/14\text{mm} = 6.8$), which had been collected in the Gulf of Aden. The second specimen ($R/r = 39\text{mm}/6\text{mm} = 6.5$) was collected from the Maldives. Fisher (1919) recorded 2 specimens of *N. squamulosa* from the Philippine Islands. H.L. Clark (1921) considered *carinata* and *squamulosa* to be congeneric with *Certonardoa semiregularis*, the type-species of a new genus which he described. A.M. Clark (1967) recorded a pedicellariae-bearing specimen of similar size to the holotype of *Certonardoa carinata*, from Galle, Sri Lanka. Hayashi (1973a) described a new species, *Heteronardoa sagamina*, for his monotypic genus *Heteronardoa*, after examining 7 specimens ($R/r = 54\text{mm-}90\text{mm}/10\text{mm-}18\text{mm} = 4.7\text{-}5.8$) from Sagami Bay, Japan. He nominated a specimen with $R/r = 68\text{mm}/13\text{mm} = 5.2$ as the holotype on which the description was mainly based.

Table 1

	No. Specs recorded	R:r mm	R/r	No. rows abact.-lat. plates	Most frequent no. furrow spines	Maximum No. papulae/area	Presence/Absence pedicellariae
<i>Nardoa carinata</i> Andaman Islands (From Koehler, 1910)	7	40.0:10.0	4.0	3	6	c.6	-
		37.0: 7.0	5.3	-	-		
		28.0: 5.0	5.6	-	-		
		18.0: 4.0	4.5	2	-		
		10.0-18.0	-	1	-		
<i>N. squamifosa</i> Cape Negrais, Burma (From Koehler, 1910)	1	37.0-38.0: 7.0	c.5.5	3	6	c.5-6	-
'Anton Bruun' stations 449	4	23.0: 4.5	5.2	2	4-5	3-4	-
		49.0: 7.0	7.0	3	5	4-5	-
		56.0: 7.5	7.5	4 (+)	5-6	4-6	-
		65.0: 8.0	8.2	4	5-6	5-6	-
447	4	38.0: 6.0	6.3	3	5	3	-
		40.0: 6.5	6.1	3	6	3	-
		60.0: 8.0	7.5	4	5	4-5	-
		61.0: 8.0	7.5	4	5	5 (occas. 6)	-
445	2	56.0: 8.5	6.6	4	6		-
		74.0: 9.0	8.2	5	5-6 (rarely 7)	4-6	
444	2	58.0: 7.5	7.7	3	5-6	3-4	-
		60.0: 8.0	7.5	4	6	3-4	-
M.K.M.E. stations AW IV - 7 †	1	40.0: 6.0	6.6	2	5	3	+
AW I/5	1	16.3: 3.5	4.8	1	5	1 (occas. 2)	-
AM II/8-11	1	22.0: 3.0	7.3	1	5	1-2	+

Table 1 continued

AM II/4-6	1	15.0: 5.0	5.0	1	4	1	-
AM II/3	8	28.0: 4.5	6.2	2	5	1 (occas. 2)	+
		20.5: 2.5	8.2	1	4	1	-
		20.5: 3.5	5.8	1	5	1 (occas. 2)	-
		16.0: 2.7	6.0	1	5	1	+
		15.5: 2.5	6.2	1	5	1	+
		15.5: 2.5	6.2	1	5	1	+
		15.5: 2.5	6.2	1	5	1	-
		14.5: 2.5	5.8	1	4	1	-
'Diamantina' station 187	3	25.0: 4.0 17.5: 3.2 17.5: 4.0	6.2 5.3 4.4	1 1 1	5 6 5	1 1 1	- - -
N.E. Adele Id. (R.W. George)	2	17.5: 3.5 45.5: 6.0	5.2 7.6	1 2 (3)	5-6 6	1 3 (occas. 4)	- -
<i>N. squamulosa</i> Philippines (identified by Fisher 1919)	2	24.5: 4.5 42.0: 7.0	5.5 6.0	2 2	5 6	1 (occas. 2) 2-3 (occas. 4)	- -
<i>Narcissia mohamedi</i> A. Gulf of Aden B. Maldives (From Macan, 1938)	2	A. 95.0:14.0 B. 39.0: 6.0	6.8 6.5	6 3	5 4-6	4-5 2-3	- -
<i>Certonardoa carinata</i> Galle, Ceylon (From A. M. Clark, 1967)	1	42.0: - 7	6.0	2(3)	5-6	3-5	+
<i>Heteronardoa sagamina</i> Sagami Bay, Japan (From Hayashi, 1973)	7 (incl. holotype) Holotype	54.0-90.0: 10.0-18 0 68.0:13.0	4.7-5.8 5.2	3-4 4	4-6 5-6	3-4 3-4	+



Figs 1-3: *Heteronardoa carinata* (Koehler). Abactinal view, M.K.M.E. specimen Stn AM II/3, R= 15.5 mm; 20.5 mm; 28.0 mm respectively.



Fig. 4: *Heteronardoa carinata*. Abactinal view, 'Diamantina' specimen, Stn 187 (W.A.M. No. 1759-74). R= 25.0 mm.

Fig. 5: *Heteronardoa carinata* (Koehler). Abactinal view, N.E. Adele Is. specimen (W.A.M. No. 1763-74). R= 45.5 mm.

The specimens examined here fall between *Nardoa carinata* and *Narcissia mohamedii* in size (see Table 1) and show such changes in development, with increase in size, that it would seem illogical to consider that the larger *N. mohamedii* and the smaller *N. carinata* are not conspecific. Table 1 records the R/r measurements, number of abactinal-lateral rows of plates, number of furrow spines per adambulacral plate, number of papulae per papular area and the presence or absence of pedicellariae for each of the specimens

examined together with the holotype and other specimens of *N. carinata* and *N. squamulosa* (taken from Koehler, 1910), *N. mohamedi* [examined in the British Museum (Natural History)] and *H. sagamina* (from Hayashi, 1973b). The influence of arm length on the development of abactinal-lateral plates and in the number of furrow spines can be clearly seen, Figs 1-9. The R/r ratio generally increases markedly in the middle of the size range, during which time the disc does not increase in diameter at the same proportional rate. By the time the species has reached the largest size recorded (i.e. for *N. mohamedi*) arm lengthening has either slowed down or stopped while increase in disc diameter reduces the R/r ratio from over 8 to under 7 (or 6 in the Japanese specimens). This would tend to indicate that the animal has a distinctive growth pattern, through an arm lengthening phase and then a maturation phase. The extent of regularity of the abactinal plates along the arm and the number of furrow spines per adambulacral plate is variable to such a degree that *N. carinata*, *N. squamulosa*, *Narcissia mohamedi* and *H. sagamina* cannot justifiably be separated on these characters. Neither do I believe that the somewhat stouter-armed form of *sagamina* is sufficient grounds for considering it specifically distinct from the other species. From the examination of the smaller specimens of this collection, I believe that Koehler (1910) was mistaken in the number of papulae he recorded (c.6) per papular area in both *carinata* and *squamulosa* (see table 1), but I can agree with his opinion (1910: 170) that *squamulosa* would probably prove to be only a variety of *carinata* when more material was available for study. Neither Koehler nor Macan described the presence of pedicellariae on their specimens. Nor were there any pedicellariae to be found on the 'Anton Bruun' specimens or those from north-western Australia. I can confirm A.M. Clark's (1967) record of alveolar pedicellariae on a small specimen of *H. carinata* (as *Certonardoa*) from Sri Lanka. The specimen, with R= 42mm, compares in size with Koehler's holotype and differs only in its possession of pedicellariae. Also, 6 of the 12 specimens collected from the vicinity of Aru Island have pedicellariae of the type figured by Hayashi (1973b, fig. 8b). These 6 specimens have R= 15.5-40.0mm. A similar situation occurs in *Certonardoa semiregularis*, as Hayashi has indicated and which the present author can confirm, and in *Narcissia canariensis*, according to Sladen (1889). The occurrence of pedicellariae, as a species, character, in some (if not most) ophiasterids is therefore very unreliable. Clark (1921) considered the presence of pedicellariae might represent a juvenile character, though the spasmodic nature of the occurrence within single populations and the occurrence of pedicellariae on specimens ranging in size from R= 15.5 mm-90mm, could possibly indicate a genetic factor. Either suggestion needs further investigation. Hayashi (1973b) records the life colour of *H. sagamina* as 'capucine buff, papular areas scarlet and arm tips morrocco-red'. A colour transparency of the largest specimen from off Adele Island, north-western Australia, shows it to be cream coloured with a ring of radial and interradial disc plates orange. Within that ring the plates are blotched orange/cream. Along the abactinal



CM

Fig. 6: *Heteronardoa carinata* (Koehler). Abactinal view, I.I.O.E. specimen, Sta. 449 (A.M. No. J9191). R= 23.0 mm.



CM

Fig. 7: *Heteronardoa carinata* (Koehler). Lateral arm, I.I.O.E. specimen, Sta. 447 (U.S.N.M. No. E13781). R= 38.8 mm.

side of the arms some of the plates are orange or blotched orange and these form 4 or 5 irregular but recognisable transverse bands. In its dry state the specimen is uniformly off-white.



Fig. 8: *Heteronardoa carinata* (Koehler). Lateral arm, I.I.O.E. specimen, Stn 447 (A.M. No. J9187). R= 60.0 mm.



Fig. 9: *Heteronardoa carinata* (Koehler). Lateral arm, I.I.O.E. specimen, Stn 445 (U.S.N.M. No. E13780). R= 74.0 mm.

Heteronardoa diamantinae sp. nov.

(Figs 10-15.)

Nardoa semiregularis, Fisher, 1919, p. 383, pl. 105 fig. 3 (non *Scytaster semiregularis* Muller and Troschel).

Material examined: Holotype

H.M.A.S. 'Diamantina', stn 17, off Point Cloates, north-western Australia, 31.i.64, Lat. 22°59.7'S, Long. 113°25.5'E, 128m, W.A.M. No. 1762-74; 2 paratypes, 'Anton Bruun', cruise 8, stn 403E, 9.x.64, Lat. 19°09'S, Long. 36°55'E (Mozambique Channel), 88m, U.S.N.M. No. E13783(1), A.M. J9188(1).

Diagnosis

R/r= 6-7; 4 or 5 arms which taper to a narrow tip; abactinal surface with a carinal and 3-4 lateral rows of plates; no abactinal-lateral plates extend beyond 2/3 length of the arms; carinal plates squarish, similar in size to abactinal-lateral plates; superomarginal and inferomarginal plates similar, aligned along the arm; actinal-intermediate plates in 3-4 rows; adambulacral plates with 5-8 (usually 7) short furrow spines, 5-7 subambulacral spines and a second row of 5-6 slightly enlarged granules; surface with rounded to polygonal granules, those towards the centre of the plates and those around the papulae similar in size but larger than the granules towards the edge of and between the plates; papulae in groups, confined abactinally above the superomarginal plates; pedicellariae present or absent.

Description

The description is based on the holotype, followed by comments on each of the paratypes.

The holotype has 5 arms which are flat actinally, arched abactinally and taper to a narrow tip. R= 41.3mm, r= 6.3mm, R/r= 6.5 (one arm R= 32mm shows regeneration from a severance), Figs 10 & 12.

The abactinal disc plates are rounded and vary in size to a maximum of about 1.5 mm diameter. Five plates surround the anus. A ring of radial and interradial plates is evident. Along the abactinal side of the arms is a carinal row and, basally, 3 (with 2 small plates in each angle of adjacent arms indicating the 4th) lateral rows of plates each side, Fig. 11. The basal carinal plates are about 1.5 mm square, and of similar size to the adjacent lateral plates. The plates diminish gradually in size along the length of the arms. The carinal and first lateral rows of plates extend regularly along the arm to about the 10th superomarginal, only the carinal plates extend to the tip of the arms. The second lateral rows of plates do not extend beyond the 6th superomarginal plate along the arms; the third to about the 4th superomarginal and the 4th does not extend beyond the 1st superomarginal. There are 28-30 superomarginal and inferomarginal plates of similar dimensions which are aligned along the arms. There are 2 rows of actinal-intermediate



Fig. 10: *Heteronardoa diamantinae* n. sp. Holotype. Abactinal view (W.A.M. No. 1762-74). R=41.3 mm.

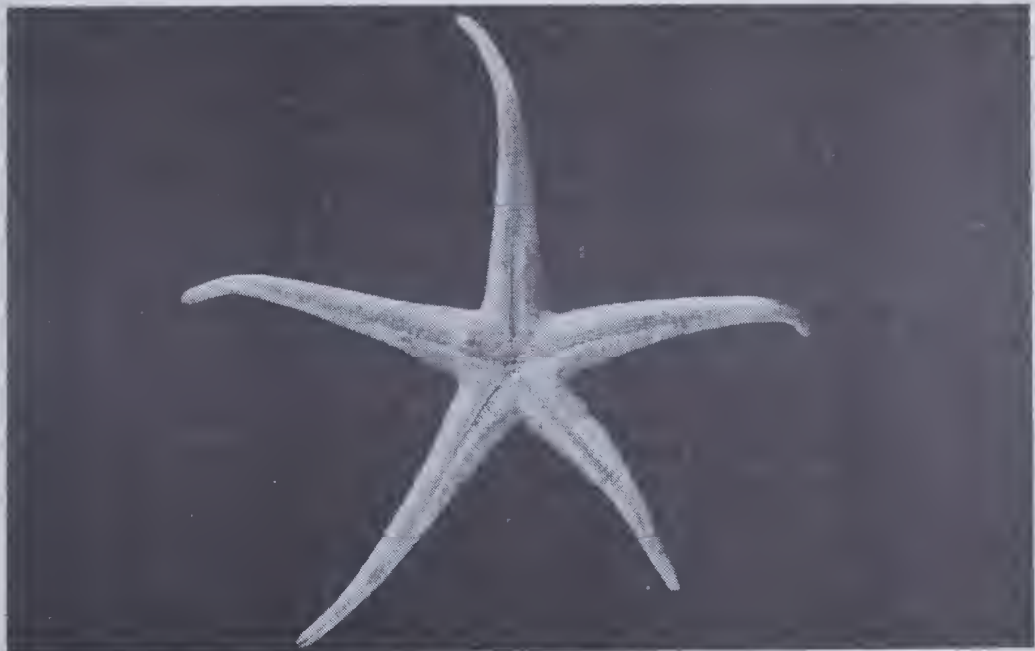


Fig. 11: *Heteronardoa diamantinae* n. sp. Holotype. Actinal view (W.A.M. No. 1762-74). R=41.3 mm.

plates, with the indication of a 3rd as 2 plates in the angle between 2 adjacent arms. The innermost row of about 31 plates extends to the 20th inferomarginal and the second row of about 4 plates to the 2nd inferomarginal.



Fig. 12: *Heteronardoa diamantinae* n. sp. Holotype. Lateral view (W.A.M. No. 1762-74). R=41.3 mm.

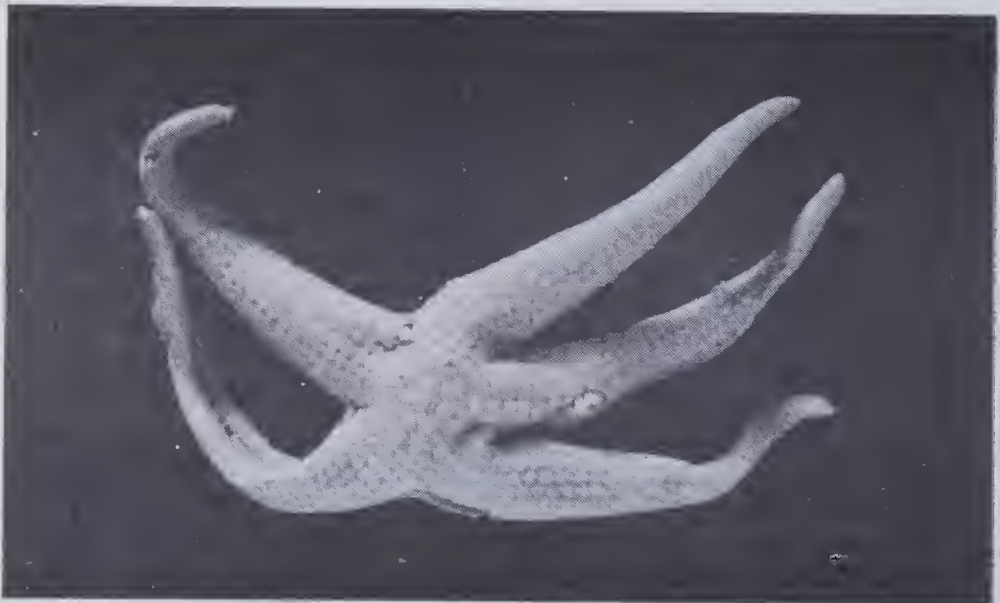


Fig. 13: *Heteronardoa diamantinae* n. sp. Paratype. Abactinal view, I.I.O.E. specimen, Stn 403E (U.S.N.M. No. E13783). R=57.0 mm.



Fig. 14: *Heteronardoa diamantinae* n. sp. Paratype. Adambulacral furrow, I.I.O.E. specimen, Stn 403E (U.S.N.M. No. E13783). R=57.0 mm.

The 48 adambulacral plates bear 6, proximally, increasing to 7 or 8 short, blunt furrow spines on the 8th to 20th plates, thereafter the number of spines decreases. The first and last 1 or 2 spines are shortest and are flattened, spatulate, the remaining spines are subequal and square in cross-section. These are backed by a row of 5-7 truncate subambulacral spines and, at least proximally, a row of 5-7 slightly enlarged granules. The mouth plate has 9 furrow spines backed by 5 stout spines and a second row of 4-5 enlarged granules, the rest of the plate being covered by about 8 or 9 coarse granules.

Papulae occur only between the abactinal plates and are not found either between the supermarginals and inferomarginals or actinally. The papulae are in groups of 3, reducing to 2 and 1 distally and laterally. There are no

papulae between the plates of the distal one fourth or one fifth of the arms. There are no pedicellariae.

The plates, where they are not rubbed bare, are covered with close granulation, but this does not obscure the limits of the plates. The granules towards the centre of the plates and those around the papulae are similar in size but larger than those towards the edge of and between the plates. The actinal granules are similar in size to the larger abactinal granules. The colour of the dry specimen is dusky-pink, the colour in life is not recorded.



Fig. 15: *Heteronardoa diamantinae* n. sp. Paratype. Abactinal view, I.I.O.E. specimen, Stn 403E (A.M. No. J9188). R= 36-42.0 mm.

The larger paratype has 5 arms with $R/r = 57\text{mm}/9\text{mm} = 6.3$, Fig. 13. The disc plates reach about 2 mm maximum diameter and only 3 plates surround the anus. There are 4 (one arm 5) abactinal-lateral rows of plates and the basal carinal plates are about 1.75 mm square. The carinal and first lateral rows of plates extend regularly to the 30th superomarginal; the second lateral row extends to about the 25th superomarginal; the third row to the 16-18th superomarginal; the fourth row to the 8-10th superomarginal and the fifth, where present, to the 3rd superomarginal. There are 42 superomarginals and inferomarginals and 3 rows of actinal intermediate plates, with a 4th row indicated by 2 plates in the angle between 2 adjacent arms. The innermost actinal intermediate row comprises 48 plates extending to the 30th inferomarginal; the 2nd row of 7-8 plates to the 5th inferomarginal and the 3rd row of 4 plates to the 2nd-3rd inferomarginal.

The adambulacral armature is similar to the holotype except that 7-8 furrow spines occur from the 10th-35th plates, Fig. 14. The mouth plate has 10-11 furrow spines backed by 6 large, stout spines and a second row of 4-5 enlarged granules, the rest of the plate being covered by 10 coarse granules. The papulae occur in groups of up to 5. There are no pedicellariae. The granulation is as in the holotype. The colour, in alcohol, is a very light pink; colour in life not recorded. The 2nd paratype has only 4 arms measuring $R = 36\text{mm}-42\text{mm}$, with $r = 6\text{mm}$; $R/r = 6-7$, Fig. 15. There are 3 rows of abactinal-lateral plates (though there is evidence of a 4th row on one side of one arm). The ring of radial plates is not distinct on the disc. There are 34 supermarginal and inferomarginal plates ($R = 42\text{ mm}$). There are 3 rows of actinal intermediate plates. There are 5-7 furrow spines but in this specimen 7 spines occur from as early as the 5th adambulacral plate. The mouth plate is as in the holotype. The papulae occur in groups of up to 4. There are no pedicellariae. The granulation and colour is the same as for the larger paratype.

The specimen identified by Fisher (1919) as *Nardoa semiregularis* has been re-examined by Miss M.E. Downey (Smithsonian Institution, U.S.A.), who informs the author that the specimen is grey-brown in colour; has usually 6 furrow spines; the granules over the papular areas seem infinitesimally smaller than those on the plates; no papulae occur intermarginally or actinally and that there are a few very tiny ophidiasterid (sugar-tong) pedicellariae on a few of the proximal supermarginals.

Similarly there are pedicellariae on the smaller specimens of *H. carinata* (see table 1). The apparent lack of difference between the granules on the plates and papular areas is surprising but with all factors considered, from both Fisher's description and plate and Miss Downey's re-examination, there seems little doubt that Fisher's specimen represents the species *H. diamantinae*. With $R = 29\text{ mm}$ this is the smallest specimen of *diamantinae* so far recorded.

Remarks

Heteronardoa diamantinae is clearly quite closely related to *H. carinata* but can be readily distinguished from that species by the fact that the abactinal-lateral plates do not extend to the tips of the arms, the similarity in size of the carinal and abactinal-lateral plates, the squarish carinal, the higher number of furrow spines and the colour.

Discussion

The genus *Heteronardoa* was established by Hayashi for a Japanese species of ophidiasterid, *H. sagamina*. It is considered (see table 1), however, that the Indian Ocean species *Nardoa carinata* Koehler, *N. squamulosa* Koehler and *Narcissia mohamedi* Macan are not only congeneric with *H. sagamina* but conspecific with it. *Heteronardoa carinata* (Koehler) has priority. Despite this synonymy, it is also apparent that a second, but new, species of

Heteronardoa, *H. diamantinae*, occurs in the Indian Ocean and Philippine Islands.

In his description of the genus 2 characters should have been given more emphasis by Hayashi. These are the lack of papulae not only actinally but also intermarginally, and the similarity in size of the granules in the central area of the abactinal plates with those around the papulae and the smaller size of the granules towards the outer margins of and between the abactinal plates. Papulae are found between the marginal rows of *Certonardoa* and *Narcissia* and the granulation is even. The presence or absence of pedicellariae is obviously variable in all three genera (Sladen, 1889; Hayashi, 1973b; Table 1).

H. carinata is geographically widely distributed, occurring from the Gulf of Aden, Arabian Sea, Maldives, Andaman Islands, off north-western Australia, Aru Islands, the Philippine Islands and Japan. *H. diamantinae* is, at present, known only from three localities as far apart as the Mozambique Channel, the North-West Cape of Australia and the Philippine Islands. This compares with *Certonardoa* which is restricted to Japan and Indonesia and *Narcissia* from the tropical Atlantic and the Gulf of California (Hayashi, 1973b). The species of *Heteronardoa* occur in depths of between 30-230m, though more generally between 60-100m, which is deeper than *Certonardoa* but probably the same depth as *Narcissia*.

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NARETHA METEORITE (Synonyms: Kingoonya, Kingooya)

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ABSTRACT

Much of the missing portion of the Naretha (Western Australia) meteorite has been located in museums as an un-named specimen and as two smaller specimens masquerading under the name 'Kingoonya' (or 'Kingooya'). The use of the junior synonyms with their implications of a South Australian site of find should be discontinued.

INTRODUCTION

Naretha meteorite, an L4 chondrite, was found in 1915 about 3 km north of the 205-mile station during construction of the Trans-Australian Railway. It was broken into at least three major pieces which were acquired by Mr John Darbyshire, Supervising Engineer for the construction of the western end of the railway (construction was proceeding simultaneously from both Kalgoorlie and Port Augusta ends — Fig. 1). Mr Darbyshire donated the meteorite to the W.A. School of Mines in Kalgoorlie where one piece was retained and exhibited with a photograph of the reassembled meteorite (Fig. 2). A second fragment which was passed on to the Geological Survey of Western Australia was noted briefly by Simpson (1922) who first used the name 'Naretha', the name which had been given to the 205-mile station. There is strong presumptive evidence that the third fragment was passed on to Mr S.F.C. Cook of Kalgoorlie, a private collector from whose inaccurate verbal statements and undocumented collection, the subsequent confusion arose.

In late 1926 Mr Cook gave a small piece of 'meteorite' to Mr G.W. Card who donated it to the Australian Museum, Sydney and reported its acquisition to Dr G.T. Prior of the British Museum (Natural History) in two letters written in March 1927. The mileage statement given by Mr Cook was inaccurate and he did not mention Western Australia. In consequence Mr T. Hodge-Smith of the Australian Museum measured the mileage from the then

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eastern end of the railway at Port Augusta, a procedure which had become usual since completion of the line in 1917 and continued to be used until subsequent extension of the line to Port Pirie in 1937, but which would have been meaningless in Western Australia when the meteorite was found in 1915. There was a gap of approximately 1000 km between the ends when construction passed through the 205-mile pegs in Western Australia and South Australia during March 1915. Thus 'Kingoonya', the name of a station 209 miles from Port Augusta, was given to the Australian Museum specimen (Prior 1927; Anon. 1928). Because Mr Cook also mentioned that the meteorite was found on the Nullarbor Plain, Spencer (1932 Fig. 1) showed the site of Kingoonya in a grossly erroneous location and subsequently had to correct it (Spencer 1936), but without being able to offer any reconciliation of the fact that Kingoonya station is more than 350 km from the Nullarbor Plain. Nor is Naretha station within the treeless (*nulla arbor*) area. However, 'Nullarbor Plain' has often been used loosely as if its boundary were coincident with those of the Eucla Basin or the Bunda Plateau. In these loose but all too common usages, Naretha qualifies for inclusion but not Kingoonya (Fig. 1).

In 1946 the South Australian Museum purchased the undocumented meteorites from the estate of Mrs V.E. Cook, widow of Mr S.F.C. Cook. Dr D.W.P. Corbett recognized the identity of one slice of meteorite with 'Kingoonya' held at the Australian Museum and catalogued it under that name (Corbett 1967).

Naretha was then known by two somewhat reduced original fragments (McCall and deLaeter 1965), the third being missing. 'Kingoonya' was known by pieces in the Australian and South Australian Museums of total mass 99 g, the location of the main mass being unknown (Hodge-Smith 1939; Corbett 1968).

The key to the existence of the synonymy was the realization that Hodge-Smith (1939 Pl. XII Fig. 1) had used the photograph of the Naretha meteorite supplied by Mr Card to illustrate the 'Kingoonya' meteorite. An enquiry was therefore directed to Dr Brian Mason of the Smithsonian Institution concerning the degree of agreement between the fayalite indices of Naretha and 'Kingoonya' (Mason 1963; 1967). Simultaneously with the enquiry, more detailed fayalite and ferrosilite indices were published and both pairs of indices are within the limits expected by variation within a meteorite and experimental uncertainty (Mason 1974 and *pers. comm.*). Additionally, Dr Mason had available thin sections of the Australian Museum specimen of 'Kingoonya' and the Geological Survey specimen of Naretha in which he noted 'identity in mineralogy and texture'.

An un-named South Australian Museum specimen from Mr Cook's collection was then recognized as a major part of the third original fragment of Naretha. It interlocks over a small area with specimens of Naretha held in Western Australian collections. The South Australian Museum specimen of

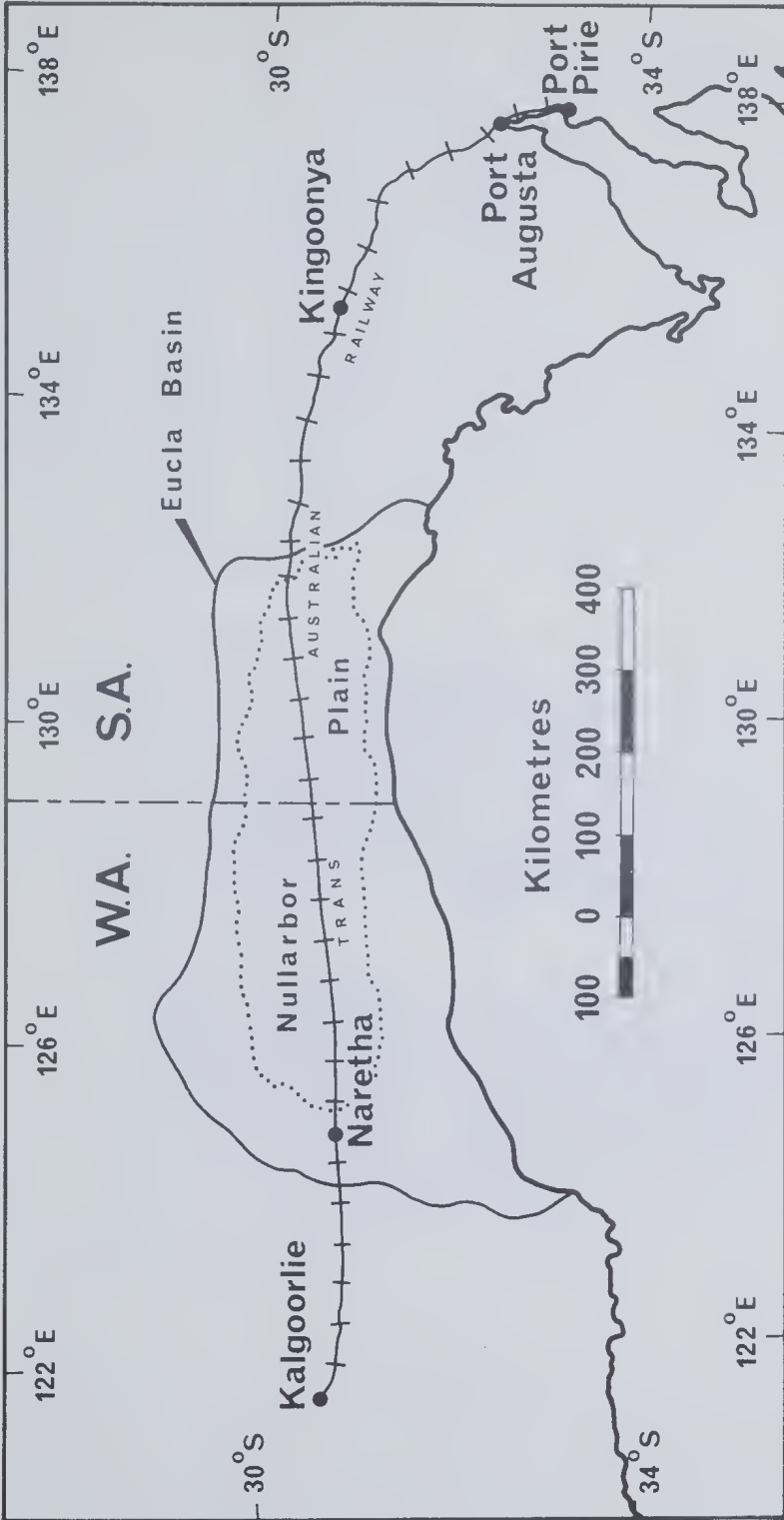


Fig. 1: Part of southern Australia showing Trans-Australian Railway in relation to Eucla Basin, Nullarbor Plain, and localities mentioned in text.

'Kingoonya', a narrow slice lacking melt skin surface, cannot be placed with certainty on the photograph. No attempt was made to place the now much reduced (12 g) Australian Museum specimen.

Partial re-assembly of Naretha meteorite made possible some observations on its morphology. The width (Fig. 2) is 14.9 cm, the height 12-13 cm, and the form a squat pyramid with well rounded corners. It was probably oriented in flight with No. 1 fragment directed forward; it is the only fragment having any regmaglypts. In that orientation, the sharper and deeper circular feature — possibly a sulphide burn pit — on No. 2 fragment would also have been on the frontal surface. The original mass stated as 2.7 kg appears to have been underestimated. Two independent methods of estimation suggest that the mass was between 3 and 3½ kg. The bulk specific gravities of the five largest pieces are in the range 3.393-3.397 with weighted mean 3.396. All larger pieces have areas of dark stained internal surface which are overlain by thin films of calcite towards the outside of the stone. These are the surfaces of the weathering cracks along which the meteorite was broken. They penetrated throughout the stone and gaped slightly towards

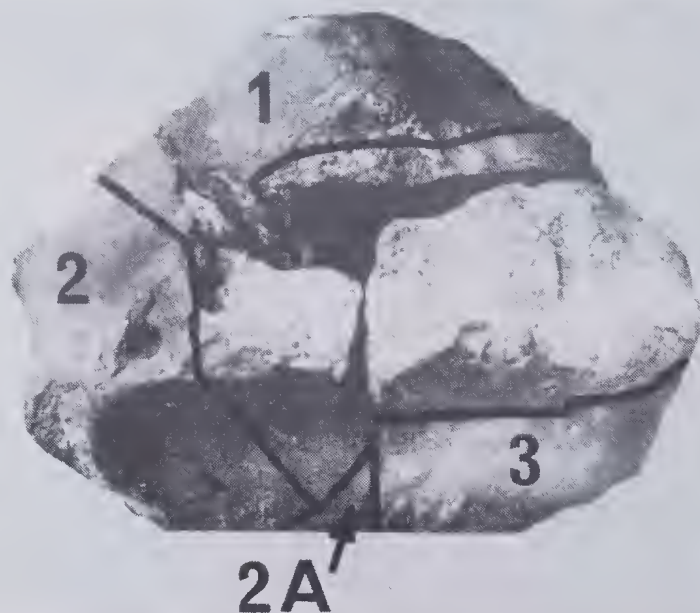


Fig. 2: Naretha meteorite. The photograph displayed with the W.A. School of Mines specimen and also used to illustrate 'Kingoonya' meteorite. Approximate limits of larger surviving fragments are shown on the front of the specimen only. Because of the flat obliquity of some cuts to the plane of the photograph, the material is more complete than might appear in this view. 1. W.A. School of Mines 3466. 2. Geological Survey of W.A. 1/4709. 2A. E.S. Simpson collection S.1177 (larger of the pieces), held in the W.A. Museum. 3. South Australian Museum G. 6062.

the outside. The presence of this typical dark grey weathering surface along one edge of the slice G.6074 (the only natural surface present) is a further feature giving confidence to identification.

Approximately 72% of the recovered portion (2.5 kg) of the Naretha meteorite is accounted for in the following distribution.

W.A. School of Mines 3466	655 g
Geological Survey of W.A. 1/4709	662
E.S. Simpson coll. S 1177, held in the W.A. Museum, three pieces, total	36
American Museum of Natural History	8
South Australian Museum G.6062 (previously un-named)	346
South Australian Museum G.6074 ('Kingoonya')	78
Australian Museum, Sydney D.R. 986 ('Kingoonya')	12

The senior name Naretha correctly describes the locality of the find. The use of the junior synonyms Kingoonya and Kingooya should be discontinued.

Note

This paper summarises a more detailed account in which the argument is given in full and explanations are offered for the discrepancies in the accounts of 'Kingoonya'. For example, 'Kingoonya' is stated to have been found in 1926 or 'before 1927', but Mr Card's letters do not mention any date of find (Spencer 1936 p.356). All that writers have known is that Mr Card first saw a piece of the meteorite a few months prior to March 1927; Mr Cook might well have owned it since 1917. Copies of the detailed account have been lodged with museums holding pieces of Naretha meteorite.

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A supplementary series to the *Records of the Western Australian Museum* has been commenced.

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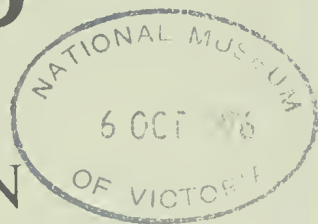
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RECORDS OF THE WESTERN AUSTRALIAN MUSEUM



Volume 4, Part 2, 1976

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Cover: Splendid Wren (*Malurus splendens*), drawn by Martin Thompson, Western Australian Museum. The male Splendid Wren is the only all-blue member of seven species of the genus in Western Australia. It is common in the South-West, favouring forests and dense vegetation along the coast.

ISSN 0312-3162

THE REDISCOVERY OF *HALITYLE REGULARIS* FISHER (ECHINODERMATA : ASTEROIDEA)

ALAN N. BAKER*

and

LOISETTE M. MARSH†

[Received 12 May 1975. Accepted 1 October 1975. Published 30 September 1976.]

ABSTRACT

New information on the morphology and colour of *Halityle regularis* Fisher is given, and its known geographic range is extended from the Philippine Islands to the eastern and western coasts of Australia, the east coast of Africa, and Madagascar. The synonymy of *H. anamesus* H.L. Clark with *H. regularis* is substantiated.

INTRODUCTION

Halityle regularis, from the Philippines, was described by Fisher in 1913, and *Culcitaster anamesus*, from Western Australia, by H.L. Clark in 1914. The genera were synonymized by Fisher (1919) and the species by Döderlein (1935), without comment by the latter.

The species was previously known only from the Philippines (Fisher, 1913, 1919; Domantay and Roxas, 1938) and from an unknown locality in Western Australia.

Recently, further specimens of *H. regularis* were collected in the waters of the Philippines, the east and west coasts of Australia, the east coast of Africa and Madagascar. The discovery of *H. regularis* in eastern Australian

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waters immediately raised the question of the status of the Western Australian species. This new material has enabled a reappraisal of the nominal species within this genus. Fifteen specimens have been examined by us, and their data, plus those for the holotype, are included in this paper. Enquiries have failed to locate the third specimen mentioned by Fisher, 1919. Only the type (USNM 32634), illustrated by Fisher and one without locality (USNM 40867) remain in the USNM collection.

Although the morphology of *H. regularis* has been well described and illustrated by Fisher (1913, 1919), details of the colour and appearance of the living starfish have not been available until now. When alive, *Halityle regularis* bears some resemblance to its close relative *Culcita*, having the same general shape and similar dorsal colouring; this may be why such a large and conspicuous shallow water asteroid was not described until 1913, and why it has gone unnoticed since. The underside of this starfish is, however, very different from *Culcita*, and has a spectacular colour pattern which distinguishes the genus at a glance.

Abbreviations used in this paper:

AM	= Australian Museum, Sydney
BMNH	= British Museum (Natural History)
JCU	= James Cook University of North Queensland, Townsville
MCZ	= Museum of Comparative Zoology, Harvard
NMNZ	= National Museum of New Zealand, Wellington
USNM	= United States National Museum, Washington
WAM	= Western Australian Museum, Perth
IIOE	= International Indian Ocean Expedition
(H)	= holotype

Measurements of R were made to the arm end, not to the end of the ambulacral furrow.

Order VALVATIDA Perrier, 1884
Suborder GRANULOSINA Perrier, 1894
Family OREASTERIDAE Fisher, 1911
Genus *Halityle* Fisher, 1913
Halityle regularis Fisher
(Plate 1, a-d)

Halityle regularis Fisher, 1913 : 211.

Culcitaster anamesus H.L. Clark, 1914 : 144-146, pl. XIX.

Halityle regularis Fisher, 1919 : 362-366, pl. 94,

figs 7, 7a; pl. 95, fig. 10; pl. 98, fig. 1; pl. 99, figs 1, 2; pl. 100, figs 2, 3.

Halityle anamesus (H.L. Clark), Fisher 1919 : 362.

Halityle regularis Fisher, Döderlein, 1935 : 108.

Halityle regularis Fisher, H.L. Clark, 1946 : 109.

Halityle anamesus (H.L. Clark), H.L. Clark, 1946 : 109.

Halityle Hyman, 1955 : 334, fig. 140 [*H. regularis* Fisher].

Halityle regularis Fisher, Clark and Rowe, 1971 : 34, 53.

Material Examined

Fifteen specimens as follows: One specimen, channel between Heron I. and Wistari reef, Queensland, 34 m, A.K. O'Gower, 16.XII.1970, NMNZ Ech. 1828; one specimen on sandy rubble, Keppel Bay, Queensland, 3 m, pres. N. Coleman, -IX.1974, AM J8662; one specimen, 20 km NE of Townsville, Queensland, trawled at 24 m, R.A. Birtles, 3.VIII.1974, JCU; one specimen, no locality, USNM 40867 (identified by W.K. Fisher); one specimen, 1.6 km north of Malanipa I., Basilan Straits, Sulu Archipelago, Philippines, 11 m, lithothamnion, B.R. Wilson on *Pele*, 12.II.1964, WAM 147-71; two specimens off Somalia coast, 9°41'N, 51°03'E, trawled at 60-70 m, R.U. Gooding on *Anton Bruun*, stn 9-445, IIOE, 16.XII.1964, ident. F.H.C. Hotchkiss, USNM E13719; one specimen, in alcohol, off Somalia coast, 10°03'N, 51°15'E, trawled, 59-61 m, *Anton Bruun*, stn 9-448, IIOE, 17.XII.1964, ident. F.H.C. Hotchkiss, USNM E13720; one specimen, North Kenya Banks, east Africa, dredged at 91 m, A.J. Bruce on R.V. *Manihine*, cr. 333, stn dr. 16, 10.XII.1971, BMNH 1974.2.6.22; one specimen, SW of Isles Mitsio, near Nosy Bé, Madagascar, 13°02.5'S, 48°21.5'E to 13°00.5'S, 48°22.5'E, trawled, 59-45 m, R/V *Vauban*, coll. A.G. Humes, 19.VI.1967, det. J.F. Clark, MCZ 4302; two specimens, SW of Isles Mitsio, near Nosy Bé, Madagascar, 13°02.5'S, 48°21.5'E to 13°05.5'S, 48°20.5'E, trawled, 59-38 m, R/V *Vauban*, coll. A.G. Humes, 19.VI.1967, det. J.F. Clark, MCZ 4303; one specimen, near Isles Mitsio, NE of Nosy Bé, Madagascar, 13°05'S, 48°22.5'E to 13°05'S, 48°21.5'E, 30 m, coll. A.G. Humes, 18.VIII.1967, det. J.F. Clark, MCZ 4296; *H. anamesus*, Holotype, said to be from Western Australia, WAM 13-62; one specimen, near Sunday I., Exmouth Gulf, W.A., trawled at 12-18 m, R. Rowe on *Jurabi*, -VIII.1973, WAM 228-73.

Description

The specimens are massive, with short, broadly based arms, inflated

abactinal and concave actinal surfaces, (Pl. 1). R/r varies from 1.18 to 1.66. The sides are perpendicular and there are up to 22 superomarginal plates and 40-50 inferomarginals, in each arc. The abactinal surface bears no spines or tubercles, but the stellate plates are joined by slightly raised, slender trabeculae, which divide the surface into regular triangular papular areas, grouped in adjacent hexagons. At the centre of the disc the hexagons may form a large pentagon.

The whole abactinal surface is finely granular, with scattered minute granuliform pedicellariae. The actinal intermediate plates are clearly outlined by sutural grooves, and their slightly tumid surfaces are covered with a close mosaic of unequal, flattish granules and occasional sunken pedicellariae. The plates are arranged in three regular chevrons of transversely oblong plates, with an odd plate at the apex, followed by about 6 less regular chevrons of radially elongate, hexagonal plates without an unpaired interradial plate. Towards the margin they become smaller and less regularly arranged, tending to impinge on the lateral wall of the disc between the lower edge of the proximal inferomarginal plates. Near the mouth are 4-8 slightly larger rhombic plates, each of which is surrounded by a double or triple row of spaced granules and pedicellariae forming a kind of frame. These plates are flat, or slightly concave, with a very close compacted mosaic of flat granules; near the margins, pit-like spaces occur between the granules. Together, the plates form a striking stellate-pentagonal pattern centred on the mouth (Pl. 1,c).

The adambulacral plates bear a perpendicular furrow comb of 8-11 slender, closely adpressed, flat spines, behind which are 2 or 3 short, domed spines with wrinkled tips. The mouth spines number 12-15. The end of each ray is turned upwards, and there is a small sharp, wide-based spine borne on the terminal plate. This spine is lost from most of the large specimens and was not included in the description of the holotype.

Variations

There is considerable variation in the shape of *Halityle*. The Philippine specimens and the two Queensland examples from Townsville and Heron Island have high lateral walls to the disc, formed by the vertical extensions of the superomarginal plates. The other Australian specimens, and those from Madagascar, have less well developed superomarginals, and the lateral walls are consequently lower.

The number of inferomarginal plates also varies (Table I), and in the larger Australian specimens their size is reduced and their placement somewhat irregular owing to intercalation and overgrowth by plates from the oral

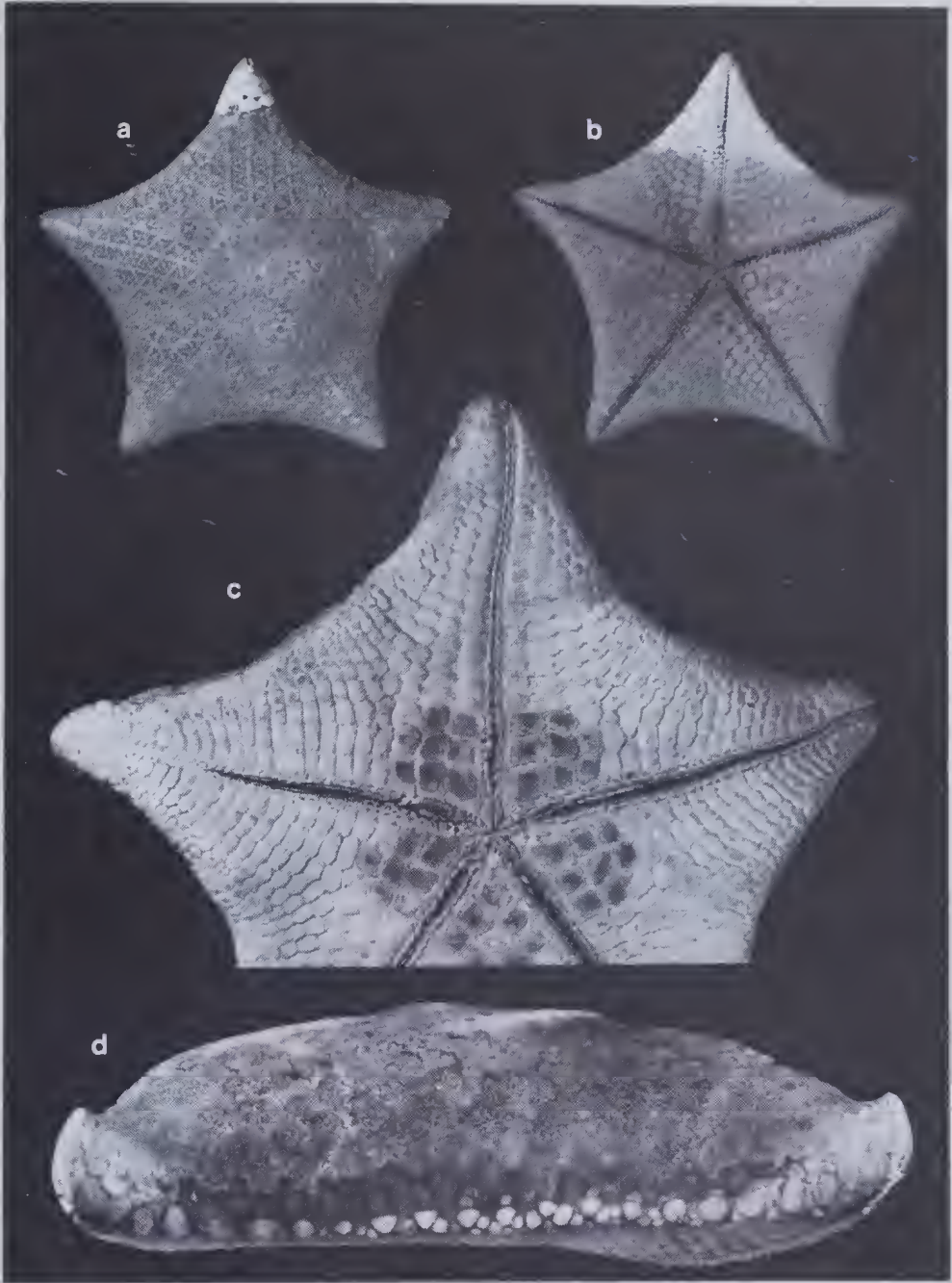


Plate 1: *Halityle regularis*. *a*, *b* abactinal and actinal views of Somalia specimens (R = 57 and 61 mm); *c* actinal surface of Exmouth specimen (R = 161 mm); *d* lateral view of Townsville specimen (R = 160 mm) showing the intercalation of actinal plates between the reduced inferomarginal plates.

surface (Pl. 1,d). Both sets of marginal plates are partly concealed by thick granular skin in the median interradial areas in the specimens from Western Australia, Keppel Bay and Madagascar.

The specimens range in size from R of 54 mm to 162 mm, but there is remarkably little change during growth.

Even the smallest specimen (R = 54 mm, from Madagascar) has a skeletal meshwork of small plates joined by trabeculae but near the ends of the rays the last 3 or 4 radial and adjacent lateral plates are larger, somewhat tumid and joined by short trabeculae. Like the larger Madagascar specimens the inferomarginals are obscured by actinal plates but the superomarginals are visible although covered by thick granular skin.

Variation in the R to r ratio (Table I) is not dependent on size but the ratio of R to arm width (20 mm from the tip) does increase with size reflecting the extended and relatively narrow arms of very large specimens.

There is considerable variation in the abundance of pedicellariae among the specimens examined but their shape varies little. There are few granuliform pedicellariae in each aboral papular area in the types of *Halityle regularis*, *H. anamesus* and in the Keppel Bay, Exmouth and Kenya specimens but they are numerous in the Basilan and Somalia specimens. On the inferomarginal plates small pedicellariae are abundant on all but the east African specimens in which they are scarce or wanting while in the Basilan specimen some are elongated, corresponding to three granules in length. On the actinal intermediate plates bivalved pedicellariae corresponding to one to three granules in length are numerous on all but the east African specimens. Large lanceolate pedicellariae occur outside and sometimes between the groups of subambulacral spines. These pedicellariae are somewhat irregular in shape but most frequently square tipped or pointed. In the types of *H. regularis* and *H. anamesus* both square and pointed pedicellariae are found.

The number of papular pores per area increases with size from 20 to 30 in the smallest specimens to about 100 in the largest. The type of *H. regularis* has 50 to 70 pores in an area.

The material at hand shows three colour variations, but no colour notes are available for the Somalia specimens; they are now 'museum colour' with the four prominent oral interradial plates light orange with a deeper orange border. The Kenya specimen, although faded, has four prominent violet plates, outlined with orange granules, near the mouth ~interradially.

In the Heron Island specimen the trabeculae of the abactinal surface and sides were maroon in the living animal, and the triangular papular areas were conspicuously lighter, being orange-yellow with spots of dark maroon

TABLE 1. Data from 16 specimens of *Halityle regularis*.

Locality	Reg. No.	R	r	R : r	Arm width at 20 mm	Ratio R : Arm W	No. of inferomarginals
Madagascar	MCZ 4302	54	37	1.46	38	1.42	26
Somalia	USNM E13719	57	40	1.43	28	2.04	24
Somalia	USNM E13719	61	41	1.49	27	2.26	32
Somalia	USNM E13720	73	48	1.52	21	3.48	30
Madagascar	MCZ 4303	86	73	1.18	50	1.70	35
Madagascar	MCZ 4303	95	78	1.21	56	1.70	37
Kenya	BMNH 1974.2.6.22	93	64	1.45	24	3.87	28
Philippines	USNM 32634 (H)	122	89	1.37	40	3.05	40
Philippines	USNM 40867	126	90	1.40	42	3.00	40
Philippines	WAM 147-71	139	100	1.39	38	3.66	40
Madagascar	MCZ 4296	150	90	1.66	30	5.0	40
Keppel Bay	AM J8662	154	95	1.62	30	5.13	48
Heron I.	NMNZ 1828	154	96	1.60	34	4.53	50
Townsville	JCU	160	105	1.52	34	4.70	40
Exmouth	WAM 228-73	161	100	1.61	28	5.75	43
Western Australia	WAM 13-62 (H)	162	102	1.59	28	5.78	48

pigment. The actinal surface was very strikingly coloured in a distinct pattern. The inferomarginal and bordering intermediate plates were maroon, but this colour lightened to pink on the underside proper, although the sutural grooves between the plates remained dark. The mouth spines, adambulacral furrow combs, and the row of tubercular spines behind, were pure white, and the tubefeet orange. At the tip of each arm there was a lens-shaped patch of orange either side of the ambulacral groove, and the terminal spines were also orange. The stellate group of plates at the mouth angles were bright violet, and each plate was surrounded by a band of vivid orange.

The dried Keppel Bay specimen is brown with the stellate group of violet plates near the mouth angles bordered by orange granules.

The colour of the Philippine specimen, WAM 147-71, was recorded shortly after preservation. The plates and trabeculae of the aboral surface were a rich purple, the papular areas pale yellow; the central four to six plates near the mouth angles were orange and the adambulacral spines dirty white.

The colour of the Exmouth, W.A., specimen, WAM 228-73, was recorded when the asteroid was received frozen at the Western Australian Museum.

The aboral surface was a uniform bright orange, the oral surface light apricot orange and the furrow spines cream. The eight plates near the mouth angles were bright violet bordered by a band of orange granules.

Distribution

Halityle regularis is now known from the Philippine Islands south to about the tropic of Capricorn on both east and west coasts of Australia, and from the coasts of east Africa and Madagascar. It may be expected to occur along the northern shore of the Indian Ocean. The species is still known from a few widely distributed specimens, taken in fairly shallow water (3 to 90 m). The substrate, where recorded, was sandy rubble, coral or lithothamnion.

Remarks

The new material of *Halityle regularis* agrees well with Fisher's (1913, 1919) descriptions. The size range now available shows that there is little morphological change throughout growth. The arms become slightly longer and narrower with increasing size and the marginal plates, prominent in most small and medium sized specimens, tend to be obscured by thick skin and intercalated by actinal plates in very large specimens.

The most startling new feature of the specimens is their fresh colour, particularly that of the oral surface.

Fisher's description of the living colour of the types as "maroon red on ventral surface; darker on dorsal surface" was of course second-hand, being based on notes recorded by the collectors on board the USFS *Albatross* while in Philippine waters. Considering that the colour notes on the *Albatross* specimens are few and far between in Fisher's report, and that there is not even a mention of the spectacular colours of such genera as *Asterodiscus* and *Oreaster*, one must assume that the notes on *Halityle* were minimal. Among the Australian specimens, the one from Heron Island is closest to the above description, with the exception of the spectacular violet plates near the mouth, which were not mentioned by Fisher. Although the general colour is variable, there is some constancy in the colour of the plates near the mouth: violet in the Kenyan and Australian examples, and bright orange in the Philippine and Somalia specimens.

The second nominal species, *H. anamesus* (H.L. Clark), synonymized with *H. regularis* Fisher by Döderlein (1935), was originally described under the new generic name of *Culcitaster*. Fisher (1919) subsequently synonymized that genus with *Halityle* but did not comment on the status of the species.

Döderlein listed *H. anamesus* in the synonymy of *H. regularis* without comment and apparently without examining any specimens. Observations on the present specimens show that despite considerable difference in appearance between the types of *H. regularis* and *H. anamesus*, due to concealment of the inferomarginal plates by the overgrowth and intercalation of actinal plates and increase in skin thickness over the superomarginals in the latter, the differences are a matter of degree rather than a real difference. Fisher noted the intercalation of actinal plates among the inferomarginals in an incipient form in the type. The specimens examined show great variation in this feature which is most obvious in very large Australian specimens but was also seen in the four Madagascar specimens which ranged in size from R of 54 mm to 150 mm whereas it is not at all evident in the other four east African examples (Pl. 1, a,b).

The present study therefore confirms Döderlein's hitherto unsubstantiated view that *Halityle anamesus* is a junior synonym of *H. regularis*.

ACKNOWLEDGEMENTS

We are grateful to the following persons for assistance in obtaining specimens of *Halityle*: Messrs Alastair Birtles, Neville Coleman, Kenneth O'Gower, and Richard Rowe.

We also thank Drs F.H.C. Hotchkiss and D.L. Pawson for drawing to our attention and lending us the Smithsonian Institution's International Indian Ocean Expedition material. The Keppel Bay specimen was kindly provided by Dr F.W.E. Rowe of the Australian Museum.

We thank the Smithsonian Institution for sending Fisher's USNM 40867 to A.N.B. for examination, the British Museum (Natural History) for allowing L.M.M. to examine the Kenya specimen, and the Museum of Comparative Zoology for the loan of the Madagascar specimens.

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BIRDS OF LAKE MAGENTA WILDLIFE SANCTUARY, WESTERN AUSTRALIA

JOHN DELL*

[Received 16 July 1975. Accepted 1 October 1975. Published 30 September 1976.]

INTRODUCTION

Lake Magenta Wildlife Sanctuary (no. A25113) was proclaimed an 'A' Class Reserve on 5 September 1958 for the purpose of maintaining in perpetuity a representative sample of southern mallee country and is vested in the Western Australian Wildlife Authority. It has an area of 94170 ha and is located east of Pingrup and north of Jerramungup near the southeastern edge of the Western Australian wheatbelt. A notable physiographic feature of this region is the absence of rivers and the presence of salt lakes. Included in the reserve are many of the salt pans of Lake Magenta with its chain of small, mostly ephemeral freshwater lakes to the south. There are some laterite-capped kaolinized north-south ridges and gentle undulating country sloping east to Lake Magenta and south towards the sources of the Fitzgerald and Gairdner Rivers (Fig. 1).

There are several soaks along Hall Track which crosses the reserve in an east-west direction about 8 km south of the northern boundary. It is unlikely that there was any permanent potable water outside of the chain of small lakes to the south of the main Magenta salt pans. A small dam (Government Dam or Reidy's Dam) is now present midway along Hall Track in an area where there was formerly a small farm.

Beard (1967) indicates that the dominant vegetation is mallee and heath. A feature of the vegetation is an almost insular block of mallee (of which *Eucalyptus platypus* forms almost pure stands) and Salmon Gum (*E. salmonophloia*) woodland. This block is surrounded to the north, west and south by scrub and heath of varying height and to the east by Lake Magenta with its fringes of *Melaleuca*.

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In February 1972, a fierce fire burnt through ca 10,000 ha from the northwest boundary, through Sullivan Soak, across the wide firebreak along Hall Track before stopping at a previously burnt area of *Eucalyptus tetragona* about 5 km south of Hall Track.

Mean annual rainfall at the Lake Magenta Wildlife Sanctuary is about 350 mm (the mean at Lake Grace, 64 km to the northwest is 357 mm with recorded extremes of 212 and 596 mm). Most rain falls in the four months May to August.

With the exception of a brief survey of its birds in 1953 and 1963 by G.M. Storr (unpublished), little is known of the biota of this reserve. For this reason it was chosen as part of the vertebrate faunal survey by the Western Australian Museum (Kitchener, 1976). Because of the size of the reserve, the diversity of vegetation types, and the limited access, only the information gained on birds and reptiles was adequate for publication.

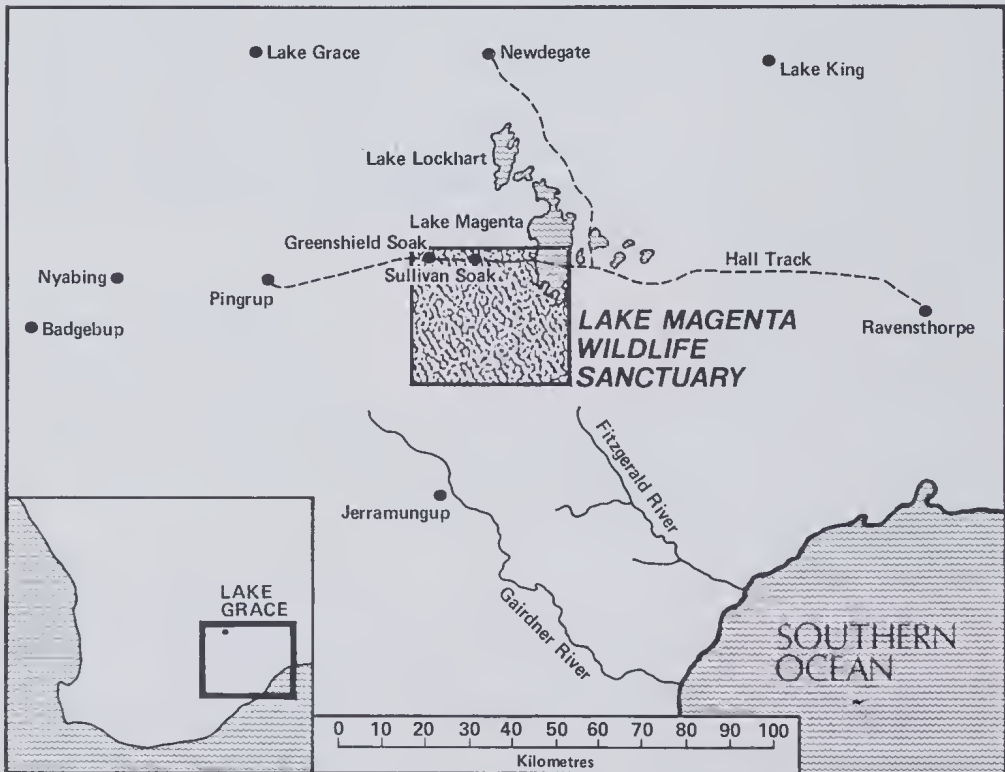


Fig. 1: Map of Lake Magenta Wildlife Sanctuary showing location of places mentioned in text.

Although various ornithologists have remarked on range extensions resulting from clearing for agriculture, little emphasis has been placed on documenting the resultant fragmentation of bird distributions. This reserve is in an area where clearing for agriculture has expanded rapidly in the last two decades, and it is important to document present distributions. This contribution examines the distribution and habitat of birds of the Lake Magenta area and makes comparisons with a list for nearby Lake Grace (Carnaby, 1933) published 40 years previously. It combines the observations of Storr who travelled between Pingrup and Lake Magenta along Hall Track during 3-5 February 1953 and from Pingrup to Lake Grace, to Newdegate, south to Hall Track (east of Lake Magenta) and west to Pingrup during 25-27 November 1963; of L.A. Smith compiled during 3-13 April 1971; and of the author during 4-13 October 1972. Unless otherwise indicated data refer to information gained within Lake Magenta Sanctuary.

ANNOTATED LIST

Emu (*Dromaius novaehollandiae*). Sparse throughout Reserve and adjacent country. Breeding: adult with three half-grown young on farmland west of Greenshield Soak on 5 February 1953; adult with seven small chicks on firebreak in low regrowth mallee on 12 October 1972; old nest with eggshells in *Eucalyptus platypus* mallee in October 1972.

Hoary-headed Grebe (*Podiceps poliocephalus*). Twenty on freshwater lake ca 500 m x 400 m, and two on freshwater lake ca 1600 m x 1400 m at southwest fringes of Lake Magenta in October 1972.

Pelican (*Pelecanus conspicillatus*). Four over Newdegate on 26 November 1963 at 0750 hours.

White-faced Heron (*Ardea novaehollandiae*). One at freshwater swamp, 35 km south of Newdegate on 27 November 1963, and one on swamp 19 km north of Hall Track on east side of Lake Magenta on 27 November, 1963.

Black Swan (*Cygnus atratus*). Approximately 50 on freshwater lake ca 1600 m x 1400 m and five on smaller lake at southwest fringes of Lake Magenta in October 1972. Two on salt lake 6.5 km west of Pingrup on 25 November 1963.

Mountain Duck (*Tadorna tadornoides*). Approximately 1,000 on salt lake 6.5 km west of Pingrup on 25 November 1963; ca 27 on salt lake

8.4 km south of Newdegate on 27 November 1963; ca 30 on small freshwater lake on southwest fringes of Lake Magenta in October 1972.

Grey Teal (*Anas gibberifrons*). Approximately 200 on salt lake 6.5 km west of Pingrup on 25 November 1963; ca 300 on small freshwater lake 14 km north of Pingrup on 25 November 1963; ca 100 on small lake 13 km south of Lake Grace on 25 November 1963; 15 on freshwater swamp 19 km north of Hall Track on east side of Lake Magenta on 27 November 1963; ca 300 on freshwater lake, 500 m x 400 m, and ca 50 on freshwater lake, 1600 m x 1400 m, on southwest fringes of Lake Magenta in October 1972.

Black Duck (*Anas superciliosa*). Remains of dead bird in sedges lining freshwater lake on southwest fringe of Lake Magenta in October 1972. Ten adults, one pair with 15 young, on small lake 13 km east of Lake Grace on 25 November 1963.

Blue-winged Shoveler (*Anas rhynchotis*). Nine among large flock of Grey Teal on freshwater lake on southwest fringes of Lake Magenta in October 1972.

Wood Duck (*Chenonetta jubata*). A male on freshwater lake 19 km north of Pingrup on 25 November 1963; a male on swamp 18 km south of Lake Grace on 25 November 1963; ten on swamp 19 km north of Hall Track on east side of Lake Magenta on 27 November 1963: seven on one freshwater lake and four on another at southwest fringe of Lake Magenta in October 1972.

Musk Duck (*Biziura lobata*). A pair on freshwater lake at southwest fringe of Lake Magenta in October 1972.

Square-tailed Kite (*Lophoictinia isura*). Frequent throughout Reserve in October 1972, hunting over Salmon Gum (*Eucalyptus salmonophloia*) woodland, mallee, and heath.

Whistling Kite (*Haliastur sphenurus*). Two over Lake Magenta on 27 November 1963; one over sandplain and mallee on northwest side of Lake Magenta on 7 October 1972.

Brown Goshawk (*Accipiter fasciatus*). A pair in Salmon Gums 25 km east of Pingrup on 3 February 1953; pair with nest 10 m from ground in Salmon Gum 7 km west of Lake Magenta during October 1972.

Little Eagle (*Aquila morphnoides*). A white-phase bird recorded in 'woodland' on 4 February 1953.

Wedge-tailed Eagle (*Aquila audax*). One at Sullivan Soak on 5 February 1953; recorded in April 1971; one high over Salmon Gum woodland on 9 October 1972.

Little Falcon (*Falco longipennis*). One chasing Yellow-throated Miners at dusk in burnt Salmon Gums at Sullivan Soak on 10 October 1972.

Brown Falcon (*Falco berigora*). Several outside Reserve in February 1953 and November 1963. Recorded in Reserve in April 1971. Occasionally along tracks in mallee and Salmon Gums; more plentiful in burnt country in October 1972.

Nankeen Kestrel (*Falco cenchroides*). One over farmland 14 km south of Newdegate on 26 November 1963; one carrying lizard, probably *Amphibolurus*, 10 km west of Greenshield Soak on edge of burnt area on 27 November 1963.

Mallee Fowl (*Leipoa ocellata*). Adult bird on road 9 km east of Pingrup on 3 February 1953; nest in use 7 km east of Sullivan Soak on 3 February 1953; old nest in burnt area at Greenshield Soak in November 1963; old nests recorded in April 1971. No sightings of old nests or birds in October 1972.

Little Quail (*Turnix velox*). One recorded 14 km east of Lake Grace on 25 November 1963; one in mallee/heath 39 km south of Newdegate on 26 November 1963; two at Greenshield Soak in burnt area on 27 November 1963.

Coot (*Fulica atra*). Approximately 70 on freshwater lakes at southwest fringes of Lake Magenta in October 1972.

Bustard (*Otis australis*). One near Greenshield Soak in April 1971.

Banded Plover (*Vanellus tricolor*). Three at Pingrup on 3 February 1953; ten sheltering in shade of mallees 27 km south of Newdegate on 26 November 1963.

Red-capped Dotterel (*Charadrius ruficapillus*). One at Hall Track crossing of Lake Magenta on 4 February 1953; ca 30 on salt pans of Lake Magenta

and 14 at freshwater lakes at southwest fringes of Lake Magenta in October 1972.

Hooded Dotterel (*Charadrius cucullatus*). One on small salt lake 25 km south of Newdegate on 26 November 1963; three on salt pans of Lake Magenta in October 1972. A specimen collected on 7 October 1972 had developing ovarian follicles, the largest 3.1 mm. The stomach contained fragments of gastropod shells, probably *Coxiella*.

Black-fronted Dotterel (*Charadrius melanops*). One at edge of freshwater lake at southwest fringe of Lake Magenta on 5 October 1972.

Sharp-tailed Sandpiper (*Calidris acuminata*). One on small salt lake 23 km south of Newdegate on 26 November 1963.

White-headed Stilt (*Himantopus himantopus*). Two on small lake 18 km south of Lake Grace and three 12 km east of Lake Grace on 25 November 1963.

Banded Stilt (*Cladorhynchus leucocephalus*). Approximately 50 at 7 km west of Pingrup on 25 November 1963.

Avocet (*Recurvirostra novaehollandiae*). Seven at 14 km south of Lake Grace on 25 November 1963; one on shore of nearly dry lake 14 km south of Newdegate on 27 November 1963; 18 in shallows of freshwater swamp with partially submerged Swamp Yates 44 km south of Newdegate on 27 November 1963; one on small lake 10 km north of Pingrup on 4 October 1972.

Common Bronzewing (*Phaps chalcoptera*). In February 1953 five single birds sighted in the Reserve; in November 1963 one sighted; in October 1972 four in Salmon Gum and mallee. During February 1953 twenty-three were sighted in a 28 km drive between Badgebup and Nyabing. I doubt whether similar counts could be made in this region now.

Brush Bronzewing (*Phaps elegans*). Possible sighting of single bird at granite outcrop near Greenshield Soak on 10 April 1971.

Purple-crowned Lorikeet (*Glossopsitta porphyrocephala*). Approximately 20 in Salmon Gums and four in mallee in Reserve in February 1953. Not recorded in November 1963. Recorded in April 1971. During October 1972

at least 50 pairs breeding in Salmon Gums. Young heard being fed in some of the nests on 8 October. Paired birds were combining into small flocks to feed in flowering *E. sargentii* mallee.

White-tailed Black Cockatoo (*Calyptorhynchus baudinii*). A pair in Salmon Gums 4 km southeast of Lake Magenta on 5 October 1972.

Smoker Parrot (*Polytelis anthopeplus*). One recorded 27 km east of Pingrup on 3 February 1953; six in Salmon Gums between Sullivan Soak and Lake Magenta on 4 February 1953. Large flocks recorded in the Nyabing area on 3 February 1953. Not recorded in November 1963, April 1971 or October 1972. This decline is evident throughout the Wheatbelt, as sightings of up to five birds are now only made at widely scattered localities.

Western Rosella (*Platycercus icterotis*). Recorded in Salmon Gums 7 km west of Lake Magenta on 4 February 1953. A pair in flowering *Melaleuca acuminata* among Salmon Gum woodland in the same area on 10 October 1972.

Port Lincoln Parrot (*Platycercus zonarius*). Occasional birds recorded each time the Reserve was visited.

Elegant Parrot (*Neophema elegans*). Two at 12 km east of Nyabing on 5 February 1953; five at 22 km north of Pingrup on 25 November 1963.

Pallid Cuckoo (*Cuculus pallidus*). One on west side of Lake Magenta on 5 October 1972.

Fan-tailed Cuckoo (*Cuculus flabelliformis*). Sighted occasionally in Salmon Gum woodland during October 1972.

Horsfield Bronze Cuckoo (*Chrysococcyx basalis*). One on east side of Lake Magenta on 5 October 1972, and another at the southwest end of Lake Magenta on 8 October 1972.

Golden Bronze Cuckoo (*Chrysococcyx lucidus*). Frequent in Reserve during October 1972. Mostly singly or in pairs, in mallee and Salmon Gum woodland. Three pairs in Salmon Gums on 10 October 1972 were in close proximity and displaying and calling loudly.

Boobook Owl (*Ninox novaeseelandiae*). Not recorded in February 1953 or November 1963. Heard during April 1971. During October 1972 heard nearly every night in Salmon Gums. Several seen while spotlighting along Hall Track in Salmon Gums.

Tawny Frogmouth (*Podargus strigoides*). Two in tall mallee 9 km east of Pingrup on 3 February 1953. Recorded in April 1971. During October 1972 five birds seen in mallee, chiefly *E. platypus*, during a 6 km spotlighting run along Hall Track. Nest with adult sitting, on top of Salmon Gum stump, 4 m from ground on 8 October 1972.

Crested Owlet-nightjar (*Aegotheles cristatus*). Heard nearly every night in Salmon Gums during the October 1972 survey. One flushed from hollow tree during daytime.

Laughing Kookaburra (*Dacelo gigas*). Heard during April 1971. One calling near Sullivan Soak during October 1972.

Black-tailed Bee-eater (*Merops ornatus*). Three at Greenshield Soak on 5 February 1953; four at Sullivan Soak on 8 October 1972; two on fire-break in sandplain near freshwater lakes at southwest fringe of Lake Magenta on 8 October 1972.

Welcome Swallow (*Hirundo neoxena*). Sparse outside Reserve in towns and farm country. Recorded at Newdegate on 25 November 1963; at farm tank 42 km south of Newdegate on 27 November 1963; at farm 50 km south of Newdegate on 27 November 1963.

Tree Martin (*Hirundo nigricans*). Recorded at 27 km and 28 km east of Pingrup on 3 February 1953; in Salmon Gums 5 km west of Lake Magenta, and open *Melaleuca* and *Eucalyptus spathulata* woodland east of Lake Magenta on 4 February 1953. Not recorded in November 1963. Recorded five times during October 1972, total approximately 40 birds including 20 flying south over freshwater lakes at southwest fringe of Lake Magenta.

Richard's Pipit (*Anthus novaeseelandiae*). Recorded frequently in February 1963 in cleared country. Sparse in Reserve in October 1972 round edges of Lake Magenta, on firebreaks, and in bare burnt country near Sullivan Soak.

Black-faced Cuckoo-shrike (*Coracina novaehollandiae*). Recorded in Reserve during February 1953; at and to the south of Newdegate in Nov-

ember 1963; and in Reserve during April 1971. Nine sightings totalling twelve individuals in Salmon Gums and mallee, including burnt mallee, in October 1972.

White-winged Triller (*Lalage sueurii*). Pair in regenerating mallee on firebreak on 13 October 1972.

Southern Scrub-robin (*Drymodes brunneopygia*). Recorded during February 1953, November 1963 and October 1972. In 1972 it was widespread in mallee, especially under dense understories of *Melaleuca*, *Hakea* and *Daviesia*.

White-browed Babbler (*Pomatostomus superciliosus*). Sparse in woodland in Reserve. Three groups recorded in 1953: in Salmon Gums 7 km west of Lake Magenta on 4 February; in 'woodland savannah' 2 km east of Lake Magenta on 4 February; in mallee an Greenshield Soak on 5 February. Only one pair recorded in 1972 on 5 October in Salmon Gums feeding under *Melaleuca acuminata*. This bird is rare in large blocks of undisturbed vegetation, but is much more frequent in road-verges and fringes of cleared country. It has no doubt increased since clearing.

Blue-breasted Wren (*Malurus pulcherrimus*). Recorded in February 1953 and October 1972. Widespread in Reserve in heath, dense vegetation round freshwater lakes, and mallee with under-shrubbery of *Melaleuca*, *Hakea*, *Daviesia*, and *Exocarpus aphyllus*. Nuptial male, female ratio in October 1972 was 5 : 6.

Western Warbler (*Gerygone fusca*). Single bird feeding in *Melaleuca thyoides* and *Eucalyptus spathulata* on eastern side of Lake Magenta on 5 October 1972 and single bird in *E. annulata* mallee at Greenshield Soak on 10 October.

Broad-tailed Thornbill (*Acanthiza pusilla apicalis*). Recorded in February 1953 and October 1972. In 1972 all sightings were of pairs of birds. A fledgling scarcely able to fly was being fed in *Exocarpus aphyllus* under mallee on 8 October.

Chestnut-rumped Thornbill (*Acanthiza uropygialis*). Recorded 2 km east of Lake Magenta on Hall Track on 4 February 1953 in 'savannah woodland'. This species inhabits open vegetation and its absence from the mostly dense vegetation at Lake Magenta reserve was predictable.

Yellow-rumped Thornbill (*Acanthiza chrysorrhoa*). Recorded in February 1953 and October 1972 in Salmon Gum woodland, open grassy flats at Sullivan and Greenshield Soaks, in mixed eastern fringes of freshwater lakes, and open grassy edges of Lake Magenta. Two adults feeding two young among *Melaleuca thyoides* on east side of Lake Magenta on 11 October; two adults with nest, 2 eggs, one metre from ground in *Melaleuca thyoides* at extreme west edge of Lake Magenta on 12 October.

Spotted Scrub-Wren (*Sericornis frontalis maculatus*). Recorded in February 1953 and October 1972 in *Melaleuca thyoides* fringing Lake Magenta.

Weebill (*Smicrornis brevirostris*). Recorded in February 1953, November 1963 and October 1972. In 1972 particularly common in *Eucalyptus annulata* and *E. spathulata*. Also feeding in *Melaleuca thyoides*.

Shy Ground-wren (*Hylacola cauta*). Recorded in February 1953, November 1963 and October 1972. Widespread in heath with *Eucalyptus tetragona* and *Eucalyptus* sp. emergents and in mallee regrowth to one metre with low shrubs and sparse litter.

Field Wren (*Calamanthus fuliginosus*). Several flushed in heath at northern end of Reserve 40 km south of Newdegate on 26 November 1963.

White-fronted Chat (*Epthianura albifrons*). Recorded twice in samphires at Lake Magenta in October 1972.

Brown Flycatcher (*Microeca leucophaea*). Two recorded in 'savannah woodland' 2 km east of Lake Magenta on 4 February 1953.

Red-capped Robin (*Petroica goodenovii*). In February 1953 a pair recorded in woodland 7 km west of Lake Magenta and another at 2 km east of Lake Magenta in 'savannah woodland'. In October 1972 fairly plentiful in *Eucalyptus spathulata* and *Melaleuca thyoides* association fringing Lake Magenta but sparse on the west side where the *E. spathulata* and *M. thyoides* were less than half the stature of those growing on deeper wind-deposited soils on the east side.

The population on the east side of Lake Magenta was very dense and comparable to that in *Melaleuca pubescens* thickets fringing the salt lakes on Rottnest Island (Dell, unpublished). At Lake Magenta the preferred habitat included *E. spathulata* which forms many-branched often thick-trunked trees to 11 m, mainly in groups or scattered on higher ground.

Mingled throughout the *E. spathulata* and becoming dominant in lower areas and depressions were dense, often rounded *M. thyoides* to 4.5 m with bluebush (*Kochia oppositifolia*) to a height of 80 cm. Many of the glades were carpeted with grasses and composites to 5-10 cm and there was considerable bare ground. Decaying logs of *M. thyoides* were abundant as were carpets of moss among which the birds were feeding.

A nest with two newly hatched young was 2.3 m from the ground in a *M. thyoides* on 11 October. The rim and exterior of the nest was composed largely of moss.

Western Yellow Robin (*Eopsaltria australis griseogularis*). Pair recorded in tall mallee 8 km east of Pingrup on 3 February 1953; two pairs engaged in territorial fighting under *Melaleuca acuminata* in *Eucalyptus salmonophloia* woodland on 5 October 1972.

Grey Fantail (*Rhipidura fuliginosa*). Recorded during February 1953, April 1971 and October 1972. In 1972 five sightings totalling six birds in *E. spathulata* fringing Lake Magenta and in Salmon Gums.

Willie Wagtail (*Rhipidura leucophrys*). Recorded in February 1953, November 1963 and October 1972. In 1972 six sightings totalling seven birds in Salmon Gum woodland and near freshwater lakes fringing the southwest end of Lake Magenta.

Restless Flycatcher (*Myiagra inquieta*). One near freshwater lakes at southwest fringe of Lake Magenta and a pair recorded four times in Salmon Gum woodland during October 1972.

Golden Whistler (*Pachycephala pectoralis*). One pair recorded in February 1953. Not recorded in November 1963 or April 1971. In October 1972 frequent in Salmon Gum woodland and adjacent mallee; and sparse east of Lake Magenta in *E. spathulata* and *Melaleuca thyoides*.

Rufous Whistler (*Pachycephala rufiventris*). One in Salmon Gum woodland 7 km west of Lake Magenta on 27 November 1963.

Western Shrike-thrush (*Colluricincla harmonica rufiventris*). Not recorded in February 1953 or November 1963. Recorded in April 1971 and widespread in Salmon Gums and mallee in October 1972.

Crested Bellbird (*Oreoica gutturalis*). Recorded on each trip to the

Reserve mainly in shrubbery under mallee and in heath. Two adults feeding fledgling not able to fly on 6 October 1972 in *Melaleuca* under mallee. Nest (clutch 3) in *Exocarpus aphyllus* under mallee, 70 cm from ground on 8 October.

Black-capped Sittella (*Neositta chrysoptera pileata*). Four in Salmon Gum woodland on 11 October 1972.

Rufous Tree-creeper (*Climacteris rufa*). Recorded twice in woodland 7 km west of Lake Magenta on Hall Track in February 1953; single bird in same area in October 1972.

Mistletoe-bird (*Dicaeum hirundinaceum*). One in Salmon Gums at Greenshield Soak on 5 February 1953 (D.L. Serventy pers. comm.).

Spotted Pardalote (*Pardalotus punctatus*). Common in Reserve in October 1972 throughout mallee and sandplain where there were mallee emergents. Breeding burrows along all tracks and firebreaks throughout Reserve.

Red-tipped Pardalote (*Pardalotus striatus substriatus*). Recorded in February 1953, November 1963 and October 1972 feeding among foliage of eucalypts. In October apparently moving south through Reserve, feeding as they went.

Western Silvereeye (*Zosterops lateralis gouldi*). Not recorded in 1953, 1963 or 1971. In October 1972 common in *Melaleuca thyoides* fringing Lake Magenta, sparse in heath with *Eucalyptus tetragona* emergents and in scrub on laterite ridges.

Brown Honeyeater (*Lichmera indistincta*). Recorded three times in February 1953. In October 1972 frequent in flowering *Melaleuca* fringing freshwater lakes and occasional in mallee. A pair giving broken-wing distraction display among *Eucalyptus calycogona* on 8 October were probably nesting.

Singing Honeyeater (*Meliphaga virescens*). Recorded at 13 km south of Newdegate on 26 November 1963. In October 1972 a few in *Eucalyptus spathulata*/*Melaleuca thyoides* association fringing Lake Magenta, and in *Melaleuca* fringes of freshwater lakes at southwest end of Lake Magenta.

Yellow-plumed Honeyeater (*Meliphaga ornata*). A few recorded in woodland in February 1953. In October 1972 moderately common in

woodland, feeding among foliage of Salmon Gums.

Purple-gaped Honeyeater (*Meliphaga cratitia*). Recorded in mallee and woodland in February 1953 and October 1972. Feeding in flowering *Eucalyptus annulata* and *Grevillea patentiloba* at Greenshield Soak in October. Parent feeding two newly-flying young in low mallee with shrub layer to 1.5 m on 10 October.

White-eared Honeyeater (*Meliphaga leucotis*). Possible record at 26 km east of Pingrup in dense whipstick mallee merging into Salmon Gum on 3 February 1953; recorded at Sullivan Soak in open Salmon Gum woodland surrounded by mallee and *Acacia* on 5 February 1953. The apparent scarcity of this bird near Lake Magenta was not expected considering its abundance in mallee elsewhere in the wheatbelt.

Brown-headed Honeyeater (*Melithreptus brevirostris*). Recorded during February 1953 in Salmon Gum woodland and *Eucalyptus platypus* mallee. In October 1972 flocks of up to seven feeding among foliage of Salmon Gums, *E. platypus*, and *E. calycogona* and taking insects from flower-buds of *E. annulata*.

Tawny-crowned Honeyeater (*Phylidonyris melanops*). Recorded in February 1953, April 1971, and October 1972 in heath and sandplain. Breeding at Greenshield Soak : 5 October, two juveniles being fed; 10 October, nest with clutch two; 12 October, nest with clutch three.

Yellow-winged Honeyeater (*Phylidonyris novaehollandiae*). Frequent in Reserve in October 1972 in Salmon Gum woodland feeding among flowering *Melaleuca acuminata*.

Yellow-throated Miner (*Manorina flavigula*). Recorded on 3 February 1953 at Pingrup; 4 February at Sullivan Soak; 26 November 1963 at 2 km south, 13 km south, and 19 km south of Newdegate; 27 November at Sullivan Soak; October 1972, five at Sullivan Soak.

Red Wattle-bird (*Anthochaera carunculata*). Recorded in February 1953, November 1963, April 1971 and October 1972. Mainly in Salmon Gum woodland and mallee. Numbers increased during latter part of October 1972 when noisy flocks of up to twenty birds were feeding among flowers *E. annulata* and *E. sargentii* mallee. These flocks were possibly migrating southwards.

Magpie-lark (*Grallina cyanoleuca*). Recorded on 25 November 1963 at Pingrup, at 18 km north of Pingrup, at 18 km south of Lake Grace, at 12 km south of Lake Grace, and at 12 km east of Lake Grace; on 26 November 1963 at Newdegate, and at 9 km north of Hall Track on each side of Lake Magenta; in October 1972 a pair on grassy flats at Sullivan Soak.

Black-faced Wood-Swallow (*Artamus cinereus*). Recorded on 25 November 1963 at small lake 13 km south of Lake Grace, at 10 km south of Lake Grace, at 19 km west of Newdegate, at 23 km west of Newdegate.

Dusky Wood-Swallow (*Artamus cyanopterus*). Recorded in February 1953 and October 1972 in Salmon Gum woodland.

Grey Currawong (*Strepera versicolor*). Recorded on all visits. Nest with large young in Salmon Gum, 8 m from ground on 8 October 1972.

Grey Butcher-bird (*Cracticus torquatus*). Recorded in February 1953, April 1971 and October 1972 in mallee and Salmon Gum woodland.

Western Magpie (*Cracticus tibicen dorsalis*). Sparse in Reserve and adjacent country. In Reserve only in open Salmon Gum woodland or burnt areas.

Australian Raven (*Corvus coronoides*). Moderately common in Reserve and adjacent country. Bird sitting on nest in *Eucalyptus spathulata*, 10 m from ground on east side of Lake Magenta on 11 October 1972.

Little Crow (*Corvus bennetti*). Small flock on 9 October 1972 and eight in thermal over Lake Magenta on 11 October 1972.

DISCUSSION

Carnaby (1933) made the first attempt to list the avifauna of an inland district of southern Western Australia. It is noteworthy that his list of 132 species is still the largest for inland Western Australia, cf Tarin Rock Reserve with 86 species (Dell & Johnstone, 1976) and Lake Magenta with 98 species (this report). Carnaby (1938) provided further comments on Lake

Grace birds together with a list for Hatters Hill, approximately 145 km east of Lake Grace.

Some of the lake or littoral birds recorded by Carnaby at Lake Grace could also occur at Lake Magenta. These include : Black-tailed Native Hen (*Gallinula ventralis*), Red-kneed Dotterel (*Charadrius cinctus*), White-necked Heron (*Ardea pacifica*) and Chestnut Teal (*Anas castanea*). Ten species of land birds included in the Lake Grace list but not recorded at Lake Magenta were Australian Dotterel (*Peltohyas australis*), King Parrot (*Purpureicephalus spurius*), White-backed Swallow (*Cheramoeca leucosterna*), Scarlet Robin (*Petroica multicolor*), Gilbert Whistler (*Pachycephala inornata*), Western Shrike-tit (*Falcunculus frontatus leucogaster*), Redthroat (*Pyrrholaemus brunneus*), Pied Honeyeater (*Certhionyx variegatus*), Spiny-cheeked Honeyeater (*Acanthagenys rufogularis*) and Pied Butcher-bird (*Cracticus nigrogularis*). Several of these probably occur in suitable habitat at Lake Magenta.

Birds recorded as common or frequent at Lake Grace in 1933 but evidently much scarcer now at Lake Magenta are Brown Hawk (*Falco berigora*), Smoker Parrot (*Polytelis anthopeplus*), Western Rosella (*Platycercus icterotis*), Restless Flycatcher (*Myiagra inquieta*), Western Warbler (*Gerygone fusca*), White-browed Babbler (*Pomatostomus superciliosus*) and Yellow-throated Miner (*Manorina flavigula*). Most of these are species which have undergone a general decline throughout the wheatbelt. The situation regarding the Redthroat, Spiny-cheeked Honeyeater and Pied Butcher-bird is obscure. The southern limit of the Redthroat is Lake Grace and Lake King (Serventy and Whittell, 1967). It is fairly frequent around the fringes of Lake Grace (W.K. Youngson, *pers. comm.* March 1973) but is absent in similar vegetation at Lake Magenta; it occurs at Bendering (Dell, unpublished) but is absent from Tarin Rock (Dell & Johnstone, 1976). The Spiny-cheeked Honeyeater was listed as plentiful at Lake Grace (Carnaby, 1933) and present at Hatters Hill (Carnaby, 1938) but was not recorded at Tarin Rock, Bendering or Lake Magenta. Serventy & Whittell (1967) indicate its distribution as west and south to Kojonup, Broomehill and Bremer Bay. The range of the Pied Butcherbird is south to Lake Grace although scarce south of a line joining Wongan Hills, Wyalkatchem, Merredin and Kalgoorlie (Serventy & Whittell, 1967). Carnaby (1933) listed it as rather scarce at Lake Grace and also occurring at Hatters Hill. Its present status in the southern wheatbelt probably has not altered since Carnaby's time.

The Blue-breasted Wren (*Malurus pulcherrimus*) and Purple-gaped Honeyeater (*Meliphaga cratitia*) are moderately common at Tarin Rock and Lake

Magenta, and it is likely that they have increased in abundance since Carnaby listed them as rare in 1933 at Lake Grace. The Spotted Pardalote (*Pardalotus punctatus*) was common at Lake Magenta in October 1972. Although Carnaby (1933) described it as plentiful at Lake Grace, this record was ignored by subsequent authors (e.g. Serventy & Whittell, 1967) who stated that this species was only found west of a line joining Moora and the Stirling Range.

Only 15 of the 98 species listed in this report were noted to be breeding, but probably many more breed in the Lake Magenta area. Limited current knowledge precludes any statement about breeding seasons.

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TWO NEW SPECIES OF DAMSELFISHES (POMACENTRIDAE) FROM WESTERN AUSTRALIA

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ABSTRACT

Two new species of damselfishes belonging to the genus *Chromis* are described from Western Australia. *C. megalopsis* is described from two specimens taken by bottom trawl in 70-85 metres near Bernier Island and off Cape Cuvier. The salient features of this species include a large eye (2.3 to 2.4 in head length) and exposed suborbital margin. *C. westaustralis* n.sp. is closely related to *C. fumea* Tanaka from Taiwan, the Ryukyu Islands and Western Australia. The two species are separable, however, on the basis of coloration, maximum size, anal ray count, and the condition of the preopercle margin. In addition to the description of new taxa, the species of Pomacentridae of Western Australia, including 26 previously unrecorded forms, are briefly reviewed.

INTRODUCTION

Pomacentridae is one of the largest families of reef fishes, containing approximately 250 species. They occur primarily in the tropics, but several are found at temperate latitudes. The distribution includes Atlantic, Mediterranean, and Indo-Pacific reefs, but the majority of species are confined to the latter region.

Whitley (1948) listed the following representatives from Western Australia (if no longer valid present allocation indicated in parentheses): *Actinochromis victoriae* Günther (*Parma victoriae*); *Amphiprion melanostolus* Richardson (*A. clarkii* Bennett); *A. milii* Bory de St. Vincent (*A. clarkii*); *A. rubroinctus* Richardson; *Chromis klunzingeri* Whitley; *C. scotochil-*

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opterus (non Fowler; = *C. westaustralis* n.sp.); *Dischistodus perspicillatus* (non Cuvier and Valenciennes; = *D. prosopotaenia* (Bleeker)); *Glyphisodon septemfasciatus* Cuvier and Valenciennes (*Abudefduf septemfasciatus*); *Glyphisodon palmeri* Cockrell (*Abudefduf bengalensis* (Bloch)); *Parapomacentrus* n.sp. (not described in subsequent literature, but probably synonymous with *Neopomacentrus filamentosus* (Macleay); *Parma maccullochi* Whitley; *Pomacentrus obreptus* Whitley (*Eupomacentrus obreptus*); *Pseudopomacentrus fasciatus* (Macleay) (*Dischistodus fasciatus* (Cuvier)).

Mees (1960) recorded *Amphiprion melanopus* Bleeker from Yampi Sound. This is a misidentification and actually represents *A. rubrocinctus*. McKay (1970) listed several new pomacentrid records for Western Australia including *Abudefduf anabatoides* Bleeker (= *Neopomacentrus filamentosus*); *A. coelestinus* (Cuvier); *A. saxatilis* (Linnaeus); *A. sordidus* (Forskål); *Amphiprion percula* (non Lacépède; = *A. ocellaris* Cuvier); *Chromis caeruleus* (non Cuvier; = *C. atripectoralis* Welander and Schultz); *Daya jerdoni* (Day) (= *Pristotis jerdoni*); *Dascyllus aruanus* (Linnaeus); *D. reticulatus* (Richardson); *D. trimaculatus* (Rüppell); *Pomacentrus lividus* (Bloch and Schneider) (*Eupomacentrus lividus*); *P. tripunctatus* (non Cuvier; = *P. milleri* Taylor).

During 1974-75 the author examined the pomacentrid collection at the Western Australian Museum and made underwater observations and collections at Albany, Geographe Bay, Rottnest Island, the Houtman Abrolhos, Shark Bay, Northwest Cape, and the Dampier Archipelago. These efforts produced 26 additional records, including two new *Chromis* which are described herein. The known pomacentrid fauna of Western Australia is summarised in Table 1. There are 50 species now recognized from the state, which makes it the fourth largest family, being surpassed only by the Labridae, Serranidae, and Gobiidae.

METHODS OF COUNTING AND MEASURING

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 at which the spine emerges from the scaly sheath. Measurements were made with dial calipers to the nearest 0.1 millimetre (mm). Standard length is abbreviated as SL. The counts and proportional measurements of the holotype are followed by the range of the paratypes in parentheses. The last element of the dorsal and anal fins, which in some specimens appears as a bifurcation of the adjacent ray, is counted separately.

Table 1: Species of Pomacentridae from Western Australia.
 (* represents new record; † = endemic to W.A.)

Species	Approximate distribution in W.A.
<i>Abudefduf bengalensis</i> (Bloch)	Perth northwards
<i>A. coelestinus</i> (Cuvier)	Perth northwards
<i>A. saxatilis</i> (Linnaeus)	Perth northwards
<i>A. septemfasciatus</i> (Cuvier)	Perth northwards
<i>A. sordidus</i> (Forskål)	Carnarvon northwards
* <i>Amblyglyphidodon curacao</i> (Bloch)	Dampier northwards
<i>Amphiprion clarkii</i> (Bennett)	Abrolhos northwards
<i>A. ocellaris</i> Cuvier	Derby northwards
* <i>A. perideraion</i> Bleeker	Carnarvon northwards
<i>A. rubrocinctus</i> Richardson	Carnarvon northwards
* <i>A. sandaracinus</i> Allen	Carnarvon northwards
* <i>Cheiloprion labiatus</i> (Day)	Dampier northwards
<i>Chromis atripectoralis</i> Schultz & Welander	Abrolhos northwards
* <i>C. cinerascens</i> (Cuvier)	Dampier northwards
* <i>C. fumea</i> (Tanaka)	Northwest Cape northwards
<i>C. klunzingeri</i> Whitley	† Albany to Perth
* <i>C. megalopsis</i> Allen	† Shark Bay vicinity
* <i>C. margaritifer</i> Fowler	Carnarvon northwards
* <i>C. weberi</i> Fowler & Bean	Carnarvon northwards
<i>C. westaustralis</i> Allen	† Albany to Northwest Cape
<i>Dascyllus aruanus</i> (Linnaeus)	Abrolhos northwards
<i>D. reticulatus</i> (Richardson)	Abrolhos northwards
<i>D. trimaculatus</i> (Rüppell)	Abrolhos northwards
<i>Dischistodus fasciatus</i> (Cuvier)	Dampier northwards
<i>D. prosopotaenia</i> (Bleeker)	Carnarvon northwards
* <i>Eupomacentrus fasciolatus</i> (Ogilby)	Carnarvon northwards
<i>E. lividus</i> (Bloch & Schneider)	Carnarvon northwards
* <i>E. nigricans</i> (Lacepede)	Carnarvon northwards
<i>E. obreptus</i> (Whitley)	Abrolhos northwards
* <i>Hemiglyphidodon plagiometopon</i> Bleeker	Dampier northwards
* <i>N. azysron</i> (Bleeker)	Carnarvon northwards
* <i>N. cyanomos</i> (Bleeker)	Carnarvon northwards
<i>Neopomacentrus filamentosus</i> (Macleay)	Shark Bay northwards
* <i>Paraglyphidodon behni</i> (Bleeker)	Carnarvon northwards
* <i>P. melas</i> (Cuvier)	Carnarvon northwards
<i>Parma mccullochi</i> Whitley	† Albany to Abrolhos
<i>P. occidentalis</i> Allen & Hoese	† Geographe Bay to Carnarvon
<i>P. victoriae</i> (Günther)	S.A. border to Geographe Bay
* <i>Plectroglyphidodon dickii</i> (Liénard)	Abrolhos northwards
* <i>P. johnstonianus</i> Fowler & Ball	Abrolhos northwards
* <i>P. lacrymatus</i> (Quoy & Gaimard)	Abrolhos northwards
* <i>P. leucozonus</i> (Bleeker)	Abrolhos northwards
* <i>Pomacentrus alexanderæ</i> Evermann & Seale	Dampier northwards
* <i>P. amboinensis</i> Bleeker	Dampier northwards
* <i>P. coelestis</i> Jordan & Starks	Abrolhos northwards
* <i>P. milleri</i> Taylor	Perth northwards
* <i>P. popei</i> Jordan & Seale	Carnarvon northwards
* <i>P. vaiuli</i> Jordan & Seale	Carnarvon northwards
* <i>P. sp.</i>	Carnarvon northwards
<i>Pristotis jerdoni</i> (Day)	Shark Bay northwards

A summary of counts for the dorsal, anal, and pectoral fin rays, gill rakers on the first arch, and tubed lateral-line scales is presented in Table 2.

Type material has been deposited at the following institutions: Australian Museum, Sydney (AM); Bernice P. Bishop Museum, Honolulu (BPBM); British Museum (Natural History), London (BMNH); United States National Museum of Natural History, Washington, D.C. (USNM); Western Australian Museum, Perth (WAM).

Chromis megalopsis n.sp.

(Fig. 1; Tables 2 and 3)

Holotype. — WAM P25207-001, 84.1 mm SL, collected with bottom trawl approximately 40 nautical miles west of Bernier Island, Western Australia (24° 59'S, 112° 27'E) in 71 fathoms by R. George and crew of "Dimantina" on 8 October 1963.

Paratype

WAM P2234, 102.0 mm SL, collected with bottom trawl about 37 nautical miles northwest of Cape Cuvier, Western Australia (approximately 24° 59'S, 113° 00'E) in 70-85 fathoms by J. Penn on 29 July 1972.

Diagnosis

A species of *Chromis* with the following combination of characters: dorsal rays XIII,15 or XIV,14; anal rays II,12 to 13; eye relatively large, 2.3 to 2.4 in head length. suborbital margin exposed. body depth 2.1 in SL; colour generally pale, silvery or whitish on ventral half of body; small diffuse dark spot on uppermost part of pectoral base and dark spot covering most of outer face of pectoral axil.

Description

Dorsal rays XIII,15 (XIV,14); anal rays II,13 (II,12); pectoral rays 19; pelvic rays 1,5; gill rakers on first arch 8 + 20 = 28 (10 + 20 = 30); tubed lateral-line scales 17; horizontal scale rows from terminal lateral-line scale to base of dorsal fin 1-2; from lateral-line to origin of anal fin 9; procurrent spines on upper and lower edge of caudal fin 2.

Body ovate, laterally compressed, the greatest depth 2.1 in the standard length. Head profile conical, the head length contained 2.9 (3.0) in the standard length. The following proportions are expressed into the head



Figure 1: *Chromis megalopis* holotype, 84.1 mm SL, west of Bernier Island, Western Australia.



Figure 2: *Chromis westaustralis*, holotype, 84.0 mm SL, Abrolhos Islands, Western Australia.

length: snout 4.0 (4.3), eye diameter 2.4 (2.3), interorbital width 3.5 (3.2), least depth of caudal peduncle 3.5 (2.3), length of caudal peduncle 4.5 (3.7), of pectoral fin 1.0, of pelvic fin 1.1 (1.0), of caudal fin 1.0 (1.2).

Single nasal opening on each side of snout; mouth oblique, terminally located; lateral-line gently arched beneath dorsal fin, terminating 1-2 scale rows below base of last dorsal spine; lips, chin, isthmus, posterior and inferior limb of preopercle, and area around nostrils naked; remainder of head and body scaled; scales finely ctenoid; preopercle with two large scale rows and additional row of small scales on inferior limb; small sheath scales covering basal 1/2-2/3 of dorsal, anal, and caudal fins; edge of suborbital, preopercle, and opercle entire except flattened spine at angle of opercle; suborbital narrow, about 1/3 pupil diameter.

Teeth of jaws conical, multiserial, an outer row in each jaw consisting of 36 to 37 enlarged teeth and inner series of irregularly arranged smaller teeth; height of largest teeth of upper jaw about twice nostril diameter.

Origin of dorsal fin at level of fourth tubed scale of lateral-line; spines of dorsal fin gradually increasing in length to fourth, fifth, or sixth spine, remaining spines gradually decreasing in length. The following proportions are expressed into the head length: length of first dorsal spine 3.2, of fifth dorsal spine 1.9, of last dorsal spine 2.8 (2.7); of longest soft dorsal ray 1.8; of first anal spine 5.1 (3.7), of second anal spine 1.7 (1.5), of longest soft anal ray 1.6.

The following proportions are expressed into the standard length: snout to origin of dorsal fin 2.6 (2.4); snout to origin of anal fin 1.3 (1.5); snout to origin of pelvic fin 2.3 (2.5); length of dorsal fin base 1.6, length of anal fin base 4.3 (4.0).

Colour of holotype in alcohol: head and body mostly pale; upper part of head and back light brown; lower half of sides whitish or silvery with faint dusky patches; fins yellowish-tan except slightly dusky on basal portions; pectoral with diffuse dark spot on uppermost portion of fin base; pectoral axil with dark spot covering most of outer face.

Remarks

This species is known only from the types. It is distinguished from other species of *Chromis* on the basis of the combination of characters given in the diagnosis. It is named *megalopsis* with reference to the unusually large eye.

Chromis westaustralis n.sp.

(Fig. 2; Tables 2 and 4)

Holotype

WAM P25317-008, 84.0 mm SL, collected with multiprong spear at Long Island, Wallabi Group, Houtman Abrolhos, Western Australia (approximately 28° 30'S, 113° 47'E) in 2-8 metres by G. Allen on 21 May 1975.

Paratypes

AM I.18475-001, 68.0 mm SL, collected with trawl west of Koks Island, Shark Bay, Western Australia in 75 metres by W. and W. Poole, on 1 October 1964; BM(NH) 1975.9.23.9, 62.0 mm SL, collected at Mandurah (approximately 50 km south of Fremantle), Western Australia by N. Wall on 29 June 1972; BPBM 19058, 2 specimens, 56.2 and 61.0 mm SL, collected at the Houtman Abrolhos, Western Australia by J. Alchin in March-June, 1960; BPBM 19059, 3 specimens; 59.1-67.3 mm SL, collected with trawl approximately 9 km west of Garden Island (off Perth-Fremantle district), Western Australia by L. Marsh and M. Sheperd aboard M.R.V. "Flinders" on 8 March 1972; BPBM 19163, 45.5 mm SL, collected with multiprong spear on outer reef off Tantabiddi Creek, Northwest Cape, Western Australia in 15-18 metres by G. Allen on 30 June 1975; USNM 214702, 2 specimens, 53.3 and 66.2 mm SL, collected at Shark Bay, Western Australia in 75 metres by E. Barker on 24 October 1964; WAM P2789, 45.0 mm SL, collected at Dirk Hartog Island, Western Australia in November 1944; WAM P24853, 26.5 mm SL, collected with rotenone near Middleton Beach, Albany, Western Australia in 3 metres by G. Allen on 24 July 1974; WAM P25307-011, 71.2 mm SL, collected with multiprong spear at Goss Passage, Beacon Island, Houtman Abrolhos, Western Australia in 2-3 metres by G. Allen on 16 May 1975; WAM P25308-006, 2 specimens, 50.5 and 59.6 mm SL, collected with multiprong spear and rotenone at Seal Island, Wallabi Group, Houtman Abrolhos, Western Australia in 12-16 metres by G. Allen on 17 May 1975; WAM P25317-009, 84.0 mm SL, collected with multiprong spear at Long Island, Wallabi Group, Houtman Abrolhos, Western Australia in 2-8 metres by G. Allen on 21 May 1975; WAM P25376-002, 50.0 mm SL, collected with quinaldine at Northwest Cape, outer reef off Tantabiddi Creek, Western Australia in 16-18 metres by G. Allen on 3 July 1975.

Diagnosis

A species of *Chromis* with the following combination of characters: dorsal rays XIII,11 to 12; anal rays II,10 to 11; suborbital margin hidden; body

Table 2: Selected counts for specimens of new *Chromis* from Western Australia.

Species	Soft dorsal rays					Soft anal rays				Pectoral rays		Lateral-Line Scales				Gill Rakers					
	11	12	13	14	15	10	11	12	13	19	20	17	18	19	20	28	29	30	31	32	33
<i>C. megalopsis</i>				1	1			1	1	2		2				1					1
<i>C. westaustralis</i>	2	14					1	15		9	7	1	7	7	1		3	7	4	1	1

Table 3: Morphometric proportions (in thousandths of the standard length of type specimens of *Chromis megalopsis*).

Characters	Holotype	
	WAM P25207-001	WAM P2234
Standard length (mm)	84.1	102.0
Greatest body depth	482	466
Head length	344	333
Snout length	87	78
Eye diameter	145	142
Interorbital width	98	104
Least depth of caudal peduncle	98	143
Length of caudal peduncle	76	89
Snout to origin of dorsal fin	382	412
Snout to origin of anal fin	741	686
Snout to origin of pelvic fin	436	398
Length of dorsal fin base	628	642
Length of anal fin base	232	221
Length of pectoral fin	351	337
Length of pelvic fin	319	328
Length of 1st dorsal spine	108	105
Length of 7th dorsal spine	184	176
Length of last dorsal spine	125	125
Longest soft dorsal ray	187	182
Length of 1st anal spine	67	91
Length of 2nd anal spine	206	221
Longest soft anal ray	209	204
Length of caudal fin	341	280

Table 4: Morphometric proportions (in thousandths of the standard length) of selected types of *Chromis westaustralis*.

Characters	Holotype		Paratypes		WAM P24853
	WAM P25317-008	WAM P25307-011	WAM P25308-006	WAM P25308-006	
Standard length (mm)	84.0	71.2	59.6	50.5	26.5
Greatest body depth	440	421	403	396	418
Head length	286	309	319	317	330
Snout length	65	70	76	69	70
Eye diameter	101	103	117	119	132
Interorbital width	89	94	97	89	88
Least depth of caudal peduncle	143	140	143	119	143
Length of caudal peduncle	131	140	134	139	132
Snout to origin of dorsal fin	339	379	386	376	385
Snout to origin of anal fin	738	681	696	713	703
Snout to origin of pelvic fin	458	435	419	446	418
Length of dorsal fin base	595	562	570	535	571
Length of anal fin base	190	190	201	182	187
Length of pectoral fin	310	309	336	307	308
Length of pelvic fin	286	281	268	277	297
Length of 1st dorsal spine	71	70	67	79	75
Length of 7th dorsal spine	137	140	151	139	165
Length of last dorsal spine	107	112	101	99	132
Longest soft dorsal ray	185	190	201	186	220
Length of 1st anal spine	42	53	59	59	77
Length of 2nd anal spine	155	166	176	168	176
Longest soft anal ray	173	169	185	178	198
Length of caudal fin	345	323	336	327	308

depth 2.3 to 2.5 in SL; preopercle margin smooth or crenulate without distinctive serrae; colour generally light brown, darker dorsally with prominent dark streak on each lobe of caudal fin; pectoral axil with black spot extending on to upper half of external part of pectoral base; white spot present at base of posterior soft dorsal rays in live individuals.

Description

Dorsal rays XIII,12 (XIII,11 to 12); anal rays II,11 (II,10 to 11); pectoral rays 19 (19 to 20); pelvic rays I,5; gill rakers on first arch $9 + 22 = 31$ (29 to 33); tubed lateral-line scales 19 (17 to 20); horizontal scale rows from terminal lateral-line scale to base of dorsal fin $1\frac{1}{2}$; from lateral-line to origin of anal fin 9; procurrent spines on upper and lower edge of caudal fin 2.

Body relatively elongate, laterally compressed, the greatest depth 2.3 (2.3 to 2.5) in the standard length. Head profile conical, the head length contained 3.5 (3.0 to 3.2) in the standard length. The following proportions are expressed into the head length: snout 4.4 (4.2 to 4.7), eye diameter 2.8 (2.5 to 3.0), interorbital width 3.2 (3.3 to 4.0), least depth of caudal peduncle 2.6 (2.2 to 2.7), length of caudal peduncle 2.2 (2.2 to 2.5), of pectoral fin 0.9 (1.0 to 1.1), of pelvic fin 1.0 (1.1 to 1.2), of caudal fin 0.8 (0.9 to 1.1).

Single nasal opening on each side of snout; mouth oblique, terminally located; lateral-line gently arched beneath dorsal fin, terminating $1\frac{1}{2}$ scale rows below middle of soft dorsal fin; tip of snout, lips, chin, and isthmus naked; remainder of head and body scaled; scales finely ctenoid; preopercle with two large scale rows and row of smaller scales on inferior and posterior limb; small sheath scales covering basal $\frac{1}{2}$ to $\frac{3}{4}$ of membranous portions of dorsal and anal fins and most of caudal; edge of suborbital hidden; rear margin of preopercle entire or slightly crenulate; edge of bones of opercle series entire except a single flattened spine on upper portion of opercle.

Teeth of jaws conical, multiserial, about 40 to 46 in outer row of upper jaw and 34 to 42 in outer row of lower jaw; teeth at front of jaws slightly enlarged, the largest about 1.0 to 1.5 nostril diameter; irregular series of smaller teeth behind outer row teeth at front of jaws.

Origin of dorsal fin at level of third tubed scale of lateral-line; spines of dorsal fin gradually increasing in length to about sixth or seventh spine, remaining spines gradually decreasing in length. The following proportions are expressed into the head length: length of first dorsal spine 4.0 (3.3 to 4.8), of seventh dorsal spine 2.1 (2.0 to 2.3), of last dorsal spine 2.7 (2.5 to 3.2), of last dorsal spine 2.7 (2.5 to 3.2), of longest soft dorsal ray 1.5

(1.5 to 1.7), of first anal spine 6.9 (4.3 to 5.9), of second anal spine 1.8 (1.6 to 1.9), of longest soft anal ray 1.7 (1.5 to 1.8).

Colour of holotype in alcohol: ground colour of head and body brown, darker dorsally, grading to silvery on breast and abdomen; dorsal and anal fins brown except posteriormost portion translucent; pectoral fins pale with black spot in axil and invading upper half of outer pectoral base; pelvic fins slightly dusky; caudal fin with broad dark streak on each lobe, inner portion of fork pale. There is considerable variation in the ground colour of the paratypes. Generally the specimens which have been in preservative for several years are pale yellowish-brown to tan.

Colour in life: live colours are similar to those described above except there is a small white spot, less than pupil size, below the base of the posteriormost dorsal rays. In addition, the dorsal, anal, and caudal fins have a narrow blue margin.

Remarks

McKay (1970) reported five specimens of an unidentified *Chromis* from the Houtman Abrolhos and Shark Bay. They are identifiable as *C. westaustralis* and are among the designated paratypes. McKay also indicated that the record of *C. scotochilopterus* (non Fowler) by Whitley (1948) was incorrect and refers to this species.

C. westaustralis is closely allied to *C. fumea* Tanaka which is known from Taiwan, the Ryukyu Islands and Western Australia. The latter locality represents a new locality record which is based on four specimens, 32.5-55.0 mm SL, at BPBM and WAM from Northwest Cape and Kendrew Island, Dampier Archipelago.

Both species have the same general shape and are similar in coloration, particularly with regards to the dark caudal streaks and small white spot in live individuals at the base of the posterior dorsal rays. However, they differ in several important respects. *C. westaustralis* generally has an additional soft anal ray (11 vs 10 for *C. fumea*) and lacks the distinct preopercle serrae which are typical of *C. fumea*. Furthermore, the black spot on the pectoral axil of *C. westaustralis* extends onto the outer portion of the pectoral base, covering most of the upper half. Finally, there appears to be a significant difference in maximum size. The largest of many individuals of *C. fumea* observed at Northwest Cape and the Dampier Archipelago was approximately 60 mm SL compared with many species of *C. westaustralis* in excess of 80 mm SL seen at the Abrolhos Islands.

The species inhabits coral areas and rocky reefs at depths ranging from two metres to at least 75 metres. Over the southern portion of its range

C. westaustralis is usually encountered at depths greater than 25 metres, but on the coral reefs of the Houtman Abrolhos (between 28 and 29°S latitude) it is common in depths of less than 10 metres. Indeed, it is perhaps the most abundant reef fish in that island group, occurring in huge aggregations, which feed on plankton up to several metres above the bottom.

The species is known only from Western Australia and is therefore named *westaustralis*.

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LARVAL DEVELOPMENT OF TWO WESTERN AUSTRALIAN
SHRIMPS, *PALAEMONETES AUSTRALIS* DAKIN AND *PALAEMONETES*
ATRINUBES BRAY (DECAPODA, PALAEMONIDAE), REARED IN
THE LABORATORY.

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ABSTRACT

Larvae of the freshwater-estuarine species *Palaemonetes australis* pass through 3 zoeal stages without feeding and closely resemble those of the freshwater species *Macrobrachium australiense*. Larvae of the marine-estuarine species *Palaemonetes atrinubes* pass through 7 zoeal stages which require food and resemble those of the marine-estuarine species *Macrobrachium intermedium*. The number of zoeal stages, the development of pereopods and pleopods, and the morphology of the fifth abdominal somite appear to be related to habitat in these species and in North American species of *Palaemonetes*.

INTRODUCTION

Although larval development has been described for numerous species of Palaemoninae there have been few recent attempts to review differences in development between species and genera within this subfamily. Dobkin (1971) compared the number of larval stages in 6 North American species of *Palaemonetes* and found abbreviated development in the freshwater species (*P. paludosus* and *P. cummingi* but not in *P. kadiakensis* which was also from freshwater habitats). Williamson (1972) found that larval development in the African freshwater species *Macrobrachium niloticum* was not abbreviated when compared with development in *Macrobrachium intermedium* from marine habitats in east Australia.

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In this paper descriptions of larval development in 2 Western Australian species, *Palaemonetes australis* from freshwater and estuarine habitats and *Palaemonetes atrinubes* from marine and estuarine habitats, provide an opportunity for comparisons between: 1. larvae of species of *Palaemonetes* from different habitats in Australia, 2. larvae of species of *Palaemonetes* from Australia and North America, and 3. larvae of *Palaemonetes* and *Macrobrachium* from similar habitats in Australia.

MATERIALS AND METHODS

General

Ovigerous females of *Palaemonetes australis* were collected from freshwater habitats (salinity about 0.7‰) in the Canning River at the Kent St Weir and from estuarine habitats (salinity 25-35‰) in the lower Swan River at Nedlands Baths and held in water from the collecting sites. Larvae hatched from these females were maintained in compartments of polyethylene ice-cube trays. The trays were floated in water from the collecting site and the walls of each compartment were perforated to allow free exchange of water. Specimens of each larval stage were killed in 1% KOH, washed in tap water, fixed in 5% formalin and mounted in glycerol. Camera lucida drawings were prepared from larvae and exuvia of the Canning River series.

Ovigerous females of *Palaemonetes atrinubes* were collected from the lower Swan River at Point Walter in salinities of 25-35‰. Larvae hatched from these females were maintained as for *P. australis*. Specimens of each stage were prepared and drawn by the same method as for *P. australis*.

Feeding

In preliminary studies larvae of *P. australis* completed development to the megalopa stage without feeding and did not feed when supplied with particles of commercial fish food or *Artemia* nauplii.

Larvae of *P. atrinubes* died in the first or second larval stage unless fed. These larvae fed on particles of commercial fish food or *Artemia* nauplii. Survival was greatest when *Artemia* nauplii were supplied and they were used in the present study.

Terminology

The terminology suggested by Williamson (1969) is adopted here. A larva with natatory exopods on thoracic appendages and rudimentary pleopods is classed as a zoea with the stage given in roman numerals. A larva with setose natatory pleopods is termed a megalopa.

RESULTS

Palaemonetes australis

Egg Size

The size of eggs on specimens preserved in formalin varies with the stage of development. In the early stage of development, before eye spots are visible, eggs measure 1.0 by 1.4 mm and eggs with fully developed embryos measure 1.3 by 1.8 mm.

Incubation period

The duration of egg development varied with temperature and ranged from 73 days at 15°C (2 shrimp) to 19 days at 28°C (3 shrimp).

Number of larval stages

Of 50 larvae hatched from eggs at each of the salinities, 1‰ and 35‰, all reached the megalopa stage after passing through 3 clearly recognised zoeal stages with a single moult at each stage.

Duration of larval development

Time from hatch to the megalopa stage varied with temperature and ranged from 4.5 days at 28°C (10 larvae) to 17 days at 15°C (10 larvae). The zoeal stages were of about equal duration.

Size of stages

The overall length for 21 stage I larvae ranged from 4.4 to 5.6 mm and averaged 5.0 mm. No growth was apparent in other stages and 30 megalopa stage shrimp ranged in length from 4.5 to 5.8 mm and averaged 5.2 mm.

Development of larvae

Carapace (figures 3-6) with rostrum shorter than antennular peduncle in all stages; without dorsal spines in stage I, with single dorsal spine in stages II and III and 3 dorsal spines in megalopa; with single epigastric tubercle in stage III; with supra-orbital spines in stages II and III; with branchiostegal groove in megalopa; with single pair of small spines on antero-ventral margins in stage I and 2 pairs of such spines in stages II, III and megalopa.

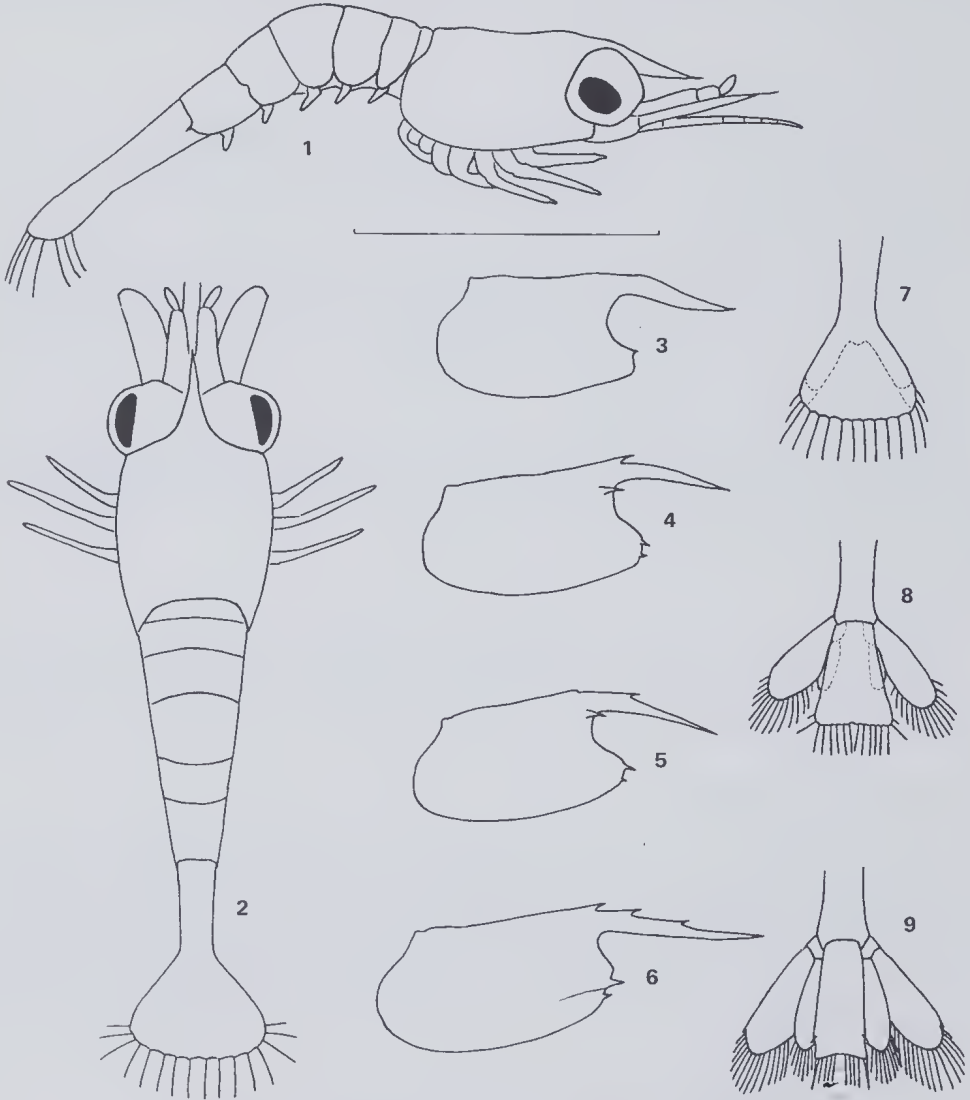
Abdomen (figures 26-29) with posterior margin of fifth somite pointed in stages I and II and bluntly angled in stage III and megalopa.

Telson (figures 2,7-9) triangular, posterior margin convex with 8+8 processes in stages I and II; articulated with sixth somite, elongated in shape, posterior margin straight with 8+8 processes in stage III; rectangular,

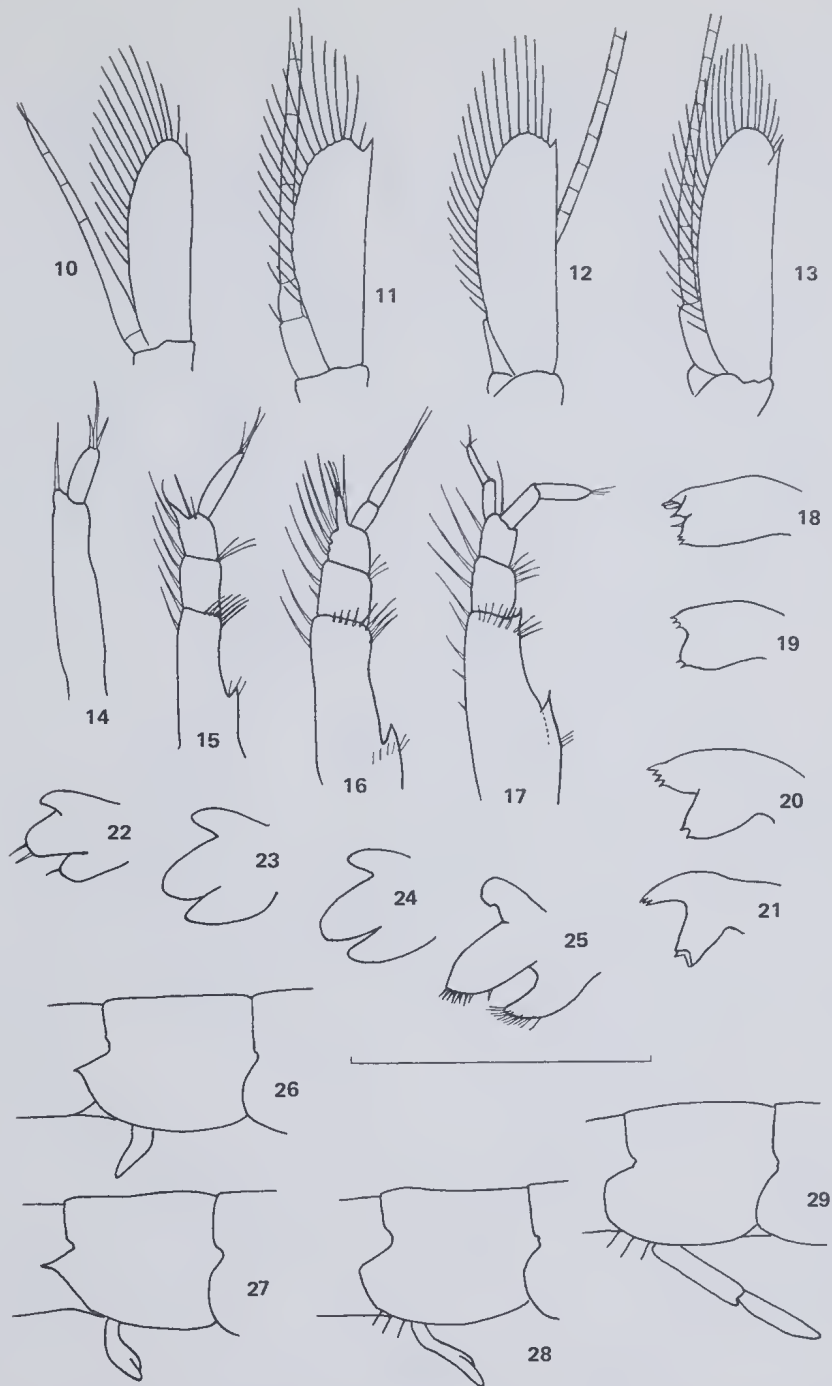
posterior margin concave with 5+5 processes, lateral margins with single pair of small processes in megalopa.

Uropods (figures 8-9) present in stage III and megalopa, with small spine on postero-lateral margin of exopod in megalopa.

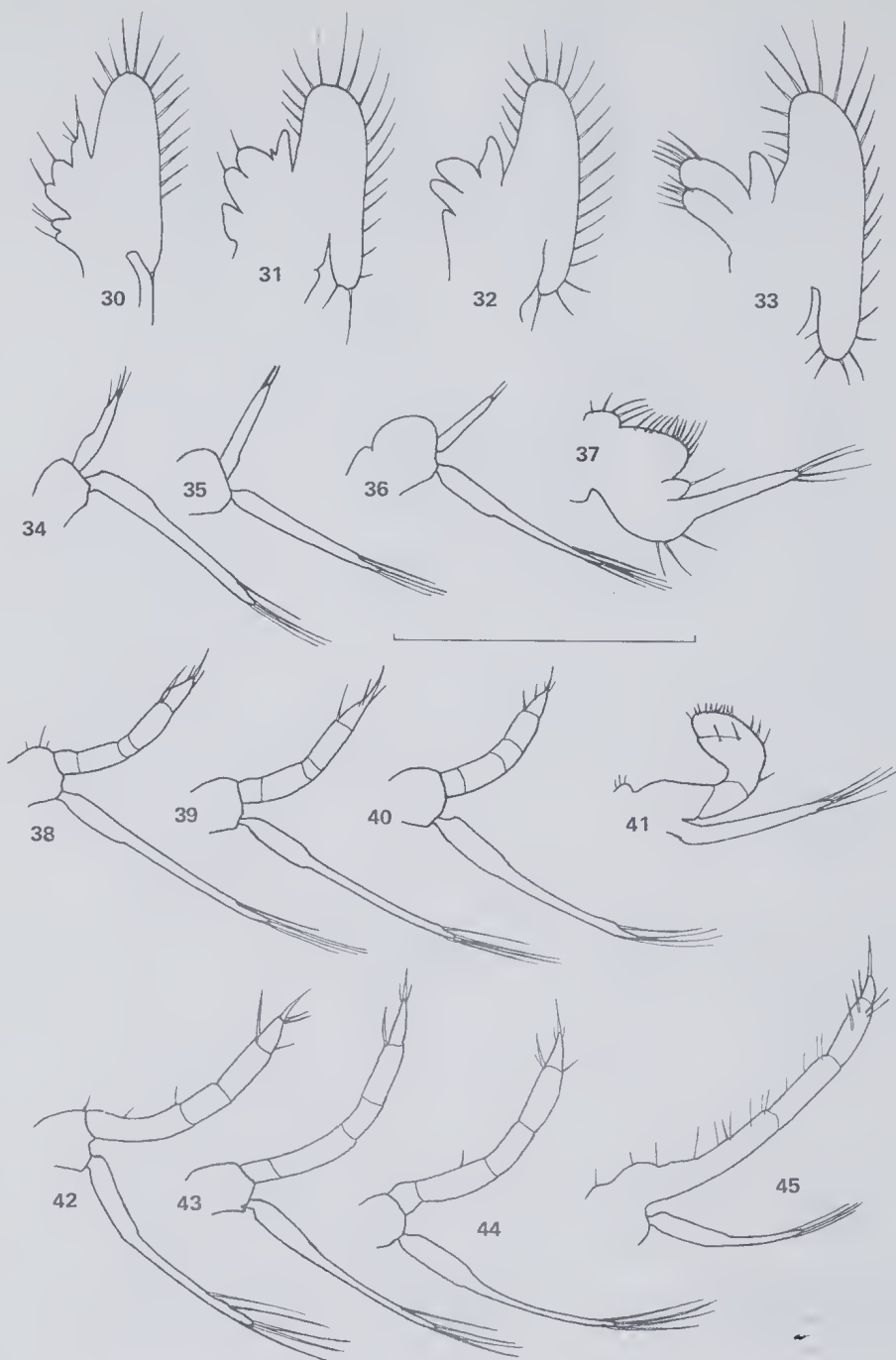
Antennular penduncles (figures 14-17) straight, unsegmented in stage I; of 3 segments with stylocerite on outer margin of basal segment in



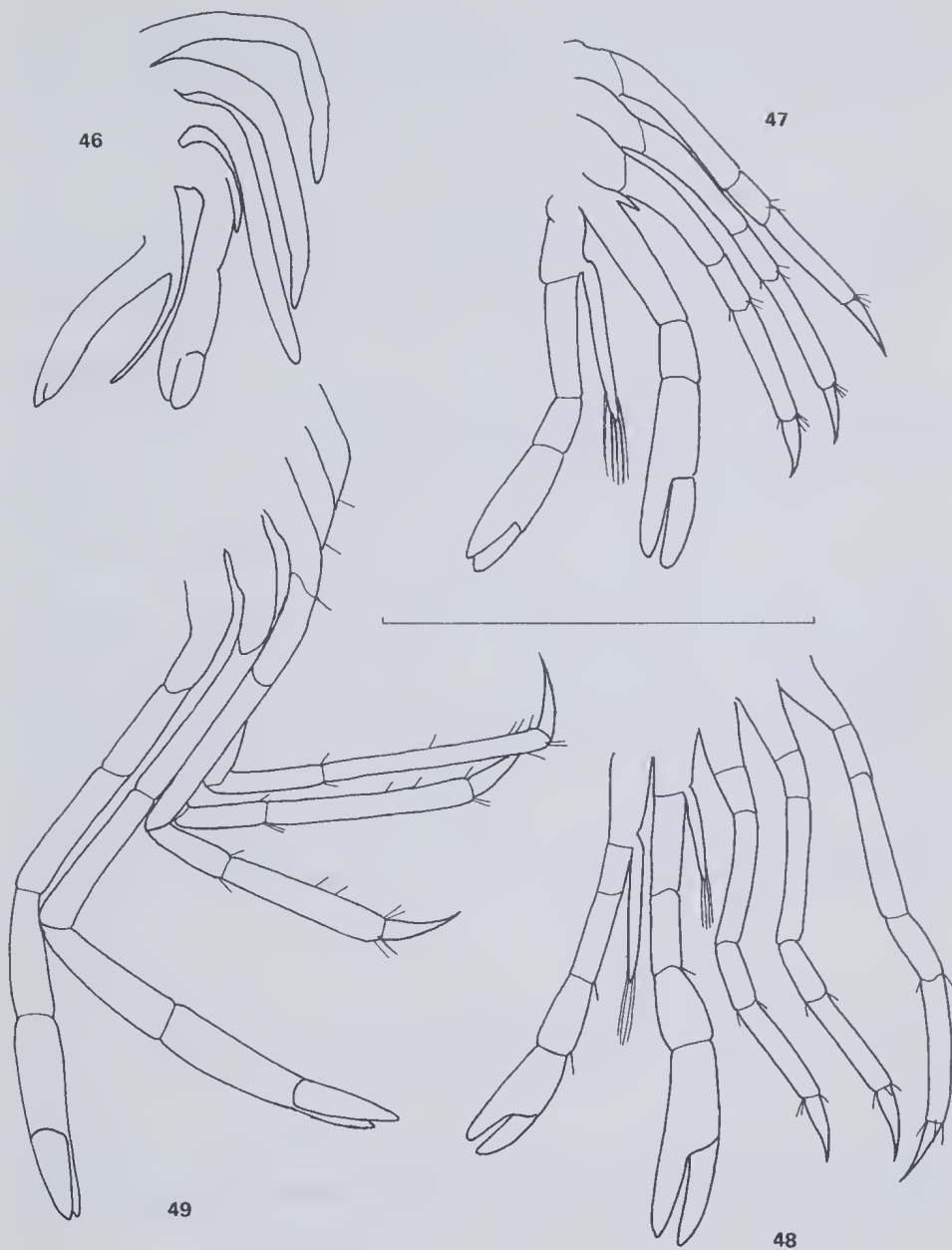
Figures 1-9, *Palaemonetes australis*. 1, 2 zoeal stage I; 3-6 carapace, zoeal stages I-III, M (megalopa); 7-9, telson, zoeal stages II-III, megalopa. Scale line represents 2 mm. Setae omitted from appendages in 1-6.



Figures 10-29, *P. australis*. 10-13, antenna I-III, M; 14-17, antennule I-III, M; 18-21, mandible I-III, M; 22-25, maxillule I-III, M; 26-29, fifth abdominal somite I-III, M. Scale line represents: 10-13, 1 mm; 14-17, 26-29, 0.8 mm; 18-21, 0.4 mm; 22-25, 0.5 mm.



Figures 30-45, *P. australis*. 30-33, maxilla I-III, M; 34-37, first maxilliped I-III, M; 38-41, second maxilliped I-III, M; 42-45, third maxilliped I-III, M. Scale line represents: 30-33, 0.5 mm; 34-45, 0.7 mm.



Figures 46-49, *P. australis*, pereiopods I-VI, stages I-III, M. Scale line represents 1 mm.

stages II+; outer ramus of antennule segmented in stages III+ and inner ramus segmented in megalopa.

Antenna (figures 10–13) with endopod segmented and longer than exopod in all stages; exopod (scale) unsegmented with straight outer margin in all stages and antero-lateral spine in stages II+.

Mandible (figures 18–21) with molar and incisor processes in all stages and with 2 spines between these processes in stage I.

Maxillule (figures 22–25) trifold; with endopod unsegmented, bearing a single seta in stage I and numerous setae in megalopa; centre lobe with numerous short setae in megalopa.

Maxilla (figures 30–33) with 3 inner lobes; exopod with narrow lobe terminating in single seta in stage I and 2–4 setae in stages II+.

First maxilliped (figures 34–37) with endopod small and unsegmented in all stages; exopod with 4–6 setae in stages I–III and short with 4 setae in megalopa; inner lobe with numerous setae in megalopa.

Second maxilliped (figures 38–41) with endopod segmented and fifth segment terminating in a stout spine in stages I–III, hook shaped with numerous short setae on terminal segment in megalopa; exopod longer than endopod in stages I–III, shortened in megalopa.

Third maxilliped (figures 42–45) with endopod segmented, terminating in stout spine in all stages; exopod as long as endopod in stages I–III, without exopods in megalopa.

Third, fourth and fifth pereopods (figures 46–49) without exopods in all stages, unsegmented in stage I, segmented with stout terminal spine in stages II+.

Pleopods (figures 1,26–29) present as uniramous buds in stage I, biramous in stages II–III, segmented with setae in megalopa.

Palaemonetes atrinubes

Egg Size

Eggs on specimens preserved in formalin measured 0.6 by 0.8 mm in early stages of development and 0.7 by 0.9 mm when mature.

Incubation period

At 25°C the incubation period was 11 days for a single female which laid eggs in the laboratory.

Number of stages

In 30 larvae hatched from eggs the first 6 moults corresponded to well defined zoeal stages. Morphology was little changed in subsequent moults and 5 larvae reached the megalopa stage after 7–10 moults. For this description 7 zoeal stages and 1 megalopa are recognised.

Duration of larval development

The time from hatch to megalopa stage varied with temperature and ranged from 20–24 days at 29°C (3 larvae) to 40–44 days at 19°C (2 larvae). Larvae moulted regularly to reach stage V at about $\frac{1}{3}$ of the total development time and subsequent moults were less frequent.

Size of stages

First stage zoeae were 2.9–3.1 mm overall length (10 larvae), stage III zoeae were 4.0–4.5 mm (10 larvae) and stage VII zoeae were 7.0–8.1 mm (6 larvae).

Development of larvae

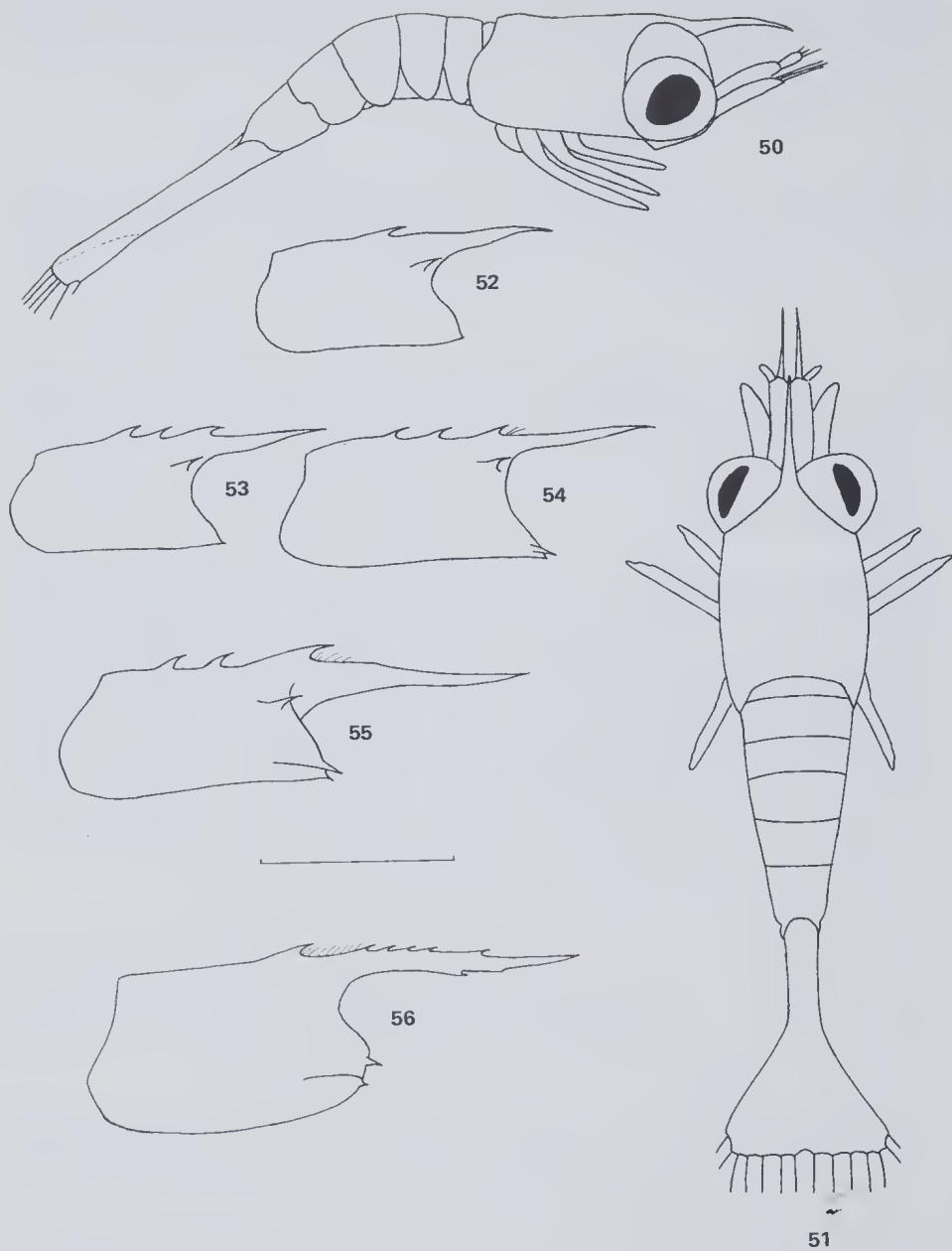
Carapace (figures 50–56) with rostrum about as long as antennular peduncle, unarmed in all zoeal stages and with rostral formula 5/2 in megalopa; with single epigastric spine in stage II, 3 epigastric spines in stages III+; supra-orbital spines in zoeal stages II+; pterygostomial spine small in stage I, progressively elongated in stages II–V, raised above ventral margin with a new smaller spine in pterygostomial position in stages V–VII; antennal and branchiostegal spines on anterior margin of carapace in megalopa; branchiostegal groove present in megalopa.

Abdomen (figures 50, 57–59) with strong spine on posterior margin of fifth somite in all zoeal stages and small spine in megalopa.

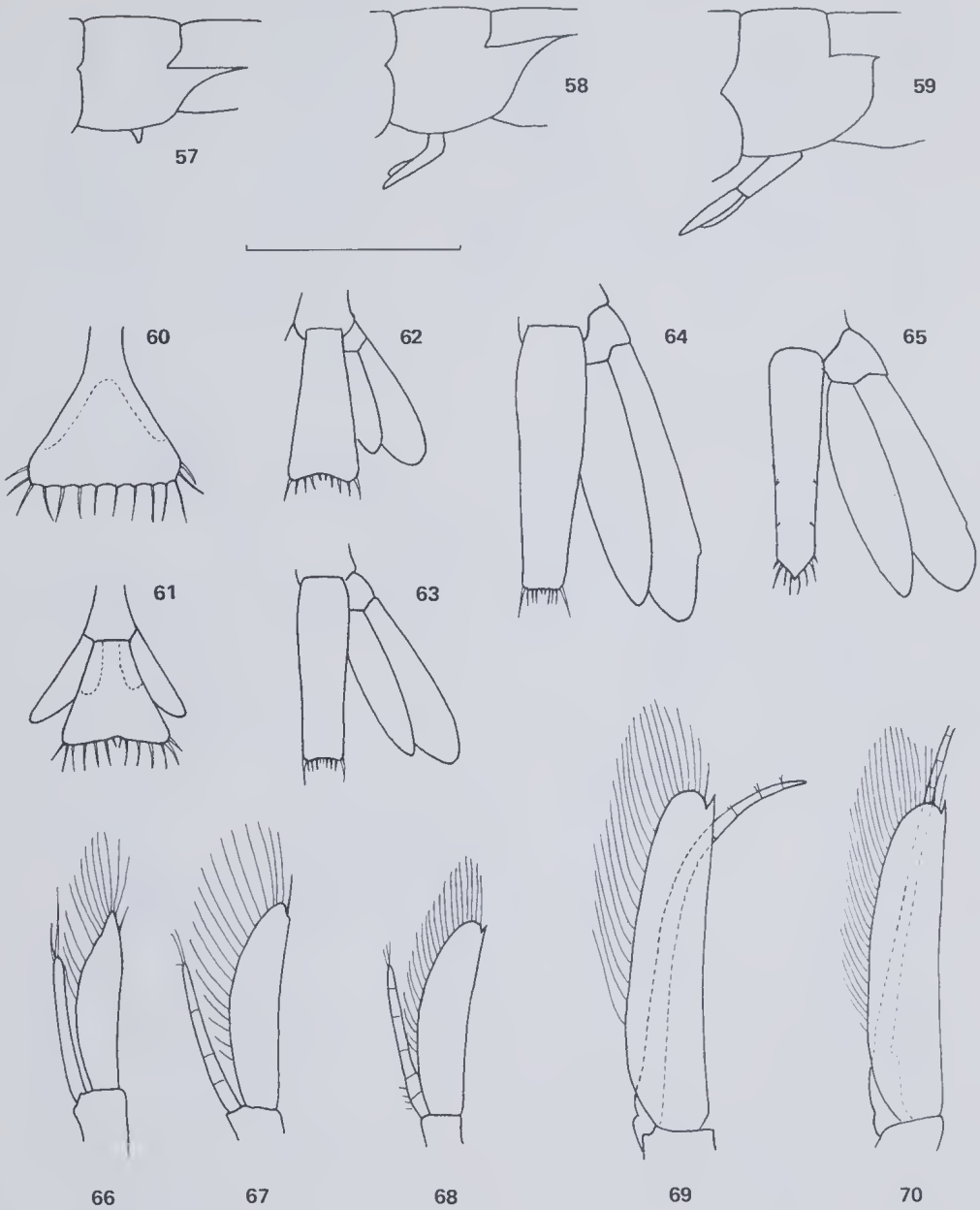
Telson (figures 51, 60–65) triangular in stages I–III, elongated rectangular in all other stages; with posterior margin straight with 7+7 processes in stages I–II, concave with 7+7 processes in stage III, concave with 5+5 processes in stages IV–VII, pointed with 4+4 processes in megalopa; with 2 pairs of dorsal setae near lateral margins in megalopa.

Uropods (figures 61–65) present in stages III+, segmented in stages IV+; with indentation on postero-lateral margin of exopod in stage VII, postero-lateral spine on exopod in megalopa.

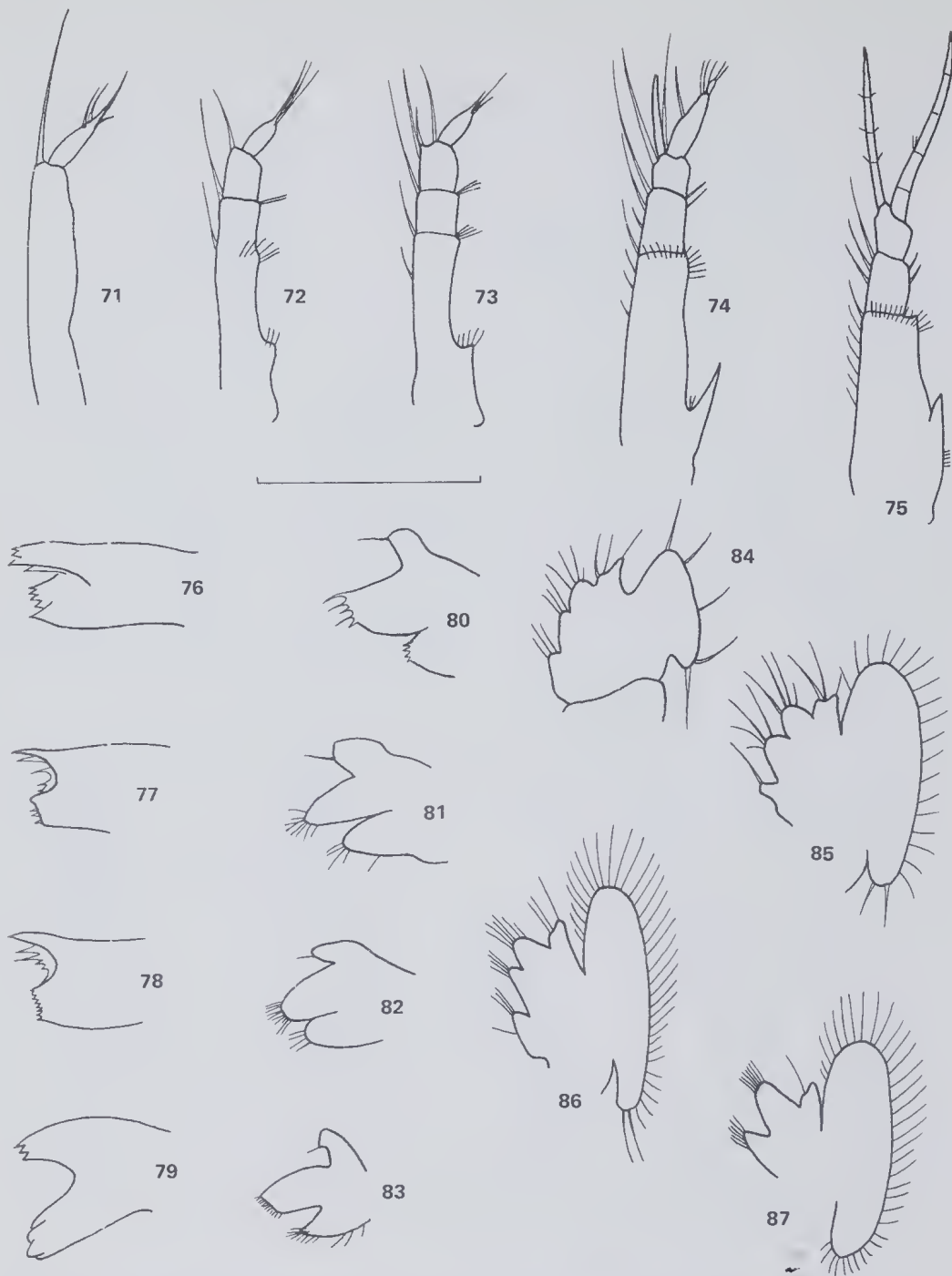
Antennular peduncle (figures 71–75) unsegmented in stage I, with 2 segments in stage II and 3 segments in stages III+; stylocerite as a lateral lobe on basal segment in stages II–III, pointed in stages IV+; inner ramus unsegmented in all zoeal stages, segmented in megalopa; outer ramus unseg-



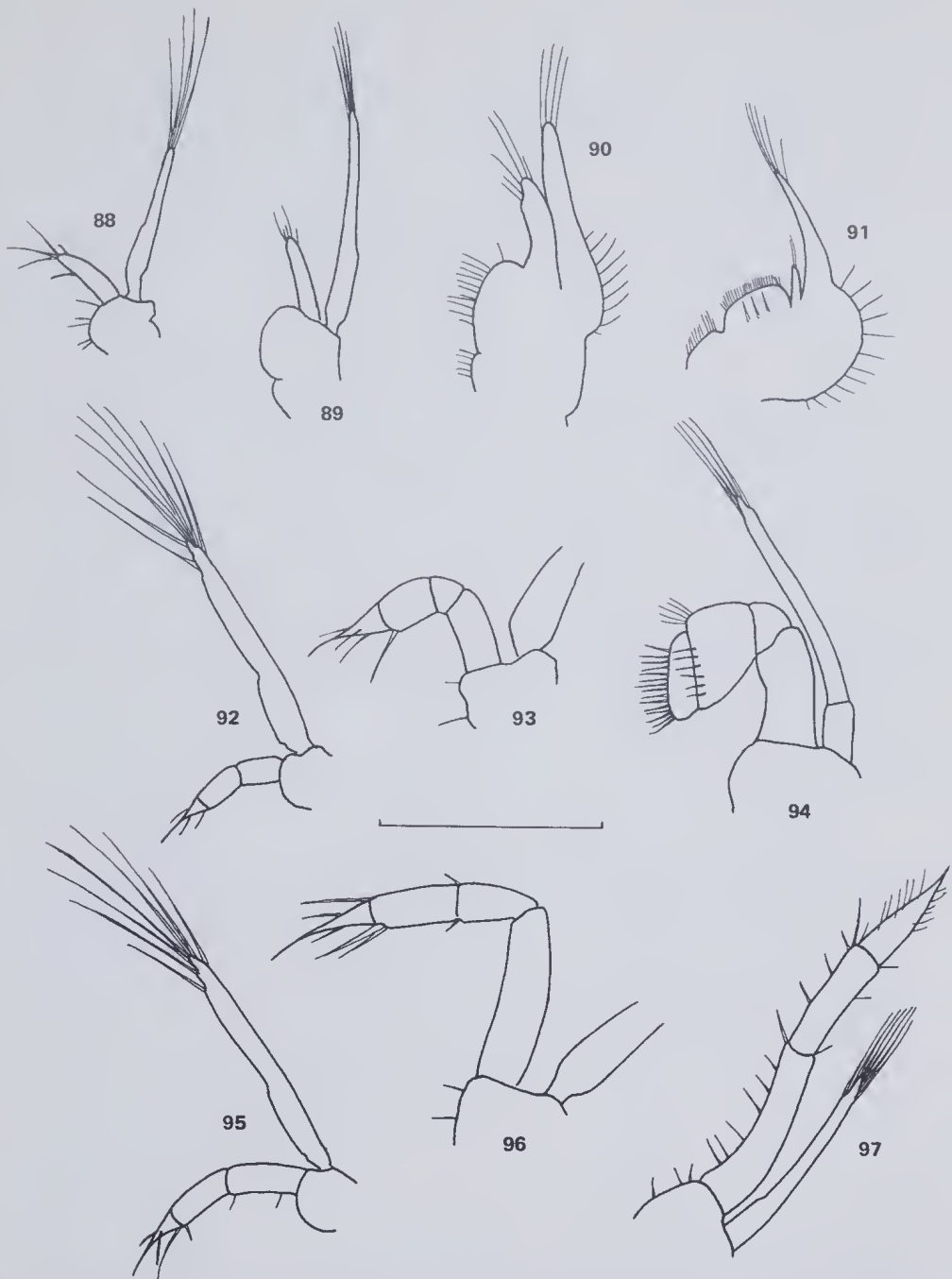
Figures 50-56, *P. atrinubes*. 50-51 zoeal stage I; 52-56 carapace, stages II, III, V, VII, M. Scale represents 1 mm.



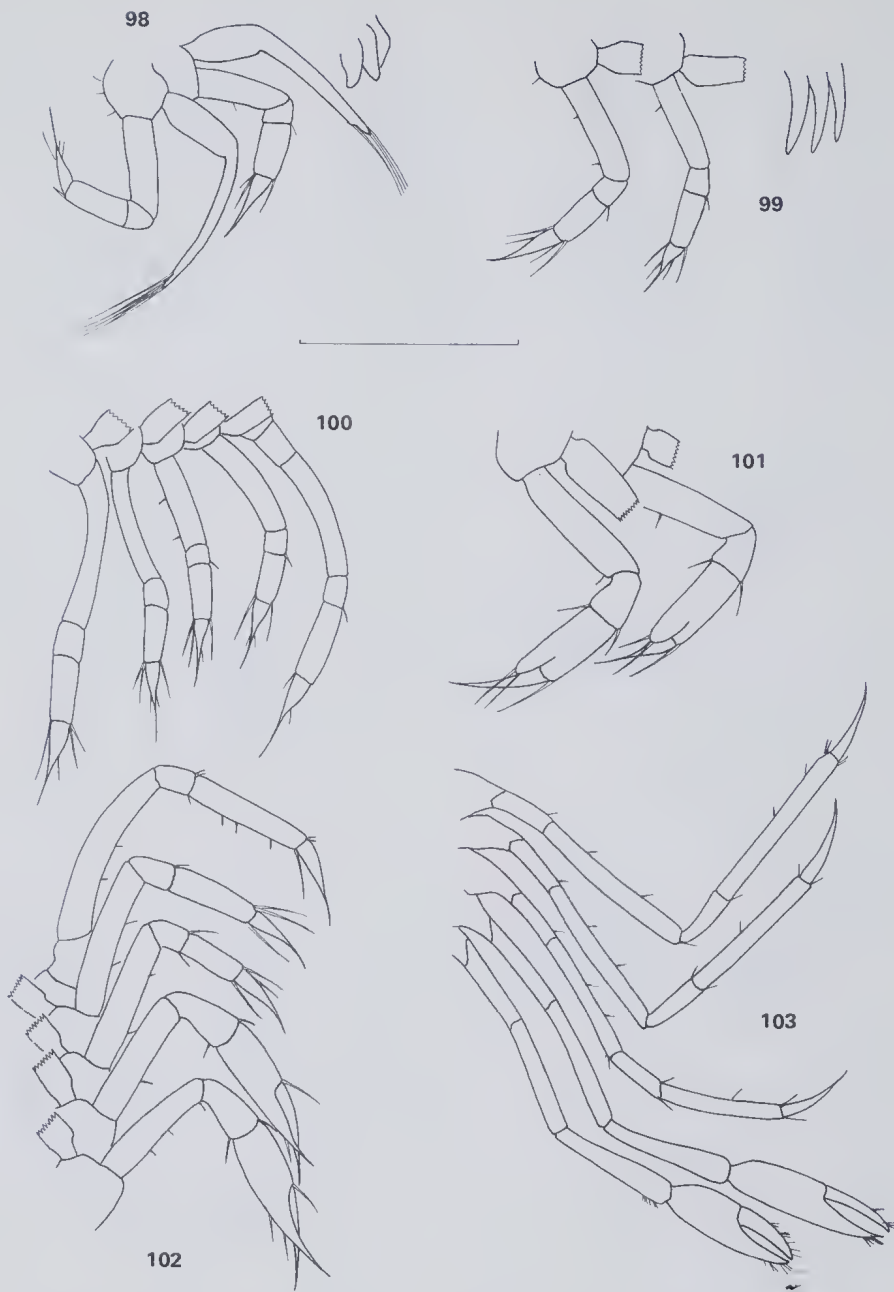
Figures 57-70, *P. atrinubes*. 57-59, fifth abdominal somite, stages IV, VII, M; 60-65 telson, stages II, III, IV, VI, VII, M; 66-70 antenna, stages II, III, V, VII, M. Scale represents: 57-59, 66-67, 0.6 mm; 60-65, 68-70, 0.8 mm.



Figures 71-87. *P. atrinubes*. 71-75 antennule, stages I, II, III, VII, M; 76-79 mandible, stages I, VI, VII, M; 80-83 maxillule, stages I, VI, VII, M; 84-87 maxilla, stages I, VI, VII, M. Scale line represents: 71-75, 0.5 mm; 76-79, 0.25 mm; 80-87, 0.35 mm.



Figures 88-97, *P. atrinubes*. 88-91 first maxilliped, I, III, VII, M; 92-94 second maxilliped, I, VII, M; 95-97 third maxilliped, I, VII, M; exopods partly omitted in 93, 96. Scale line represents: 0.5 mm.



Figures 98-103, *P. atrinubes*, pereiopods I - V, stages II, III, IV, VI, VII, M. Exopods partly omitted 99-102. Legs III-V omitted, 101. Scale line represents: 98-100, 0.5 mm; 101-103, 0.7 mm.

mented in stages I–VI, with 2 segments in stage VII and 5 segments in megalopa.

Antenna (figures 66–70) with endopod shorter than exopod and unsegmented in stages I–II, as long as exopod and segmented in stages III–V, longer than exopod and segmented in stages VI+; exopod (scale) with 5 terminal segments in stage I, 4 segments in stage II, unsegmented in stages III+.

Mandible (figures 76–79) with 2 spines between molar and incisor processes in stage I, 3 such spines present in stages II–VII but not present in megalopa.

Maxillule (figures 80–83) trifold with exopod terminating in single seta, inner lobes with numerous terminal setae.

Maxilla (figures 84–87) with 4 inner lobes in all zoeal stages, 3 inner lobes in megalopa; exopod with 5 setae in stage I and numerous setae in later stages.

First maxilliped (figures 88–91) with endopod smaller than exopod, unsegmented; exopod with 4–6 terminal setae; inner lobes with numerous short setae in megalopa.

Second maxilliped (figures 92–94) with endopod segmented and terminal segment with stout spine in all zoeal stages, hook shaped with numerous setae on terminal segment in megalopa; exopod longer than endopod.

Third maxilliped (figures 95–97) with endopod segmented and terminating in stout spine; exopod slightly longer than endopod in zoeal stages, about half length of endopod in megalopa.

First and second pereopods (figures 98–103) present as bifid rudiments in stage I; with fully developed exopod in stages II–VII; endopod segmented with strong terminal spine in stages II–V, terminal segment bifid in stage VI and chelate in later stages.

Third, fourth and fifth pereopods (figures 98–103) absent in stage I; present as rudiments in stages II–III; with exopods on third and fourth pereopod, but not on fifth pereopod, in stages IV–VII; endopods segmented with strong terminal spines in stages IV+.

Pleopods (figures 57–59) present as buds in stage IV, bifid in stage VII and with setae in megalopa.

Discussion

Larval development is more rapid in the freshwater species *Palaemonetes australis* than in the marine-estuarine species *Palaemonetes atrinubes*. Larvae of *P. australis* did not feed and completed the 3 zoeal stages in 4–17 days while larvae of *P. atrinubes* required food and completed the 7 zoeal stages in 20–44 days. Pereiopods and pleopods are present

in stage I larvae of *P. australis* while *P. atrinubes* larvae are without third, fourth and fifth pereopods until stage II and without pleopods until stage IV. Larvae of these species also differ in the postero-lateral margins of the fifth abdominal somite which bear strong spines in all zoeal stages of *P. atrinubes* while in *P. australis* short spines occur in stages I–II but not in stage III.

Comparison between larval development in Australian and North American species of *Palaemonetes*, using published descriptions, indicates that the differences between larvae of *P. australis* and *P. atrinubes* may be related to habitat. The American freshwater species *Palaemonetes paludosus* and *Palaemonetes cummingsi* undergo abbreviated larval development (Dobkin, 1963, 1971) similar to that in *P. australis*. These larvae do not feed and the postero-lateral margin of the fifth abdominal somite is without spines. Larvae of the American species *Palaemonetes pugio* and *Palaemonetes vulgaris* from estuarine-marine habitats pass through 7–11 zoeal stages (Broad, 1957) which resemble those of *P. atrinubes*. All stages require food and postero-lateral spines are present on the fifth abdominal somite in all zoeal stages except stage I. Development in the American freshwater species *Palaemonetes kadiakensis* appears to be intermediate between the other groups, with 6 zoeal stages all of which require food and with pleopods absent from stages I–II (Broad and Hubschman, 1963). However, in common with the other freshwater species the postero-lateral margin of the fifth abdominal somite is without spines. Thus species of *Palaemonetes* from Australia and North America exhibit abbreviated larval development and reduction, or absence, or the postero-lateral spines of the fifth abdominal somite in freshwater habitats.

Similar adaptation of larval development to habitat is apparent in 2 Australian species of the genus *Macrobrachium*. In the freshwater species *Macrobrachium australiense* larvae develop, without feeding, through 3 zoeal stages all without postero-lateral spines on the fifth abdominal somite (Fielder, 1970). These larvae closely resemble corresponding stages in *P. australis*, *P. paludosus* and *P. cummingsi*. Larvae of the marine-estuarine species *Macrobrachium intermedium* require food and pass through 10 zoeal stages with strong postero-lateral spines on the fifth abdominal somite in stages II–X (Williamson, 1972). Thus larval development in *M. intermedium* resembles that in *P. atrinubes*, *P. pugio* and *P. vulgaris*.

Although larval development in the Australian species *P. australis*, *P. atrinubes*, *M. intermedium* and *M. australiense* appears to be related to habitat specific differences occur and identification of larvae of these species can be facilitated by the use of the following key:

1. Three zoeal stages. Stage I with pereopods III–V and pleopods rudimentary. Stages II–III with pereopods III–V segmented, without

- strong postero-lateral spine on fifth abdominal somite. Freshwater or estuarine habitats 2
- Seven or more zoeal stages. Stage I without pereopods III-V or pleopods. Stages II+ with strong postero-lateral spine on fifth abdominal somite. Marine or estuarine habitats 3
2. Stage I zoeae with posterior margin of telson convex and bearing 8+8 processes. Stages II-III with single dorsal carapace spine *Palaemonetes australis*
- Stage I zoeae with posterior margin of telson straight and bearing 7+7 processes. Stages II-III without dorsal carapace spines *Macrobrachium australiense*
3. Stage I zoeae with postero-lateral spines on fifth abdominal somite. Stages II+ with 3 dorsal carapace spines *Palaemonetes atrinubes*
- Stage I zoeae without postero-lateral spines on fifth abdominal somite. Stage II with single dorsal carapace spine and stages III+ with 2 such spines *Macrobrachium intermedium*

ACKNOWLEDGEMENTS

I would like to thank Dr. R.W. George who provided helpful criticism of the manuscript.

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THE GENUS *OMOLEPIDA* (LACERTILIA, SCINCIDAE) IN WESTERN AUSTRALIA

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ABSTRACT

The two species occurring in Western Australia are described, namely *Omolepida branchialis* (Günther) and *O. maxima* nov.

INTRODUCTION

The genus *Omolepida* has had a chequered history. It was introduced by Gray when he removed *O. casuarinae* from *Cyclodus* (= *Tiliqua*). Günther (1867) combined *Omolepida* with *Hinulia*, a genus mainly comprising Australian species that are now placed in *Ctenotus* and *Sphenomorphus*. Boulenger (1887) went much further when he merged *Omolepida*, *Hinulia* and numerous other genera in his huge genus *Lygosoma*. For half a century workers accepted Boulenger's classification, though they often recognized *Omolepida* as a subgenus or section of *Lygosoma*.

Malcolm Smith (1937) returned *Omolepida* to *Tiliqua*; in this he was followed by Mitchell (1950). Glauert (1961) placed the Western Australian congeners of *Omolepida casuarinae* in *Tiliqua*, but he invalidly retained the name *Omolepida* for a subgenus of *Lygosoma* consisting of certain short-limbed skinks currently referred to *Sphenomorphus*.

Omolepida casuarinae (Duméril & Bibron), *O. branchialis* (Günther) and *O. maxima* (described herein) form a close-knit group of species. I believe they can be no more rightly included in *Tiliqua* than in *Egernia*.

All the material used in this revision is lodged in the Western Australian Museum. I am grateful to Mrs Ariadna Neumann for translating the original description of *Lygosoma (Homolepida) petersi*.

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Genus *Omolepida*

Omolepida Gray, 1845: 89. Type species (by monotypy): *Cyclodus casuarinae* Duméril & Bibron.

Homolepida Boulenger, 1887: 211. Emendation of *Omolepida* Gray.

Diagnosis

Moderately large to very large pentadactyl skinks with interparietal completely separating parietals. Distinguishable from *Egernia* by very short limbs with fourth digit not longer than third and by small ear aperture without pointed lobules. Distinguishable from *Tiliqua* by fragile tail, absence of occipital scales, and unpigmented (rather than blue-black) tongue.

Distribution

Australia and Tasmania. Three species.

Description

Nasals usually in contact. No supranasal or postnasal, but *O. branchialis* and *O. maxima* have vertical groove behind nostril. Prefrontals separated or in contact. Frontal in contact with two supraoculars. Frontoparietals paired, much shorter than interparietal. Enlarged nuchals usually present. Loreals 2, in horizontal series. Supraoculars 3 or 4. Supraciliaries 4-7. Lower eyelid movable, without transparent disc. Subocular series interrupted by third-last labial. Temporals 4, uppermost largest. Upper labials 6-8. Scales smooth, in 20-28 rows at mid-body, median pair much wider than other dorsals.

Omolepida branchialis

Hinulia branchialis Günther, 1867, Ann. Mag. Nat. Hist. (3) 20: 47. Champion Bay, W.A. (F.H. DuBoulay).

Lygosoma melanops Stirling & Zietz, 1893, Trans. Roy. Soc. South Aust. 16: 173. Between Everard Range, S.A., and Barrow Range, W.A. (Elder Expedition).

Lygosoma gastrostigma Boulenger, 1898, Proc. Zool. Soc. London 1898: 922. Sherlock River, W.A. (E. Clement).

Lygosoma (Homolepida) branchiale var. *elongatum* Werner, 1910, Fauna Südwest-Australiens 2: 479. Boorabbin, W.A. (Michaelsen & Hartmeyer).

Lygosoma (Homolepida) petersi Sternfeld, 1919, Senckenbergiana 1: 81. Hermannsburg, N.T. (M. von Leonhardi).

Lygosoma (Homolepida) wood-jonesii Proctor, 1923, Trans. Roy. Soc. South Aust. 47: 80. St Francis Island, S.A. (F. Wood Jones).

Diagnosis

A small *Omolepida* distinguishable from *O. casuarinae* by post-narial groove and four (rather than three supraoculars) and from *O. maxima* by

much smaller size (snout-vent length up to 130 mm) and lack of white spots in adults.

Distribution

Greater part of Western Australia from east Kimberley south to the Swan River, Norseman and Nullarbor Plain; including some islands off west coast (Dolphin, Barrow, Bernier, Dirk Hartog, Baudin and Lancelin). Extralimital in western South Australia and south of Northern Territory.

Description

Snout-vent length (mm): 30-130 (N 332, mean 86.4). Length of appendages (% SVL): foreleg 11-25 (N 312, mean 15.8), hindleg 14-26 (N 304, mean 19.8), tail 73-130 (N 146, mean 99).

Nasals forming a median suture. Prefrontals separated. Supraoculars 4, second largest, first and last smallest. Supraciliaries 4-7; usually 5, with first and second widest, and first and fourth highest. Upper labials 6-8 (N 330, mean 7.3). Ear aperture small, usually with a moderately large rounded lobule on anterior margin and occasionally one or two smaller lobules elsewhere. Enlarged nuchals 0-5 (N 332, mean 3.0) on each side. Midbody scale rows 20-28 (N = 327, mean 24.6). Lamellae under fourth toe 10-18 (N 302, mean 13.4), each with a narrow to wide, smooth or tuberculate, dark brown callus.

Upper surface and sides pale olive grey to dark olive brown, each dorsal and lateral scale with or without a small anterior dark brown spot or one or more short blackish longitudinally orientated dashes or streaks. Underneath whitish, with or without brown or black dots, small spots or short dashes. Juveniles (also subadults in Kimberley) dorsally and laterally pale to dark reddish brown, dotted or spotted with white or pale brown; underneath whitish, usually unmarked.

Remarks

At first it seemed possible to divide *O. branchialis* into subspecies, e.g. *melanops* for the populations inhabiting spinifex (*Triodia* spp.) in the arid and semi-arid zones from the Kimberley south to the Norseman district, and *branchialis* for the inhabitants of coastal limestone from Shark Bay south to the Swan River. However, such an arrangement was made difficult by the discovery near Yuna, 70 km inland from the west coast, of a spinifex-inhabiting population like typical *branchialis* in most respects but with coloration intermediate between *branchialis* and *melanops*.

Another contender for subspecific recognition is the cave-inhabiting population near Madura on the Nullarbor Plain (briefly described below).

Geographic variation

Relative length of appendages decreases from north to south, e.g. tail averages 118% of snout-vent length in the Kimberley Division and 89% in the South-west Division. In other characters inter-regional variation seems to be

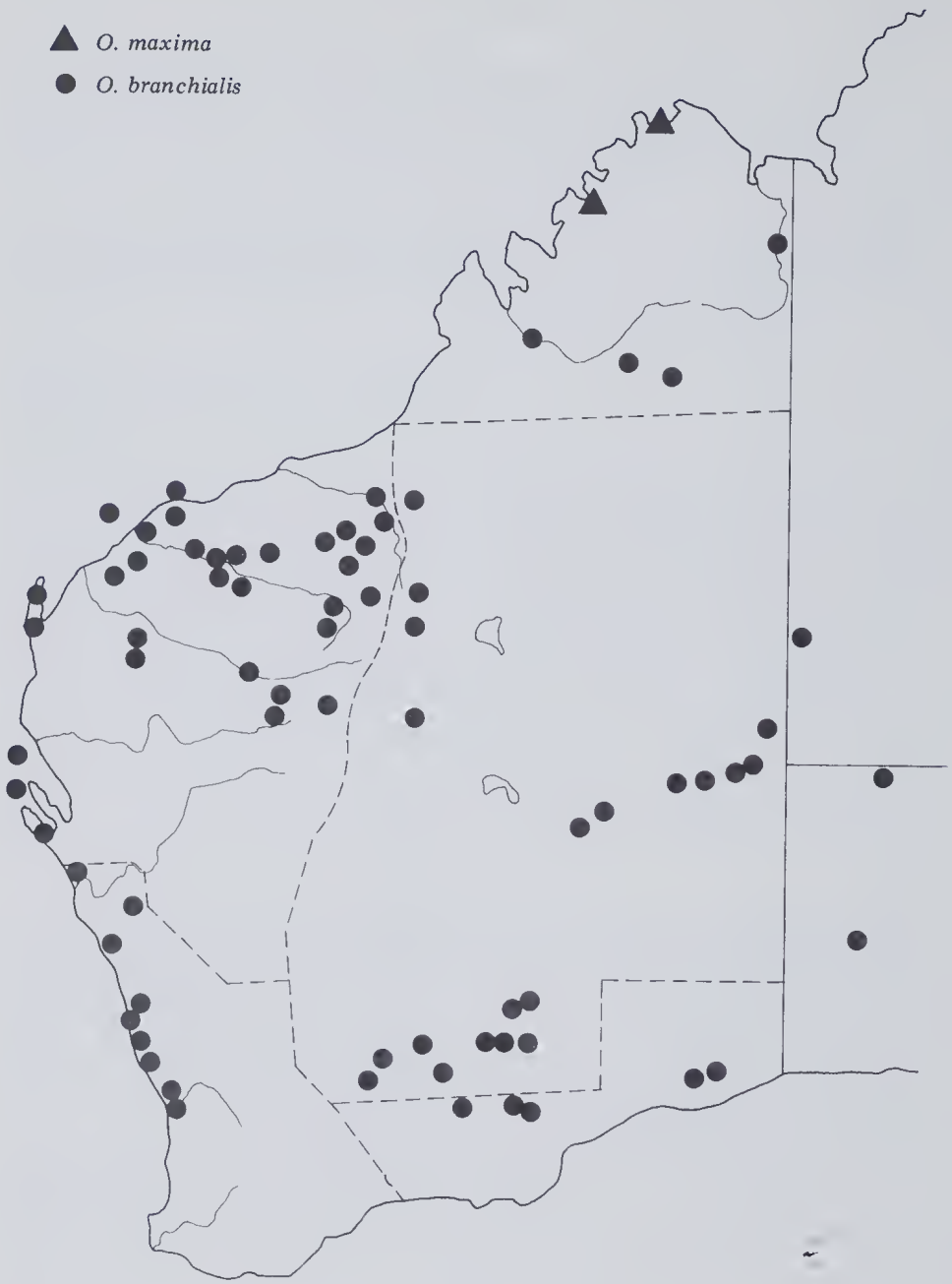


Fig. 1: Map of Western Australia showing location of specimens of *Omolepida branchialis* and *O. maxima*.

of a random or unpredictable nature, which is in keeping with the patchy distribution of this species.

Kimberley specimens are characterized by small size (maximum SVL 98), relatively narrow separation of prefrontals, low number of nuchals (mean 2.5) and of upper labials (only 2% with 8), high frequency of low flat-topped fourth supraciliary (rather than a high scale with pointed top), and retention of juvenile coloration by subadults and occasionally even by adults.

Specimens from the North-west Division are large; it is only here that SVL exceeds 115 mm. On the mainland, but not Barrow Island, frequency of 8 labials (53%) is much higher than elsewhere. In the Pilbara, but not in the south of the Division or on Barrow Island, number of midbody scale rows (mean 26.1) is considerably higher than elsewhere. At Kumarina, in the south-east of the Division, most specimens lack ventral spotting, a trait shared with the next population.

Specimens from the mallee/spinifex zone of the far south-west of the Eastern Division, adjacent parts of the Eucla Division, and similar country on Eyre Peninsula, South Australia, are small (maximum SVL 95 mm) and usually unspotted below. Their subdigital lamellae are more narrowly callose than elsewhere, and their plantar scales usually bear a dark tubercle.

Specimens from the northern and central parts of the Eastern Division, north-western South Australia and the Northern Territory are generally intermediate between Kimberley and Pilbara specimens, though a higher proportion of them, especially in the south, lack ventral spotting.

Specimens from the lower west coast from Bernier Island south to the Swan River are the most distinctive. Dorsally they are pale olive grey rather than dark olive brown as in most spinifex-inhabiting populations, and the dorsal and lateral scales are usually marked with one or more blackish longitudinal short streaks or dashes rather than a dark brown anterior spot. (Only in the type locality (Geraldton district) are found specimens with the gill-like markings that gave the species its name.) Number of midbody scale rows (mean 22.0) and of subdigital lamellae (mean 11.6) are low. The ear aperture is smaller than elsewhere and usually lacks a lobule (as distinct from a pre-auricular scale that tends to lie over anterior part of aperture). Upper labials are fewer than in most regions, and it is only here that counts of 6 have been observed (5%).

The two specimens (36165, 36719) from the Nullarbor Plain, like most specimens from the lower west coast, have 22 rows of midbody scales. They, too, are pale olive or olive brown above but completely lack dorsal or ventral spotting.

Material

Kimberley Division (W.A.): Lake Argyle (47490-521); 13 km E of Margaret River HS (46111-2); Louisa Downs (46050-3); 26 km SSE of Gogo (23038-9); Mt Anderson (27759).

North-west Division (W.A.): Dolphin Island (14277); Barrow Island (27757-8, 28460, 28684-91, 47546-84); Karratha (22933); Mardie (13862); 16-27 km E of Yarraloola (25631, 25641, 25647, 25656, 25659-60); 16 km N and 16 km W of Peedamulla (26512-3); Millstream (20170-4, 20176-7, 20182, 20186); near Kangiangi (20175, 20184); Mt Ulric (20179, 20185); Tambrey (20178); Coolawanyah (20181); Hooley (34731); Asbestos Creek (20180, 20183); Wittenoom and vicinity (13322, 37071, 37086); Woodstock (13090, 13227*a-b*, 27751); Warrawagine (13236*a-d*); Ripon Hills (13238*a-d*); 5 km SE of Mt Edgar (45761-2); 8 km S of Corunna Downs (13237*a-f*); Mosquito Creek (13242*a-f*); 15 km S of Nullagine (36337); Balfour Downs (19850); Poonda (27756); Mt Newman (25176); Exmouth (31416); Yardie Creek (13231*a-h*) and 65 km S (27752-5); Ningaloo (13199, 13232, 32029) and 40 km NE (21767); 5-13 km S of Learmonth (22402-4); 20 km NW of Ullawarra (25265); Kookhabinna Gorge, Barlee Range (25355); 30 km NW of Mt Vernon (25235); Ethel River (22804-5, 25227); Mulgul (22701); Kumarina (23953-64, 25188-92); Bernier Island (20497); Dirk Hartog Island (42371-3); Baudin Island (25735); Carrarang (39029).

Eastern Division (W.A.): Barromine, 50 km E of Warrawagine (13236*a-d*); Talawana (39129-30, 42232-3); 32 km E of Jiggalong (25187); 27 km N of The Weld Spring (15842); 37 km SE of Giles (20752); Blackstone Mining Camp (44347) and 7 km NE (20980); Cavenagh Range (20736) and 14 km W (20991); Jameson Range (28992); Mt Palgrave, Barrow Range (20999); near Warburton Range (15157, 16554, 22176); 18 km SW of Muggan Rockhole (20708-9); 10 km SW of Nullye Soak (47452-3); Queen Victoria Spring (12985-6, 13547, 16551, 39995); 20 km NW of Cundeelee Mission (12988, 21689); near Zanthus (16552-3, 26424-5); Chifley (21654); Karonie (14232-3); near Coolgardie (19141-2); 28 km W of Bullabulling (30692); 25 km S of Karalee (33968); near Widgiemooltha (30847).

Eucla Division (W.A.): 8 km E of Norseman (30777); 13 km E of Fraser Range (30693-701, 30716); 25 km SE of Fraser Range (25562); 13 km N of Madura (36719); 38 km NE of Madura (36165).

South-west Division (W.A.): 34 km N of Murchison House (34040); 32 km NE of Yuna (26496, 47522-45); near Geraldton (1724-5, 1727, 31545); Beagle Point (19757-9); Stockyard Gully (13413); Green Head (37719); near Jurien Bay (15859, 30480, 30494-6, 46576); Lancelin Island (16544-8, 17878-9); Lancelin (16549-50); near Wanneroo (11002, 41784); Marmion (46130); North Beach (4783, 21272); City Beach (10664, 12645); Perth (416, 444); Dalkeith (12914).

Northern Territory: 10 km SW of Barrow Creek (24315) and 15 km SW (24362); Davenport Range (40142); Owen Springs (20847-8); 44 km WNW of Mt Olga (20790).

South Australia: 45 km W of Musgrave Park (20958-9); 160 km N of Cook (31862); 37 km ENE of Wirrulla (24531); 16 km S of Kimba (25566-7).

Omolepida maxima sp. nov.

Holotype

R27760 in Western Australian Museum, collected by W.H. Butler on 6 January 1966 at Kalumburu, Western Australia, in 14°18'S, 126°38'E.

Paratype

R46885 in Western Australian Museum, collected by R.E. Johnstone on 25 August 1974 in the Prince Regent River Reserve, Western Australia, in 15°34'S, 125°25'E.

Diagnosis

A very large *Omolepida*, similar to *O. branchialis* in all respects but size and coloration.

Distribution

Sandstone plateaux of north-west Kimberley.

Description

Snout-vent length (mm): 201-230. Length of appendages (% SVL): foreleg 13-14, hindleg 17-19, tail 108.

Nasals forming a median suture. Prefrontals widely separated. Supraoculars 4, second and third largest, last smallest. Supraciliaries 5, second widest, first and fourth highest. Upper labials 7. Ear aperture moderately large with one or two obtuse or truncate lobules. Enlarged nuchals 3 or 4 on each side. Midbody scale rows 22. Subdigital lamellae smooth, 15-17 under fourth toe.

Upper and lateral surfaces reddish brown; back, tail and flanks spotted with brownish white. Underneath whitish.

Remarks

In everything but size *O. maxima* is so like *O. branchialis* that its speciation can only have taken place recently. In coloration it is fairly similar to juvenile *branchialis*, which reminds one that it is in the geographically nearest population of *branchialis* that the white-spotted juvenile coloration is retained longest.

Omolepida maxima joins the growing list of reptiles endemic to the sub-humid zone of north-west Kimberley. Other examples are *Amphibolurus microlepidotus*, *Diporiphora superba*, *Diporiphora convergens* and *Ctenotus mastigura*.

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FISH TRAPS IN THE SOUTH-WEST OF WESTERN AUSTRALIA

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and

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INTRODUCTION

Among the Aboriginal artifacts noted by the first European visitors to the south-west coast of Western Australia were stone structures which they concluded were used for catching fish. For example, accounts by Vancouver 1791, the Baudin expedition in 1803, and King in 1818, of their visits to King George Sound prior to settlement include descriptions of 'fish traps' (Vancouver 1798, vol. 1, p.38; Péron 1816, vol. 2, pp. 149-151; King 1827, vol. 1, p.16).

Today the remains of such structures are known at Oyster Harbour and Kalgan River near Albany (King George Sound), Wilson Inlet near Denmark and Broke Inlet at the mouth of the Shannon River (fig. 1a).

Hammond (1933, 1936) and Paterson (1896) later described fish traps made from brushwood on the Serpentine River, and a photograph in the W.A. Museum (Plate 1), which was taken about 1900, shows what are believed to be the remains of a brushwood fish trap on the Murray River. However no evidence of these structures appears to have survived.¹

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1. Since this paper was written, we have been informed that the remains of a wooden fish trap have been discovered at Windy Harbour, about 45 km west of Broke Inlet. These are to be described by C.E. Dortch and G. Gardner (*pers. comm.* Dortch).

STRUCTURES AT OYSTER HARBOUR

The Oyster Harbour traps were first recorded by Vancouver (1798, vol.1, p.38) when he visited King George Sound in October 1791. He described them as follows:

On the sides of this stream, as well as on the shores of Oyster Harbour, were seen the remains of several fish wears, about eight to nine inches high, evidently the sorry contrivance of the wretched inhabitants of the country; some of these were constructed with loose stones, others with sticks, and stumps of wood; . . .

Menzies (1791, MS.), who accompanied Vancouver, included further details in his account of them:

. . . as we walked along the beach towards it [?Kalgan River] we saw rude fish wares which did not bespeak much ingenuity in the contrivers; — they consisted of a row of small boughs of trees struck close together in the sand about two or three foot and kept close at the top by cross sticks along both sides fastened together with small withies and along their bottom some stones to prevent the fish escaping.

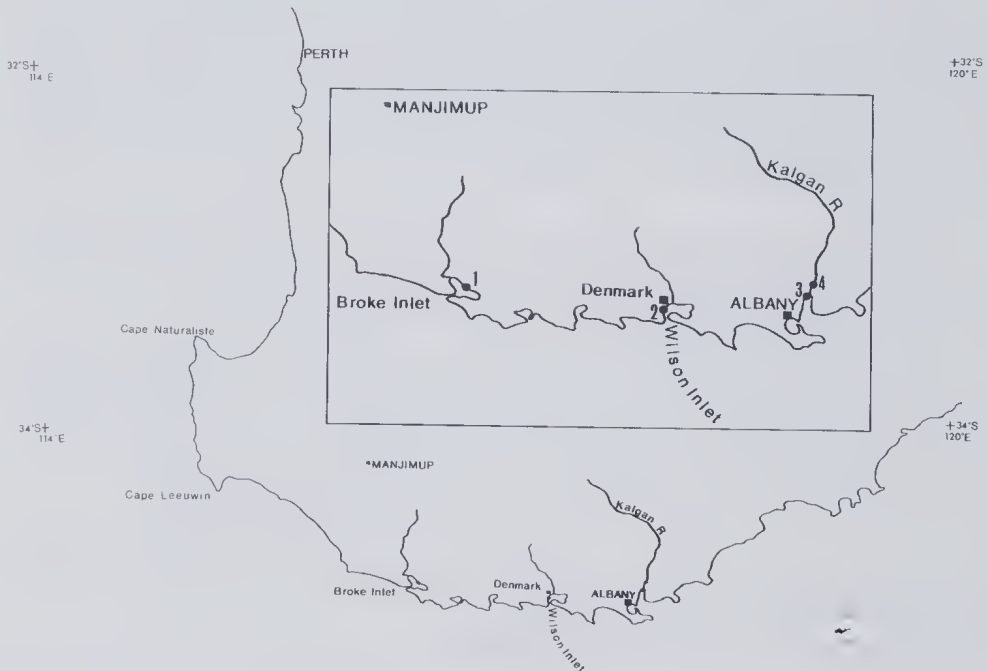


Fig. 1a: Locations of stone structures believed to be fish traps in the south-west of Western Australia.

1 — Broke Inlet, 2 — Wilson Inlet, 3 — Oyster Harbour, Albany, 4 — Kalgan River.



Plate 1: Structure of brushwood believed to be a fish trap, Murray River, Western Australia, circa 1900. Photographer not known.

On his visit to King George Sound in 1818 King (1827, vol. 1, p.16) noted:

The mouths of all the creeks and inlets were planted with weirs, which the natives had constructed for the purpose of catching fish. Mr Roe, on his excursion round the harbour, counted eleven of these weirs on the flats and shoals between the two rivers, one of which was a hundred yards long, and projected forty yards, in a crescent shape, towards the sea; they were formed by stones placed so close to each other as to prevent the escape, as the tide ebbed, of such fish as had passed over at high water.

Neither Vancouver nor Menzies nor King saw the traps in use, and it is not known whether King's account, which specifies that their use was dependent upon tidal movement, is based upon speculation or on information given to him by others.

Nind, who was Medical Officer at Albany from 1826 to 1830, described how Aborigines herded fish into pens made from bushes (see p.174). It is unclear from his description whether these pens were formed in association with the stone structures in the area. However

if they were it might explain the structures described by Menzies (see p.172).

In the autumn, when the smaller species of fish approach the shores in large shoals, they [the Aborigines] surround them, and keep them in shallow water upon the flats until the tide falls and leaves them, when they are easily speared, and very few escape. For this purpose they use a very small spear, without a barb, and throw it by hand; should it so happen that the tide does not sufficiently fall to enable them to take the fish, they gather bushes, and plant them round so thickly, as to enclose them, when they are speared at leisure. (Nind, 1831, p.33.)

The remains of fish traps at Oyster Harbour, east of Albany (plates 2-4), which were reported by King and Vancouver (*op.cit.*), today consist of eight semi-circles of low loose stone walls lying along the shore which is backed by a steep hill. There are also various smaller rings of stones associated with them (fig. 1c). The well defined medium-sized stone semi-circles, i.e. traps 3 and 4, are approximately 47 m long and 27 m wide, and 62 m by 29 m respectively. The diagram (fig. 2) based on a plane table survey illustrates traps 3 and 4.

The walls of the traps are wedge-shaped in section; four or five stones have been placed on the bottom, then two or three stones, with another one or two on top. Today in some places the walls have collapsed and the stones are spread out on the sand. The walls of trap 7 are the most complete, and in some parts, reach a height of about 40 cm. The configuration of this trap differs from the others in that it has a deeply indented 'entrance' or gap. The stones used to build the walls are irregularly sized and shaped but are generally about 15 cm in the smallest dimension. A small number are larger (labelled 'boulder' in the diagram); many smaller stones are scattered throughout.

Some walls appear to have collapsed; in places they are represented by a scatter of stones. The stones are more widely scattered in the shallows nearer the shore, compared with the denser lines of up to three or four stones in height which occur near the gap; this may reflect a pattern of construction related to water depth.

All the stones in the traps are of a dark, almost black, lateritic material found naturally in fair abundance on the strand, particularly west of trap 6. There are also quite anomalous heaps of granite stones within the reef to the south-west. They are of material not available in the immediate vicinity; they are evenly sized, very much like stones once carried for ballast in sailing vessels, but only a dinghy could have come so close to shore at this

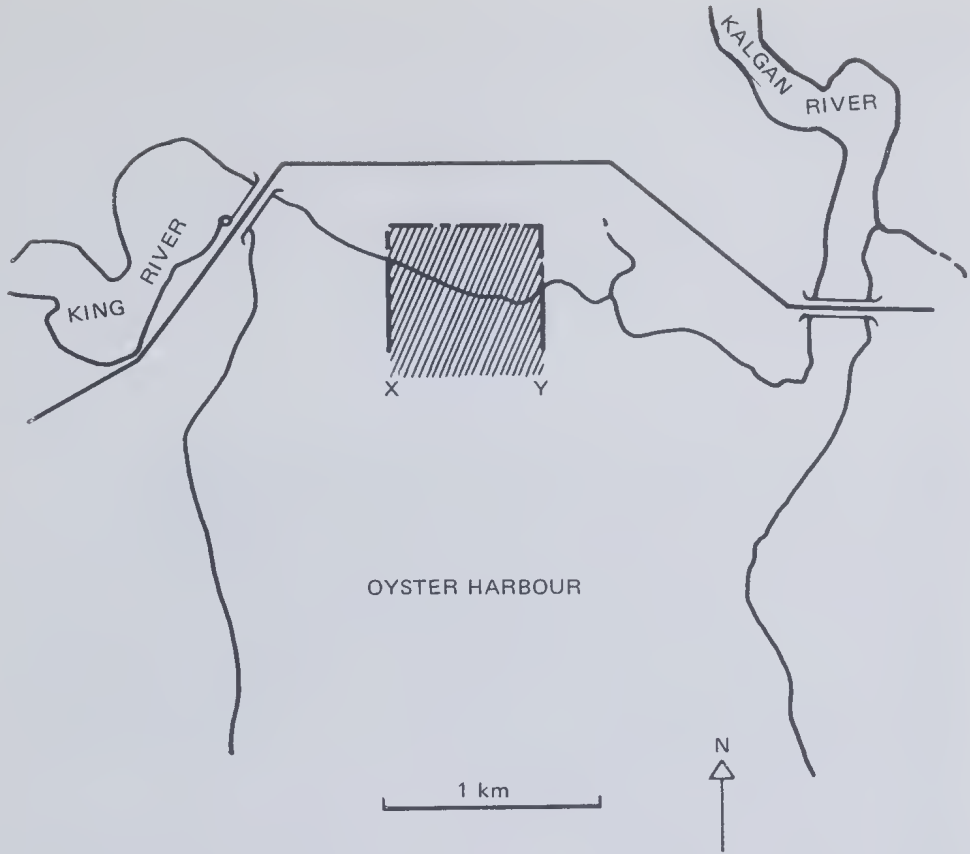


Fig. 1b: Oyster Harbour showing the location in which stone structures occur (X-Y), and the mouths of the King and Kalgan Rivers.

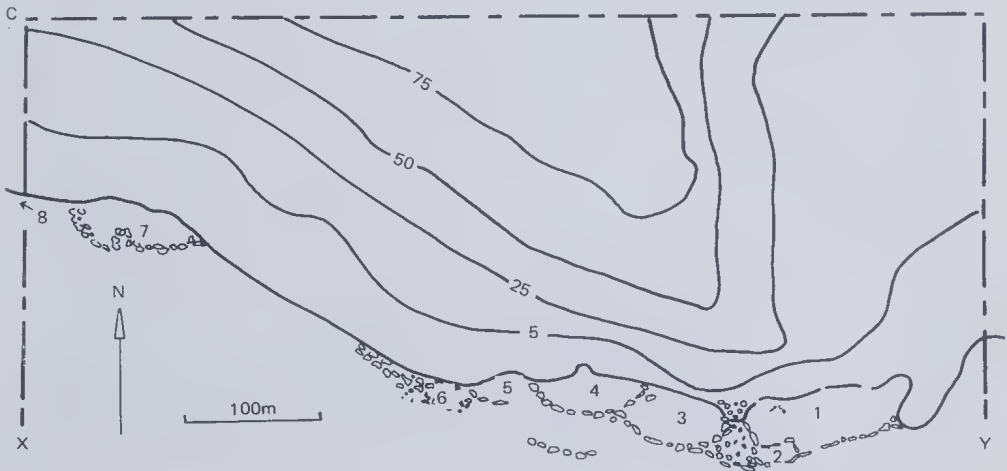


Fig. 1c: Diagram showing the arrangement of stone structures in the area indicated in X-Y in Fig. 1b.

location to have discarded them. They do not appear to have any connection with the stone structures.

The reef in the south-west does not seem to have been part of the structure of trap 4; however, a similar reef in the south-east forms one end of trap 3 (fig. 2). Trap 2 (fig.1c) almost entirely consists of natural reef, and it is reasonable to suppose that the presence of a natural trap formed by the reef may have initiated the construction of the remainder. Similar 'natural traps' have been noticed by one of us (Dix) at sites in the West Kimberley of Western Australia (see p.185).

No early observers (see above) mention the breaches or gaps in the lines, which occur in traps 1, 2, 3, 4 and 7. A number of other features apparently



Plate 2: Oblique aerial photograph from X-Y (see legend to Fig. 1c). Photograph by courtesy of D.A.P. West.

associated with the traps remain unexplained, namely circles of stones outside traps 4 (plate 5) and 6 and within trap 6, lines of stones within traps 1 and 3, and heaps of stones within trap 3 east of the large boulders.

We have not found any remains of wooden extensions to the stone walls which were mentioned by Menzies (see p.172).

Oyster Harbour is open to the sea in King George Sound through a channel at Emu Point 5.7 km south of the site. Although the channel is narrow, it is deep enough to permit a flow of tidal water causing appreciable high and low tides at the site. The estuary is shallow, and has sheltered water, whereas the Southern Ocean outside is notably rough.

King George Sound has a Mediterranean climate with cool summers. The flow of water in the rivers and through the estuary reduces to a trickle in the summer even though there are modest falls of rain during that season; however, water moves over the structures as a result of the tides. During spring tides in summer the stones are quite dry at low tide but covered at high tide. Neap tides do not leave the site quite dry.

STONE STRUCTURES IN OTHER ESTUARIES

Structures similar to those at Oyster Harbour have been found at two other sites, Wilson Inlet near Denmark, and Broke Inlet near Walpole.

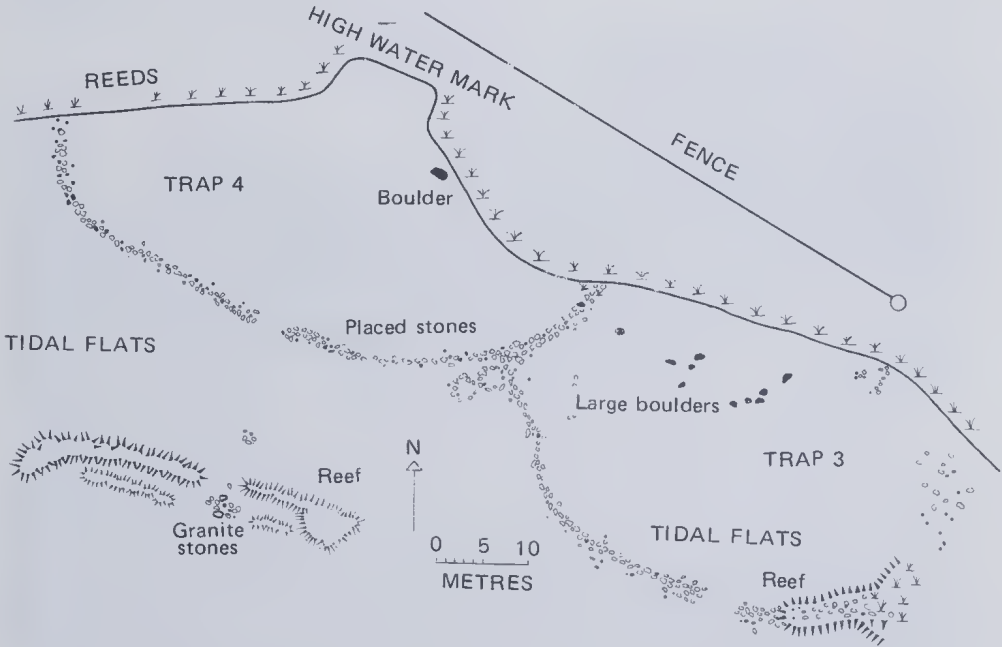


Fig. 2: Diagram of Oyster Harbour structures 3 and 4 (see Fig. 1c). Based upon plane table survey by W.C. Dix.



Plate 3: Photograph of trap 3 taken at low tide across the eastern edge of trap 4.



Plate 4: Trap 4 showing opening in wall and the reef beyond.

Although no direct reference to their existence appears in any published literature, Neill (1845, p.426) noted that during the winter the Aborigines from neighbouring areas gathered at Wilson Inlet to catch mullet, which was plentiful there at that time.

We have not made detailed surveys of these sites, but, on inspection, they do not appear to be functionally different from the structures at Oyster Harbour. At these other localities each structure forms an enclosure, resulting from a barrier of stones placed between upper and lower tide limits. Breaches in the lines of stone occur at both locations, but the apparently non-functional features characteristic of the Oyster Harbour structures (such as placed heaps of stones, lines, or circles of stones) have not been found by us at these other sites.

At Wilson Inlet the site consisting of several ill-defined enclosures (plate 6) is located on a promontory, backed by a steep hill as at Oyster Harbour. The inlet is sealed from the ocean by a sand-bar in summer, but it is opened in winter through the combined effect of flood water from the river and winter storms on the coast. During the time the inlet is open to the ocean the stones are exposed at low tide and covered at



Plate 5: Circle of stones outside trap 4 with line of stones within trap 3 beyond it.



Plate 6: Probable fish trap at Wilson Inlet.

high tide. During most of the year the structures could not function as tidal fish traps, but the sealing of the estuary by the sand-bar may be a recent phenomenon, and irrelevant to the use of the structures by Aborigines in earlier times.

At Broke Inlet there are at least eight separate enclosures, which occur along less than one kilometre of the shoreline of the estuary. The land in the immediate area is nearly flat, rising only gently away from the shore, which, being nearly level, does not have a clearly defined high water mark. Shallow tidal channels penetrate the general line of the shore at intervals, and three of the structures are clearly no more than lines placed across channels. The most intact example (plate 7) extends for 24 m between natural abutments. The remaining structures are more like those at Oyster Harbour, the most intact of which is 18 m across at its widest point. Three have obvious breaches in the line, and others have gaps, but we are unable to say whether or not these are intentional because of the deteriorated conditions of the structures.

Broke Inlet experiences no tides. It has not been open to the sea for any length of time in living memory. Following winter flood peaks, when the swollen river and inlet burst the bar, the inlet drains rapidly, then closes again. Even when the bar is open, there is reputedly little tidal influence at the site, which is at the far end of the inlet from the narrow channel. Presumably, if they were tidal fish traps they would have been constructed

when the inlet was open to the sea regularly, at least, if not permanently; there is no apparent way of gauging how long ago that may have been or whether it occurred. People who frequented the inlet about fifty years ago report to Dix that at that time the inlet was also sealed but there were abundant schools of fish in the waters.



Plate 7: Probable fish trap at Broke Inlet.

ESTUARINE STRUCTURES MADE OF BRUSHWOOD

As has been stated above, we have been unable to find any accounts describing Aboriginal use of estuarine fish traps made from stones. However the post-settlement accounts contain descriptions of the use of traps or enclosures made from bushes. Collie (Anon. [Collie] 1834) said that when a shoal of fish was sighted a watch was kept on it from the shore, or it was shepherded by a few Aborigines, while the other members of the group, men and women, gathered bushes to construct an enclosure, which was built out from the shore in either a semi-circle or a rectangle. The only indication of the size of one of these enclosures is that given by Collie (*op.cit.* p.335), "about 12 yards wide and about 20 yards long". The enclosure was either built around the shoal of fish, or the fish were herded into it through a gap left during its construction. Once the fish had been enclosed they were either speared or taken by hand. Descriptions of such operations indicate that from ten to fifty people were engaged on any occasion. This method

of taking fish was used mainly during summer and autumn. (Anon. [Collie] 1834, p.335; Browne 1856, pp.492-3; Chauncy 1878, p.248; Nind 1831, p.33.)

It is uncertain whether nets were used in conjunction with fish traps. Although some of the post-settlement accounts mention the use of nets (Grey 1841, vol.2, p.276; Hackett 1886, p.343; Paterson 1896, p.288), other accounts indicate that nets were not used before European settlement (Armstrong 1871, p.27; Nind 1831, p.27; Roth 1903, p.47).

RIVERINE STRUCTURES

In 1803 Fauré found a series of stone structures (plate 8a) built across the Kalgan River. The following is a translation of an account of them recorded by Péron (1816, vol.2, p.151):

Two dykes solidly built in dry stone joined from left and right a little island situated in the middle of the river and presented an obstacle for our boat; at intervals this wall had openings, placed mostly below the level of low tide; the openings on the sea-side were very wide while the openings facing the interior of the country were much narrower. By this means the fish, which at high tide ascended the river, could easily pass the dyke but then their escape being almost impossible, they remained in the reservoir where it was easy for the fishermen to catch them . . . within less than a third of a mile they counted six of these.

The same structures were described by Dumont d'Urville (1835, vol.2, p.276), but neither of the descriptions includes an account by a witness of their use. The location described by Fauré has been identified; one of the structures remains today between a small island and the north bank of the Kalgan River (plate 8b). On the southern side of the island and at two other places the probable remains of structures also occur; some are said to have been destroyed by explosives just before the turn of the century to permit the passage of river craft. That part of the river in which the structures occur is tidal.

The remaining structure lies across a channel of some 10 m at the narrowest, and comprises a series of curved lines or loops of placed stones linking natural rocks, which create five or six enclosures adjacent to one another. The stones are fully covered at high tide, and exposed at low tide.

We know of no descriptions, either pre-settlement or post-settlement, of Aborigines using riverine fish traps made from stones. Post-settlement



Plate 8a: Illustration from Dumont d'Urville illustrating the structure in the Kalgan River described by Fauré.



Plate 8b: Photograph of stone structure in the Kalgan River believed to be that described by Fauré.

accounts of the use of riverine traps, which include descriptions of their construction, say that they were made from bushes or sticks (Armstrong 1871, p.27; Hammond 1933, p.46; Nind 1831, p.32; Paterson 1896, p.288; Roth 1903, p.47). Other post-settlement accounts of Aborigines catching fish in riverine traps do not say from what, or how, they were made (Anon. [Collie] 1834, p.331; Bunbury 1930, pp.69, 87; Grey 1841, vol.2, p.275; Ilberry 1927, p.25; Irwin 1835, p.23).

Riverine fish traps were called by the Aborigines *manga* (Bunbury 1930, p.69; Irwin 1835, p.25), *mungo* (Paterson 1896, p.288), or *mungur* (Hammond 1933, p.46). They were built and used at the beginning of winter (Anon. [Collie] 1834, p.331; Bunbury 1930, p.87; Hammond 1933, p.46; Paterson 1896, p.288).

The most detailed description of the construction and use of a riverine trap is the following given by Hammond (1933, p.46) of one built in a narrow section of the Serpentine River:

A wicker fence was built across the stream, completely enclosing it from bank to bank, except in the centre, where a small opening was left. Through this opening a race was constructed by driving two parallel rows of stakes in the river bed. The bottom of this race was filled with bushes, until there was only about eight inches of clear water above the bushes for the fish to swim through. On either side of this race was built a platform, about two feet six inches below the top of the water. On these platforms the natives stood to catch the fish as they swam through the race. The fish were caught by hand as they passed over the bushes and were thrown to natives who were waiting on the bank to receive them.

According to Hammond the trap was constructed in the same place on the river every year. Hammond also noted (p.25) that this type of trap was liable to be washed away by floods.

Another description of a similar trap built in the Serpentine River is given by Paterson (1896, p.288):

. . . they used to build these weirs, called Mungo by them, where the water narrowed . . . These Mungos were very carefully constructed of long fine sticks of spearwood (a kind of titree) laid at the bottom as smooth as a carpet, and ending in narrow openings. Near these the blacks would watch, catching the fish as they were coming over the smooth sticks, and nick them at the back of the head with their teeth, before flinging them on to the land. Or a net would be set at the end below the narrows.

Sometimes very large catches would be made in this way, particularly at the beginning of the winter, when, with the increased rains, the fish returned from the spawning places upstream. At this time the blacks would watch day and night for the fish to come, relieving each other.

A photograph in the Western Australian Museum taken about 1900 shows the remains of a fish trap made from sticks on the Murray River (plate 1). There are no accounts or further reports of this fish trap, and it is most unlikely that it still exists.

DISCUSSION AND SUMMARY

If the estuarine structures described in this paper depended, for their use as fish traps, on a daily tidal flow, then their construction at Wilson and Broke Inlets predated the more-or-less permanent closure of the estuaries by sand-bars, which is the present condition. The descriptions by Nind (1831) and Anon. [Collie] (1834) of the use of brushwood traps suggests an alternative use for them (i.e. that they may have been pens into which fish were driven); such traps could have functioned in closed estuaries.

In the case of the riverine traps in the Serpentine River described by Paterson (1896) and Hammond (1933, 1936) their use seems to have depended upon seasonal movement of fish in the river. At the Kalgan River site the tide may have played some part in the functioning of these as well as the movement of fish.

One of us (Dix) studied stone fish traps near La Grange, south of Broome, where they were still in use. Aborigines visited these traps regularly after high tide to gather fish. At intervals a group of men also operated them actively; this group would partly block the 'gate', or breach, in the wall during tidal outflow. Fish were either taken by hand or speared while they tried to escape through the reduced gap. We are cautious in ascribing either of these methods employed in the Kimberley to the south-west of Western Australia because of the great differences in tidal conditions in the two places.

Despite the fact that the information on the function, as fish traps, of the stone structures described in this paper is very limited, we have little doubt that they were used by the Aborigines to catch fish. However, we do not know whether or not they were in use at the time of European settlement. There are no reliable accounts which either describe them in use or reveal the manner in which they were used. It is possible that the estuarine traps depended upon tidal flow to function but they may have been pens into which fish were driven. They may have been used in both ways. Similar

traps near Broome employed the outgoing tide, and either stranded fish or concentrated them so that they might be more easily taken.

ACKNOWLEDGEMENTS

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THE GENUS *MENETIA* (LACERTILIA, SCINCIDAE) IN WESTERN AUSTRALIA

G.M. STORR*

[Received 1 July 1975. Accepted 1 October 1975. Published 30 September 1976.]

ABSTRACT

The Australian genus *Menetia* comprises at least five species, three of which occur in Western Australia, namely *M. greyii* Gray, *M. maini* nov. and *M. surda* nov. A lectotype is designated for *M. greyii*.

INTRODUCTION

Until recently all skinks with an immovable transparent lower eyelid were placed in *Ablepharus*. Fuhn (1969) broke up this polyphyletic assemblage, allotting the Australian species to nine groups, including the genus *Menetia*. Fuhn, and indeed all workers till now, regarded *Menetia* as monotypic. Greer (1974) believes that *Menetia* is derived from the genus *Carlia*.

All the material used in this revision is lodged in the Western Australian Museum.

Genus *Menetia* Gray

Menetia Gray, 1845, 'Catalogue of the specimens of lizards in the collection of the British Museum', p.65. Type-species (by monotypy): *M. greyii* Gray.

* Curator of Birds and Reptiles, W.A. Museum.

Diagnosis

Very small, smooth, terrestrial skinks with lower eyelid immovable and bearing a large circular transparent disc incompletely surrounded by granules; digits 4 + 5; first supraocular long and narrow and obliquely orientated.

Distribution

Most of Australia except the wettest and coolest regions. At least five species, three of them in Western Australia.

Description

Snout-vent length up to 38 mm. Tail fragile, 1.2-2.0 times as long as snout to vent.

Nasals usually separated widely. No supranasals or postnasals. Prefrontals usually separated very narrowly. Frontal small, little if any larger than prefrontals. Frontoparietal single, much the largest head-shield. Interparietal small to very small. Mostly one pair of nuchals. Supraoculars 1 or 2 (excluding a large upper postocular that could be construed as a supraocular). Supraciliaries 2-4 (excluding a small upper postocular that could be construed as a supraciliary), second largest. Circumocular granules interrupted (or partly hidden) by large second supraciliary. Loreals 2, in horizontal series. Upper labials normally 6, fourth subocular and much the widest. Temporals 3, uppermost largest. Midbody scale rows 18-26. Lamellae under fourth toe 13-24, smooth, callose or feebly keeled.

Generally drab in colour, with little or no pattern except in *M. greyii*.

KEY

1. First supraocular nearly three times as long as wide; uppermost circumocular granule not enlarged; ear aperture small or minute 2
First supraocular about twice as long as wide; uppermost circumocular granule much enlarged; no ear aperture *M. surda*
2. Second supraciliary much larger than first and in contact with prefrontal; white mid-lateral and dark upper lateral stripe well

developed or only discernible anteriorly *M. greyii*
 Second supraciliary a little larger than first
 and not in contact with prefrontal; no lateral
 stripes *M. maini*

Menetia greyii

Menetia Greyii, Gray, 1845, 'Catalogue of the specimens of lizards in the collection of the British Museum', p.66. W.Australia.

Diagnosis

First (and only) supraocular much more than twice as long as wide, and separated from first supraciliary by very large second supraciliary (see Fig. 1). Uppermost circumocular granule not greatly enlarged. Ear aperture minute. Usually some indication (especially anteriorly) of white midlateral and dark upper lateral stripes.

Distribution

Greater part of Western Australia from Derby and Lake Argyle south to Nannup, Rocky Gully and Mt Barker (i.e. all but the wettest parts of the State). Extralimital in Northern Territory, South Australia and New South Wales.

Description

Snout-vent length (mm): 11-38 (N 326, mean 28.7). Tail up to 1.76 times as long as snout to vent.

Nasals separated, usually widely. Prefrontals usually separated (usually very narrowly, occasionally moderately narrowly); very rarely in short contact. Nuchals usually 1, occasionally 0 or 2, rarely 3 or 4. Supraciliaries 2, second greatly enlarged and usually in contact with prefrontal. Upper labials 6 (rarely 5). Midbody scale rows 20-24 (22 in 74% of specimens, N 191, mean 22.1). Lamellae under fourth toe 13-22, mostly (84%) 17-20 (N 191, mean 18.4).

Dorsally pale to dark olive-grey or olive-brown, usually with obscure dark brown or blackish spots roughly aligned in 2 or 4 longitudinal rows. Broad dark brown or black upper lateral stripe usually present, occasionally margined above by narrow indistinct, pale dorsolateral stripe, and extending forward narrowly through orbit to lores. White midlateral stripe usually present, extending forward as labial streak. Ventral surfaces usually immaculate.

Geographic variation

In this continuously distributed species much of the variation is clinal. Most clines are from north to south, including

- 1) slight increase in body size
- 2) marked decrease in relative length of tail
- 3) decrease in diameter of ear aperture (in southern specimens a slight depression is more easily discerned than the aperture itself, which tends to be hidden anteriorly by a scale)
- 4) decrease in length of toes and in number of subdigital lamellae
- 5) toes changing from slightly compressed with fine, weakly mucronate subdigital keels in north to cylindrical with narrow to wide subdigital calli in south
- 6) increasing darkness of coloration and obscurity of pattern. First the dark upper lateral stripe becomes narrower on body than in front of forelegs, and the white midlateral stripe becomes increasingly suffused with greyish brown. In the southernmost specimens these stripes are usually discernible only in front of forelegs and even there they tend to be faint and irregular. The lips, chin and under tail become increasingly spotted with dark brown or grey.

Non-clinal variation is exemplified by number of midbody scale rows. Counts of 24 are most frequent in the Perth Metropolitan Area and on Eyre Peninsula (S.A.). Counts of 20 are almost as frequent as 22 in the Northern Territory and northern South Australia.

Remarks

I am grateful to Mr A.F. Stimson of the British Museum (Natural History) for the loan of five of Gray's syntypes from the series of twenty-five (XI 7a-e), collected in "West Australia" and purchased from a Mr Turner. I hereby designate one of them (1946. 8. 16. 9) as lectotype.

Material

Kimberley Division (W.A.): Lake Argyle (42917, 49167); Derby (20294).

North-west Division (W.A.): Port Hedland (18470); 10 and 24 km E of Mundabullangana (18465-9); Depuch Island (14558); 32 km S of Marble Bar (22786); Tambrey (20068); N of Wittenoom (37076); near Tom Price (31014); Poonda (27984); Junction Well, Oakover River (42261); 34 km NNW of Ullawarra (25254); Marrilla (5337); Ningaloo (16866); Quobba (32639); islet off Point Charles (18473); Callagiddy (40666); Faure I. (13193); Yaringa (18461, 19049); 14 km W of Hamelin Pool (18472); Mileura (15809, 28341, 40226); 32 km N of Meekatharra (20542); Nannine

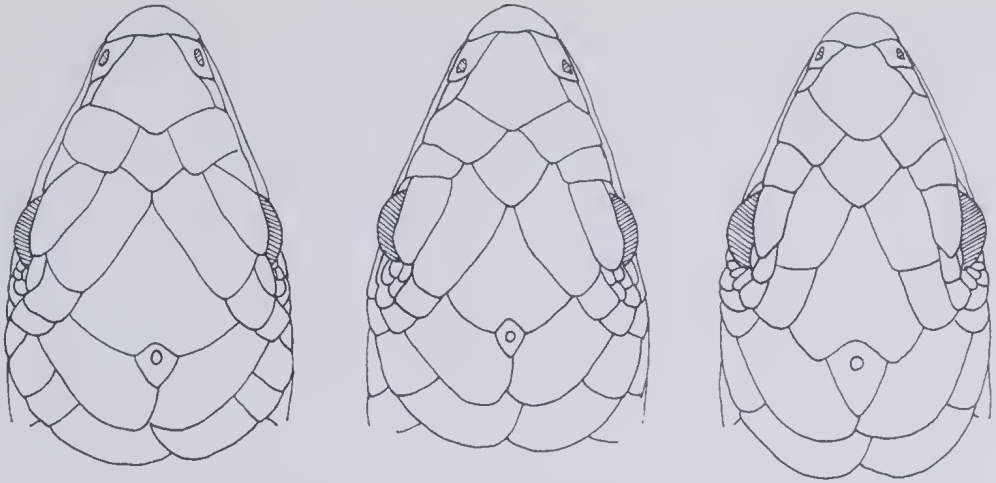


Fig. 1. Heads of *Menetia* species showing differences in supraocular and supraciliary shields. Left to right: *M. greyii*, *M. maini* and *M. surda*.

(18474-6); Meka (29274-9); Marloo (30853); Rothsay (27979).

Eastern Division (W.A.): Well 46, Canning Stock Route (40906); Swindells Field (29384-5); Well 35, CSR (26974-6); 56 km E of Talawana (27107); SW corner of Lake Disappointment (42320); Well 30, CSR (40944); Jupiter Well (45151); Pollock Hills (40176); Giles (34154); Wingelinna Mining Camp (34306); Cavenagh Range (20734); 19 km W of Warburton Mission (18429); Aerodrome Lake, N of Well 11, CSR (40367); Lake Nabberu (3897); Carnegie (45152); 8 km W of Yelma (21107); Terhan R.H. (18428); 16 km SW of Point Wool ($27^{\circ}19'S$, $126^{\circ}20'S$) (41577); Beegull R.H. (18430); Yamarna (20692); Youanmi (18537); 56 km NW of Leonora (18432); Mt Margaret (17680); Smith's Station, 145 km N of Loongana (18458-9); 96 km S of Neale Junction (41585); Plumridge Lakes ($29^{\circ}42'S$, $125^{\circ}14'E$) (48727); 110 km NW of Rawlinna (33629-30); Queen Victoria Spring (18433-4); 5 km NW of Callion (22536); Kalgoorlie (18431, 28875); 10 km E of Karonie (17327-9); Emu Rocks, 24 km N of Coonana (30263, 30265); Coonana (12958); 30 km W of Naretha (12237); 48 km N of Norseman (47254).

South-west Division (W.A.): Gee Gie Outcamp, 34 km NNW of Murchison House (34049); Culcurdoo, 32 km N of Kalbarri (34341); Kalbarri (33844, 33934, 34140); Meanarra Hill, 6 km E of Kalbarri (33933); Junga Dam, 23 km E of Kalbarri (33835); Lockwood Spring, Kalbarri National Park (37564); Binu (22319); East Yuna Reserve, 30 km ESE of Yuna (48111, 48252); Eastern I., Wallabi Group, Houtman Abrolhos (25977); Suomi, Rat, Leo and Morley Is, Easter Group, Houtman Abrolhos (37503, 41236-7, 41520, and 41527 respectively); 6 km E of Dongara (30313); Caron

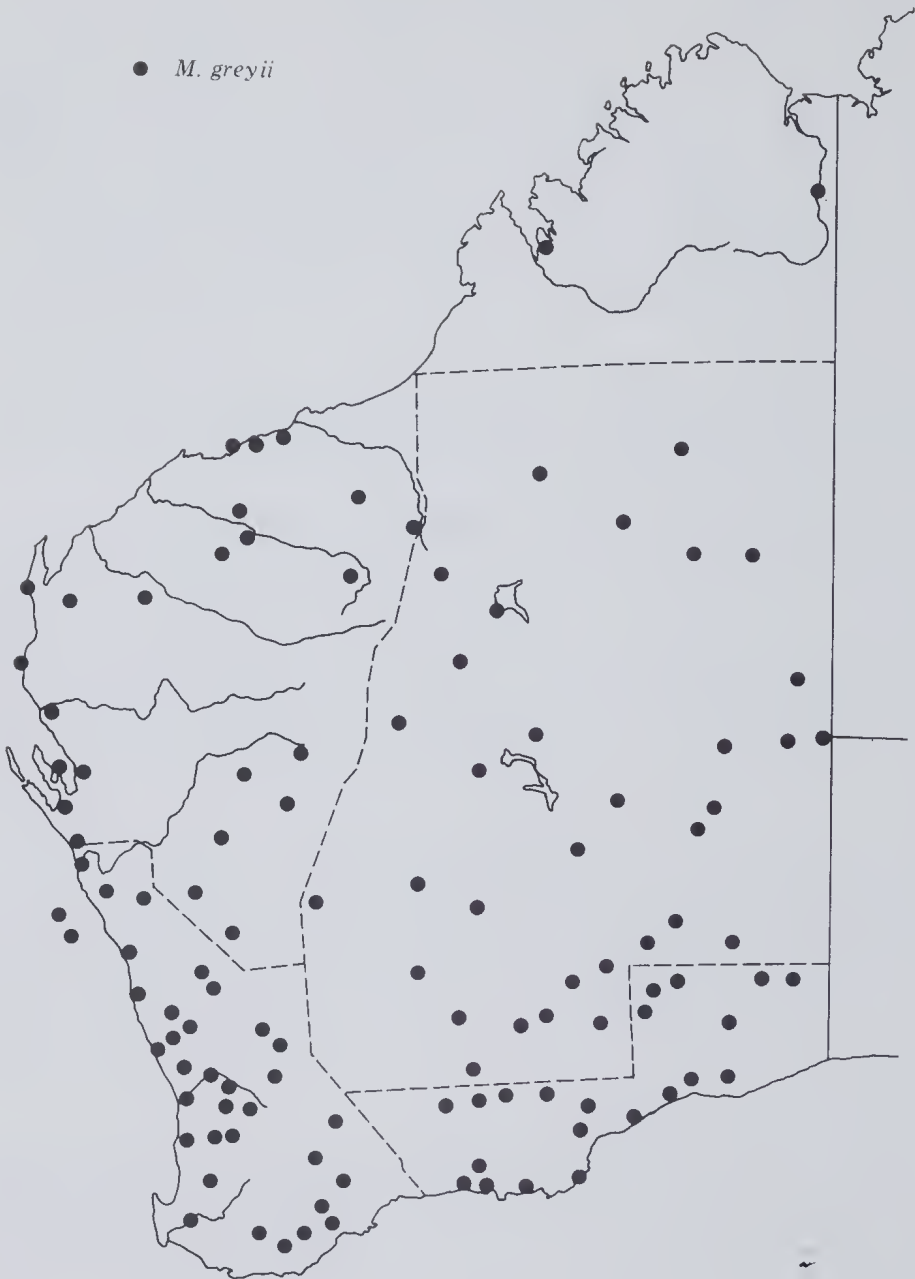


Fig. 2. Map of Western Australia showing location of specimens of *Menetia greyii*.

(22301); Buntine Reserve (44922); 5 km E of Green Head (49071); Eatha Spring (30°07'S, 115°03'E) (49139-41); 4 km E of Mt Peron (49000); 10 km NE of Cockleshell Gully (22233-4); Cockleshell Gully (49128); 5 km W of Padbury HS (30°10'S, 115°04'E) (49076, 49088-9); 24 km W of Watheroo (25822); Miling (48146); Moora (18457, 25300); Dandaragan (25990); 24 km N of Lancelin (18455); Koorda (7804, 22837); Trayning Reserve, 11 km NE of Kununoppin (46142-3, 46146-7, 46374); Gingin (34104); Chittering East (12835); Julimar Forest (47814); Walyunga (12884); Culham (22458); Toodyay (18435, 36342); Tammin (39086); Northam (29522, 31447); 8 km N of Wanneroo (31451-64); Upper Swan (18453-4); Herne Hill (4778-82); John Forrest National Park (14048); Mundaring (21237); Mundaring Weir (18554, 19828); 8 km E of Kalamunda (19981); Helena Valley (47987-9); Swan View (14085); Guildford (19862, 22856); Mt Lawley (29053); Perth (389, 3417); West Perth (23820); Wembley (14007, 18441-6, 21271, 21641, 39957); Floreat Park (26232); Crawley (18456); Nedlands (14178); Dalkeith (18451); Bentley (32384, 40018); Kenwick (18437-40); Lesmurdie (18447-50, 19668); Bickley Camp (29895); Seaforth (18436); Spearwood (2767); Thompsons Reserve (36563-5); East Rockingham (18452); Boyagin Reserve (41019-24); near Beverley (4506); Tutanning Reserve (21646); Bending Reserve (43413); Hyden (44891); Wave Rock (48623); Lake Varley (19806-7, 27258); Culeenup I., Yundurup (37750-2, 39161, 42611-2); Banksiadale (34260); Boddington (13606); Dryandra (39008); Yornaning (19752); 20 km SE of Williams (29691); Harris River, near Collie (46393); 5 km SW of Collie (18425); north end of Lake Grace Reserve (44205-6, 44232); Lake Grace south (42605); Lake Chinocup Reserve (43494, 44100-01); 25 km E of Pingrup (39825); Ongerup (34268) and 10 km SE (42628); Nannup (45743, 47399); 10 km W of Rocky Gully (18420-4); 16 km E of Rocky Gully (18416-9); Mt Barker (37971-3); Chester Pass, Stirling Range (18415); middle Fitzgerald River (36878, 36947, 39911); Boondardup River (34°13'S, 119°31'E) (37211).

Eucla Division (W.A.): 112 km NE of Rawlinna (34024); 96 km N of Rawlinna (37050-1); 80 km NNE of Rawlinna (39062-4, 41209, 43588-9); 72 km N of Seemore Downs (25869); Seemore Downs (18462-3, 40193); 8 km N of Rawlinna (26430); 27 km E of Rawlinna (37662-3); 103 km NNE of Loongana (41627); 8 km S of Loongana (29432-7, 34503); 80 km N of Forrest (41621); 16 km NE of Eucla (24592); Wilsons Bluff (43798); Eucla Pass (31073); Eucla (24640-3); Madura Airstrip (29461-3); Cockle-biddy (36556-7, 40950); Cardanumbi R.H. (291); 40 km WSW of Caiguna (24672); Balladonia HS (17403-4, 29891) and 19 km SW (17415, 17421); 9 km E of Noondonia (17401-2); 8 km SW of Noondonia (17393); 11 km S of Balladonia Hotel (17387, 17468); 13 km E of Frazer Range (30761); 29 km E of Norseman (18426-7); Norseman (30778-9); Moir Rocks (18406-7); 6 km S of Nanambinia (17429); Toolinna R.H. (45348);

Coragina Rock (18408); Israelite Bay (17618, 18409); 3 km NW of Duke of Orleans Bay (41980); 23 km E of Esperance (18410); 35 km N of Esperance (18411-3); Esperance (13369); Dalyup River (18414).

Northern Territory: 15 km SE of Elliott (24162); 23 km N of Wauchope (24276); 42 km SW of Barrow Creek (24373); 26 km NE of 'Teatree' (24378); Aileron (24410-1); Kintore Range (31033); Alice Springs (20905); Hermannsburg (20871-2); Curtin Springs (20815); Ayers Rock (46642); 35 km W of Victory Downs (20930-2).

South Australia: 8 km S of Mt Davies (31706, 44356-8); 17 km S of Mt Davies (31707); Cheesmans Peak (44378-81); 61 km E of Vokes Hill (36651); 27 km E of Emu (36630); 43 km E of Emu (36629); Churina Well, 214 km N of Cook (36654); 10 km N of Kokatha (24501-4); Fowlers Bay (24580-2); Ceduna (25552-3) and 6 km E (24570); Smoky Bay (24531); Kyancutta (25516); Arno Bay (27317); Port Neill (27325); Marree-Birdsville Track (40573); Milurina (44933-4); Etadunna (44935, 44940); Wild Horse Plain (27306); Lower Light (27305); 10 km N of Murray Bridge (27272-4).

New South Wales: 16 km N of Mt Hope (46137).

Menetia surda sp. nov.

Holotype

R13249 in Western Australian Museum, collected by Mr A.M. Douglas in May 1959 at Budjan Creek, Corunna Downs, Western Australia, in 21°42'S, 119°50'E.

Diagnosis

First of two supraoculars not much more than twice as long as wide, and in contact with first supraciliary (see Fig. 1). Uppermost circumocular granule greatly enlarged. No indication of ear aperture or of white mid-lateral stripe.

Distribution

Western arid zone of Western Australia from the Pilbara south to the far northern Wheat Belt, including islands in the Dampier Archipelago and Shark Bay.



Fig. 3. Map of Western Australia showing location of specimens of *Menetia maini* and *M. surda*.

Description

Snout-vent length (mm): 20-32 (N 35, mean 27.0). Tail up to 2.01 times as long as snout to vent.

Nasals widely separated. Prefrontals very narrowly separated or forming a short to moderately long suture. Nuchals 0 or 1, rarely 2. Supraciliaries 3 or 4, second largest but not in contact with prefrontal. Upper labials 6 (rarely 7). Midbody scale rows 20-24 (N 23, mean 21.7). Lamellae under fourth toe 20-24 (N 22, mean 21.9), smooth.

Dorsally and laterally pale to dark olive-brown, usually without pattern, but dark upper lateral stripe faintly discernible in some of palest northern specimens, and a dark median stripe discernible on dorsal and lateral scales of most southern specimens. Upper labials and ventral surfaces pale.

Geographic variation

In the north prefrontals are almost as often contiguous as separated; in the south they are always separated. Subdigital lamellae are slightly fewer in the north than south, counts averaging 21.4 in the North-west Division and 22.4 in the South-west Division. Coloration tends to be paler and more uniform in the north, and darker and more striate in the south.

Paratypes

North-west Division (W.A.): Warrawagine (13248); Ripon Hills (13247); Junction Well, upper Oakover River (42228-9, 42239-40); Dolphin I., Dampier Archipelago (14329-30); Yardie Creek HS (13192*a-b*) and 50 km S (27980-3); 3 km E of Norwegian Bay, Ningaloo (32030); 21 km NW of Ullawarra (25262-4); Bernier I. (20524-5); 27 km E of Tamala (18271).

South-west Division (W.A.): Meanarra Hill, 7 km E of Kalbarri (33536); East Yuna Reserve, 30 km ESE of Yuna (48109, 48112-3, 48124-5, 48225, 48235-7, 48253); Bindoo Hill Reserve, 20 km NNW of Tenindewa (48194, 48203).

Menetia maini sp. nov.

Holotype

R18464 in Western Australian Museum, collected by A.R. Main on 3 November 1961 at 23 km SSE of Derby, Western Australia, in 17°29'S, 123°43'E.

Diagnosis

First (and only) supraocular much more than twice as long as wide, and in contact with first supraciliary (see Fig. 1). Uppermost circumocular granule not enlarged. Ear aperture small. No indication of lateral stripes.

Distribution

North-west coast and coastal plains of the Kimberley Division from the Prince Regent River south-west to King Sound.

Description

Snout-vent length (mm): 19-28 (N 17, mean 24.3). Tail up to 1.55 times as long as snout to vent.

Nasals widely separated. Prefrontals usually narrowly separated, occasionally in very short contact. Nuchals usually 1, occasionally 2, rarely 0. Supraciliaries 2, second not in contact with prefrontal. Upper labials 6. Midbody scale rows 22-26 (N 12, mean 23.7). Lamellae under fourth toe 16-21 (N 15, mean 18.1), smooth.

Upper surfaces brown, dorsal scales sometimes with an indistinct dark median streak. Laterally brown, indistinctly flecked with dark brown and occasionally with brownish white. Ventral surfaces generally pale, but scales (especially of throat and under tail) often edged with greyish brown.

Geographic variation

The single specimen from the Prince Regent River differs from the remainder (all from the Derby district) in being the only specimen with (1) more than 24 midbody scale rows, (2) more than 19 subdigital lamellae, (3) with no nuchals (on one side of neck), and (4) snout-vent length greater than 27 mm. This specimen was misidentified by Storr and Smith (1975) as *Menetia greyii*.

Remarks

Named after Professor A.R. Main, University of Western Australia, in appreciation of his services to Western Australian herpetology.

Paratypes

Kimberley Division (W.A.): Prince Regent River Reserve (15°28'S, 125°40'E) (46945); Derby (20283-93, 20343-6).

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A supplementary series to the *Records of the Western Australian Museum* has been commenced.

No. 1 KITCHENER, D.J.; CHAPMAN A. & DELL, J.
A Biological Survey of the Cape le Grand National Park.

No. 2 KITCHENER, D.J. *et al*
Biological Surveys of the Western Australian Wheatbelt,
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RECORDS
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Cover: The Common Rabbit Bandicoot (*Macrotis lagotis*), drawn by Martin Thompson, Western Australian Museum. This is a medium-sized carnivorous marsupial. Once common in the wheatbelt of Western Australia, they are no longer found there. Populations still occur in some remote parts of the State such as Dampier Land, the Pilbara, and desert areas of central Australia.

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A REVIEW OF THE PLESIOPID FISH GENUS
ASSESSOR, WITH DESCRIPTIONS OF TWO NEW SPECIES

GERALD R. ALLEN*

and

RUDIE H. KUITER†

[Received 24 October 1975. Accepted 11 May 1976. Published 15 October 1976.]

ABSTRACT

The plesiopid fish genus *Assessor* Whitley was formerly known on the basis of a single specimen of *A. macneilli* collected at Hayman Island, Queensland. In the present paper the range of this species is extended, including widespread localities on the Great Barrier Reef and an observation record from New Caledonia. In addition, two new species are described, *A. flavissimus* from the northern Great Barrier Reef and *A. randalli* from the Ryukyu Islands. Important characters for separating the species of *Assessor* include coloration, scalation (particularly of the cheek and above the lateral-line), and counts for the gill rakers, soft dorsal rays, and soft anal rays. A key to the species is included and detailed observations are presented on the reproductive habits of *A. macneilli*.

INTRODUCTION

Whitley (1935) described *Assessor macneilli* as a new genus and new species of plesiopid fish from a single specimen, 45 mm in standard length collected at Hayman Island, Queensland in 1934. It has subsequently been taken by us at various localities on the Great Barrier Reef from Lizard Island, north of Cooktown, as far south as the Capricorn Group near the southern extremity of the Barrier Reef. In addition, it was observed by the senior author off Noumea, New Caledonia. During June and July 1972, the senior author collected reef fishes at Pixie Reef, off Port Douglas, Queensland. These included several specimens of *A. macneilli* and a bright yellow *Assessor*

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which was undescribed. Additional specimens were procured on subsequent trips to the northern Barrier Reef in late 1972 and 1974. Dr John E. Randall kindly sent 13 specimens of *A. "macneilli"* which he collected in 1968 at Ryukyu Islands, off southern Japan. These proved to be another undescribed species. The present paper includes a review of *Assessor* with descriptions of the new species and detailed observations of the unusual habit of oral egg incubation exhibited by *A. macneilli*.

We have deposited specimens of the new species in the Australian Museum, Sydney (AM), Bernice P. Bishop Museum, Honolulu (BPBM), British Museum (Natural History), London (BM[NH]), United States National Museum of Natural History, Washington, D.C. (USNM), and the Western Australian Museum, Perth (WAM).

GENUS *ASSESSOR*

Assessor Whitley, 1935. Rec. Austr. Mus., 19(4): 231 (type species, *A. macneilli* Whitley by original designation).

Dorsal rays XI, 8 to 10½ (rarely with XII spines); anal rays III, 9½ to 10½; pectoral rays 14 to 16; pelvic rays I,4; tubed scales in lateral-line 16 to 23 + 1 to 9; gill rakers on first branchial arch 23 to 36.

Body elongate, the depth 3.0 to 3.6 in standard length, and moderately compressed, the width at gill opening 1.9 to 2.4 in depth; head short, 3.2 to 3.8 in standard length; snout short, obtuse, 4.4 to 5.8 in head length; eye large, 2.5 to 3.6 in head, near upper profile; interorbital space convex, the bony width 3.2 to 5.1 in head; caudal peduncle depth about equal to its length, 1.5 to 1.8 in head.

Mouth terminal, oblique (about 45°), the maxillary scaled and reaching to beneath posterior part of eye; teeth of jaws villiform, in a single row except multiserial at front of jaws; a few enlarged teeth on each side of median symphysis at front of lower jaw; upper jaw with edentulate indentation at median symphysis; palatines with band of small granular teeth; vomer toothless.

Six branchiostegal rays; gill membranes united across isthmus; posterior nostrils in a short tube; a series of relatively large pores around eye and on top of head; most of body scales finely ctenoid, those of head either cycloid or finely ctenoid; lateral-line with series of tubes running along back to below base of soft dorsal fin, interrupted and then continuing with a few tubed scales along middle of caudal peduncle; low scaly sheath on all fins except pelvics.

Dorsal spines gradually increasing in length posteriorly, last spine 1.9 to 3.2 in head length; longest soft dorsal ray 0.9 to 1.8 in head length; origin of

anal fin below middle of dorsal fin; caudal fin forked; pectoral fins rounded, the longest ray 0.9 to 1.1 in head length; pelvic fins pointed, their origin directly below base of pectorals, the longest ray 0.8 to 1.2 in head length.

Table 1. Fin ray and gill raker counts for species of *Assessor*.

Species:	<i>A. macneilli</i>	<i>A. flavissimus</i>	<i>A. randalli</i>
Soft Dorsal Rays			
7		1	
8		1	
9	2		1
9½	14		2
10		2	9
10½		18	1
Soft Anal Rays			
9			
9½	16	1	1
10		1	11
10½		20	1
Gill Rakers:			
Upper Limb			
7		12	
8		10	12
9			1
10	3		
11	5		
12	8		
+			
Lower Limb			
16		1	1
17		13	8
18		5	4
19		3	
20			
21			
22			
23	13		
24	3		

KEY TO THE SPECIES OF *ASSESSOR*

- 1a. Gill rakers on lower limb of first branchial arch 23 to 24, total rakers 33 to 36; cheek (preopercle) scales cycloid; colour primarily dark brown to black, blue in life (Great Barrier Reef, New Caledonia) *macneilli* Whitley

- 1b. Gill rakers on lower limb of first branchial arch 16 to 19, total rakers 23 to 27; cheek (preopercle) scales finely ctenoid, colour either brown or pale tan, blue or yellow in life 2
- 2a. Colour generally brown to dark brown, blue in life; scales above lateral-line finely ctenoid; 3rd or 4th from last dorsal and anal ray usually the longest; width of bony interorbital 3.2 to 3.7 in head length (Ryukyu Islands) *randalli n.sp.*
- 2b. Colour generally pale tan, yellow in life; scales above lateral-line cycloid; penultimate soft dorsal and anal ray usually the longest; width of bony interorbital 4.1 to 5.1 in head length (northern Great Barrier Reef) *flavissimus n.sp.*

Assessor macneilli Whitley
(Figs. 1, 2 and 3; Tables 1 and 2)

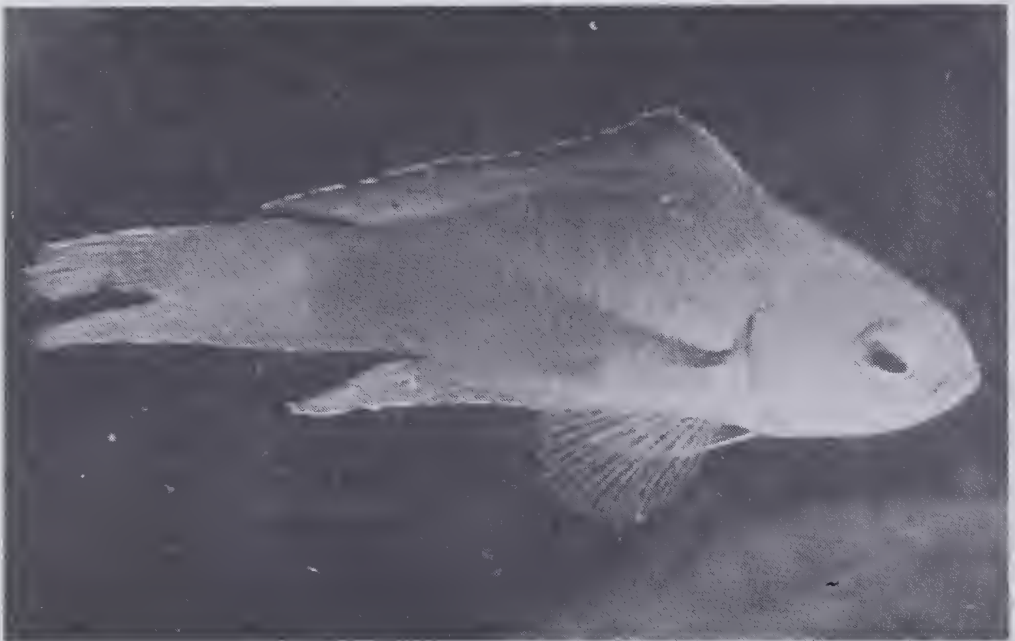


Fig. 1. *Assessor macneilli*, approximately 40 mm SL, photographed in 4 metres at One Tree Island. The photo has been inverted as the fish was swimming upside down.

Assessor macneilli Whitley, 1935. Rec. Austr. Mus., 19(4): 231 (type locality, Hayman Island, Whitsunday Passage, Queensland.)

Diagnosis

The following counts and proportional measurements are from 16 specimens, 37.2 to 47.5 mm in standard length.

Dorsal rays XI,8½ to XI,9½; anal rays III,9½; pectoral rays 15; pelvic rays I,4; tubed scales in first part of lateral-line 16 to 21, in second part 1 to 7; gill rakers 10 to 12 + 23 to 24, total rakers 33 to 36.

Greatest body depth 3.0 to 3.3; head 3.2 to 3.4, both in the standard length. Snout 4.7 to 5.2; eye 3.0 to 3.6, bony interorbital 3.9 to 4.3; least depth of caudal peduncle 1.6 to 1.7, length of pectoral fins 0.9 to 1.0, of pelvic fins 0.9 to 1.1, of caudal fin 0.6 to 0.7, all in the head length.

Colour in life: head, body, and all fins except pectorals dark blue; narrow pale blue margin on dorsal, anal, and pelvic fins; pectoral fins more or less translucent.

Colour in 70% ethanol: head, body, and all fins except pectorals dark brown or black; pectoral fins pale.

Remarks

A. macneilli is clearly distinguished from the other members of the genus by the combination of characters given in the key.

The authors have made close observations of *A. macneilli* at One Tree Island and at various places on the northern Great Barrier Reef between Green Island and Lizard Island. The species dwells in caves, crevices, and under ledges, always in areas of subdued light at depths ranging from about two to three metres to at least 15 metres. It commonly forms aggregations which may include more than 100 individuals. The fish are frequently seen swimming upside down near the roof of the cavern, apparently orienting dorsally to the lighter bottom which is often composed of sand or fine silt. The gut contents of eight specimens of *A. macneilli* and *A. flavissimus* collected in the same cave at Spur Reef, off Port Douglas, Queensland contained primarily copepods, ostracods, and amphipods.

During September 1974 the junior author collected three live adult specimens, about 32 to 38 mm standard length, at One Tree Island. These were transported to Sydney and placed in a filtered (600-800 litres per hour) aquarium with a capacity of 300 litres. There were nine other fishes in the tank including two *Nemateleotris magnifica*, *Canthigaster* sp., *Doryrhampus negrosensis*, *Centropyge flavicauda*, *Coris* sp., *Cleidopus gloriamaris*, and *Labropsis* sp. Several months later in mid-November, at the onset of warm summer weather, one of the *Assessor* suddenly exhibited an enlarged gular swelling. Closer inspection revealed the presence of a large

egg mass in the mouth cavity. During the next several months spawning occurred at regular intervals. A record for several of these is shown in Table 2. The same individual, 35.6 mm standard length, orally incubated the eggs in every case. Subsequent preservation of this fish and examination of the gonads revealed it to be a male. The egg mass which it was incubating contained 216 spherical eggs approximately one mm in diameter.

In spite of intensive observation, the actual spawning was never seen. Perhaps it occurs during the night. When they first appear in the male's oral cavity, the eggs are semi-transparent, slightly milky in colour. Several days later they become more transparent as the eyes of the embryo begin to develop.

During incubation the male swims out in the open and behaves more or less normally except it does not appear to feed. No obvious behavioural interactions were observed between the male parent and the other fishes in the tank, including the two *Assessor*. The incubation period generally lasts for 15-16 days. Several days prior to hatching the male's mouth is continually held open and the eggs are shifted back and forth at intervals ranging between two to eight minutes.

Hatching was not witnessed. Evidently it takes place at night as the fry were usually discovered in the early morning. The larvae, which swim close to the surface, are mostly transparent and four to five mm in total length. Unfortunately they did not live more than a few hours.



Fig. 2. *Assessor macneilli*, 35.6 mm SL, male with egg mass in oral cavity.



Fig. 3. Head-on view of male *Assessor macneilli* showing egg mass during last stages of incubation.

Material examined

Eighty one specimens, 24.0-50.0 mm SL, all except the holotype collected on the Great Barrier Reef, Queensland, Australia: AM IA.6383 (holotype), 45 mm SL, Hayman Island, Whitsunday Passage, Queensland; WAM P24932, 26 specimens, 43.0-46.0 mm SL, One Tree Island; WAM P24756, 54 specimens, 24.0-50.0 mm SL, Lizard Island.

Table 2. Record of aquarium spawnings of *Assessor macneilli*.

Eggs First Appear in Male's Oral Cavity	Hatching Date	Incubation Period (days)
7 December 1974	21-22 December	14-15
24 December 1974	8-9 January	15-16
10 January 1975	25 January	15
26 January 1975	11 February	16
27 February 1975	4 March	(collected)

Assessor randalli, n.sp.

(Fig. 4; Tables 1 and 3)



Fig. 4. *Assessor randalli*, holotype, 32.5 mm SL, Ishigaki, Ryukyu Islands (photo by J.E. Randall).

Holotype

BPBM 19261, 32.5 mm SL, collected with rotenone at Ishigaki, Ryukyu Islands in 6 to 23 metres by J. Randall, A. Banner, P. Helfrich, and W. Newhouse on 22-24 May 1968.

Paratypes

(Same collecting data as holotype.) AM I.18503-001, 2 specimens, 31.7 and 39.7 mm SL; BPBM 11542, 4 specimens, 31.2-40.0 mm SL; USNM 214832, 3 specimens, 33.5-40.0 mm SL; WAM P25419-001, 3 specimens, 37.2-40.1 mm SL.

Description

Proportional measurements of the holotype and selected paratypes are presented in Table 3. Certain counts are summarised in Table 1. The range of counts and proportional measurements for the paratypes appear in parentheses in the following description.

Dorsal rays XII,10 (XI,9 to 10½); anal rays III,10 (III,9½ to 10½); pectoral rays 15; pelvic rays I,4; tubed scales in first part of lateral-line 17 (19 to 22), in second part 5 (5 to 7); gill rakers 8 + 17 (8 to 9 + 16 to 18), total rakers 25 (25 to 26).

Body elongate, the depth 3.1 (3.2 to 3.5) in standard length, and compressed, the width 2.2 (1.9 to 2.3) in depth (this measurement taken at level of gill opening); head 3.3 (3.3 to 3.8) in standard length; snout 4.9 (4.6 to 5.2) in head; eye 2.6 (2.5 to 2.8) in head; interorbital space convex, the bony width 3.3 (3.2 to 3.7); least depth of caudal peduncle 1.5 (1.2 to 1.5) in head.

Maxillary reaching a vertical at posterior part of eye; mouth oblique, opening dorsally, the anterior end approximately horizontal with middle of pupil; upper and lower lip relatively thin, about $\frac{1}{3}$ pupil width; upper and lower jaw with row of villiform teeth, becoming multiserial at front of jaws; teeth of lower jaw slanted posteriorly and somewhat depressible; upper jaw with edentulate indentation at median symphysis; palatines with tiny granular teeth; vomer toothless.

No spines on opercle or preopercle; upper edge of gill opening at level of top of eye; a tubular nostril on each side of snout about midway between eye and tip of snout; a pair of large pores (posterior nares?) just behind tubular nostril; other head pores in several series, a group of five pores on the dentary, 22-24 circumorbital pores, a mid-interorbital pore, a small pore on each side of the snout tip, 8-10 pores on rear edge of preopercle, and several pores behind eye in nape region and upper opercle, which are difficult to detect because of the poor condition of the type specimens.

Head and body entirely scaled except tip of snout, area around nostrils, lips, and isthmus; scales relatively large, about 26 vertical rows; 10 to 11 horizontal scale rows at level of anal fin origin; scales on body and most of head finely ctenoid, those of antero-dorsal part of head cycloid; maxillary scaled; 3-4 transverse scale rows on cheek; low scaly sheath present at base of all fins except pelvics.

Origin of dorsal fin level with pectoral fin base; dorsal spines slender, but pungent, the first short, less than $\frac{1}{4}$ length of second dorsal spine, remaining spines gradually increasing in length posteriorly; 6th to 8th soft dorsal rays the longest, their length 0.9 to 1.3 in the head length; all except first three soft rays branched.

Caudal forked with 13 to 15 branched rays; pectorals rounded; the middle rays longest, 1.0 to 1.1 in the head length; pectoral rays branched except two uppermost and lowermost rays; origin of pelvic fins directly below pectoral base; pelvics pointed, the outermost soft ray the longest, 0.8 to 1.1 in the head length.

Origin of anal fin level with origin of soft dorsal fin; first anal spine short, slightly greater than $\frac{1}{4}$ length of second; second anal spine about 1.2 to 1.4 in length of third; 7th soft anal ray the longest, its length 1.4 to 1.9 in the head length.

Colour in life: head, body, and fins dark blue.

Table 3. Measurements of the holotype and selected paratypes of *Assessor randalli*.
(Measurements in millimetres)

Morphometric measurement	Holotype			Paratypes		
	BPBM 19261	USNM 214832	WAM P25419-001	BPBM 11542	USNM 214832	BPBM 11542
Standard length	32.5	40.0	37.2	39.5	33.5	31.2
Greatest body depth	10.5	11.5	11.5	11.5	10.3	9.8
Greatest body width	4.8	6.0	5.0	5.8	4.8	4.5
Head length	9.8	11.5	11.0	10.5	10.2	9.5
Snout length	2.0	2.2	2.2	2.3	2.0	1.9
Eye diameter	3.7	4.4	4.0	4.1	4.0	3.8
Interorbital width	3.0	3.6	3.0	3.0	3.0	2.6
Caudal peduncle depth	5.9	6.8	6.5	7.0	6.0	5.5
Caudal peduncle length	6.5	8.3	7.5	9.0	7.7	7.0
Snout to origin of dorsal fin	11.0	12.5	12.0	13.0	11.0	10.0
Snout to origin of anal fin	19.5	24.2	23.9	23.5	20.3	18.5
Snout to origin of pelvic fin	10.6	12.6	11.8	12.2	10.9	9.5
Dorsal fin base length	17.0	19.7	19.2	20.0	16.0	15.1
Anal fin base length	6.8	8.8	7.1	9.0	6.5	6.2
Length of pectoral fin	10.0	11.0	10.0	11.0	9.0	8.5
Length of pelvic fin	9.2	11.5	10.0	12.5	9.2	9.2
Length of longest dorsal spine	4.5	4.6	4.9	5.0	4.5	3.7
Length of longest soft dorsal ray	8.0	9.2	10.0	11.3	8.5	7.5
Length of longest soft anal ray	7.5	9.0	8.5	9.8	7.8	6.5
Length of caudal fin	11.2	15.0	13.0	15.5	13.0	10.0

Colour in 70% ethanol: head and body mostly brown, darker on paratypes; pelvics and median fins dark brown; pectoral fins pale brown.

Remarks

The only known specimens were collected from caves at Ishigaki, Ryukyu Islands.

A. randalli resembles *A. macneilli* in general appearance and coloration. However, the two species differ significantly with respect to the gill raker count, and scalation of the cheek and the portion of the body above the lateral-line. The scales in this region are cycloid in *A. macneilli* and ctenoid in *A. randalli*.

It is named *randalli* in honour of Dr John E. Randall, Curator of Fishes at the Bishop Museum, Honolulu and the collector of the type series.

Assessor flavissimus, n. sp.

(Fig. 5; Tables 1 and 4)



Fig. 5. *Assessor flavissimus*, approximately 35 mm SL, photographed in 12 metres at Spur Reef, Queensland (photo inverted).

Holotype

WAM P25322-001, 38.8 mm SL, collected with rotenone at Pixie Reef, Great Barrier Reef, off Cairns, Queensland in 12 metres by G. Allen on 3 July 1972.

Paratypes

AM I.18460-001, 4 specimens, 25.1-36.8 mm SL, collected with rotenone at Lizard Island, northern Great Barrier Reef, Queensland in 5 metres by

G. Allen on 4 May 1974; BM(NH) 1975.8.27.1-3, 3 specimens, 26.0-38.0 mm SL, same data as preceding specimens; BPBM 18861, 3 specimens, 35.0-45.5 mm SL, collected with holotype; USNM 214680, 2 specimens, 38.0 and 40.7 mm SL, collected with holotype; WAM P25323-001, 8 specimens, 26.0-37.8 mm SL, collected with rotenone at Lizard Island, Northern Great Barrier Reef, Queensland in 5 metres by G. Allen on 4 May 1974.

Description

Proportional measurements of the holotype and selected paratypes are presented in Table 4. Certain counts are summarised in Table 1. The range of counts and proportional measurements for the paratypes appear in parentheses in the following description.

Dorsal rays XI,10 (XI,8 to 10½); anal rays III,10½ (III,9½ to 10½); pectoral rays 15 (14 to 16); pelvic rays I,4; tubed scales in first part of lateral-line 21 (17 to 23), in second part 8 (3 to 9); gill rakers 8 + 19 (7 to 8 + 16 to 19), total rakers 27 (23 to 27).

Body elongate, the depth 3.5 (3.4 to 3.6) in standard length, and compressed, the width 2.0 (2.0 to 2.3) in depth (this measurement taken at level of gill opening); head 3.6 (3.3 to 3.8) in standard length; snout 5.1 (4.4 to 5.8) in head; eye 2.8 (2.6 to 3.2) in head; interorbital space convex, the bony width 5.1 (4.1 to 4.5); caudal peduncle depth about equal to its length, 1.6 (1.5 to 1.8) in head.

Maxillary reaching a vertical at posteriormost part of eye; mouth oblique, opening dorsally, the anterior end approximately horizontal with middle of pupil; upper and lower lip relatively thin, about ½ pupil width; upper and lower jaw with row of villiform teeth, becoming multiserial at front of jaws; teeth of lower jaw slanted posteriorly and somewhat depressible; upper jaw with edentulate indentation at median symphysis; palatines with tiny granular teeth; vomer toothless.

No spines on opercle or preopercle; upper edge of gill opening at level of top of eye; a tubular nostril on each side of snout about midway between eye and tip of snout; a pair of large pores (posterior nares?) just behind tubular nostril; other head pores in several series, a group of five pores on the dentary, 22 circumorbital pores, a mid-interorbital pore, a small pore on each side of the snout tip, 8-10 pores on rear edge of preopercle, and about 10 pores behind eye in nape region and upper opercle.

Head and body entirely scaled except tip of snout, area around nostrils, lips, and isthmus; scales relatively large, about 27 vertical rows; scales on most of body and head finely ctenoid, those above lateral-line and on dorsal part of head cycloid; maxillary scaled; 3-4 transverse scale rows on cheek; low scaly sheath present at base of all fins except pelvics.

Table 4. Measurements of the holotype and selected paratypes of *Assessor flavissimus*.
(Measurements in millimetres)

Morphometric measurement	Holotype		Paratypes			
	WAM P25322-001	BPBM 18861	USNM 214680	BPBM 18861	WAM P25323-001	WAM P25323-001
Standard length	38.8	45.5	40.7	35.0	31.4	26.0
Greatest body depth	11.1	12.7	11.6	10.2	9.1	7.5
Greatest body width	5.6	5.6	5.6	4.4	4.0	3.8
Head length	10.7	12.9	11.6	9.1	9.4	8.0
Snout length	2.1	2.5	2.0	2.0	1.7	1.8
Eye diameter	3.8	4.0	3.9	3.5	3.2	2.8
Interorbital width	2.1	3.1	2.7	2.2	2.1	1.8
Caudal peduncle depth	6.7	7.8	7.2	5.9	5.2	4.6
Caudal peduncle length	6.7	7.8	7.0	6.3	5.8	5.2
Snout to origin of dorsal fin	12.0	14.0	12.4	11.0	10.7	8.3
Snout to origin of anal fin	24.3	26.8	25.0	20.3	19.7	15.8
Snout to origin of pelvic fin	11.0	13.2	12.3	10.0	9.6	7.8
Dorsal fin base length	21.6	25.0	21.3	17.5	16.2	13.2
Anal fin base length	9.0	11.5	8.6	7.6	7.2	6.5
Length of pectoral fin	10.1	12.6	11.0	9.3	8.2	7.0
Length of pelvic fin	10.4	11.3	10.8	8.5	7.8	7.8
Length of longest dorsal spine	5.0	5.2	4.2	4.2	3.3	2.5
Length of longest soft dorsal ray	8.5	9.7	8.2	7.0	5.2	4.8
Length of longest soft anal ray	7.4	9.5	7.5	5.6	4.8	4.3
Length of caudal fin	16.5	17.5	*	14.7	12.8	9.5

* damaged

Origin of dorsal fin level with pectoral fin base; dorsal spines slender, but pungent, the first short, less than $\frac{1}{2}$ length of second dorsal spine, remaining spines about equal or gradually increasing in length posteriorly; penultimate soft dorsal ray or one just anterior to this the longest, the length 1.3 to 1.8 in the head length; all except first three soft rays branched.

Origin of anal fin level with origin of soft dorsal fin; first anal spine short, about $\frac{1}{2}$ length of second; second anal spine about 1.3 to 1.4 in length of third; penultimate soft anal ray the longest, its length 1.4 to 1.9 in the head length.

Caudal forked with 13 to 14 branched rays; pectorals rounded; the middle rays longest, 1.0 to 1.1 in the head length; pectoral rays branched except two uppermost and lowermost rays; origin of pelvic fins directly below pectoral base; pelvics pointed, the outermost soft ray the longest, 1.0 to 1.2 in the head length.

Colour in life: head, body, and fins mostly bright yellow except oblique red-orange stripe extending from rear corner of eye to upper edge of gill opening and submarginal red-orange stripe at distal edge of dorsal and anal fins, these fins bordered with narrow black margin.

Colour in 70% ethanol: head and body mostly light brown or tan; faint pale stripe behind eye extending obliquely to upper edge of gill opening; dorsal and anal fins slightly dusky with narrow submarginal pale band, and black distal margin; remainder of fins yellowish.

Remarks

This species was observed at Lizard Island and off Cairns at Pixie, Hastings, and Spur Reefs. It occupies the same habitat and exhibits the same behaviour as *A. macneilli*. The two species are frequently found together in the same cavern. *A. macneilli* generally appears to be more numerous, but large numbers of *A. flavissimus* were seen at Spur and Hastings Reefs.

In addition to the characters outlined in the key, this species differs from the sympatric *A. macneilli* in the configuration or profile of the dorsal fin of live individuals. Although similar in shape for both species, the anterior part of the dorsal is usually held erect in *A. macneilli* (Fig. 1) and tapers in height posteriorly, while in *A. flavissimus* (Fig. 5) the fin gradually increases height and the posteriormost part is generally held erect.

This species is known only from the northern Great Barrier Reef, approximately from Euston Reef off Cairns, northward to Lizard Island.

It is named *flavissimus* with reference to the striking yellow coloration.

ACKNOWLEDGEMENTS

We thank Dr Frank Talbot, former Director of the Australian Museum, and the Board of Trustees of that institution for allowing us to utilise the museum field stations at One Tree and Lizard Islands. The senior author expresses his gratitude to Dr Walter A. Starck II, who assisted with the 1972 collections at Pixie Reef and provided his research ship *El Torito* for these activities. Dr John E. Randall kindly provided specimens and a photograph of *A. randalli*.

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WHITLEY, G.P. 1935—Studies in ichthyology. No.9. Rec. Austr. Mus., 19(4): 215-250.

SOME ASPECTS OF AUSTRALITE DISTRIBUTION PATTERN IN WESTERN AUSTRALIA

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ABSTRACT

The original australite distribution pattern was further complicated by the transport, concentration or burial of australites by the action of running water and other natural agents. Aboriginal man was probably responsible for introducing australites into areas from which they had formerly been absent; he also made artifacts on australites, and particularly on the Nullarbor Plain, he might be partly responsible for the generally small size of the specimens found there.

The australite collections constitute an extremely unsatisfactory sample of the Western Australian portion of the strewnfield because of poor documentation and very uneven collecting.

A belt of abundant australite occurrence appears to be present in the Eastern Goldfields. It trends 337° and is convergent northward with the more defined belt of abundant occurrence in eastern South Australia. The reality of the belt and its trend are unproven because of deficiencies in the sample and because of close relationship to the distribution of human activity.

The distribution of australites having mass >20 g supports the suggestion already seen in the distribution of those of mass >100 g that mass grading could be present in the distribution.

Only 17 australites, or about 0.04% of those examined, were accepted as having been found in the northern half of Western Australia under conditions which might indicate that they were at their sites of fall. Other specimens and reported occurrences were rejected for a variety of reasons. The northern boundary of 'multiple' occurrence (minimum of 10 specimens from any site) is likely to be the original strewnfield boundary, the few widely dispersed northern specimens having been introduced by man.

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INTRODUCTION

Though the most refined developments in chemistry, geochronology and aerodynamics have been applied to the tektite problem, the fundamental questions of tektite genesis, parent material and provenance remain as enigmatic as ever. Additionally, the time (times?) of fall of australites and their unity with east Asian tektites and with 'microtektites' are still in dispute. There might be pointers to the solution of some of these problems in the distribution pattern. Before considering the distribution in Western Australia, it is desirable to review briefly the agencies responsible for the distribution and to examine the quality of the sample represented by the collections.

The abbreviation P.S. is used throughout this paper for Pastoral Station; also H.S., meaning Head Station, the principal homestead and business centre of a pastoral property. Institutions and their collections are referred to thus: BM — British Museum (Natural History), WAM — Western Australian Museum, SAM — South Australian Museum, WASM — W.A. School of Mines.

The Distribution of Australites

It has been very generally conceded that the concentration density of the newly fallen australites varied from one part of the strewnfield to another. This has been recognised by some authors in their use of localized strewnfield names. Superimposed upon the initially irregular distribution have been the effects of agents responsible for removal, concentration, destruction, burial, and sometimes the re-exposure of previously buried australites. Most maps showing sites of find are very inadequate expressions of the distribution because they do not distinguish between the find of a single specimen or of many. Nor is it evident whether blank areas represent absence of australites or lack of collecting; examples of both types of blank area are known.

Rainwash in semi-arid and arid terrain has been especially effective in transporting australites. The most impressive evidence is their concentration into certain lakes of internal drainage in arid regions, the extreme example being the Yindarlgooda-Lapage-Cooragooggine lake complex east of Bulong, from which >20 000 australites have been collected. It is generally evident from the environments of these concentrations that the distance of transport of any specimen is unlikely to have exceeded a few kilometres and would average much less. These movements are generally so small relative to the area of the general strewnfield ($c.3 \times 10^6 \text{ km}^2$ exposed on land, or

c.5 x 10⁶ km² if using the northern boundary as defined by previous authors), that the error involved in accepting the site of find as the site of fall is insignificant on a regional scale.

The recovery of australites from alluvial workings and from the spoil of earth dams sited on rainwash channels and alluvial flats also shows the ability of running water to transport australites and bury them in alluvium. The rarity of australite recoveries from that southern portion of Western Australia having coastal drainage by perennial and semi-permanent streams could be partially accountable to stream processes, but there are other contributory factors arising from circumstances of collection referred to in the next section of this paper. Lake concentrations are often essentially marginal, particularly in the flat outwash fans of streams. Australites also occur in lag gravels formed by solifluction aided by rainwash and as residuals after deflation of inter-dune corridors (Lovering *et al.* 1972).

Aboriginal man had many uses for australites and carried them about (Baker 1957). To some extent these movements within the strewnfield could have been random in distance and direction and for some purposes compensatory, but the aborigine is also one of the agents capable of introducing australites into areas from which they were formerly absent. Prior to white colonisation, he bartered a wide variety of articles along numerous routes within Australia and also to nearby countries (McCarthy 1939). Baker (*op.cit.*) could find no indubitable evidence for the barter of australites but it cannot be dismissed as impossible. Bates (1947, p.124) noted the trade of 'curiously shaped meteorites' over north-south trade routes. Meteorites *sensu stricto* are extremely rare objects and there is no record of the aborigine making use of them, but australites were readily available in the Eucla area of which Mrs Bates wrote and many would qualify as 'curiously shaped'. Australites were certainly carried by the aborigine over long distances as ritual objects. Mr K. Akerman (*pers.comm*) reports seeing such a specimen at Derby in 1973. It had been carried from Hooker Creek, N.T. along portion of a well-known circuitous trade cycle, a distance >1100 kilometres.

The aborigine destroyed many larger australites in making artifacts on the Nullarbor Plain where the only other suitable raw material is the siliceous crust developed sporadically over the limestone surface. Around rock holes (natural holes capable of holding water) and around some dongas (shallow sink features sometimes capable of holding water), struck flakes which include australite flakes are often plentiful but australites of usable size are rare or lacking (items 1 - 5, Table 1). Australite flakes constitute 14% of the total number collected at Waddalina Rockhole (item 5, Table 1) and 7% of the total mass. The sample is an insignificant

fraction of the material strewn about the rock hole. Akerman (1975) has reported on 385 australite flakes from a rockhole 15 km N.E. of this site. Localities 4 and 5 were searched because of a growing conviction that australite flakes would be found around almost any source of water on the Nullarbor Plain. The choice of the localities was random to this extent that they were conveniently close to the route taken in connection with an entirely different investigation.

The situation around water sources on the Nullarbor Plain is less marked on the small granite inliers in the western fringe of the Bunda Plateau (item 6, Table 1). Some of the other materials used there can be closely matched with those available in the Precambrian area a few tens of kilometres further west.

The making of artifacts was probably fairly localized to the sources of water as can be seen by the reversed proportions in the material from an area centred 5 km from Billygoat Donga which is the only evident source of water in the vicinity (item 7, Table 1). However, australite distribution over a considerable area was probably affected by the 'import' of australites to the centre of manufacture. The major vehicle tracks on the Nullarbor Plain follow for considerable distances the tracks of an earlier generation which had some dependence on natural water supplies. The nature of the australite sample collected has certainly been affected by the destruction of larger specimens, but collecting by the white man has contributed to the situation now found because — from personal observation on two occasions — he will collect only complete specimens and natural fragments but ignore the flakes unless advised of their scientific interest.

Other raw materials are available on Earraheedy P.S. but 277 (16%) of the 1414 Earraheedy australite specimens in WASM collection are flakes or flaked cores, the majority with well developed patina. A sample received recently from Earraheedy comprises 144 fractured specimens and 31 very small or naturally broken specimens, being the discard from a collection made for sale; the total number in the original collection is unknown. Many flakes in both Earraheedy samples have been confirmed as artifacts; a few very freshly fractured specimens can be dismissed as the result of testing (Baker 1957 p.14).

On the other hand, careful searches around four rock holes within 40 km of Kalgoorlie resulted in no recoveries, though a few artifacts made on australites are known from the district, two of them from the vicinities of the rock holes searched. It was not expected that complete australites or well-formed artifacts would be found because all rock holes in the region were much frequented by the white man during the gold prospecting

episode, but it seemed likely that small discard flakes would have been ignored by any except a scientist collector.

Australite flakes are uncommon in the Tillotson collection of >9000 specimens from an area centred upon Kalgoorlie except in samples from parts of the Bulong area and a sample from a granite rock with numerous water holes at McAuliffe Soak on Yerilla P.S. Inclusive also of WASM 11704, material from the Yerilla site comprises 10 complete specimens or weathered natural fragments, only one of which might have been of usable size, and 167 flakes or flaked cores. The lengths of some flakes (to 22 mm) and their curvatures indicate derivation from australites of probable mass >15 grams. An enormous number of chalcedonic and opaline flakes strewn over the granite, grinding stones and a stone arrangement indicate a much used aboriginal site. Mr Tillotson collected 85 australites in a few hours at the lake edge about 3 km distant. It appears that australites were initially so common that they were utilised despite the ready availability of siliceous weathering products over the ultrabasic rocks of nearby hills.

Wangine Soak (90 km N.W. of Kalgoorlie) is a reliable source of water and was an important gathering ground for aborigines until after the arrival of the white man. An australite artifact received from Wangine Soak (WASM 10933) prompted a search of the area. The most obvious signs of aboriginal occupancy are on low sandhills overlooking the soak where deflation has left areas of lag 'gravels' consisting almost entirely of artifacts — flakes and flaked cores of opaline, chalcedonic and cherty materials and grinding stones — mostly broken and consisting of basic igneous rocks which are also foreign to the area. Australites are a minor component of the 'gravels'. From blown out areas totalling about a third of a hectare, five small complete or naturally broken australites and 106 australite flakes or flaked cores were recovered (WASM 11755). As at McAuliffe Soak, australites were used despite an evidently ready availability of suitable alternative materials.

The flaking of australites by aborigines in the Ord region dates from c.18 000 years B.P. (Cleverly and Dortch 1975.) Reference is made by Akerman (1975) and also in the Appendix to this paper to small numbers of flaked australites from many other Western Australian localities, most of which have never been closely searched. The limited available data suggest that outside the Nullarbor Plain where alternative raw materials were available, the destructive usage of australites was more casual except where they were so abundant as to be readily noticed, or conceivably where some custom had developed involving their use. It is emphasised that the majority of localities from which flakes have been recovered have never

been closely searched and even if they have been searched, flakes are likely to have been ignored.

At least two of the larger birds of general distribution in Australia are known to use australites as gizzard stones. To judge by the example described by Fenner (1949), the Australian bustard (*Eupodotis australis*) uses stones of mean mass c.2½g and evidently uses australites abundantly (49 taken from a single bird). The emu (*Dromaius novae-hollandiae*) 'uses stones of an inch or so in size' (Baker 1957) i.e. of mass up to c.20g for australites.

It is improbable that transport of australites by man or birds could have affected significantly the distribution pattern in areas of abundance, but it could account for — and at some sites demonstrably does account for — the specimens in areas of rare or diffuse occurrence. Concerning one of the three types of occurrence which he recognises in north-western South Australia, Johnson (1965) states '... australites have been found sporadically over the face of the whole region, particularly among the debris of aboriginal campsites, old and new, reflecting the activities of man, and to a lesser extent, of birds using gizzard stones'. It is likely that the destructive usage of australites by aborigines is partly responsible for the small size of specimens collected from the Nullarbor Plain.

REPRESENTATION OF THE AUSTRALITE STREWNFIELD BY COLLECTIONS

Australite distribution pattern is necessarily judged by documented collections.

Eastern Australian collections contain >10 000 australites from Western Australia and the immediately adjoining portion of South Australia. More than 52% of them are attributed to 'Kalgoorlie and district', but this group contains labelled specimens from Hogan's Find (55 km S.E. of Kalgoorlie) and Lake Carey (190 km to N.E.). The private collectors from whom these specimens were obtained were residents of Kalgoorlie; the locality attribution probably has no more meaning than that. A further 39%, principally the W.H.C. Shaw collection (SAM) are from Israelite Bay, points around the Great Australian Bight and northward to the Trans-Australian Railway Line. These are unlocated except that Fenner (1934) quotes Mr Shaw as saying that the majority is from Israelite Bay. Only 8.4% of the specimens in Eastern States collections have the minimal locality information necessary for use in this paper.

Western Australian official collections (including WASM) contain only about 4000 australites but more than 95% of them have sufficient locality information. There are two major private collections. The Tillotson collection of 9000 australites from the Eastern Goldfields is located to within a kilometre or so of various key points, but the even larger C.B.C. Jones family collection has no details beyond the fact that it is almost entirely from Hampton Hill P.S. which has an area of 2430 square kilometres. However, 70% of the Tillotson collection is from the same area and from it a centre of occurrence has been calculated as about $121^{\circ}57'E.$, $30^{\circ}38'S.$ The bulk of the Hampton Hill component of the Tillotson collection was found within 10 km of that point; the same is probably true for the bulk of the Jones collection.

Inclusive also of some minor official and private collections, c.40 000 Western Australian australites were reviewed. Only 39% have usable locality information; 31% have vague documentation of limited value; the remaining 30% have no value for present purposes.

The collections also have inadequacies resulting from very uneven collecting. Some examples follow.

Fewer than 200 australites represent that part of the State southwest of a line from Geraldton to Esperance (fig. 2), an area of almost $2 \times 10^5 \text{ km}^2$, but nearly 30% of the specimens have mass >50g, i.e. are of unusually large size. In contrast, a much smaller area centred upon Kalgoorlie is known by 100 times as many australites, only 0.03% of which have mass >50 grams. Some of the differences between these samples could be real, but they are attributable in part to the relative ease of detection of australites on the bare ground and dry lake basins in the Eastern Goldfields as contrasted with the difficulties of detection on the cultivated ground or well-vegetated country in the south-west of the State.

An area of c.40 000 km^2 south-west of Coolgardie (fig.2) is represented by only ten specimens, though both from report and brief personal observation, australites are not uncommon in the Bremer Range which is about central to it. There is no permanent habitation in the area.

The Nullarbor Plain has yielded thousands of specimens, mostly to private collectors, but because the majority has no locality details, this enormous area is represented by only a few scattered points of occurrence which are quite inadequate to represent the known wide distribution. The Yarri-Yundamindera and the Cosmo Newbery-Warburton Range areas have likewise yielded large numbers of australites, principally to mineral dealers and lapidaries. Most of the specimens seen have either the vaguest and most untrustworthy locality details ('somewhere east of Cosmo Newbery') or

none at all, being intermixed with those from other areas on the basis of some superficial characteristic such as size or shape i.e. sale value.

It is evident from the collections that australites are common on Granite Peaks, Carnegie and adjoining pastoral properties but only Earraheedy P.S. is well represented. This is one of several such examples resulting from the interest and energy of one or two persons while large and equally promising areas are almost unknown.

The Tillotson collection, which contains more documented Western Australian australites than all other collections combined, is subject to the severe restraints that it was gathered from places within a day's reach of Kalgoorlie by persons who did not have a 4-wheel drive vehicle available and who have therefore never searched some of the most promising areas.

Private and commercial collectors continually return to areas of known abundant occurrence such as Lake Yindarlgooda and the Menangina-Mt Remarkable area, avoiding those areas of sparse occurrence or unknown potential. Few scientists can afford the time for search except briefly and as a side issue to other field work. The natural differences in distribution density tend to be further emphasized by such collecting.

The collections thus have deficiencies in documentation and severe distributional bias. Only the most cautious and tentative conclusions can therefore be offered in the sections which follow.

I. THE TREND OF AUSTRALITE OCCURRENCES IN THE EASTERN GOLDFIELDS

McColl and Williams (1970) calculated straight regression lines for belts of australite occurrence in southern central Australia. A less defined belt appears to be present in the Eastern Goldfields of Western Australia and its trend has been calculated in a similar manner i.e. weighting the co-ordinates of sites of find of (1 - 10), (>10 - 100), (>100 - 1000) and >1000 australites by 1, 10, 100 and 1000 respectively. The closest significant recoveries outside the belt are from Corrigin (180 km west of the area, >10 specimens) and from Rawlinna (100 km east of the area, >100 specimens, mostly flakes). The resulting line (fig. 1A) has azimuth 337° and is therefore gradually convergent northward with the more eastern and more reliable line of McColl and Williams, which trends 330°.

McColl and Williams had reasons for confidence in the australite deficiency of the areas surrounding the belts of dense occurrence, but no such confidence is possible for the Eastern Goldfields (see comments on areas

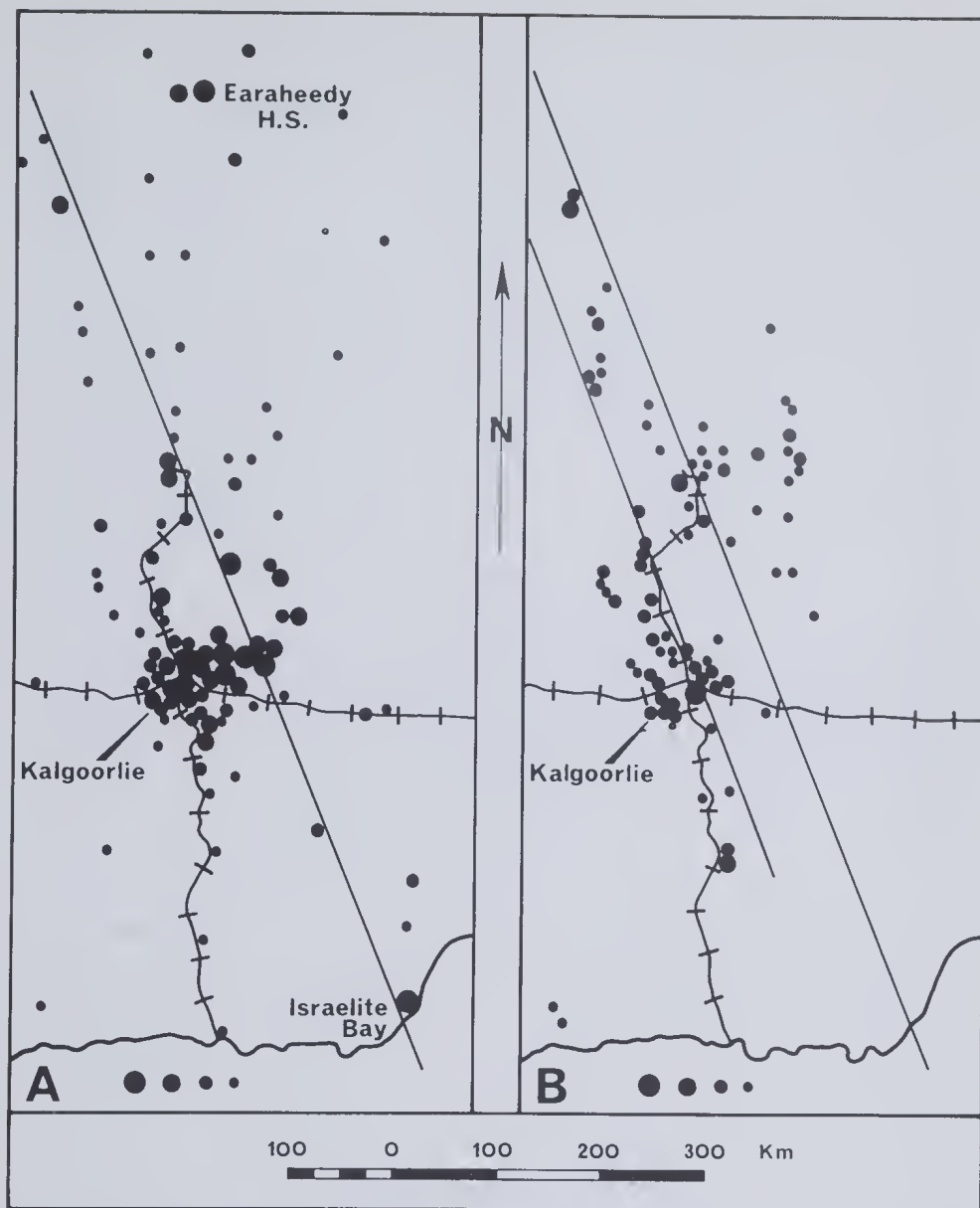


Figure 1A. Portion of southern Western Australia centred upon the Eastern Goldfields showing sites of recovery of australites and first order regression line. The circles, in sequence of decreasing size, represent >1000 , $>100-1000$, $>10-100$ and $1-10$ australites.

Figure 1B. Same area as in A showing centres of gold production and first order regression line on left. The circles in sequence of decreasing size represent total gold production of $>10^7$, $>10^6 - 10^7$, $>10^5 - 10^6$ and $>10^4 - 10^5$ ounces respectively. The line at right is the australite regression line transferred from A.

A - C of fig. 2). The belt of dense occurrence is sub-parallel to the railway system and to the distribution of human population and those are in turn the consequences of the N.N.W. strike of the Precambrian rocks with their contained centres of mineralization. The four centres with the greatest totals of gold production in Western Australia lie within the belt as well as such major base metal discoveries of recent years as Kambalda, Windarra, Agnew and Yeelirrie.

To examine the relationship of australite recoveries to human activity, a regression line was calculated for centres of gold production because the search for and mining of gold have been the major human activities during 75 of the 82 years of white occupation. The co-ordinates of centres with total production ($>10^4 - 10^5$), ($>10^5 - 10^6$), ($>10^6 - 10^7$) and $>10^7$ ounces of gold were weighted by 1, 10, 100 and 1000 respectively. The nearest significant gold recoveries outside the belt under consideration were from Sandstone and Southern Cross (each about 50 km west of the area and belonging to the second of the above four categories; there have been no significant recoveries to the east of the area. The resulting line (fig. 1B) differs 3° in azimuth from the australite line but is displaced about 60 km westerly from it. The major australite recoveries of the Earraheedy and Israelite Bay areas (fig. 1A) are unrelated to gold mining activity but their omission affects the trend of the australite line by only two degrees and displaces it c.15 km closer to the gold line.

Because of deficiencies and bias in the australite sample and its relationship to opportunity to collect, the reality of the australite trend is, at best, not proven. At worst, it could be but a large scale example of the same kind of relationship which exists between meteorite sites and rabbit burrows on the Nullarbor Plain. Rabbit trappers, who have found many meteorites, generally travel by vehicle from one group of burrows to another, but they are on foot and see the ground closely in the immediate vicinity of the burrows.

II. MASS GRADING

The australites of mass >100 g known from Western Australia were found within a broad belt extending north-east, the greater number of specimens and the most massive specimens (>200 g) towards the southern end of the belt (Cleverly 1974). A similar but less populous belt extends north-west from western Victoria to the vicinity of Charlotte Waters, and the same features are evident in the distribution. These observations suggest the possibility of mass grading, i.e. a systematic areal variation in the masses of

individual specimens related to peculiarities of their distribution in the shower and/or to circumstances of fall.

Collections were searched for well-located Western Australian australites of mass >20.0 grams. The 336 specimens found were listed in sequence of decreasing mass (stated to 0.1g) with geographical co-ordinates (to 0.1°). Three numerically equal categories (nos. 1 - 3) were defined in descending sequence of mass and for each category the mean latitude and longitude were determined i.e. the 'mean sites'. Calculations were also made with the co-ordinates weighted by the masses of the specimens, thereby determining the 'centre of mass' of each category. Similar sets of calculations were made with categories (nos. 4 - 6) containing sub-equal total mass (33,102,201 specimens respectively) and also with categories (nos. 7 - 10) of the type ($<320 - 160$), ----- ($<40 - 20$) grams. All calculations yielded points falling very closely along the same line as the particular result illustrated (fig. 2).

The trend of the line is approximately normal to the isohyets of annual rainfall and it might therefore have been influenced by the terrain effect which makes for increasing ease of observation inland. However, the trend is unlikely to be dominated by the terrain effect while attention is limited to the largest and most readily detectable specimens constituting $<2\%$ of located specimens available. The terrain effect can account for the large numbers and small average mass of specimens in the eastern collections but it does not explain why those large collections made under ideal observational conditions contain only half as many specimens of mass $>50g$ as the small western collections. As a check, some trial calculations were made with the WAM collection and the E.S. Simpson collection (held at WAM). Though numerically small (c.2000 australites), these collections are remarkable for their wide areal representation. Because they have been acquired from such numerous sources and over a period of more than 70 years, it is possible that they could be a more representative sample of australite distribution than the much larger general sample with its evident bias to certain localities. The resulting mean points were well aligned, somewhat more widely spaced than in fig. 2 and trending 15° more northerly (i.e. roughly parallel to the belt of unusually large australites), but the general style of the result persisted. It is noted that the two belts of large australites radiate from within central Australia and the 'coarse structure distribution pattern' of some major chemical types (Chapman 1971 fig. 2) may also be visualised as sectors of distribution radiating from the same general vicinity e.g. HCu,B type (except a Tasmanian specimen), HCa type, HMg type (except the Wyloo specimen — see Appendix) and normal australite-phillipinite type.

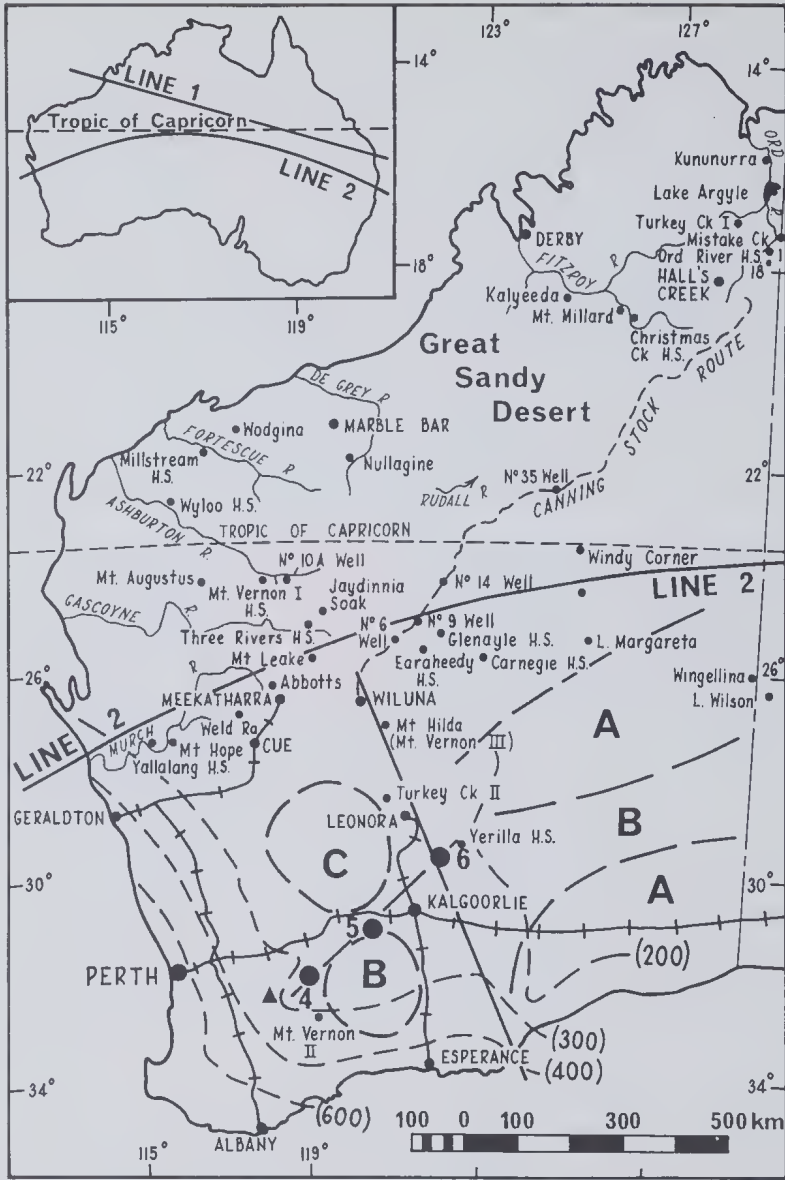


Figure 2. Western Australia. The line trending N.N.W. is the first order regression line for auriferous recoveries in the Eastern Goldfields. A — indicates areas from which many auriferous areas have been recovered, most of which are undocumented. B — uninhabited areas almost unrepresented in collections. C — sparsely inhabited area from which few auriferous areas are known. Points 4, 5, 6 are 'centres of mass' for three categories of auriferous areas containing sub-equal total mass. The triangle is the site of find of the most massive auriferous known. Broken lines are smoothed isohyets with annual rainfall in millimetres shown thus: (300).

Inset — Australia showing northern limit of 'multiple' occurrence of auriferous areas (Line 2) and the strewnfield boundary as usually shown (Line 1).

Only five of the 336 specimens used in the original calculations are from the Nullarbor Plain. The low Nullarbor representation is only partly the result of lack of documentation. Most Nullarbor specimens are small, and to that, aboriginal usage could have been contributory.

The results cannot be regarded as strong evidence for the existence of a graded distribution but they support the impression already evident in the distribution of specimens of mass >100 grams. Extended studies to incorporate eastern Australian specimens are desirable, preferably with the mass range extended down to (say) 10 grams. With the larger and more general sample a more rigorous mathematical treatment should be possible and one which is uncomplicated by the artificiality of a State boundary.

Proven mass grading in a certain direction would not necessarily indicate flight in the direction of increasing mass. Unlike meteorites, the fragmentation of which is an atmospheric event, australites were pre-formed individuals when they encountered the atmosphere. Factors such as temperature-dependent viscosity at the site or origin could have influenced the size range and size distribution within different parts of the shower (Chapman 1971) and hence, ultimately, the distribution upon the earth's surface. Nor is the result necessarily incompatible with the trend deduced in section I of this paper. The result could indicate progressive differences between lines of fall, each of which had N.N.W. trend.

III. THE NORTHERN BOUNDARY OF THE STREWNFIELD IN WESTERN AUSTRALIA

The northern boundary of the australite strewnfield has generally been shown as Line 1 (inset to fig. 2) e.g. by Baker (1957). Line 2 marks the northern limit of multiple occurrence, defined here as sites from which at least 10 specimens have been collected. These are distinguished from occurrences of single, usually isolated specimens which, whether north or south of Line 2, are often suspect as transported specimens. The eastern Australian portion of Line 2 is based upon generally well known and for the most part documented occurrences of the Uralla district, S.W. Queensland (including the strip discovered in recent years from which nearly 1000 specimens have been taken), Mulka, Charlotte Waters, Finke, Henbury (33 specimens in SAM), eight km N. of Alice Springs (24 specimens in Australian Museum), and Mt Davies-Lake Wilson area. In Western Australia, multiple occurrences include Wingellina, L. Margareta (Chapman 1971), a point c.100 km S. of Windy Corner (14 specimens in University of Adelaide collection), Glenayle, Earraheedy and neighbouring pastoral stations, and

Wiluna. The western end of Line 2 is somewhat arbitrarily placed. Isolated specimens from immediately south of the line - no. 9 Well, no. 6 Well, two points in the general vicinity of Mt Leake, Abbots (G.M.L. White Horse),* 18 km E.S.E. of the same, Weld Ra., Mt Hope, Yallalong P.S. — are not much more plentiful or concentrated than those to the north of it.

The separation of Lines 1 and 2 is so great in Western Australia that the questions arise whether the specimens found north of Line 2 are genuine australites found at the stated localities, and if so, whether they were at their sites of fall. A search of collections and literature disclosed only 17 australites which might have been at their sites of fall in Western Australia north of Line 2. For details of these and other specimens, see Appendix. The total of 17 is generous in that it includes vaguely located specimens from 'east Kimberley' and 'north-west Australia'. It also includes two specimens from Hall's Creek, which is on a recognised native trade cycle, a specimen from Argyle Downs P.S. 'found on a path near a house' (Fenner 1935), concerning which there must be considerable doubt that they were in situ, and a specimen 'found by a native'. Australite flakes and a complete specimen found in cave shelters in the Ord region (Cleverly and Dortch 1975) were clearly not in situ and other specimens were rejected for a variety of reasons. There is no direct evidence that the 17 specimens were found other than has been stated (Table 2) or that they were not in situ.

The 17 australites comprise about 1/2300 of those known from Western Australia but they were dispersed over nearly 49% of the area of the State. The Great Sandy Desert constitutes a major gap in the distribution. No specimens or record could be found to justify the desert occurrences indicated by Fenner (1955 fig. 2). The gap is not necessarily the result of lack of opportunity to collect. Talbot (1910 p.29) specifically sought australites along the Canning Stock Route and there is a later report from Mr R. Verbugt (see no. 35 Well in Appendix).

It is conceivable that australites were transported from the abundant southern sources to the Kimberley region by aborigines, either along the coast or directly across the desert where rock holes and native wells exist (Talbot *op.cit.*). The relationship of the Kimberley sites of find to the valleys of the two major rivers is doubtfully significant because most of the sparse white population is also in those areas i.e. there has been maximum opportunity to collect.

* Gold mining leases of the same name existed also at Laverton, Mt Ida, and Bulong. Abbots is the locality indicated by Baker (1959 fig. 4), but Bulong, where australites are extremely abundant, is a much more likely locality from which a Kalgoorlie collector (S.F.C. Cook) would have obtained the specimen.

Pearl shell ornaments made on the Kimberley coast were traded all over Western Australia, central and South Australia (McCarthy 1958). Presumably the Kimberley native received something not available locally in exchange for his goods. Australites were one such possibility. Bates (1927 p.124) records that 'pearl shell of the north (was) treasured as magic in the deserts of the south' and almost simultaneously refers to the trade in 'curiously shaped meteorites'. As recently as 1973 a Kimberley pearl shell artifact reached Cundeelee (160 km E. of Kalgoorlie) along native routes; meanwhile, an australite ritual stone had been seen at Derby.

With the exception of four specimens of large size or lacking abrasion, the northern specimens might also have been carried by birds, but there is some slight evidence against transport by either birds or man in the proportions of the shape types of the northern specimens. No particular shape type appears to have been favoured. Round forms predominate and oval forms are common; a boat and a dumbbell represent the less common forms. This is as good a representation of the usual shape proportions as could be expected in a small random sample. On the other hand, the average mass of reasonably complete specimens is 13g, a high figure which may be compared with the average 19g for the very rare, more or less complete specimens recovered over a period of more than 70 years from the Murray-Darling confluence region (Baker 1973), within which they must also be suspected to have been dispersed by Aboriginals.

There are important differences between the circumstances in which the northern australite specimens were found and those of the uniquely isolated Martha's Vineyard tektite, concerning which a strictly conservative scientific attitude has always been adopted, though it was found 'just below the point where most tourists view the cliffs' (Kaye *et al.* 1961). Searches have been made for further specimens which would demonstrate that Martha's Vineyard is a strewnfield rather than any ready acceptance that the specimen was an import to the area; the nearest recognised strewnfield is in Georgia, distant >1700 kilometres. The Martha's Vineyard tektite has been the subject of intensive study. The differences here are that the northern australites were thinly dispersed over an area contiguous with a strewnfield and formerly inhabited by tribes who had developed inter-tribal barter routes which spanned the continent (McCarthy 1939). Moreover, these people used australites in ways ranging from ritual objects and charms to the making of items such as knives, micro-adzes and piercers. Unlike the Martha's Vineyard tektite (if we exclude the tourists), there is therefore a prime suspect for the dispersal of the australites and he had uses for them even in the far north of the State from very early times (Cleverly and Dortch 1975).

This study has considered only the Western Australian material but a perusal of some reported occurrences between Lines 1 and 2 in eastern Australia suggests that there also, a critical review would raise serious doubts that the specimens were genuine and/or in situ. For example, at least two authors have indicated australite occurrence at Bullock's Head, N.T. but the original report (Jensen 1915) is hearsay unsupported by specimens and no confirmation of the occurrence has been forthcoming in the 60 years since the report was made. Specimens from four localities in south eastern Queensland are single specimens or hearsay. West of Blackbutt, 'several were found by a miner, the *one* examined . . .' (Dunstan 1913). Gold miners are notable for itinerancy. Miners from the declining Victorian fields were already widely scattered by 1913 and eventually La Paz (1938) was to note that tektites from the gold fields of Australia were 'exhibited occasionally in placer mining camps in the United States'.

If the occurrence of one australite to an average of $>68\ 000\ \text{km}^2$ requires acceptance of an area as strewnfield, the whole of Western Australia should be included (c.f. O'Keefe 1969 fig. 1), but it is then also accepted that the natural concentration density in the northern half of the State was less than 1/2000 of that in the southern half. Because there is no historical record of the observation of a tektite shower, such a possibility cannot be dismissed.

It is considered more probable that the northern boundary of multiple occurrence was the approximate strewnfield boundary and that the rare northern specimens were introduced, though this contention is not capable of proof. One of the difficulties is that most northern specimens have no documentation except a locality statement which lacks detail and the name of the donor who was not necessarily the finder. An awareness of the problem might have resulted in the recording of significant details of the circumstances of occurrence, associated materials and the reliability of the finder. A further problem is that australite flakes lacking such positive evidence as reworking cannot be attributed with any degree of certainty to the work of man if they have been removed from their context. It is difficult to ignore the probability that all flakes from a site such as McAuliffe Well are the work of man despite the lack of evidence on most individual flakes.

A considerable gap would have existed between the newly-fallen australites and the nearest east Asian tektites in Java. Such a gap need not be critical to the unity of 'australasianites' but it would require explanation. If australasianites indeed originated, as some have supposed, from an impact event in S.E. Asia, conceivably a critical angle of elevation for the ejected material (or alternatively, a critical entry angle from an extra-terrestrial source)

could account for the gap as well as for the south easterly gradation from puddle and splash forms through primary shapes of rotation to Javaites with 'proto-australite flanges' (von Koenigswald 1967) and the australites with well-developed features resulting from atmospheric transit.

The suggested northern boundary is regarded as a minimal limit which is to be moved further north and refined in shape as further reliable occurrences become known. The criteria advocated for 'reliable' occurrence are multiple, tangible specimens with flakes constituting a small minority, collected by persons of known integrity from sites which have been searched for signs of aboriginal occupation. It is urged that curators of collections endeavour to obtain maximum information on australites received from any locality north of Line 2.

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Table 1. Australites found near sources of water on and marginal to the Nullarbor Plain

Item	Locality	Number of australite specimens		Most massive specimens of preceding column and its largest dimension	Registered number of specimens
		recently fractured	not recently fractured		
1.	Rock hole c.86 km N of Loongana	34	3	1.9 g 16 mm	WASM 9492
2.	Laundry R.H., 43 km N of Madura Pass	15	1	1.4 g 15 mm	WASM 9493, 10272, 10312
3.	26-mile R.H., c.33 km NNW of Nurina	24	4	0.7 g 15 mm	WASM 11643
4.	Rock holes 3 km SW of Ryan's Well (25 km W of Rawlinna)	20	Nil	-	WASM 11646(b)
5.	Waddalinya R.H., 14 km SW of Rawlinna	109	2	3.2 g 23 mm	WASM 11647(b)
6.	Ray's Rock, 123° 34'E., 33° 05'S.	9	3	0.7 g 13 mm	WASM 11668
7.	Area centred 5 km N of Billygoat Donga	18	85	22.9 g 34 mm	WASM 10273, 10872, 11028

Table 2. Physical details of tektites found in northern Western Australia.

Collection and Registered number	Site of find	Shape type	Mass g	Dimensions mm	S.G.	Notes
Not known	Atkyle Downs P.S.	'Flat oval without flange'	-	-	-	
W.A. Museum B2150	Gundarium Hill rock shelter	Broad oval	6.222	28.6 x 21.3 x 9.1	2.448	Reported by Fenner (1935)
W.A. Museum B888	Monmouth rock shelter	Flake (artifact)	0.750	16.4 x 9.9 x 4.3	2.476	Clevery and Dorich (1975)
W.A. Museum B938	Monmouth rock shelter	Flake (artifact)	0.390	16.0 x 13.8 x 2.3	2.46	Clevery and Dorich (1975)
W.A. Museum B250	Mitrawun rock shelter	Curving fragment (artifact)	0.050	11.2 x 2.6 x 2.0	2.43	Clevery and Dorich (1975)
W.A. Museum B249	Mitrawun rock shelter	Flake (artifact)	0.328	11.6 x 9.9 x 3.7	2.40	Clevery and Dorich (1975)
W.A. Museum B2079	Mitrawun rock shelter	Flake (artifact)	0.318	15.1 x 8.4 x 2.9	2.43	Clevery and Dorich (1975)
W.A. Govt. Chem. Labs. 3278	Ord River P.S.	Round core, conical as result spallation losses	2.750	(17.6 - 16.9) x 9.0	2.30	Low S.G. accountable to bubble cavity beneath posterior surface
Priv. coll. P. J. W. Nevell	Vicinity Mistake Cr. P.S.	Discoidal	3.389	c.20 x 9.7	2.389	(?) Philippinite. See additional notes
Aust. Museum 4737	Hall's Creek	Narrow oval	4.727	c.26.9 x 14.5 x 11.4	2.381	Incomplete (cut). Length taken from cast
Aust. Museum 4737	Hall's Creek	Narrow oval	3.397	c.25.4 x 12.8 x 9.5	2.436	As above
Aust. Museum 4736	East Kimberley	Round core	2.951	c.17.8 diam. x 10.9	2.435	As above. Diameter taken from cast
E.S. Simpson coll. 13	Christmas Creek	About ¾ of artificially broken round core	19.801	32.3 x 23.5 x 22.3	2.428	Form and deeply etched grooves resemble those of some philippinites
E.S. Simpson coll. 85	Mt Millard	Round core	40.08	(38.2 - 37.0) x 21.5	2.47	
E.S. Simpson coll. 14	Kalyeeda	Dumbbell	36.65	67.2 x 21.9 x 17.8	2.456	
E.S. Simpson coll. 15	Wodgina	Spalled fragment of small core	2.039	11.9 x 9.5 x 10.2	2.438	
Aust. Museum 8152	North-west Australia	Round core	13.131	(27.2 - 25.6) x 15.7	2.441	
E.S. Simpson coll. 16	Rudall River	Broad oval core	4.392	18.5 x 15.5 x 13.5	2.457	
W.A. Museum 12161	Millsstream P.S.	Round core	11.225	23.9 x 22.2 x 18.0	2.420	
Brit. Mus. (N.H.) 1925.1079	Wyloo P.S.	-	11	-	-	Not examined. See additional notes
E.S. Simpson coll. 21	Mt Vernon P.S. (Mt Vernon I).	Round core	5.086	(19.5 - 17.4) x 12.9	2.453	
W.A. Museum 12755	Mt Augustus P.S.	Boat core with remnants of stress shell	4.285	30.7 x 13.6 x 8.8	2.502	5 km N of No. 10A Well on Peak Hill to Nallagine Stock Route
E.S. Simpson coll. 18	Jaydima Soak	Round core	15.884	(29.0 x 28.2) x 14.7	2.432	'Indicator' of 'trihobite' type
E.S. Simpson coll. 17	Three Rivers P.S.	Round core	29.276	(34.5 - 32.4) x 21.5	2.452	

APPENDIX

Tektites from Western Australia north of Line 2 (inset to fig. 2)

Physical details of tektites from northern Western Australia are shown in Table 2 and localities are indicated on fig. 2. Supplementary notes, if required, are given below together with notes on unacceptable specimens and reported occurrences which are unsupported by specimens. Multiple usage of two locality names is indicated by I, II, III.

Turkey Creek I (unacceptable). Thorp (1914) first listed this locality and indicated it on the accompanying map (Pl. XVII). Though the name was not used officially for a second creek (II) in the Mt Clifford area until 1936, this usage was already known to Mr L. Glauert of the WAM (Fenner 1935) and could have been established when Thorp was writing because Mt Clifford had been an active mining centre since 1900; australites are abundant in the nearby Leonora area. A third usage on Mt Vernon P.S. (I) is — at least officially — much more recent. Fenner (*op.cit*) stated that the specimen was in the WAM collection but no such specimen is registered. Nor is it listed by Hey (1966) in the BM collection which received Thorp's private collection from his estate (J. Hall *pers. comm.*). Dunn (1912; 1914) did not list the locality though "Mr Thorp, of Derby" was a contributor to the additional localities in the second publication. Only a few months later in Perth Thorp (1914) gave the address in which Turkey Creek was first mentioned. It therefore appears likely that the report arose from Thorp's west Kimberley experience and it would be wrong to dismiss it as a southern locality. It was in Derby that Mr K. Akerman (*pers.comm.*) saw an australite ritual stone in 1973, and Turkey Creek I is within easy reach of the trade cycle which he describes.

Mistake Creek P.S. (unacceptable). The locality is stated as "Duncan Highway, about 100 miles south of Kununurra" and hence in the vicinity of Mistake Creek H.S. The surface of the specimen is coarsely scoriaceous and the general appearance is similar to the "spongy" type of phillipinite (Type II of Chapman *et al.* 1964 fig. 11). The bubble cavities are closely crowded, sometimes interconnected by circular "windows", but evidently confined to the outer part of the specimen because an artificial fracture surface across the thickness reveals only rare, small (to 0.4 mm) cavities. Thin edges of the liquid — immersed specimen show abundant, small, usually ovoid inclusions which are isotropic and of lower refractive index than the enclosing glass. The inclusions are evidently lechatelierite which is

common in tektites, but the specimen is morphologically quite unlike australites.

Kalyeeda P.S. "Found by a native near Kallaida" (now Kalyeeda) is taken to mean that H.W.B. Talbot acquired the specimen from an aborigine and accepted the locality statement which he made. Though the specimen has areas of close and deep pitting (c.f. Baker 1959 Pl. V A), the form is that of a typical australite. Specimens with similar pitting are rare in Western Australia except in the Corrigin-Yealering district (10 specimens distributed in three collections).

Fitzroy Valley (unacceptable). An undescribed specimen additional to those of Christmas Creek, Mt Millard and Kalyeeda reported by Fenner (1935) cannot be traced.

Nullagine (unacceptable). WAM 12358 is catalogued with anomalous locality "Nullagine near Cue". The towns are 680 km apart and on opposed sides of Line 2. The donor could not be contacted.

Wyloo P.S. Hey (1966) records a BM specimen (1925, 1079) from Peake (*sic*) P.S., Ashburton River. It was formerly in the collection of C.G. Thorp who obtained it from M. McGrath. Records of the Lands and Surveys Department show the McGrath family as the original holders of Peak P.S., now part of Wyloo P.S. The mis-spelling of the name suggested a confusion with Peake P.S., South Australia, a known source of australites to which Thorp (1914) had once referred. Because of the traceable history, attribution to the Western Australian station now appears genuine, though this does not mean that it was necessarily at its site of fall.

Mt Vernon P.S. (Mt Vernon I). A specimen from no. 10A Well on Mt Vernon P.S. has been accepted but two further specimens, one of which gave anomalous chemical results (Lieberman 1966), are believed to have been incorrectly attributed to this area. The two specimens (SAM T 515) were from the collection of S.F.C. Cook, who made his collection during a period of active gold mining and prospecting. Excluding the two Mt Vernon specimens and about 50 from the Nullarbor Plain or outside the State, 100% of the remaining 4700 specimens in the collection are from gold mining centres. There is another Mt Vernon (II) in an area where australites are known but that also has no gold mining associations. A third Mt Vernon (III) was the site of Corboys (gold find) and was so named by Mr Corboy. The name later adopted officially is Mt Hilda. This last, in an area of known australite occurrence, was most active as a gold mining centre 1925-31 when Cook was collecting and is therefore the most likely source of the specimens. The chemical anomaly was resolved without recourse to locality considerations. Present occupants of Mt Vernon P.S. state that occasional

australites seen in the possession of aborigines are imports from the Wiluna area.

No. 14 Well, Canning Stock Route (unacceptable). Australites were reported by Talbot (1910) in the area of good pasture about this well. It is an isolated area completely surrounded by sand dune country. Talbot was an acute observer and a contributor of australites to the Simpson collection. The veracity of his report is not doubted but there is doubt that the australites were in situ. Talbot's map shows a native well and rock holes in the general vicinity. The area was thus known to and hunted over by the aborigine in good seasons and there were abundant australite supplies less than 100 km to the south. No specimens could be located in collections. It needs to be verified that australites other than flakes and the occasional specimen found about rock holes occur naturally at no. 14 Well.

The fragments of an australite (W.A. Govt. Chem. Labs. coll. 305) from "200 miles N.E. of Wiluna" (Anon. 1946 p.136) are not from no. 14 Well as would be inferred if the distance is scaled direct. They were found "out from no. 9 Well" (The Weld Spring), the finder having evidently stated the distance by the only trafficable but circuitous access road via Earraheedy P.S. and Glen Ayle P.S.

No. 35 Well, Canning Stock Route (unacceptable). Mr R. Verbugt, who collected australites from c.100 km S. of Windy Corner — the most northerly acceptable multiple occurrence in W.A. — also reported verbally to D.H. McColl that australites occur much further north at 125°13'E., 22°15'S., i.e. in the general vicinity of no. 35 Well on the Canning Stock Route. No specimens were lodged in collections. There are three native wells and several rock holes along the stock route in the general area. The site is marginal to an extensive area which is free of dunes or has few dunes compared with the surrounding desert. The environment of the site and the circumstances of the report closely parallel those of no. 14 Well. Tangible, un-flaked specimens are considered pre-requisite to acceptance as a site of natural occurrence.

REVISIONARY NOTES ON THE *LERISTA* (LACERTILIA, SCINCIDAE) OF WESTERN AUSTRALIA

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ABSTRACT

Five new species and subspecies are described: *Lerista separanda*, *L. xanthura*, *L. kalumburu*, *L. connivens petersoni* and *L. apoda*. Additional data, mainly distributional, are given for several other taxa. A key is provided for the 29 species and subspecies inhabiting Western Australia.

INTRODUCTION

It is only five years since I revised this genus (Storr, 1972), but so many specimens of *Lerista* have been recently added to our collection that a partial revision is warranted. Described as new are two members of the *elegans* group (*L. separanda* and *L. xanthura*), a close relation of *L. walkeri* and *L. borealis* (namely *L. kalumburu*) and two members of the *bipes* group (*L. connivens petersoni* and *L. apoda*). Because the last-mentioned species is completely limbless and almost blind, a new generic diagnosis is necessary.

It is now possible to redescribe *L. walkeri*, a species formerly unrepresented in our collection. Three other taxa are partially redescribed, viz. *L. m. microtis*, *L. borealis* and *L. nicholli*; and additional locality data are provided for a further 13 species.

All the material cited in this paper is lodged in the Western Australian Museum.

Diagnosis

Small to moderately large, elongate, smooth-scaled cryptozoic or fossorial skinks with fragile tail, minute ear aperture, and limbs (when present) small and widely separated. Forelimb with 1-5 fingers, or reduced to a clawless style or tubercle, or represented merely by a groove, or

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entirely without trace. Hindlimb with 1-5 toes, or reduced to a clawless style, or entirely without trace. No supranasal or postnasal. Prefrontals widely separated or absent. Frontal wider than supraocular region. Frontoparietals paired, or fused to each other, or fused to each other and to interparietal. Parietals in contact behind interparietal. Transversely enlarged nuchals present or absent. Loreals 1 or 2. Eyelid movable (with a transparent disc) or immovable (a spectacle) or absent (eye covered by a transparent ocular scale). Temporals 1+2 or 1+1. Upper labials 4-7, third-last subocular. Midbody scale rows 14-24. Preanals enlarged.

KEY

- | | | | | | | | | | | | | |
|-----|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------------------------------|
| 1. | Digits 5 + 5 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 6 |
| | Digits fewer | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 2 |
| 2. | Digits 4 + 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 7 |
| | Digits fewer | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| 3. | Digits 3 + 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 11 |
| | Digits fewer | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 4 |
| 4. | Digits 2 + 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 12 |
| | Digits fewer | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 5 |
| 5. | Digits 2 + 2 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 17 |
| | Fingers fewer than 2 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 20 |
| 6. | Dark upper lateral stripe wider than white midlateral stripe and margined above with white | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | <i>L. microtis microtis</i> |
| | Dark upper lateral stripe narrower than white midlateral stripe and not margined with white | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | <i>L. microtis arenicola</i> |
| 7. | Eyelid movable | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | <i>L. frosti</i> |
| | Eyelid immovable | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 8 |
| 8. | Dark upper lateral stripe present; supraciliaries 3-4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 9 |
| | No upper lateral stripe; supraciliaries 5 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | <i>L. xanthura</i> |
| 9. | Nasals forming a median suture | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 10 |
| | Nasals separated | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | <i>L. distinguenda</i> |
| 10. | Back olive brown; midbody scale rows normally 16 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | <i>L. elegans</i> |
| | Back pinkish buff; midbody scale rows 18... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | <i>L. separanda</i> |

11. Eyelid movable; supraoculars 4 *L. terdigitata*
 Eyelid immovable; supraoculars 3 *L. muelleri*
12. Eyelid immovable; midbody scale rows 16... .. *L. lineata*
 Eyelid movable; midbody scale rows 20-24... .. 13
13. Strong ventrolateral keel; temporals 1 + 1... .. *L. planiventralis*
 No ventrolateral keel; temporals 1 + 2 14
14. Dark upper lateral stripe present *L. desertorum*
 No upper lateral stripe 15
15. Frontoparietals fused *L. walkeri*
 Frontoparietals not fused 16
16. Frontoparietals forming a median suture *L. borealis*
 Frontoparietals separated... .. *L. macropisthopus*
17. Frontoparietals fused or forming a median
 suture *L. walkeri*
 Frontoparietals separated or just touching... .. 18
18. Dark upper lateral stripe present *L. picturata picturata*
 No stripes... .. 19
19. Back strongly spotted *L. neander*
 Back not or faintly spotted *L. macropisthopus*
20. Digits 1 + 3 *L. kalumburu*
 Toes fewer than 3 21
21. Digits 1 + 2 22
 Digits fewer 25
22. Dark upper lateral stripe conspicuous 23
 Upper lateral stripe faint or absent 24
23. Dark vertebral stripe present *L. gerrardii*
 No vertebral stripe (only 4 dark dorsal lines)... .. *L. picturata picturata*
24. No upper lateral stripe; nasals usually separ-
 ated; first supraocular contacting frontal;
 supraciliaries 3-5 *L. macropisthopus*
 Dark upper lateral stripe indistinct; nasals
 usually forming a median suture; first supra-
 ocular usually not contacting frontal;
 supraciliaries 1-2 *L. picturata baynesi*
25. Digits 0 + 2 26
 Digits fewer 33
26. Forelimb represented by a clawless style or
 tubercle or groove; prefrontals present; nasals

	usually forming a median suture	...	...	...	...	...	...	...	...	27
	No trace of forelimb or forelimb groove; no prefrontals; nasals usually separated	...	...	...	...	...	...	...	...	32
27.	Dark vertebral stripe present	...	...	...	...	...	...	...	...	28
	No vertebral stripe	...	...	...	...	...	...	...	...	30
28.	Loreals 2	...	...	...	...	...	...	...	...	29
	Loreal 1 (second fused to prefrontal)	...	...	...	...	...	...	...	<i>L. nichollsi</i>	
29.	Eyelid movable	...	...	...	...	...	...	...	<i>L. connivens connivens</i>	
	Eyelid immovable	...	...	...	...	...	...	...	<i>L. connivens petersoni</i>	
30.	Dark upper lateral stripe conspicuous	...	...	...	...	...	...	...	<i>L. picturata picturata</i>	
	Upper lateral stripe faint or absent	...	...	...	...	...	...	...	...	31
31.	Frontoparietals and interparietals not fused	...	...	...	...	...	...	...	<i>L. picturata baynesi</i>	
	Frontoparietals and interparietals fused	...	...	...	...	...	...	...	<i>L. lineopunctulata</i>	
32.	Two supraoculars contacting frontal; supra-ciliaries 1 or 2	...	...	...	...	...	...	...	...	<i>L. bipes</i>
	One supraocular contacting frontal; no supra-ciliaries	...	...	...	...	...	...	...	...	<i>L. labialis</i>
33.	Hindlimb with a digit; prefrontals present	...	...	...	...	...	...	...	...	34
	Hindlimb a clawless style or completely absent; no prefrontals	...	...	...	...	...	...	...	...	35
34.	Frontoparietals and interparietal not fused	...	...	...	...	...	...	...	<i>L. picturata baynesi</i>	
	Frontoparietals and interparietal fused	...	...	...	...	...	...	...	<i>L. lineopunctulata</i>	
35.	Hindlimb a clawless style; eyelid movable	...	...	...	...	...	...	...	...	36
	Hindlimb absent; no eyelid (eye covered by transparent ocular scale)	...	...	...	...	...	...	...	<i>L. apoda</i>	
36.	Labials 6; loreals 2; temporals 1 + 1; one supraciliary	...	...	...	...	...	...	...	<i>L. humphriesi</i>	
	Labials 5; loreal 1; temporals 1 + 2; no supraciliary	...	...	...	...	...	...	...	<i>L. praepedita</i>	

Lerista microtis microtis (Gray)

Revised distribution

Far south of Western Australia: southern half of Darling Range, from Dwellingup south to Collie; south coast from Israelite Bay west nearly to Cape Leeuwin (Scott River).

Partial redescription

Snout-vent length (mm): 22-51 (40.2). Length of appendages etc. (% SVL): foreleg 14-23 (17.1); hindleg 25-35 (29.4); tail 104-134 (117); snout to foreleg 25-36 (29.6). Nuchals 2-4 (3.2). Midbody scale rows 18 or 20 (22 in one specimen). Lamellae under longest toe 18-21 (19.3).

Additional material

South-west Division (W.A.): 5 km E of Dwellingup (40118); 25 km W of Collie (49275); Scott River (49955); Meerup River (47895); Torbay Head (51777); Two Peoples Bay (36382, 44991, 44996).

Eucla Division (W.A.): Rossiter Bay (42590).

Lerista frosti (Zietz)

Additional localities

North-west Division (W.A.): Hancock Gorge, 25 km S of Wittenoom; Marillana.

Eucla Division (W.A.): Mullendunya Tank (32°53'S, 124°35'E).

Lerista distinguenda (Werner)

Additional localities

South-west Division (W.A.): Buntine Reserve; 20 km NE of Dalwallinu; Julimar Forest; Lake Clifton; Dryandra; Tuttanning Reserve; 25 km E of Yornaning (32°54'S, 117°22'E); Dragon Rocks Reserve; Dongolocking Reserve (33°02'S, 117°43'E); 25 km W of Collie; Busselton; Lake Chinocup; Chinocup Reserve, 7 km NE of Pingrup; near Greenshield Soak (E of Pingrup); Lake Magenta; Phillips River, 26 km W of Ravensthorpe; upper Twertup Creek, Fitzgerald National Park; between upper reaches of Perup and Tone Rivers.

Eucla Division (W.A.): W of Point Culver (32°53'S, 124°32'E); Frenchmans Peak; Duke of Orleans Bay.

Lerista elegans (Gray)

Additional localities

South-west Division (W.A.): Houtman Abrolhos (East Wallabi Island); 15 km N of Marchagee; suburbs of Perth (City Beach, Alfred Cove, St James, Queens Park).

Lerista separanda sp. nov.

Holotype

R40268 in Western Australian Museum, collected by Mr W.H. Butler in winter 1971 at Coulomb Point, Western Australia, in 17°21'S, 122°09'E.

Diagnosis

Small slender *Lerista* with digits 4 + 4, eyelid immovable (i.e. a large transparent disc surrounded by an almost complete series of granules). Distinguishable from *L. elegans* by 18 (rather than 16) midbody scale rows, and from *L. distinguenda* by nasals forming a median suture; further distinguishable from both of those species by pale back without dark spots or olive tone but anteriorly with a wide faint vertebral stripe.

Distribution

Dampier Land, west Kimberley.

Description (of holotype, the only available specimen).

Snout-vent length (mm): 30. Length of appendages etc. (% SVL): foreleg 19; hindleg 33; tail 118; snout to foreleg 32.

Nasals forming a moderately long median suture. Prefrontals widely separated. Frontoparietals forming a long median suture; smaller than interparietal. Nuchals 2. Supraoculars 3, first two contacting frontal. Supraciliaries 4, last much the smallest. Upper secondary temporal much the largest; lower secondary much the smallest (on other side, primary temporal broken into two scales subequal to lower secondary). Midbody scale rows 18. Lamellae under longest toe 15-16, slightly compressed and very weakly keeled.

Upper surface pale pinkish buff, each scale finely edged with brown. A brown spot in centre of frontonasal, frontoparietals and interparietal, and a brown median streak on frontal, nape and foreback. Dark brown upper lateral stripe from tip of snout back through orbit to base of tail. Under surface whitish.

Remarks

The holotype was collected under bushes of *Crotalaria cunninghamii* growing at foot of coastal dunes (W.H. Butler, *pers. comm.*).

Lerista xanthura sp. nov.

Holotype

R40174 in Western Australian Museum, collected by Messrs J. Dell and G. Chapman on 25 May 1971 at 7 km SW of the Pollock Hills, Western Australia, in 22° 54'S, 127° 30'E.

Diagnosis

Small slender *Lerista* with digits 4 + 4, eyelid immovable (i.e. a large transparent disc surrounded by an almost complete series of granules), and no stripes or spots. Further distinguishable from *L. elegans*, *L. distinguenda* and *L. separanda* by 5 (rather than 3 or 4) supraciliaries and long tail (bright yellow in life).

Distribution

Gibson Desert (far eastern interior of Western Australia).

Description (of holotype, the only available specimen)

Snout-vent length (mm): 36.5. Length of appendages etc. (% SVL): foreleg 16; hindleg 30; tail 142; snout to foreleg 31.

Nasals forming a moderately long suture. Prefrontals widely separated. Frontoparietals forming a moderately long suture; smaller than interparietal. Nuchals 1-2. Supraoculars 3, first two contacting frontal. Supraciliaries 5, third and fourth largest, second and fifth smallest. Upper secondary temporal much the largest; lower secondary much the smallest. Midbody scale rows 18. Lamellae under longest toe 15-16, compressed and weakly keeled.

Upper surface pale pinkish buff, each scale finely edged with brown. Lower surface whitish.

Remarks

The holotype was found at a depth of *ca* 15 cm when the collectors were excavating the moist sand beneath a clump of spinifex on a spinifex-dominated sandplain (John Dell, *pers. comm.*).

Lerista muelleri (Fischer)

Additional localities

North-west Division (W.A.): Yardie Creek (the watercourse); Cockeraga River; Junction Well, upper Oakover River; Minnie Creek; Yinnietharra;

Weedarrah; Callagiddy; Errabiddy; 169 km NNE of Meekatharra; Mileura; Meekatharra; Billabalong; 20 km E of Paynes Find.

South-west Division (W.A.): Four-ways, Kalbarri National Park; Buntine Reserve; 20 km NE of Dalwallinu; Waddouring Water Reserve (S of Bencubbin).

Eastern Division (W.A.): 7 km W of Talawana; Well 11, Canning Stock Route; 7 km SW of Walyahmoning Rock; Marvel Loch; 48 km S of Widgiemooltha; Kanandah (N of Naretha).

Eucla Division (W.A.): 48 km N of Norseman.

South Australia: Mern Merna.

Lerista lineata Bell

Additional localities

South-west Division (W.A.): suburbs of Perth (Alfred Cove, Manning, Wilson, Queens Park).

Lerista planiventralis (Lucas & Frost)

Additional localities

North-west Division (W.A.): Carrarang.

South-west Division (W.A.): 5 km W of Padbury (30°10'S, 115°04'E).

Lerista borealis Storr

Diagnosis

Small *Lerista* with digits 2 + 3, eyelid movable, frontoparietals paired and forming a median suture, and pattern almost absent. Distinguishable from *L. walkeri* by large last supraciliary (subequal to third and fourth) and nasals not forming a median suture; it is also smaller, paler and less heavily spotted, and has longer limbs and more subdigital lamellae.

Distribution

Hills of the Kimberleys (far northern Western Australia).

Partial redescription

Snout-vent length (mm): 30-51 (44.9). Length of appendages etc. (% SVL): foreleg 8-11 (8.6); hindleg 16-21 (17.5); tail 114 (one specimen); snout to foreleg 27-28 (28.0).

Nasals narrowly separated (2 specimens) or just touching (3 specimens). Prefrontals widely separated. Frontoparietals forming a short to long median suture; shorter than interparietal. Nuchals 0-3 (2.5). Supraoculars 3, first two contacting frontal. Supraciliaries 5, last three largest, second smallest. Upper secondary temporal much the largest; lower secondary smallest. Midbody scale rows 20-22 (20.8). Lamellae under longest toe 10-13 (11.4).

Remarks

This species is closer to *L. walkeri* than I previously believed. Two characters formerly used for distinguishing them have proved to be not fully diagnostic, viz. condition of frontoparietals and number of toes.

Additional material

Kimberley Division (W.A.): Lake Argyle (52173-4).

Lerista walkeri (Boulenger)

Diagnosis

Moderately small *Lerista* with digits 2 + 2 (locally 2 + 3), eyelid movable, frontonasals fused or paired, and dorsal pattern of dark dots. Distinguishable from *L. borealis* by small last supraciliary (much smaller than third and fourth), long suture between nasals, darker and more heavily spotted coloration, greater size, shorter limbs and fewer subdigital lamellae.

Distribution

Coasts of north-west and west Kimberley from Prince Regent River south-west to Roebuck Bay; also Condillac and Augustus Islands.

Description (based on Prince Regent River series)

Snout-vent length (mm): 41-63 (55.7). Length of appendages etc. (% SVL): foreleg 5-8 (5.8); hindleg 10-15 (11.6); tail 75-110 (90.8); snout to foreleg 22-28 (24.9). Digits 2 + 2.

Nasals forming a long median suture. Prefrontals widely separated. Frontoparietals fused (7 specimens) or paired with long to moderately long median suture (6 specimens); shorter than interparietal. Nuchals 0-4 (2.2). Supraoculars normally 3, with first two contacting frontal (on one side of R46726 first and second supraoculars fused to each other and to second supraciliary). Supraciliaries normally 5; third and fourth largest, second and fifth smallest. Upper secondary temporal much the largest; lower secondary smallest. Midbody scale rows 22. Lamellae under longer toe 6-10 (8.2).

Upper surface dark greyish brown with a small obscure blackish brown spot in centre of each dorsal scale; spots aligning longitudinally and becoming larger and darker distally and extending to flanks and under tail. Ventrals whitish, fuzzily edged with greyish brown. Under digits grey.

Geographic variation

The single specimen from Augustus Island differs in having digits 2 + 3, shorter limbs (foreleg 4 and hindleg 7% of SVL) and browner, less greyish coloration. Its frontoparietals are fused.

Material

Kimberley Division (W.A.): Prince Regent River Reserve in 15°07'S, 125°33'E (46878, 46881), in 15°28'S, 125°29'E (46723-7), and in 15°34'S, 125°25'E (46886, 46890-1, 46953-5); Augustus Island (41299).

Lerista kalumburu sp. nov.

Holotype

R27915 in Western Australian Museum, collected by Mr W.H. Butler in summer 1965-66 at Kalumburu, Western Australia, in 14°18'S, 126°38'E.

Diagnosis

Small obscurely spotted *Lerista* with digits 1 + 3, eyelid movable, and frontoparietals separated. Further distinguishable from *L. walkeri* and *L. borealis* by smaller frontoparietals, larger primary temporal and fewer rows of midbody scales; it is also less heavily spotted under the tail, and the supraciliaries are less disparate in size.

Distribution

Vicinity of Napier Broome Bay, north Kimberley.

Description (of holotype, the only available specimen)

Snout-vent length (mm): 50. Length of appendages etc. (% SVL): foreleg 2; hindleg 13; tail 73; snout to foreleg 25.

Nasals forming a long median suture. Prefrontals widely separated. Frontoparietals separated, very much smaller than interparietal. Nuchals 2-3. Supraoculars 3, first two contacting frontal. Supraciliaries 5; first and fourth largest; second, third and fifth smallest. Upper secondary temporal largest; lower secondary much the smallest. Midbody scale rows 18. Lamellae under longest toe 8-9.

Upper surface brown, each dorsal scale with a central brown spot; spots on flanks tending to coalesce into obscure longitudinally orientated lines. Lips pale brown barred with dark brown. Under surface whitish, sparsely spotted with pale brown towards tip of tail.

Remarks

The above specimen was briefly described in Storr (1972: 65). The additional material now available of its close relatives makes it reasonably clear that *kalumburu* is not a variant of either *L. walkeri* or *L. borealis*.

Lerista macropisthopus (Werner)

Revised distribution

Western arid and semiarid zones of Western Australia: north to the Tropic; south to the central wheatbelt (Narembeen); west to Shark Bay, the mouth of the Murchison River and Wongan Hills; and east to the Robertson Range and Menzies district (Jeedamya).

Remarks

In its obscurely spotted and streaked dorsal and upper lateral scales, our northernmost specimen (R42282 from Coondra Coondra Spring in the Robertson Range) approaches *L. neander* from Mt Newman (130 km to WSW). In other respects it agrees with *L. macropisthopus*, viz. number of toes (3) and nuchals (3/4), nature of first supraciliary (not fused to supraocular), and relative length of hindleg (15.5% of SVL). Nevertheless *L. neander* (like *L. desertorum*) could well prove to be only subspecifically distinct from *L. macropisthopus*.

Additional localities

North-west Division (W.A.): Mooka, Kennedy Range; Woodleigh; Overlander Road House (Shark Bay turnoff).

South-west Division (W.A.): Trayning Reserve, 15 km ENE of Kununoppin.

Eastern Division (W.A.): Coondra Coondra Spring, 40 km NE of Jiggalong.

Lerista desertorum (Sternfeld)

Revised distribution

Eastern arid zone of Western Australia: north to lat. 25°S; south to 31°S; west to the Carnarvon Range, Albion Downs, Glenorn and Randells;

and east into the south-west of the Northern Territory (and presumably into north-western South Australia).

Additional localities

Eastern Division (W.A.): Carnarvon Range (25°17'S, 120°42'E); Agnew; Linden.

Lerista lineopunctulata (Duméril & Bibron)

Additional localities

North-west Division (W.A.): Dirk Hartog I.; Carrarang.

South-west Division (W.A.): mouth of Greenough River; Guilderton; suburbs of Perth (Wanneroo, Lake Gnangara, City Beach).

Lerista nicholli (Loveridge)

Diagnosis

Small slender *Lerista* with digits 0 + 2, forelimb groove minute, eyelid immovable, frontoparietals and interparietal fused, dark brown upper lateral stripe and brown vertebral stripe. Distinguishable from both subspecies of *L. connivens* by lesser size, fusion of second loreal to prefrontal, narrower and more sharply defined vertebral stripe, and fewer rows of midbody scales. Further distinguishable from *L. c. connivens* by immovable eyelid, more numerous nuchals, and relatively longer hindleg.

Distribution

Mid-west coast and hinterland of Western Australia from the Gascoyne south to the lower Murchison and upper Greenough, east to Mileura and Dalgarranga.

Partial redescription

Snout-vent length (mm): 31-61 (51.5). Length of appendages etc. (% SVL): hindleg 14-20 (17.2); snout to foreleg groove 21-26 (23.1).

Nasals forming a short to moderately long median suture. Prefrontals widely separated. Nuchals 1-3 (2.2). Supraoculars 3, first two contacting frontal. Supraciliaries 0 + 1, 0 + 2, 1 + 1, 1 + 2, 3 or 4. Midbody scale rows 20 (occasionally 18). Lamellae under longer toe 9-15 (11.4).

Additional material

North-west Division (W.A.): 17 km NE of Carnarvon (41208); Callagiddy (37648, 39767, 40667-8); Woodleigh (48008-9, 49932-6); Overlander Road House (44528); Meeberrie (51096).

Lerista connivens petersoni subsp. nov.

Holotype

R46197 in Western Australian Museum, collected by Mr M. Peterson in June 1973 at Yinnietharra, W.A., in 24°39'S, 116°09'E.



Fig. 1: Paratype of *Lerista connivens petersoni*.

Diagnosis

Moderately large and stout *Lerista* with digits 0 + 2, forelimb groove, eyelid immovable (i.e. large transparent disc surrounded by a series of granules), dark upper lateral stripe, and wide vertebral stripe. Distinguishable from *L. c. connivens* by immovable (rather than movable) eyelid, more numerous nuchals and subdigital lamellae, slightly longer hindleg, and occurrence of individuals with frontoparietals and interparietal free.

Distinguishable from *L. nichollsi* by greater size, two loreals (rather than one), and wider, more ragged-edged vertebral stripe.

Distribution

Mid-western interior of Western Australia, in the Gascoyne drainage.

Description

Snout-vent length (mm): 67.5-69. Length of appendages etc. (% SVL): hindleg 16-17; snout to forelimb groove 21-22.

Nasals forming a short to moderately long median suture. Prefrontals widely separated. In holotype frontoparietals narrowly separated, much smaller than interparietal; in paratype frontoparietals and interparietal fused (as in *L. c. connivens* and *L. nichollsi*). Nuchals 2-3. Supraoculars 3, first two contacting frontal. Supraciliaries 1 + 2 or 4. Upper labials 6. Upper secondary temporal much the largest, lower secondary much the smallest (when not fused to last labial). Midbody scale rows 20-22. Lamellae under longer toe 12.

Head, vertebral stripe and tail greyish brown; vertebral stripe wider than whitish laterodorsal strip of ground colour and enclosing four series of dark brown spots. Dark brown upper lateral stripe from nasal or lores back through orbit to tail. Upper labials barred with dark brown. Lower surface whitish except for grey dots on tail.

Remarks

Named after the collector of the holotype, Magnus Peterson, in appreciation of the numerous reptiles he has donated to this Museum. The paratype was collected by T.M.S. Hanlon in leaf litter on 22 December 1975; it was photographed in life (Fig. 1) by R.E. Johnstone.

Paratype

North-west Division (W.A.): Yinnietharra (51378).

Lerista bipes (Fischer)

Additional localities

Kimberley Division (W.A.): Manning Creek; Coulomb Point; Nita Downs; Granny Soak, Gardiner Range.

North-west Division (W.A.): Monte Bello Is (Trimouille I.); Dampier Archipelago (Gidley I., Kendrew I.); Point Samson.

Eastern Division (W.A.): 119 km E of Talawana; Gary Junction; 5 km S of Charles Knob (25°06'S, 124°59'E); near Miller Soak (28°10'S, 124°12'E).

Lerista labialis Storr

Additional localities

Eastern Division (W.A.): Cavenagh Range; Shell Lake (29°15'S, 127°05'E).

Lerista praepedita (Boulenger)

Additional localities

North-west Division (W.A.): Dirk Hartog I.; near Denham.

South-west Division (W.A.): Lockwood Springs; Port Gregory; Green Head; 5 km W of Padbury (30°10'S, 115°04'E); 8 km NE of Jurien Bay; Guilderton; suburbs of Perth (Sorrento, Doubleview, Wembley Downs, Balga, Dianella).

Lerista apoda sp. nov.

Holotype

R52163 in Western Australian Museum, collected by Dr B.R. Wilson and Mrs S.M. Slack-Smith on 5 September 1975 at Cygnet Bay, Western Australia, in 16°26'S, 123°01'E.

Diagnosis

Very slender *Lerista* with no trace of legs (including forelimb groove); eye very small and located under a transparent scale; snout flat, sharp and protruding well beyond mouth; tail much shorter than body and terminating abruptly and obtusely (as in Typhlopidae).

Distribution

Dampier Land, west Kimberley.

Description

Snout-vent length (mm): holotype 70.5, paratype 77. Length of tail (% SVL): holotype 56, paratype 20.

Nasals very large, forming a moderately long suture. No prefrontals. Frontonasal and frontal much wider than long. Frontoparietals and interparietal fused into a large triangular shield. Parietals long and narrow, in

short contact. No nuchals. Two apically pointed scales between frontal and ocular. One loreal (the only scale between nasal and ocular). One postocular. Temporals 3, upper secondary a little larger than primary, lower secondary much the smallest. Upper labials 4. Ear aperture minute (as in all *Lerista*). Midbody scale rows 16.

Upper surface whitish with a few faint brown blotches on head and four series of faint brown dots along back and tail. Lateral and lower surfaces dark brown, obscurely spotted with still darker brown, except for whitish under snout, lips, chin, throat and preanal scales, and for anterior half of tail (which is whitish, sparsely spotted with brown).

Remarks

At first glance these specimens, especially the extremely short-tailed paratype, look more like an *Aprasia* than a skink. Degeneration of the eye has proceeded beyond that in *Aprasia* and seems to be approaching the condition in blind-snakes (Typhlopidae). Nevertheless, *apoda* is very much a *Lerista*. Indeed it fits easily into the *bipes* group, where some of its peculiarities are foreshadowed in *L. praepedita*.

The holotype was found when its collectors were searching for molluscs under small limestone rocks half buried in leaf litter; the lizard would not have been more than a centimetre or two below the surface of the calcareous sand (B.R. Wilson, *pers. comm.*). The paratype was collected by W.H. Butler in pindan country in winter 1971.

Paratype

Kimberley Division (W.A.): Coulomb Point (40267).

REFERENCE

- STORR, G.M. (1972). The genus *Lerista* (Lacertilia, Scincidae) in Western Australia. *J. Proc. R. Soc. West. Aust.* 54: 59-75.

ARCHAEOLOGICAL INVESTIGATIONS IN THE NORTHCLIFFE DISTRICT, WESTERN AUSTRALIA

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ABSTRACT

Traditional Aboriginal land use and subsistence in the Northcliffe district, Western Australia was probably similar to that recorded in other south western coastal districts during the 19th century. Examination of prehistoric Aboriginal campsites in the vicinity of Northcliffe and on the coastal plain reveals that Aboriginal stone workers used local chert, silcrete, quartz, and other stone. They quarried silcrete extensively at an outcrop near Northcliffe from before 6780 years BP until at least 3000 years BP. Area stone artifact assemblages contain diverse retouched tools made on flakes and blades, notably geometric microliths.

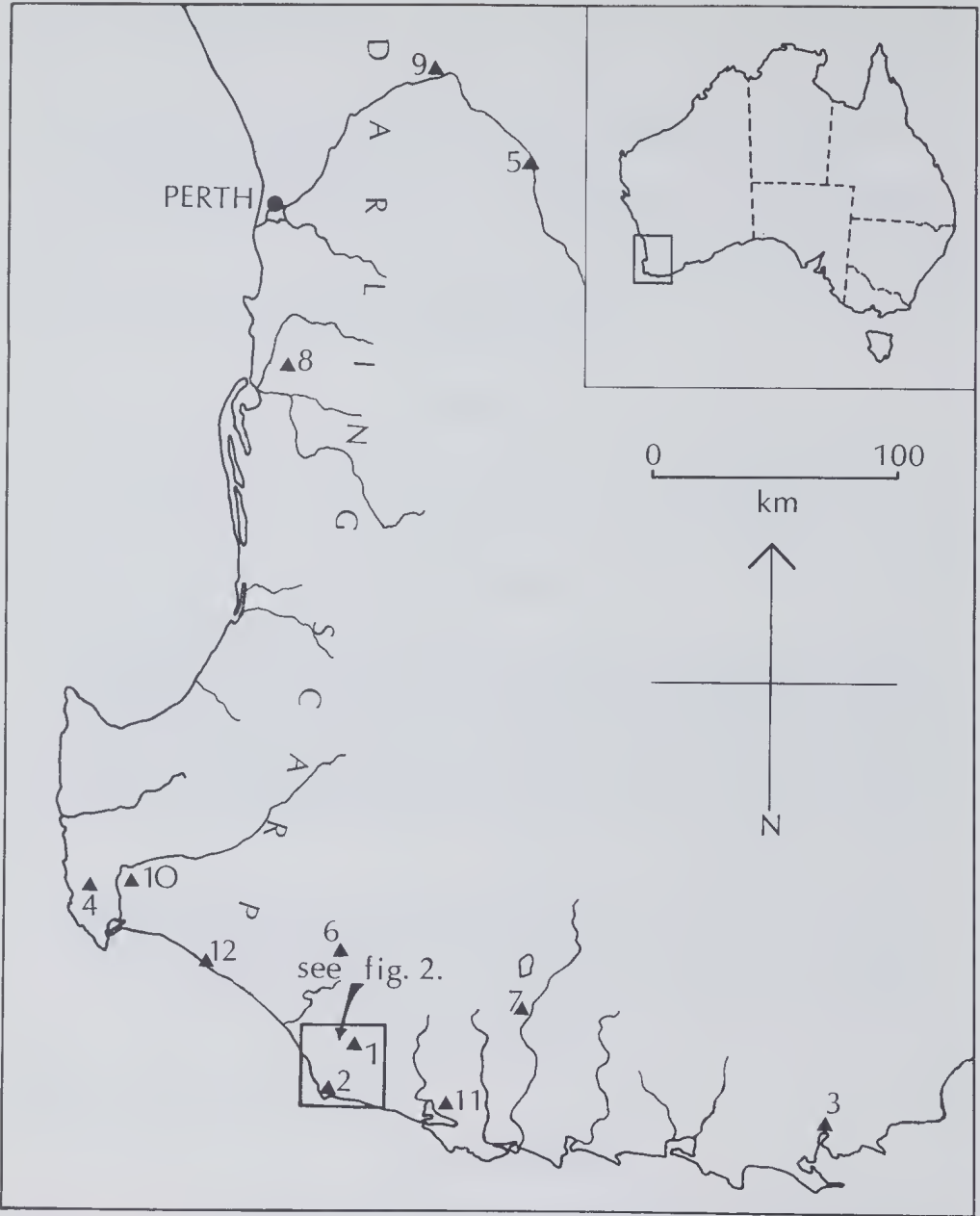
A wooden fish trap on a freshwater creek near Point d'Entrecasteaux suggests that traditional freshwater fishing methods were highly developed. Marine mollusc shells at archaeological sites in coastal dunes around Malimup are tentatively interpreted as food remains. The scarcity of biotic material in known archaeological deposits at present prevents definitive assessment of prehistoric Aboriginal subsistence and land use.

INTRODUCTION

For the past few years Mr A. Jackson and ourselves have recorded archaeological sites in the area around the town of Northcliffe, W.A. and on the coastal plain between Northcliffe and Point d'Entrecasteaux 25 km to the south (Maps 1, 2). In this account we describe some of these sites and

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Map 1: South western Australia. The map numbers refer to the following localities mentioned in the text.

- | | |
|-------------------------------|----------------------------------|
| 1. Northcliffe | 7. Frankland River |
| 2. Point d'Entrecasteaux | 8. Serpentine, Murray Rivers |
| 3. King George Sound (Albany) | 9. Swan-Avon River |
| 4. Devil's Lair | 10. Hardy Inlet, Blackwood River |
| 5. York | 11. Broke Inlet |
| 6. Pemberton | 12. Cape Beaufort |

archaeological material collected from them and assess traditional Aboriginal economy in the district.

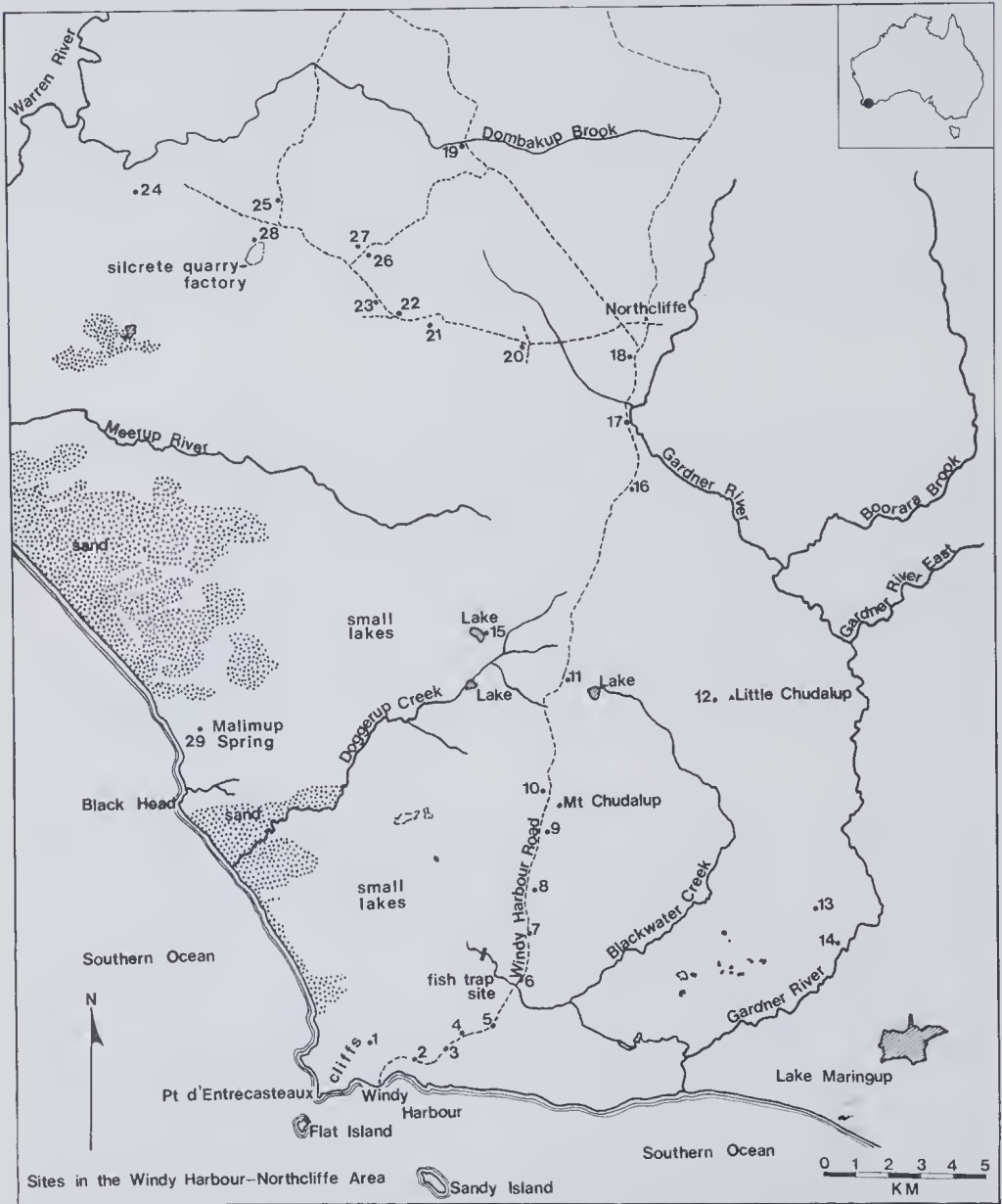
Prior to the early 1920s the Northcliffe district had not been settled by Europeans. At that time the district began to be farmed by British migrants of the group settlement scheme, and timbering became important, the main trees exploited being karri (*Eucalyptus diversicolor*) and jarrah (*E. marginata*). The coastal plain to the south has never been occupied or used by Europeans on a year-round basis, and except for a small summer resort at Windy Harbour one km east of Point d'Entrecasteaux, the coastal plain remains unsettled. The Malimup Spring area (Map 2) was used by pastoralists for summer cattle grazing as early as the 1880s and for several decades following. Traditional Aboriginal culture disappeared on the south coast during the 19th century, and the last visits to the Northcliffe district by small groups of culturally disoriented south western Aborigines took place in the 1920s.

THE AREA

The study area comprises the zones of forest, woodland and open plain between Dombakup Brook and Point d'Entrecasteaux (Map 2). The Gardner River forms the area's eastern boundary; its western boundary is a line extending from the junction of Dombakup Brook and the Warren River southward to Malimup Spring. The climate here is of a very wet Mediterranean type with an annual rainfall average exceeding 1400 mm (McArthur and Clifton 1975: Fig. 1, Table 2) and a nine month growing season. Periods of summer drought are not usually prolonged. Frost is rare and the winter is characterised by drizzle, rain and occasional periods of high winds.

In broadest terms area stratigraphy comprises leached sands of Quaternary age overlying a Pre-Cambrian basement of igneous and metamorphic rocks (Western Australia, Geological Survey 1975). Siliceous stone of probable Tertiary age outcrops locally though until now these have not been described, and their stratigraphical positions are not fully resolved. Formations of Quaternary limestone occur along the coast, the most dominant of these being the 105 m high headland of Point d'Entrecasteaux. The soils of the district consist very largely of podzols and podzolised sands. There are also smaller areas of gravelly red earths and patches of laterite (McArthur and Clifton 1975). The coastal plain, particularly the southern part, is covered by extensive marshes separated by east-west oriented low sand ridges. Further to the north west are massive inland sand hills (notably the Yeagerup Dunes) which encroach on a vast area of heathland and scrub. These sand hills consist of undifferentiated white siliceous

sands, whereas extensive beach and coastal dunes are unconsolidated calcareous sands (McArthur and Clifton 1975, Fig. 6). The principal streams are the Gardner River and its western tributaries, Doggerup Creek, the Meerup and Warren Rivers and Dombakup Brook (Map 2). There are numerous small lakes and swamps in the poorly drained northern part of



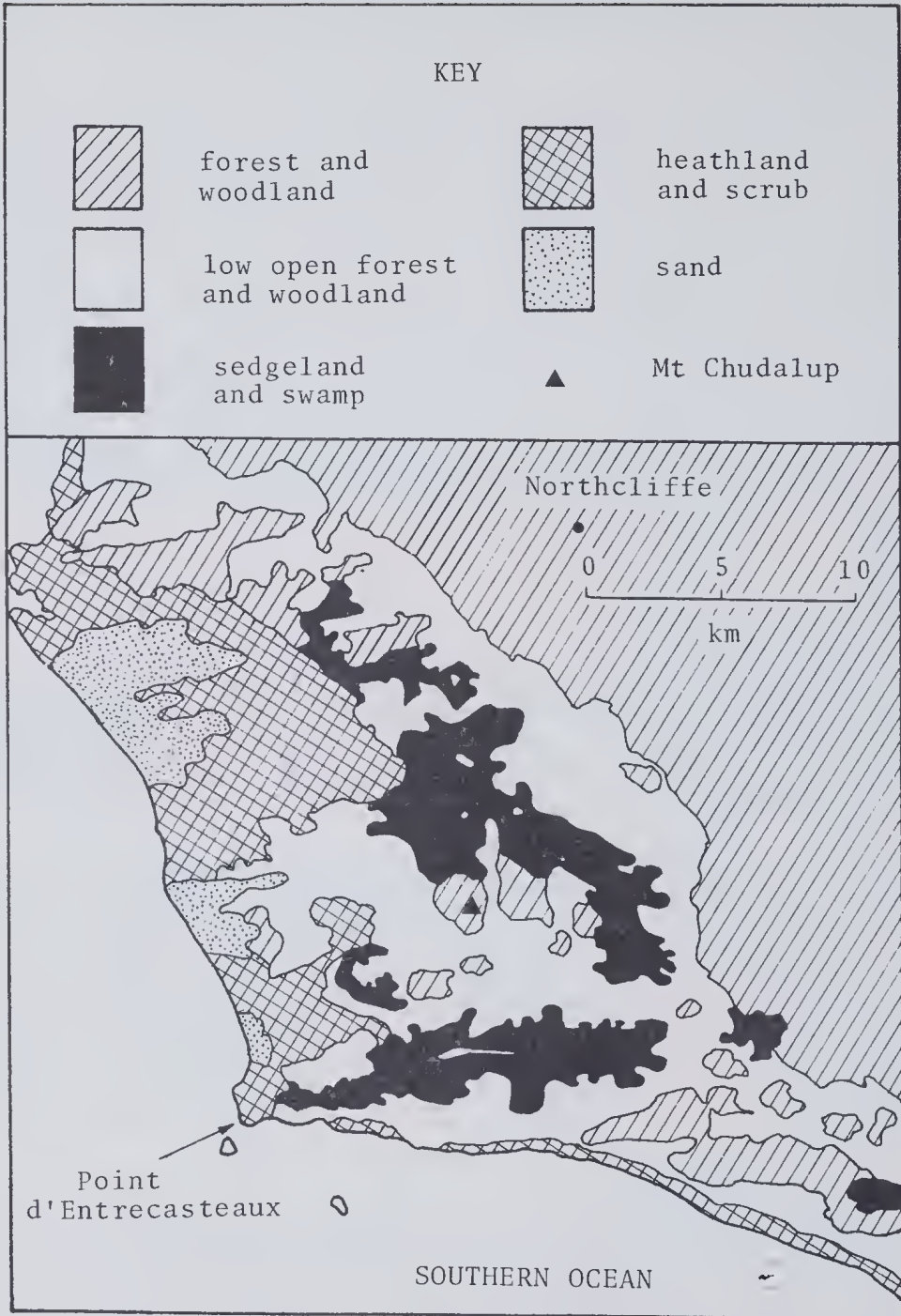
Map 2: The Northcliffe district, Western Australia with numbered archaeological sites.

the coastal plain. The southern part of the plain is drained by several tributaries of the Gardner River, the most important of these being Blackwater Creek.

The headland of Point d'Entrecasteaux and coastal dunes to the north west are covered with heath vegetation and stunted trees, principally banksias (*Banksia* spp.), peppermints (*Agonis flexuosa*) and acacias (*Acacia decipiens*) (McArthur and Clifton 1975; Smith 1972). Malimup, a complex of heath covered dunes and interdunal woodland and swamps, is notable for its abundant freshwater springs and caves developed in the limestone substrate. The northern part of the sandy coastal plain is interspersed with numerous outcrops of Pre-Cambrian granite with Mt Chudalup, the highest (185 m a.s.l.) and most conspicuous of these, occupying a central position (Maps 2, 3). The soils derived from the granite outcrops support stands of eucalypt forest and woodland of the same species which are found around Northcliffe. The sand ridges and some well drained sandy soils of the coastal plain support eucalypts (*Eucalyptus* spp.), banksias, acacias, (*Acacia* spp.), peppermints and occasional Christmas trees (*Nuytsia floribunda*). Large trees do not occur on the plain except in the well sheltered interdunal swales at Malimup, on the granitic outcrops in the Mt Chudalup area, and on the timber islands of the northern part of the plain. The chief tree species in the swamps are paperbarks (*Melaleuca* spp.), *Banksia littoralis* and Warren River cedar (*Agonis juniperina*). Smith (1972, pp. 13-14) lists the species of rushes, sedges, herbs and shrubs which dominate the swamps and sedgeland.

Uncleared areas in the sandy soils around Northcliffe support forest and woodland dominated by five species of eucalypts: jarrah, karri, marri (*E. calophylla*), blackbutt (*E. patens*) and bullich (*E. megacarpa*). Other trees, including understorey forms, are peppermints, banksias, sheoaks (*Casuarina* sp.), acacias and blackboys (*Xanthorrhoea preissii*). North of Dombakup Brook (Map 2) there are extensive stands of high karri forest growing on soils developed on the Pre-Cambrian country rocks. Karri forest extends over the whole of the dissected plateau around Pemberton 30 km north west of Northcliffe.

Thus a north-south transect of this area (Maps 2, 3) begins with karri or jarrah-marri forest or woodland formations which about eight km south of Northcliffe give way to the sedgeland, swamps, small lakes, low sand ridges and timber islands of the northern or upper part of the coastal plain. South of Mt Chudalup the lower part of the plain with its east-west oriented sand ridges and broad areas of swamp, sedgeland, heathland, scrub and low open woodland extends to the coastal dunes.



Map 3: Vegetation formations in the Northcliffe district, Western Australia, based on Smith (1972).

ABORIGINAL ECONOMY

Meagher (1974) and Hallam (1975) have used the abundant ethnohistorical sources available to infer Aboriginal land use and subsistence patterns in the south west (Map 1) at the end of traditional times. In broadest terms these seem to be that the economy was based on the systematic and to a very large extent seasonal exploitation of a very wide variety of food resources of coastal and adjacent inland districts; that economic activities often required co-ordinated group effort within a system of group land tenure; and that regular burning, used in vegetation management and animal drives, was a significant controlling device.

Hallam (1975) shows that Aboriginal economic activities as observed at King George Sound (Albany) 160 km east of Northcliffe (Map 1) were much the same as those recorded in the Perth district and other parts of the Swan (or western) Coastal Plain. The similarities in economy, and also in the food resources and environments of the Swan Coastal Plain and the South Coast, suggest to us that traditional Aboriginal economy and land use in the Northcliffe district was little different from that recorded ethnohistorically in the above mentioned districts. Therefore in the following we have used this body of ethnohistorical data in inferring some aspects of traditional land use and economy in the area round Northcliffe.

Ethnohistorical data for the Northcliffe district are minimal. Virtually the only published observation of Aboriginal activities here was recorded in April 1831 by a British naval party who before stranding their boat west of Point d'Entrecasteaux had 'heard the natives and saw their fires about a mile up the river.' (Anon. 1833, p. 116.) There is no indication whether these Aborigines were engaged in fishing, burning off the vegetation, or other likely autumn economic activities. The river referred to is the Gardner (Map 2).

A number of ethnohistorical accounts (for detailed references see Hallam 1975; Meagher 1974) suggest that to the south western Aborigines the food and other resources of the coastal plains were at least as important as those of adjacent inland districts (e.g. the Darling Scarp). Ethnohistorical accounts, notably Grey (1841, vol. 2, pp. 258-299) and Moore (1884), emphasise the variety of the coastal plain food resources which included not only marine and freshwater fish but also many terrestrial and freshwater plant and animal foods. Certainly many of the latter were available both on the coastal plains and in the interior, including most genera of mammals, many species of reptiles and amphibians and some of the same plant foods. However the wetlands of the coastal plains have a much more varied component of plant species with edible roots such as herbs, rushes and sedges, orchids,

lilies and lily-like species (Erickson *et al.* 1973), and some of these are recorded by Grey (1841, vol. 2), Moore (1884), Nind (1831) and others as being regular items of diet. Meagher, in her detailed account of south western foods writes:

'Roots, bulbs and tubers appear to have been the main sources of vegetable food, some of which were available throughout the year. Those collected and eaten by the Aborigines included species of *Caesia*, *Dioscorea*, *Haemodorum*, *Platysace*, *Prasophyllum*, and *Typha*.' (1974, pp. 24-25.)

Most of these genera occur in the coastal plain south of Northcliffe or in swamps and streams in the eucalypt forest and woodland around Northcliffe. The notable exception is *Dioscorea* (*D. hastifolia*) which is confined to soils on and east of the Darling Scarp (Erickson *et al.* 1973).

Other plants with edible parts which occur in the area are zamia palms (*Macrozamia riedlei*) the fruit of which was processed to remove toxins and then eaten raw or roasted by south western Aborigines (Grey 1841, vol. 2, p.296; Hammond 1933, p.28). Moore (1884, p.3) reports that part of the crowns of blackboys (*Xanthorrhoea preissii*) and gum from (the flower stalks of) these plants were eaten. The fruits of several plants, e.g. those of the 'emu plum' (*Podocarpus drouynianus*), were eaten by south western Aborigines (for references see Meagher 1974). Eucalypt and banksia nectar was a favourite food, and acacia seeds and gum were in some districts seasonal staples (Hammond 1933; Moore 1884). The Aborigines also ate several species of fungi (Meagher 1974, p.26). One of these, 'blackfellows' bread' (*Polyporus mylittae*), appears in quantity following burning in the karri forests, including those occurring in the Northcliffe district, and this fungus may have been commonly eaten during the summer and autumn months (pers. comms T. Macfarlane, D. Phillips-Jones). Plant genera with edible parts which may have been eaten in the Northcliffe district but have not been clearly identified in the south western ethnohistorical sources (cf. Meagher 1974, Appendix 4) include several species of aquatic herbs (e.g. *Triglochin* sp.), some of the sedges (e.g. *Scirpus* sp.), some of the lily-like plants (e.g. *Anigozanthos flavida*), and fruits or berries of *Leucopogon* sp., *Persoonia* sp. and other shrubs.

Animal foods of the coastal swamps, streams and marshes included several species of fish and water fowl, freshwater crayfish, frogs and tortoises. Grey (1841, vol. 2, pp. 280-284, 287-88) provides detailed accounts of the snaring or gathering of these animals. He observed that the streams, lagoons and marshes were utilised most in summer when their waters were shallow or dried up and the animals most easily obtained. Freshwater and

estuarine fish were taken in quantity especially during summer and autumn according to sources quoted above and others listed in Meagher (1974). Freshwater and marine molluscs abound in the waters of the district, yet evidence of Grey (1841, vol. 1, pp. 292-7; vol. 2, pp. 263, 288), Moore (1884, p.51) and Nind (1831, p.34) suggests that south western Aborigines did not eat these animals. The coast below Northcliffe has no large estuaries such as Hardy or Broke Inlets (Map 1), and it is debatable whether the open coast was ever fished. Possibly Aborigines were able to spear or trap fish in the relatively sheltered waters of Windy Harbour (Map 2). Evidence for freshwater fishing is provided by an Aboriginal fish trap located on Blackwater Creek (Map 2; see below).

Meagher (1974) provides a comprehensive ethnohistorical source list and summary of hunting methods used by south western Aborigines, and we assume that many of these methods were used by Aborigines of the Northcliffe district in hunting game both large and small. Large game, such as emu or kangaroo, was usually speared either following stalking by individual hunters, or during the course of various kinds of large scale hunts in which numbers of people co-operated in driving animals into ambushes or various kinds of traps. In summer fire drives were commonly carried out (Grey 1841, vol. 2, pp. 270-1, 290-1; Nind 1831, p.28). No animal traps are known in the Northcliffe district. However kangaroo traps consisting of narrow trenches or small pits have been recorded by Miss S.J. Meagher near the Frankland River some 70 km to the north east (Map 1; pers. comm. S.J. Meagher), and others have been reported from the district east of Hardy Inlet (Map 1; pers. comm. M. Ellis). Some of the smaller marsupials which were probably eaten by Aborigines of the Northcliffe district are small wallabies, including quokkas (*Setonix brachyurus*), bandicoots, possums, rat-kangaroos and native cats. Native rats (murids), various kinds of game birds (particularly water fowl), snakes, large lizards, frogs and freshwater crayfish were also probably eaten.

With the potential exception of the fish trap described below we have no archaeological data which can be related to specific seasons of occupation of the coastal plain. However summer and autumn was the time when many plant and animal foods of the coastal plain were in season or most easily available. This was also the time when controlled burning could be carried out to facilitate game drives and the gathering of some wetland plant foods such as sedge roots, to maintain control over the vegetation, and to enable ease of movement.

Several ethnohistorical accounts relating to Aboriginal land use and economy suggest that the south western Aborigines congregated on the

coastal plains during the summer and autumn and roamed the inland areas during the winter. Scott Nind, a medical officer at the British settlement at King George Sound (Map 1) during the late 1820s, records this in the following:

‘During the winter and early spring they are very much scattered; but as summer advances they assemble [on the coast] in greater numbers.’ (Nind 1831, p.28.)

He states further:

‘They begin to return to the coast about September or October and at this season they chiefly subsist on roots. In calm weather, however, they procure a few fish. . . . I believe that during the winter they are in small parties and much scattered [in the interior], living upon possums, bandicoots, kangaroos, etc.’ (*ibid.*, p.36.)

Stirling (1827) recorded a similar seasonal pattern in the Swan River district (Map 1).

Summer and autumn occupation of the coastal plain below Northcliffe seems particularly plausible when one compares the very pleasant conditions prevailing there in these seasons with the high winds, heavy rain, cold and floods which characterise the winter, and which at times would certainly have made the area unattractive for human occupation. This fact, in addition to the above ethnohistorical observations which suggest that the south western coastal plains were predominately occupied during summer and autumn, could lead one to conclude that this was probably the case, at least for as long as climate and other environmental factors were the same as or similar to those of the present. However in the Northcliffe district it seems unnecessary to envisage a clear division between seasonal inland and coastal occupation such as may have existed in the Swan Coastal Plain and much more arid adjacent inland districts, or inland and coastal areas around King George Sound. Instead traditional occupation patterns around Northcliffe and other parts of the high rainfall zone of the extreme south west (McArthur and Clifton 1975, Fig. 1) could have been loose-knit and subject more to a variety of ephemeral economic and environmental factors than to a strict adaptation to the seasonal availability of water and associated resources. We suggest then that advantages of topography and availability of resources, especially plentiful water, enabled many localities, either coastal or inland, within and on the margin of the high rainfall zone to be occupied at any season.

ARCHAEOLOGICAL SURVEY

Site location and stratigraphy

We have recorded 30 archaeological sites or site complexes in the Northcliffe-Point d'Entrecasteaux area (Map 2). Nearly all of the sites have been identified through the presence of stone artifacts exposed in road sections or scattered on recently bulldozed surfaces of limited size (i.e. four to 700 square m). Most sites contain less than 20 artifacts though in most cases it is probable that only a small part of the site is exposed. However hundreds of artifacts, including many retouched tools, have been collected at sites 1 and 2, located immediately east of Point d'Entrecasteaux, and at site 28, a silcrete quarry-factory (Map 2, Tables 1,2). An exceptional site not designated by a number is the Blackwater Creek fish trap (Map 2; Figs 3,4).

Very thick understorey vegetation and ground cover in most parts of the area effectively prevents intensive, systematic archaeological survey. Our survey then is essentially a compilation of sites in the better cleared areas around Point d'Entrecasteaux, the Northcliffe town site, and the road which connects them. At present we know very little about the distribution of sites in the district as a whole, and even in the above areas there are probably a number of surface sites not recorded.

It is likely that many of the known sites are broadly contemporaneous, and stratigraphical and typological considerations suggest that all are Holocene in age. This is substantiated by two radiocarbon dates relating to the stone industrial sequence identified in a test excavation in an undisturbed podzol at the silcrete quarry-factory described below. The only site of post-European age is the Blackwater Creek fish trap.

All of the stone artifacts recovered from horizontal graded exposures or road cuttings had been covered by 20-100 cm of undisturbed sandy soil. Most specimens found *in situ* in road cuttings occur in the leached zones or A2 horizons of the podzols which predominate in the district (McArthur and Clifton 1975). Similarly the horizontal exposures containing artifacts (e.g. site 1) are either the leached zones of podzols or leached, undifferentiated dune sands. Thus there has been wholesale deposition and no or only minimal deflation or erosion since the sites were occupied.

It is possible that the general inhumation of prehistoric occupation surfaces in the district is the result of sand movement within the unstable phase of a periodic soil cycle such as conceived by Butler (1959). The soil profile development which now characterises the coastal plain and sandy areas around Northcliffe may represent a stable phase, though movements of massive sand hills to the north west and natural erosion of coastal dunes at Malimup (Map 2) could perhaps equally be interpreted as the beginning of a new cycle.

Our survey suggests that the most typical sites on the coastal plain south of Northcliffe are located on dune ridges or sandy hummocks overlooking extensive marshes and small lakes which, as noted above, harbour a variety of plant and animal foods. It seems reasonable to infer that these sites are the remains of open camps used by bands of hunter gatherers engaged in the exploitation of varied wetland resources. Scatters of stone artifacts in fire breaks and other modern exposures in the forest and woodland around Northcliffe can also be interpreted as open camping places, though here the sites seem smaller in area and artifacts are generally few in number and include few retouched tools, suggesting that occupation may have been less intensive and of a more transitory nature.

Relatively few sites (Map 2) have been identified in the vicinity of Mt Chudalup. There is a large rock shelter near the hill which could have been occupied though it shows no signs of use. A few artifacts have been found in cracks in horizontal granite outcrops in the Chudalup area, and it is possible that people used these as camping areas.

Campsites in coastal calcareous dunes have until now been identified only at Malimup (see below). The limestone headland of Point d'Entrecasteaux seems devoid of archaeological sites, including such potential features as a large cave and a line of shallow shelters along the 'inland cliff' on the east face.

Stone resources

The great majority of artifacts from sites in the Northcliffe district are made of local stone. The four most important of these are silcrete, whose source we describe below, gneiss, quartz and a form of fossiliferous chert similar in several respects to that found in artifact assemblages from Devil's Lair (Map 1; Glover 1974) and numerous sites on the Swan Coastal Plain (Glover and Cockbain 1971; Glover 1975). Two small outcrops of this chert located in swampy, thickly vegetated areas within the karri forest ten to 15 km east of Northcliffe may have been sources used by prehistoric Aborigines. However we have not yet discovered signs of quarrying or any archaeological material at either outcrop.

Most of the chert used for artifacts is soft, porous and opaque grey. Nodules of this stone often contain inclusions of much finer grained chert with a flinty appearance, and sometimes this grades into opal (pers. comm. J. Glover). A number of opal artifacts have been recovered from local sites, particularly sites 1 and 2. Silicified sponge remnants (spongolite) and spicules which are sometimes incorporated in nodules of fossiliferous chert are also found on archaeological sites. (In Table 2 opal and spongolite artifacts and

sponge spicules are listed under chert artifacts.) We have also noted three artifacts (e.g. Fig. 8:15) made of a form of banded chert which may come from Cape Beaufort 60 km to the north west (Map 1).

Clear and milky white quartz was quarried from veins in the Pre-Cambrian rocks of the district, or collected as pebbles from the beaches. Clear quartz crystals and a form of translucent quartz with a yellow tinge are also found on archaeological sites. The Aborigines made use of local gneiss, either in the form of beach pebbles or fragments taken from outcrops, and including a form of highly siliceous gneiss resembling quartzite. Other stone used for tools includes amphibolite which occurs in the Archean metamorphic rocks in the north and east of the district (J. Clarke, pers. comm.), and a black glossy rock similar to obsidian which is found as vein filling in the basalt exposed at Cape Beaufort (Map 1). There are relatively rare basalt artifacts, the nearest known source of this being Cape Beaufort. We have also collected a few pebbles and fragments of a whitish-grey quartzite which probably comes from local Pre-Cambrian rocks.

Table 2 shows that at sites 1 and 2 silcrete, quartz and chert were all used extensively whereas there is a very marked preponderance of silcrete artifacts at sites within a few km of the silcrete quarry-factory and at this site itself (Table 1).

The silcrete quarry-factory (site 28)

Until now we have carried out only one systematic test excavation in the district. This was made in the face of a bulldozer cutting in a sandy soil overlying a silcrete formation (site 28) 11.5 km west north west of Northcliffe (Map 2). The excavation (Trench 1) and the finds, mostly silcrete artifacts, are described in more detail in Dortch (1975); and the latter are listed in Table 1. We estimate that the silcrete formation is at least 15 hectares in area. The stratigraphy of the site is not fully resolved; however, in exposures the silcrete, probably of Tertiary age, is only about 30 cm thick, and it overlies brown clayey sediments whose upper part contains some limonitic concretions. We interpret site 28 as a quarry-factory and the source of the numerous silcrete artifacts found throughout the district. Two radiocarbon dates based on charcoal samples taken in the Trench 1 excavation (Table 1; Fig. 1) show that the quarry-factory was in operation from before 6780 years BP until at least 3000 years BP.

Mr W.M. McArthur, Land Resources Management, CSIRO, Perth has identified the archaeological deposit as an iron humus podzol in which there is no evidence of sand movement after profile differentiation (pers. comm. W.M. McArthur). Thus, barring possible minor dislodgement by animal

Table 1: Distribution of stone artifacts in Trench 1, Northcliffe quarry-factory site, Western Australia (based on Dortch 1975: Table 2).
Siltcrete artifacts
Artifacts of other stone

Radiocarbon dates in years BP.	Depth in cm below datum	Geometric microliths ¹	Notched flakes and other retouched tools	Blades	Bladelets	Flakes	Chips ²	Cores	Debris	Artifacts of other stone
ANU-1131 3080 ± 75	46-51					2	6+			
	51-53				2	8	6+			
	53-57	1 atypical	1	3	3	39	47+			
	57-59	2 atypical	2	2	2	48	57+			1 quartz chip
	59-60		2	6	6	57	110+			
	60-62		3	2	2	76	50+		2	2 quartz chips
	62-64	2	1	2	1	54	50+			1 quartz flake
	64-66		2	6	5	81	50+		3	2 quartz chips
	66-70	6, 2 atypical	2	3	11	149	250+		2	1 quartz flake
	70-72	4, 1 atypical	2	4	2	106	250+	5	2	6 quartz flakes and fragments
	72-74	2	4	5	1	97	250+	4	1	3 quartz fragments
	74-78	1 atypical	3	1	11	112	250+			2 quartz fragments
									1 fragment of gneiss	
	78-82	3		1		38	100+	1		8 quartz chips
	82-85	1			1	14	20+	1	1	1 quartz fragment
SUA-379	85-90		2				20+	1	1	1 quartz flake
6780 ± 120	90-96		1			5	2+			1 quartz core
	96-98					5	9+			1 quartz flake
	98-103					7	1+			1 quartz bladelet
	103-c, 120						4+		2	2 quartz flakes
		18 typical	25	22	46	903	1526+	12	11	39 (Ardufact total 2609+)

¹ atypical indicates irregular or partly retouched specimens.

² + indicates that total chips were not recovered.

activity or growing roots, contained archaeological specimens are in primary position. The stone artifact assemblages (Table 1) are concentrated in the leached zone or A2 horizon of the soil (Fig. 1). These assemblages include many silcrete artifacts including retouched tools, flakes, cores, some blades and bladelets, numerous chips and some quarrying debris (i.e. irregular fragments of all sizes and large thick flakes often with cortex surfaces). We also excavated a number of quartz artifacts, a fragment of gneiss, and two chert flakes from the lower part of the excavation, one of which came from a deep depression in the B horizon or iron-enriched organic hard pan at the base of the section.

About half of the retouched silcrete tools are geometric microliths (Table 1). The radiocarbon dates (Table 1; Fig. 1) show that these were being manufactured here from 3000 to about 6000 years BP, thus making the earliest of these among the oldest radiocarbon dated geometric microliths presently known in Australia (Pearce 1974: Table 2). The geometric microlith in Fig. 6:8 is the lowermost one recovered in the deposit. It came from one to three cm above the upper limit of the 10 cm zone from which charcoal for SUA 379 (6780 ± 120 BP) was collected, and so is about 6000 years old.

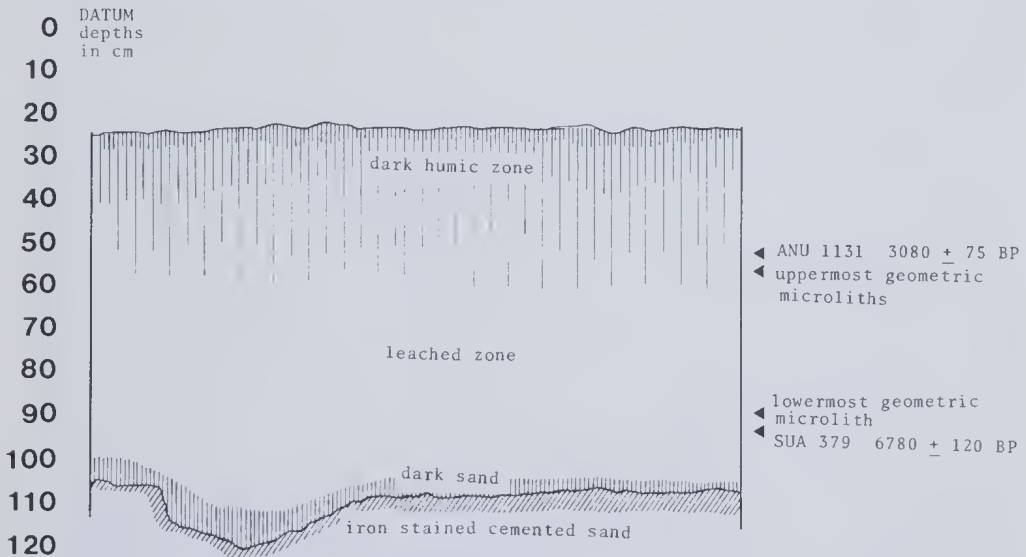


Fig. 1: North section, Trench 1, silcrete quarry-factory (site 28), near Northcliffe, Western Australia (after Dortch 1975, Fig. 2).

The presence of several stone artifacts in the channels and depressions of the hard pan but none apparently within it shows that either this eroded

surface was actually occupied or that the artifacts dropped down to it following the stripping away of the A horizons of an earlier soil. In either case the presence of the artifacts in this position and the eroded condition of the hard pan surface shows that it had been exposed before the present soil accumulated. Thus at least one full cycle of soil destruction, deposition and soil profile development began here more than 6780 years ago and was completed sometime after 3000 years BP.

Four pollen samples collected at different depths in Trench 1 (Fig. 1) were submitted to Dr B.E. Balme of the Geology Department, University of Western Australia for analysis. His report (pers. comm. B.E. Balme) states that a sample from a depth of 47 cm contained pollen grains, the dominant species being *Eucalyptus calophylla* and *E. diversicolor* though some grains 'of *E. marginata*-type were also fairly common.' A sample from 68 cm contained a similar plant microfossil assemblage though a sample from 87 cm contained no pollen. The lowermost sample from the dark sand resting on the hard pan (depth 121 cm) contained pollen grains of the three above *Eucalyptus* species with *E. diversicolor* appearing to be 'relatively more abundant' than in higher samples.

These three *Eucalyptus* species are at present dominant in the district (McArthur and Clifton 1975; Smith 1972); the pollen analysis suggests then that local climate was at various times during the Holocene perhaps much the same as it is at present. In his recent study Churchill (1968, p. 146) shows that 'the climate [of the lower south west] from 4000 to 3000 B.C. was favourable for *E. diversicolor*'. The stratigraphical position of the lowermost pollen sample within the radiocarbon dated deposit described here suggests that conditions were favourable for *E. diversicolor* even earlier during the Holocene. (Note: There is an incorrect passage in the Abstract of Dortch [1975, p.59] which, in referring to *E. diversicolor*, *E. calophylla* and *E. marginata*, states that 'the two former species and possibly the latter were present at times since [6780 years B.P.]'. In fact as noted above *E. marginata* pollen does occur in both samples dated less than 6780 years B.P.)

Silcrete artifacts are scattered in ploughed ground or bulldozer cuttings throughout the vicinity of the silcrete formation. In 1973 one of us (G.G.) found a recently uprooted blackbutt (*Eucalyptus patens*) stump located near Trench 1 which has numerous silcrete artifacts in the mass of sandy soil adhering to its base and roots (Fig. 2). The artifacts occur in two distinct layers, both of which could be seen in 'section' and one of which is seen in 'plan' at the base of the stump (Fig. 2). It is apparent that a large amount of archaeological deposit was brought up when the tree was bulldozed over.



Fig. 2: End view of base of uprooted tree stump (*Eucalyptus patens*) at silcrete quarry-factory (site 28) near Northcliffe, Western Australia. Numbers of silcrete artifacts are visible in the sandy soil adhering to the roots. The range pole is marked in 10 cm units.

Two marine shells have been collected from archaeological horizons at the quarry-factory. The first of these is a turban shell (*Turbo* sp.) found in sand exposed when the blackbutt stump described above was uprooted. The second shell, a giant creeper (*Campanile symbolicum*, Iredale: pers. comm. G.W. Kendrick) was found 20 cm below the surface in undisturbed sand overlying silcrete in another part of the site.

A fish trap on Blackwater Creek

Over the past few decades several wooden structures thought to be Aboriginal fish traps or weirs have been locally known in freshwater streams of the Northcliffe district. The only one of these which can be located at present is on Blackwater Creek, a sluggish tributary of the Gardner River which passes through several peaty swamps and sandy areas on the coastal plain (Map 2). The structure (Figs 3, 4) is situated on a winding channel which extends for approximately one km between two swamps. When one of us (G.G.), together with Messrs R.G. Hardie and A.T. Jackson,

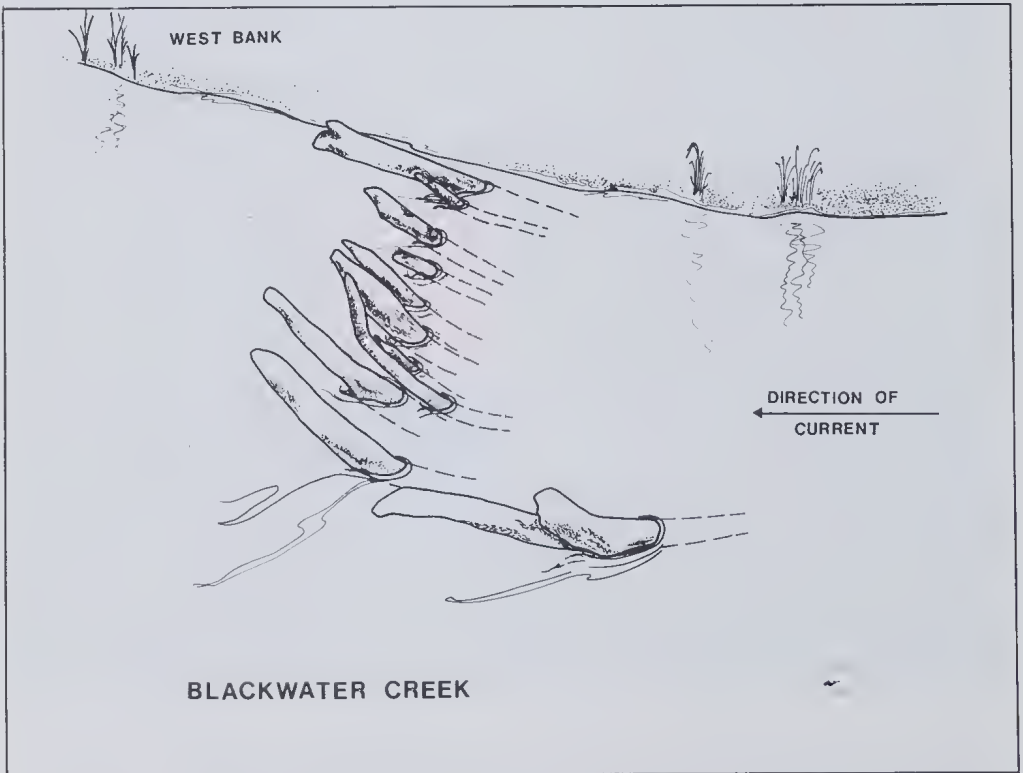


Fig. 3: Perspective view of a wooden fish trap on Blackwater Creek, Northcliffe district, Western Australia.

examined the site the channel was approximately 5.5 m wide and about 1.2 m deep (Fig. 4).

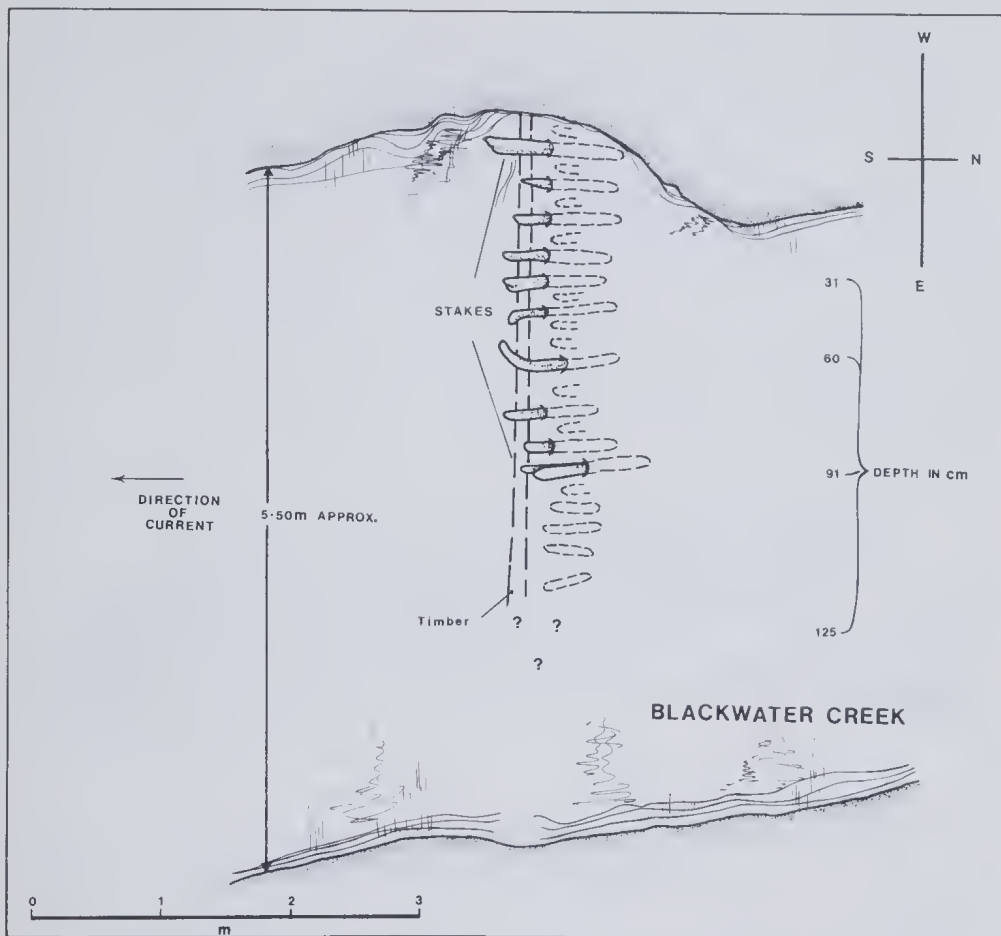


Fig. 4: Plan of the Blackwater Creek fish trap, Northcliffe district, Western Australia.

At present the structure consists of a row of over 20 wooden stakes extending about 3.5 m from the west bank of the stream, and a single horizontal timber lying alongside the stakes. The stakes are imbedded in the stream bed and lean downstream at an angle of about 45°. Between each of the stakes visible in Fig. 3 is a small, submerged stake (Fig. 4). The easternmost stakes are also smaller than the ones shown emerging from the water in Figs 3 and 4. The structure dates to the European era, as the larger stakes, which appear to be made of *Agonis* or *Banksia* wood, have pointed ends which have been cut with a steel axe. It is probable that when

in use the stakes extended right across the channel in an unbroken row, and that the channel shown in Fig. 4 is wider than it was when the trap was in use.

We interpret the Blackwater Creek structure as a fish trap or weir though it seems to be somewhat different in concept from one on the Serpentine River near Barragup (Map 1), described and illustrated by Hammond (1933, pp. 46, 47), and other south western traps observed by Armstrong (1871) and Paterson (1896). According to Hammond the main feature of the Barragup trap was a 'wicker fence' containing a central race or gap. People standing on platforms positioned on each side of the gap were able to snatch fish as they passed through the race. The anthropology collection, Western Australian Museum contains a c. 1900 photograph of a trap on the Murray River (Map 1) of this kind. A line drawing based on this photograph is illustrated in Fig. 5, and clearly shows the central gap.



Fig. 5: Sketch of a wooden fish trap on the Murray River, Western Australia, based on a c. 1900 photograph in the anthropology collection, Western Australian Museum.

We do not at present know how the Blackwater Creek fish trap was used, or which fish species or other animals were caught in it. Nor do we know if the trap was used during particular seasons. The construction is solid, and it is obvious that the trap was intended to last for a long time. The wooden stakes are all submerged during the high water levels of winter, and the trap would have been unusable then, unless there were upright sticks which enabled a mesh of sticks and brush to be raised above the stakes.

Hammond reports that the Barragup fish trap was used 'at the commencement of winter to catch the fish that were forced down the stream by the fresh water' (1933, p. 46). Paterson (1896, p. 280) writing of fish traps on the Serpentine and Murray Rivers (Map 1) also noted that they were used most extensively at the beginning of winter. Blackwater Creek is always

fresh or only slightly brackish at the trap site, and so the trap described here was not used in the same way as those observed on the Murray River and the Serpentine. At no time does Blackwater Creek have a high velocity water flow. Therefore some agency other than changes in salinity or water current seems to have been necessary to force fish or other animals into the trap. It is likely that fish were driven into the trap by people creating a disturbance at the downstream end, or perhaps either end of the channel in which the trap is centred. A clue to the trap's likely function is the way in which the stakes are angled downstream. Mr R.G. Hardie suggests that fish were driven into the trap from downstream; and that they were speared from between the angled stakes by fishermen standing on the horizontal timber (pers. comm. R.G. Hardie).

A review of the fish species likely to be living in Blackwater Creek (pers. comms R. Lenanton, R. McKay; Lenanton 1974) suggests that there are a number of different species which may have been caught, and that there are various seasons during which the trap could have been used. Further field analyses of these problems, including detailed study of the aquatic fauna of Blackwater Creek, re-examination of the trap's structure, and tests of stream salinity and water flow during different seasons will be necessary before the trap's function and mode of use can be defined clearly. Ethnographic inquiries and examination of other archaeological sites in the locality could also provide significant data.

Malimup Spring

The coastal area around Malimup Spring (Map 2) is environmentally and geomorphologically probably the most diverse in the district. Stone artifacts and sparse scatters of edible marine molluscs occur in blow outs in the calcareous coastal dunes, showing that either the present blow outs were occupied or that occupation took place on aggrading surfaces which have been subsequently exposed. The chief significance of these sites is that they show that people camped in coastal dunes, and that their subsistence may have been in part based on the exploitation of marine molluscs. (At present the Malimup sites are designated by a single number - 29.)

One of the Malimup archaeological sites is a cluster of stone artifacts and marine molluscs in a blow out, discovered by Mr G.W. Kendrick of the Western Australian Museum. The site consists of several flaked stone artifacts, several gneiss beach pebbles or boulders, and a cluster of several edible marine molluscs including 11 shells of *Nerita atramentosa* Reeve, one abalone shell (*Haliotis rolli* Gray), one limpet shell (*Patella laticostata*) and one shell of *Dicathais orbita*. This small cluster of shells hardly constitutes a shellfish midden, yet Mr Kendrick tentatively interprets this site as

the remains of an Aboriginal meal (pers. comm. G.W. Kendrick . The shells are registered in the Western Australian Museum palaeontological collection 70.906-70.909.). This site is thus one of the very few known in the south west (cf. Dortch 1974, p. 205) whose evidence does not agree with ethnohistorical records (Grey 1841, vol. 2, p. 288; Moore 1884 p. 51) which suggest that molluscs were not eaten by south western Aborigines.

The Malimup site complex is notable also for the relative abundance of pebble tools made of gneiss or amphibolite (Figs 9: 12 and 13; see below). These tools may be evidence for special activities (e.g. cracking mollusc shells); or they may simply reflect these sites' proximity to abundant beach pebbles.

A series of limestone caves in the neighbourhood of Malimup Spring have potential archaeological value as they may contain occupation deposits.

STONE ARTIFACT ASSEMBLAGES

The stone artifact assemblages collected from sites in the Northcliffe district feature a dominant flake technology. There is a small blade and bladelet element, and a smaller still but clearly characterised pebble tool component. The evidence for stone grinding is limited to a few grindstones and a single edge-ground axe. We have identified no tools shaped by hammer dressing (pecking) or polishing.

No more than 5 to 7% of the stone artifacts from any site are retouched or otherwise shaped, and thus classifiable as 'formal tools'. However the assemblages from the three most prolific sites, the silcrete quarry-factory and sites 1 and 2 (Tables 1, 2) include, in addition to retouched tools, large numbers of very small flakes and chips (i.e. flakes with maximum dimension <1 cm) showing that tools were being manufactured in quantity.

The stone artifact assemblages excavated from Trench 1 at the silcrete quarry-factory make up the only systematic samples for the area, and they are also the only large assemblages which have not been mixed by ploughing or bulldozing. The assemblages from sites 1 and 2 are simply very extensive collections of artifacts exposed on two artificially truncated sandy hummocks. Each exposure is almost certain to consist of portions of several old surfaces, and so these must be regarded as mixed assemblages. Nevertheless the tool and by-product (*débitage*) categories listed for each in Table 2 give some idea of the likely composition of typical stone artifact assemblages in the lower part of the coastal plain.

Artifact totals
Site 1 — 1856
Site 2 — 1013

TABLE 2
Classification of stone artifacts from Sites 1 and 2,
Point d'Entrecasteaux, Western Australia.

	silcrete		chert		quartz		other stone	
	site 1	site 2	site 1	site 2	site 1	site 2	site 1	site 2
backed microliths (geometric) (other)	7 segments 2 trapezes 1 rectangle	5 segments 1 trapeze	1 triangle (opal)		5 segments 3 trapezes	2 segments 1 trapeze		
	1 asymmetric point 5 irregular	2 asymmetric points 2 irregular			12 irregular	2 irregular		
flake scrapers (adze-like) (non-adze)	1 adze-like scraper 2 flat adze	1 flat adze	1 adze-like scraper					
	1 end-scraper			3				
notched pieces	2 blades 3 bladelets 16 flakes	11 flakes	21 flakes	9 flakes	7 flakes 3 bladelets			
denticulated pieces	13 flakes	4 flakes	6 flakes	5 flakes	7 flakes			
other retouched tools	6 retouched flakes 8 abruptly retouched flakes 1 dihedral burin	1 retouched flake 6 abruptly retouched flakes	5 retouched flakes 1 abruptly retouched flake 1 very small 'core-scraper'	1 retouched flake	2 very small retouched flakes	1 retouched flake		1 basalt edge-ground axe
blades	12	9	1	1	3	2		
bladelets	24	16	4	6	9	9		
flakes, chips and fragments	416	358	275	222	864	285	6 flakes and fragments made of black glossy rock (vein filling in Black Point basalt?)	4 flakes of black glossy rock (Black Point?)
cores	2 bipolar (scalar) 7 single platform flake 2 double platform flake 2 multi-platform flake 1 bladelet	4 bipolar (scalar) 3 discoidal 1 bladelet	8 bipolar (scalar) 2 discoidal 1 multi-platform flake 4 multi-platform flake	7 bipolar (scalar) 4 amorphous	22 bipolar (scalar) 2 single platform flake 2 double platform flake 27 amorphous flake	2 bipolar (scalar) 6 amorphous		1 discoidal core made of black glossy rock (Black Point?)
other stone artifacts	2 crested bladelets 1 Levallois flake? 2 flakes with use-smoothed edges	4 Levallois flakes? 6 flakes, from discoidal cores?	1 flake with use-smoothed edge	1 flake, from discoidal core?	2 split pebbles 2 crystals (manuports)	2 crystals (manuports)	1 gneiss hammerstone 5 gneiss pebble fragments	2 gneiss fragments
TOTALS								
retouched tools	69	33	36	18	39	6		
blades and bladelets	36	25	5	7	12	11		
cores	14	8	15	11	53	8		
total artifacts	540	434	332	259	972	312	12	8



The following brief description of major tool types, cores and other by-products is based on the examination which one of us (CED) has made of all the assemblages known from the district. Specimens considered to be diagnostic and in most cases typical are illustrated in Figs 6-9. These pieces come from a number of different sites though the majority are from sites 1, 2 and 28.

Backed microliths

Backed microliths as described in Australia by Campbell and Noone (1943); Glover and Lampert (1969, pp. 224-5); McCarthy (1967, pp. 40-45); and Mulvaney (1961, pp. 79-80) are tools made on small flakes, bladelets or parts of blades whose diagnostic features are very small size; and backing or abrupt retouch, sometimes bipolar, along part of their margins. All of the Northcliffe backed microliths conform to this definition, and nearly all have maximum dimensions of less than three cm.

The great majority of the Northcliffe backed microliths recovered so far are of the geometric category, a form very well known in Australian and other Old World stone industries, and one which is most clearly defined in one of the latter (Tixier 1963, p. 127). Geometric microliths, when viewed at right angles to their dorsal or bulbar faces, conform to one or another regular geometric shape, the three dominant ones in the Northcliffe and some other Australian assemblages being segments (crescents), trapezes (trapezoids) and triangles. Most of the Northcliffe geometric microliths have length:width ratios $<2:1$; the exceptions to this are discussed below. Nearly all of the geometric microliths which we have found are made of silcrete or quartz. The only typical specimen made of other stone is a very small opal triangle from site 1 (Fig. 7:4).

Here we use the term 'segment' (Campbell and Noone 1943, p. 500; Tixier 1963, p. 129) in preference to the more commonly used but less accurate labels 'crescent' or 'lunate'. The Northcliffe segments are characterised by neatly curved backs and straight, unretouched chords. They vary in their proportions between the broad specimens illustrated in Figs 6: 1, 2 and 4, and the much less common, more elongated form in Fig. 7:1. We have also identified several segments which are very elongated with length:breadth ratios $>3-4:1$, and are readily classifiable as backed bladelets. A typical example of this form is the piece in Fig. 8:1 which has a slightly curved back made by bipolar abrupt retouch extending the length of one edge. It will be necessary to obtain a larger sample of segments in order to determine whether there is a continuum between the short or robust and the elongate forms. Other of the Northcliffe segments have

asymmetric curved backs and are similar to the 'rudder-like' segments of Campbell and Noone (1943: Figs 82-84).

The trapezes are simply double obliquely truncated pieces. As with the trapezes of many Australian and other Old World microlithic assemblages the Northcliffe specimens can be divided between those in which the shorter

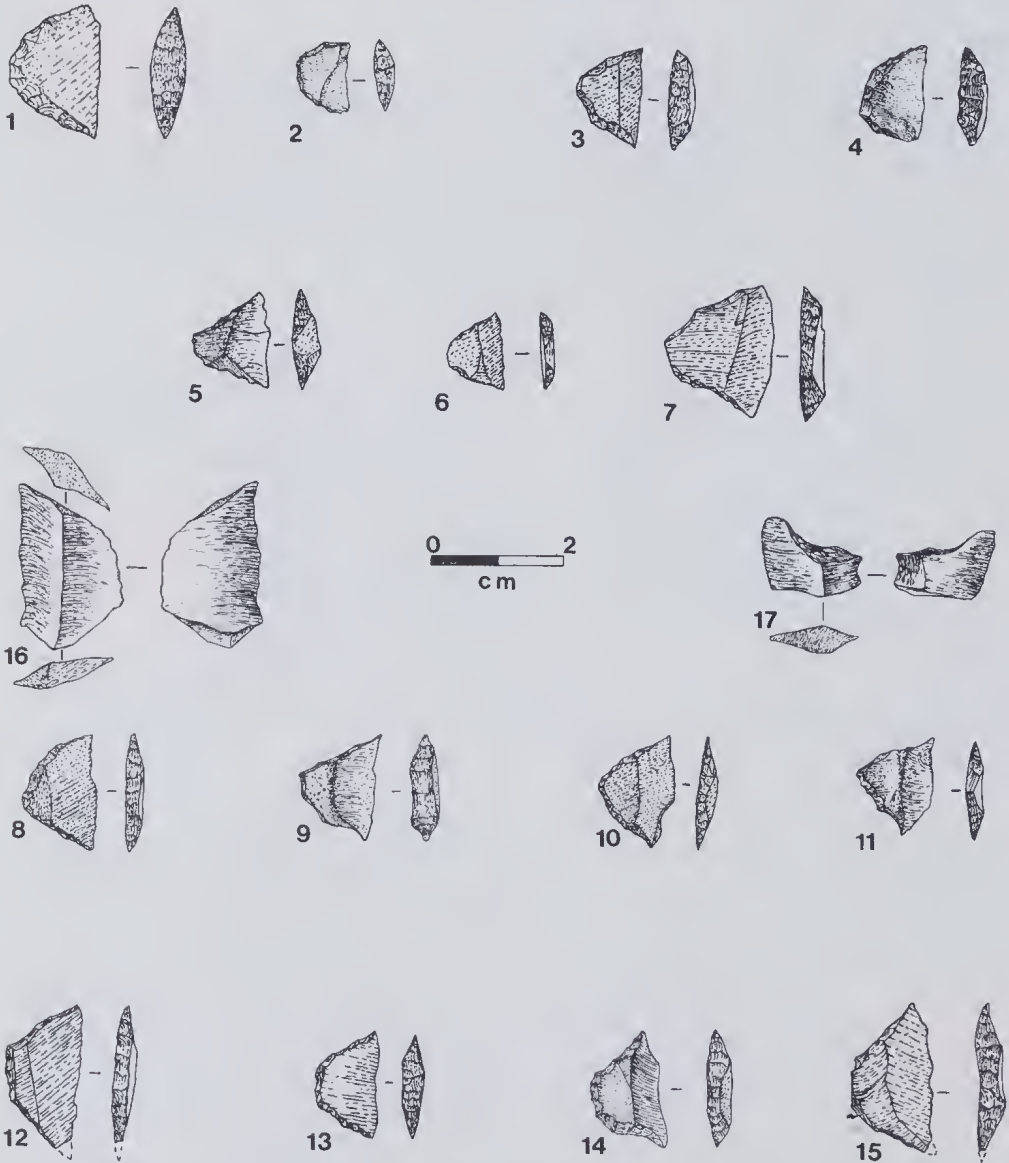


Fig. 6: Geometric microliths and other silcrete artifacts from the Northcliffe district, Western Australia.

lateral edge between the two oblique truncations has been abruptly retouched (Figs 6:9, 12, 14, 15); and those in which this is left unretouched (Figs 6: 5-7). In the latter form then the retouched 'back' is confined to the truncated extremities. We have collected only one elongated trapeze, an exceptionally large piece from the Malimup site complex (Fig. 8:8).

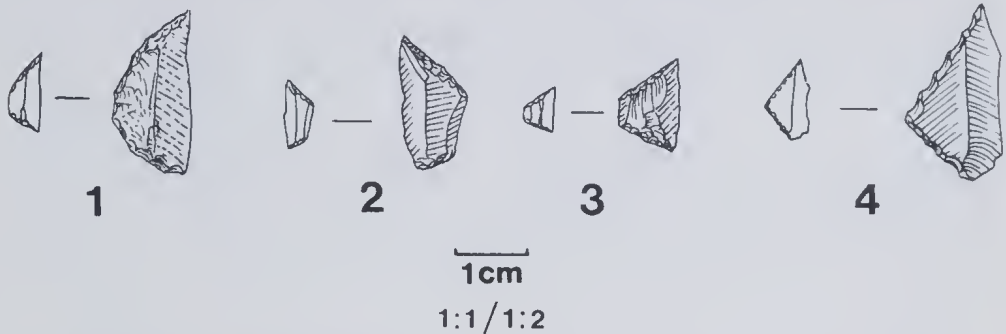


Fig. 7: Geometric microliths and an obliquely truncated bladelet from Site 1, Point d'Entrecasteaux, Western Australia.

The Northcliffe assemblages also contain a few obliquely truncated bladelets (i.e. pieces with only one extremity truncated by abrupt retouch); a minute example is the quartz specimen in Fig. 7:2.

Triangles (Figs 6:11; 7:4) are much less common than the two previous forms. Intermediate forms between the three occur frequently, and it is unrealistic to draw too fine distinctions between the differences in shape. For instance the specimen in Fig. 6:8 is illustrated in Dortch (1975, Fig. 3b) and is described there as an example of the crescentic form (*ibid.*, p. 61). However it is perhaps more accurate to regard this specimen as intermediate between the crescentic (or segment) and triangular forms. Figures 6:3 and 10 are similarly intermediate between triangles and segments, and Fig. 6:13 between the segments and trapezes.

A special feature of some Northcliffe silcrete geometric microliths of all three forms is the marked incurving of the proximal and distal retouched edges. Two specimens with very clearly incurving edges are illustrated in Figs 6:11 and 14; and Figs 6:7, 9 and 10 are examples with one incurving edge.

Many of the silcrete geometric microliths appear to be made on obliquely or transversely snapped blades or bladelets. The local silcrete is very brittle and thin blades of this stone can easily be snapped or fractured obliquely or transversely between one's fingers. A blade which was probably snapped manually is illustrated in Fig. 6:16. The transverse fracture at the lower end

of the piece consists of two fracture surfaces, and though we have been unable to replicate this fracture experimentally, we suggest that it was produced by snapping. A number of other possibly deliberately snapped blades or bladelets have been identified.

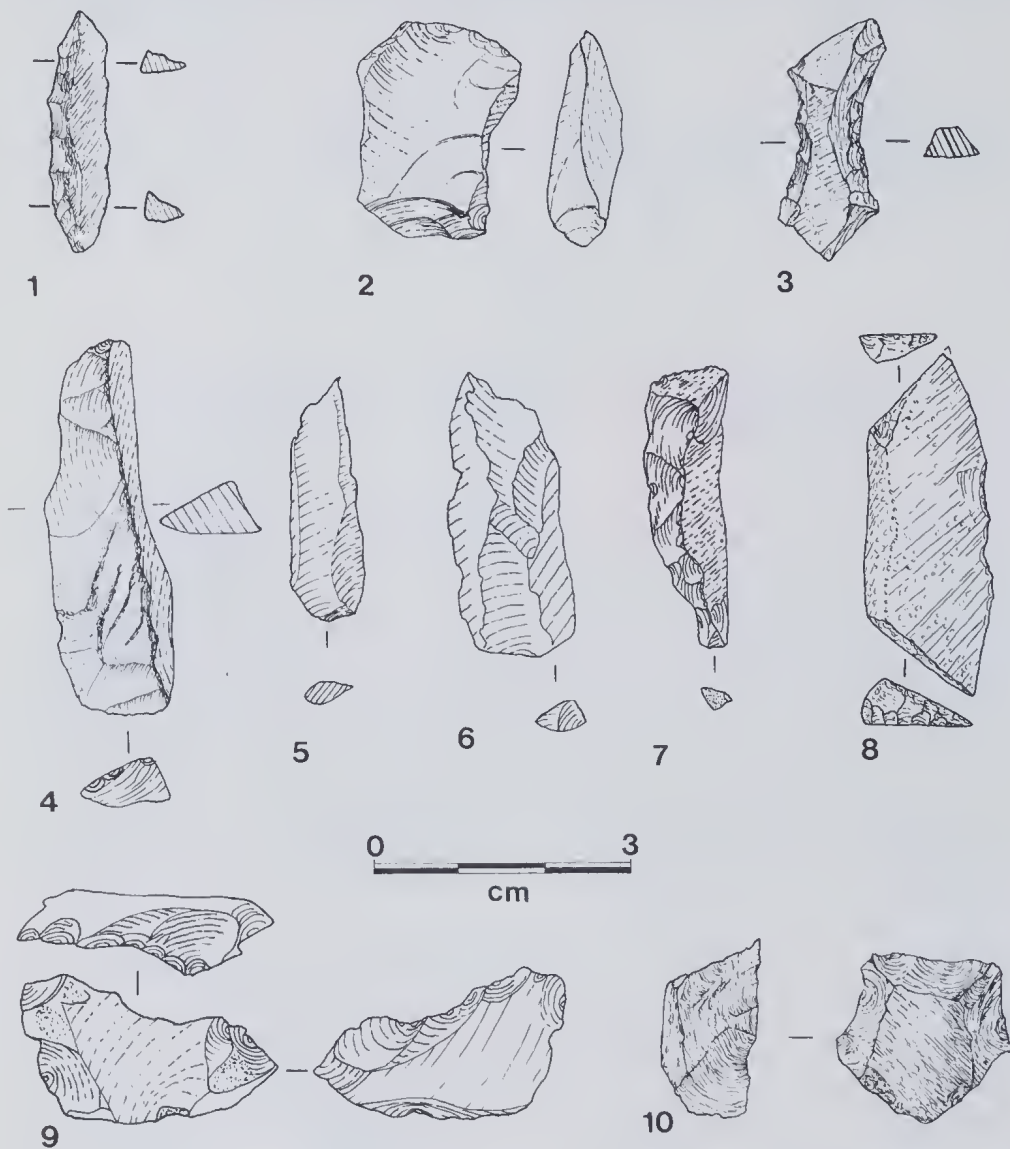


Fig. 8: Selected flaked stone artifacts from the Northcliffe district, Western Australia.

The quartz geometric microliths include far fewer typical specimens than does the silcrete group. They are also generally smaller in size than the

silcrete specimens; some are extremely small as shown by the tiny trapeze in Fig. 7:3.

We have identified three atypical but no typical asymmetrical backed points of 'bondi' form (McCarthy 1967, p. 40). There are no rectilinear backed bladelets, as occur in some of the Pilbara assemblages in the archaeology collection, Western Australian Museum (e.g. B3020), and as Glover (1967, p. 419) notes in Newall's Millstream collection. Again a larger sample of the very elongated segments (Fig. 8:1) may show that these merge into a rectilinear form.

There are a number of atypical or irregular specimens among both the quartz and the silcrete geometric microliths. These are numerically important (Tables 1, 2) though they cannot be dealt with in detail here. However all are similar in size and proportions to the more regular forms.

Other small retouched tools

The Northcliffe assemblages contain a variety of other small retouched tools made on flakes or blades, usually quite small with maximum dimensions in the range 2-5 cm. In the following we describe briefly the most numerically important and clearly defined of these.

notched pieces — These are perhaps the most common form of retouched tool in the area. Most are simple flakes of silcrete, chert or quartz with one or more small retouched notches. Some have larger notches, produced by a single blow with the hammerstone, sometimes described as 'Clactonian notches' (*encoches clactoniennes*: Bordes 1961, p. 35). The silcrete flake in Fig. 9:2 has both kinds of the above notches. It has several small retouched notches on its right lateral edge and a single inverse 'Clactonian notch' on its left proximal corner.

denticulated pieces — These differ from the above only in that they feature a number of very small, closely adjacent notches sometimes resulting in a saw-like or serrated edge. Most of the Northcliffe denticulates are rather irregular and poorly made. There are also numbers of flakes with series of extremely small notches sometimes resembling very fine denticulation. These are likely to be the result of accidental edge-damage or use rather than retouch.

scrapers — The present sample of scrapers, i.e. tools usually made on small flakes or fragments and having robust retouched working edges which in contour are rounded, straight or irregular, comprise a relatively numerous and varied group. It is useful here to divide the scrapers into two categories. The first consists of pieces whose working edges resemble those of adze

flakes, i.e. flake scrapers used as hafted woodworking tools; the second is composed of pieces whose working edges do not have the characteristic features of adze flake edges. In broadest terms Australian adze flakes are small flake scrapers which have relatively steep angles (60° to 80°) between the planes of the flaking face and the lower (generally bulbar) surface; and working edges whose diagnostic features result from a combination of use and resharpening. These features include marked crushing or rounding along the periphery of the working edge and undercutting (sometimes referred to as 'step-flaking') coming from the working edge and encroaching more or less over the flaking face (cf. Gould, Koster and Sontz 1971; Hayden and Kamminga 1973). Such characteristic wear features must be present to enable purely archaeological specimens such as these here (i.e. specimens for which no direct historical or ethnohistorical functional data exist) to be classified as probable adze flakes, and not simply as scrapers. We have been able then to classify only a minimum number of specimens as the former. Many pieces which we regard here as flake scrapers may well have been intended for use as adzes, or were used in woodworking tasks which involved little re-sharpening and left few signs of wear. For example two flake scrapers, the first of which is made of quartz and the second of silcrete, are illustrated in Figs 8:10 and 9:4. Each is of the approximate size and proportion of many known adze flakes; however neither shows the characteristic adze flake use wear patterns on its working edge which would enable it to be classified as a probable adze flake.

We have not identified adze flakes of tula form (Mulvaney 1969, pp. 71-74) in our present sample. The pieces classifiable as probable adze flakes are mostly irregular; most are made on chert or silcrete flakes or fragments. The only typologically distinctive probable adze flake which we have identified is a small flattened form, very similar to the 'flat adze' of Gould and Quilter (1972). The best Northcliffe example of this form is Fig. 8:3. The piece has opposed concave working edges typical of the form which Gould and Quilter (*ibid.*, p. 5) describe as 'strangulated' or of 'hour glass shape'. These authors note that flat adzes are known from sites at Walynunga and South Bullsbrook near Perth, and other parts of the south west. The Northcliffe specimens help to strengthen their conclusion that these tools are a standard part of south western assemblages.

Likely adze flakes include the small silcrete specimen in Fig. 6:17 which has a very heavily crushed and undercut concave flaking face. There are also the chert specimens in Figs 8:9 and 9:14. These two come from site 2, and the latter is similar to probable adze flakes made of chert which have been identified at Devil's Lair (Map 1; Dortch 1974; Dortch and Merrilees 1973).

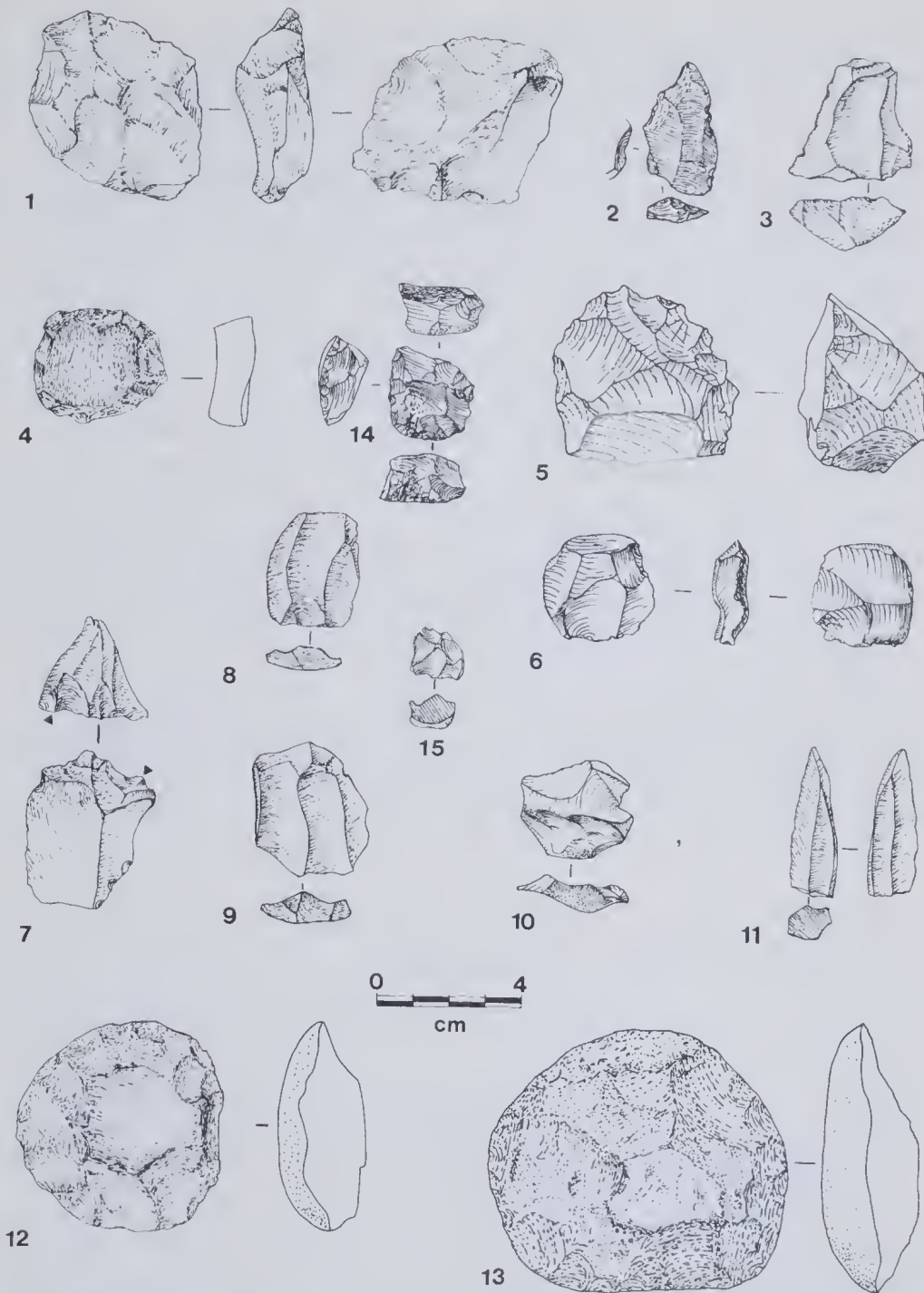


Fig. 9: Selected flaked stone artifacts from the Northcliffe district, Western Australia.

We have collected two end-scrapers on bladelets. There are also a few core-like pieces on thick flakes the peripheries of whose flaking faces have secondary chipping resembling that found on scraper working edges. Some of these 'core-scrapers' are made of quartz or gneiss; others are made of silcrete. One of the latter is illustrated in Fig. 9:7. The piece has a flaking face resembling that of a core though the periphery of this has been regularised by retouch, suggesting that it has been used as a tool. The piece is one of several from the district which closely resemble the carinated scraper (*grattoir caréné*) of the European and Middle East Aurignacian (Movius and Brooks 1972).

Most of the cores which we have recovered (e.g. Fig. 9:5; see below) lack secondary retouch along the periphery of their flaking faces, suggesting that cores or pieces resembling cores were not usually used as tools. We have found no horsehoof cores (McCarthy 1967, p. 18) though these occur in stone artifact assemblages from other parts of the south west (e.g. in the Swan-Avon valley between Perth and York, Map 1). The well known elouera of eastern Australia (McCarthy 1967, p. 26; Mulvaney 1969, p. 81) also seems absent; however one of the microlithic segments is very robust, and if it were found in an eastern assemblage it would probably be classified as an elouera.

We have identified several burins in our sample, including a few on truncation and one dihedral burin. Abruptly retouched flakes are fairly common (Table 2) though it is not certain whether the abrupt edge chipping is in fact retouch or the result of heavy use. We have also identified a few flakes with edges worn smooth through use.

Pebble tools, an axe, grindstones and hammerstones

We have relatively few pebble tools in our present sample. Because of this it is difficult to delineate the likely major types of forms among them, except by referring to those described in syntheses of regional or continental stone tool forms (e.g. Davidson and McCarthy 1957; McCarthy 1967; Mulvaney 1961; 1969). A number of gneiss, quartz or amphibolite pebbles have one end or one side removed by flaking, so enabling them to be defined as 'pebble choppers' in the sense of Movius (1944, pp. 10-11), though equally they could have been cores.

Two specimens from Malimup (Figs 9:12 and 13), respectively made of amphibolite and gneiss, have each been multi-convergently flaked over the whole of one face, leaving the opposing face an unmodified pebble surface. Unifacially flaked pebbles such as these have been collected on Kangaroo Island (Cooper 1943, Figs 66-75), in other parts of Australia (McCarthy

1967, pp. 19-20), and also in Indonesia (van Heekeren 1957, p. 73; pl. 20) and elsewhere in south eastern Asia. McCarthy (1940), Matthews (1966), Movius (1944) and Mulvaney (1961; 1969) discuss the distribution and significance of Australian and south east Asian pebble tools.

We have recovered only one stone axe in the district. This specimen is bifacially flaked and has a bifacially ground cutting edge. Davidson and McCarthy (1957, Fig. 7) considered that axes of this kind did not occur in the south west, but Ride (1958) and more recently Akerman (1973) showed that this is not the case. The Northcliffe specimen comes from site 2 and is made of basalt whose origin, as noted above, may be Cape Beaufort (Map 1).

Some of the Northcliffe sites contain simple grindstones, upper or lower; and hammerstones, most of which are simply gneiss beach pebbles or fragments of silcrete which have become rounded or abraded through use.

We have also collected a few percussion/grindstones, a form of multi-purpose tool which is a common feature of south western assemblages. These are squat, cylindrical pieces with grinding surfaces or percussion pits on one or both flat faces. Davidson and McCarthy (1957, p. 441) state that some of these tools were used as 'hammer, anvil and muller'. These artifacts are one of the most characteristic south western stone tools though unfortunately their specific functions were never recorded ethnographically. The Northcliffe specimens are made of gneiss or amphibolite.

Cores and other by-products

There are a variety of cores in the Northcliffe assemblages. The most common kinds are multi-platformed, usually amorphous or globular, and bipolar or 'scalar' cores (Dortch and Merrilees 1973; White 1968). Single platform flake cores are common and are sometimes made on thick flakes (Fig. 9:5 is a silcrete specimen).

Discoidal cores are well represented as are flakes probably produced on discoidal cores (e.g. Fig. 9:10). The pieces in Figs 9:1 and 6 are bifacially flaked discoidal cores respectively made of silcrete and chert. The very small unifacially flaked discoidal core in Fig. 9:15 is made of a banded chert whose possible source of Cape Beaufort is noted above. A few silcrete cores (e.g. Fig. 9:3) resemble Levallois flake cores, and there are numbers of silcrete flakes (Figs 9:8, 9) which are very similar to Levallois flakes. However the present sample is too small to enable us to determine with certainty whether a Levallois technique of flake production (Bordes 1961) was used in the district.

The silcrete artifacts provide by far the best evidence for blade and bladelet production. (We divide blades and bladelets on the basis of size and proportions, following Tixier 1963, Fig. 7. A silcrete bladelet is illustrated in Fig. 8:5, and a small quartz blade in Fig. 8:6.) Blade or bladelet ('prismatic') cores are rare though some silcrete cores of all kinds have flake scar facets showing where bladelets or blades were removed along with flakes. Figure 9:11 shows a silcrete bladelet core which has been worked down to a very small size.

There are a few unilaterally flaked crested blades or bladelets made of silcrete (e.g. Figs 8:4, 7) in the Northcliffe assemblages. We interpret these as the principal preparatory pieces (*lames à crête*: Barnes and Cheynier 1936) removed from the flaking faces of bladelet or blade cores. We have found no bilaterally flaked crested blades; however, the tabular silcrete used in blade and bladelet production can be broken into sharp-edged fragments which require little or no flaking to prepare them for successive blade removal. Bordes and Crabtree (1968, p. 3) point out that only 'slight modification or unifacial trimming' is necessary when using 'angular' material.

We have found no chert blade or bladelet cores; chert blades are absent; and the very few chert bladelets so far identified, all from sites 1 and 2 (Table 2), are irregular. Furthermore the only chert cores which seem typical in our present sample are bipolar (scalar) and discoidal cores. All of the others seem to be casual fragments from which a few flakes were randomly removed from convenient corners. It should be emphasised that chert nodules from the two outcrops east of Northcliffe are small, irregular, full of spongolite masses or spicules, or chalky inclusions, and are thus unsuited for blade or bladelet production. However as noted above these nodules contain small masses of very fine grained chert grading into opal. Assuming that the local chert was quarried we suggest then that it was valued by stone workers largely because of the presence of small quantities of high quality stone. It seems likely, drawing on analogies from ethnographically recorded Aboriginal quarrying methods (notably Tindale 1965, pp. 140-1), that chert nodules were simply split or smashed into pieces and the more valuable bits collected. These then could be flaked by more formal techniques.

It is clear that the raw material has had a very marked influence on tool forms and stone working techniques in the Northcliffe assemblages. Silcrete was favoured for blade and bladelet production whereas chert was used only for flake production. Quartz seems to have been the main stone used in bipolar production of flakes, and sometimes small blades and bladelets, judging by the blade-like (*lamellar*) form of the flake scar facets on some of

the quartz bipolar cores; and by the bipolar dorsal flake scar facets on a few quartz small blades or bladelets (e.g. Fig. 8:6).

We regard these assemblages as the product of three interacting influences: raw material, functional need and cultural (or typological) modes. These three working together combine to give these assemblages their special character. For example the marked predominance of geometric forms among the silcrete microliths may be as much due to the limitations of the brittle material, in which bladelets often snap, as to any cultural or functional criteria. Detailed quantitative analyses of more representative samples than are presently available should enable these findings to be developed in more detail.

TABLE 3

A. Western Australian Museum registration numbers of artifact samples from the Northcliffe district.

A17370 - 75	A21916 - 27	B1042 - 65	B1714 - 26
A17410 - 19	A22053 - 55	B1682 - 86	B1730 - 34
A21840 - 46	B295	B1689 - 90	B1765 - 67
A21901 - 02	B298 - 99	B1692 - 1710	B2400 - 23

B. Western Australian Museum registration numbers of artifacts illustrated in Figs 6 - 9.

Fig. 6

1 B1053	5 B2409	9 B2405	13 B1059
2 A219101	6 B2409	10 A21846	14 B2413
3 B2407	7 A21842	11 B2113	15 B1692
4 A21842	8 B2414	12 B2410	16 B1683
			17 B1044

Fig. 7

1 B1059	2 B1059	3 B1059	4 B1059
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Fig. 8

1 A21901	4 B1683	7 B2409	9 A21846
2 A21901	5 B2409	8 B1723	10 A21846
3 21901	6 B1696		

Fig. 9

1 B2412	5 B1043	9 B1683	13 B1690
2 A21844	6 A21901	10 A17413	14 B1694
3 B1683	7 B2412	11 A17375	15 B1051
4 B1058	8 B1683	12 B1694	

SUMMARY

Here we have used ethnohistorical and environmental data to outline tentatively some aspects of Aboriginal land use and subsistence in the Northcliffe district, and to assess the functions of some archaeological sites and assemblages. Archaeological investigations in this district are only in their early stages, yet already present data are of considerable value in evaluating various aspects of prehistoric cultural ecology. These can be summarised as follows.

1. Site function. The known archaeological sites are located within exploitative range (i.e. within two km) of a number of diverse vegetation formations or topographical features offering varying suites of food and other resources (Maps 2, 3). The functions of most of these sites and the stone artifacts by which they were identified cannot, in the almost total absence of other associated classes of archaeological material, be interpreted specifically at this stage. However we believe that some of the larger and more diverse assemblages, notably those from sites 1 and 2, represent campsites where people were employed in stone tool manufacture and other domestic tasks such as food preparation and woodworking. These two and other sites located on the edges of freshwater swamps may have been occupied by groups whose subsistence was based on the wetland foods noted above.

2. The silcrete quarry-factory. We interpret this site as a long established centre for the dispersal of an economically important commodity, and one which may have had far reaching influences upon group movement, economy, and intergroup contact.

3. Malimup. The presence of some marine molluscs and stone artifacts at several coastal sites around Malimup suggests that on this coast Aborigines occasionally ate shellfish. This proposition should be tested in field investigations in the Malimup area and other undisturbed south western coastal districts before all coastal dunes become contaminated by modern development.

4. The fish trap on Blackwater Creek. This site shows that the freshwater creeks were fished, and that fishing may have involved a relatively high degree of long term planning and co-operative effort. Food yields from traps such as these may have been sufficiently high to have enabled quite large groups of people to remain here for prolonged periods (cf. Hammond 1933, p. 46).

5. Environmental data. It is not clear at this stage whether the soil periodicity for which there is evidence in this district results from instability brought on by Aboriginal firing of the countryside (see Hallam 1975), naturally caused

bushfires or other localised natural phenomena, climatic change or any combination of these. The preliminary pollen studies resulting from the investigations at the silcrete quarry-factory mark an important first step in reconstructing the vegetational history of this area.

More systematic field investigations will be necessary for the recovery of archaeological and other material, particularly biotic remains, which can be used in formulating and testing hypotheses concerned mainly with ecological aspects of prehistoric Aboriginal culture in this district.

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EPTESICUS DOUGLASI, A NEW VESPERTILIONID BAT FROM KIMBERLEY, WESTERN AUSTRALIA

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INTRODUCTION

Eptesicus is a wide ranging genus, most species of which occur in warm temperate and subtropical Asia and Africa. Smaller numbers of species are found in Europe, America, and Australia (Tate 1942). In Australia, Tate recognises only *Eptesicus pumilus* (Gray, 1841) and its weakly differentiated races: *E. pumilus caurinus* Thomas, 1914; *E. pumilus vulturinus* Thomas, 1914; *E. pumilus darlingtoni* G.M. Allen, 1933. The type of *E. pygmaeus* (Becker, 1858) is lost but Tate suggests from Becker's description that it also belongs to the *Eptesicus pumilus* group.

Tate (1942) considers that the Australian *Eptesicus* are separated from Asian mainland *Eptesicus* by about 2,000 miles. The six species of *Eptesicus* found in southern Asia do not extend eastwards from the Malay states; none are known from the Philippines or the East Indian islands west and north of New Guinea or Australia. More recent collections confirm that *Eptesicus* is not found in North Borneo (Davies, 1962), New Guinea, Celebes, and adjacent islands (Laurie, 1952; Laurie and Hill, 1954; Brass, 1959; Lidicker and Ziegler, 1968; and McKean, 1972), or New Caledonia, Solomon Islands and New Hebrides (Sanborn and Nicholson, 1950). There is, however, a doubtful record of *Eptesicus* from Sarawak (Perlot, 1968).

This paper describes a new species of *Eptesicus*, similar to *Eptesicus pumilus caurinus* but larger and of different colour. This new species occurs in sympatry with *E. pumilus caurinus*; both forms were captured in the same mist net at Tunnel Creek, Napier Range, and both were shot at the same place at approximately the same time in the Drysdale River National Park, and from nearby localities in the Prince Regent River Reserve.

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Holotype

M3405C; Western Australian Museum, male in alcohol, collected by D. Farner and D.L. Serventy, 10 October 1958, mist-netted at entrance of cave (this is the first specimen of *E. douglasi* collected).

Type locality

Tunnel Creek, Napier Range, Western Australia (17° 37'S, 125° 09'E).

Paratypes

(All are spirit specimens in Western Australian Museum.)

Tunnel Creek, Napier Ranges (17° 37'S, 125° 09'E):

M3405A (female) and M3405B (male), D. Farner and D.L. Serventy, 10 October 1958, mist-netted at entrance of cave. M14557 (male), M14558, M14559 (female), W.H. Butler, 22-23 June 1965, shot in cave, field numbers B1388-90, respectively, weights all 6.0 gm.

Prince Regent River Reserve (15° 31'S, 125° 13'E):

M12251 (male) and M12250 (female), N.L. McKenzie and J. Dell, respectively, 29 August 1974 and 25 August 1974, respectively, shot in Fern Gully which is described in detail in Miles *et. al.* (1975), field numbers W3/16 and W3/4, respectively, weights 4.5 and 4.3 gms, respectively.

Drysdale River National Park (14° 43'S, 126° 54'E):

M14016 (male), M14015, M14017 and M14018 (females), W.K. Youngson, 20-21 August 1975, shot flying against cliffs near water, field numbers C3-8, C3-7, C3-9 and C3-15 respectively, weights 3.0, 4.0, 3.0 and 3.0 gms, respectively.

Other *E. douglasi* specimen

M14014, Western Australian Museum, female in alcohol, W.K. Youngson, 20 August 1975, shot against cliffs along with paratypes from Drysdale River National Park, field number C3-1, weight not recorded. This specimen was badly damaged when shot.

Diagnosis

E. douglasi is a large *Eptesicus* with a long slender forearm. The head, foot and forearm when compared to the rest of the body are contrastingly light coloured. The baculum is large and in the lateral view is more strongly curved and with a larger and more rounded head proximally than *E. pumilus caurinus* (Fig. 1).

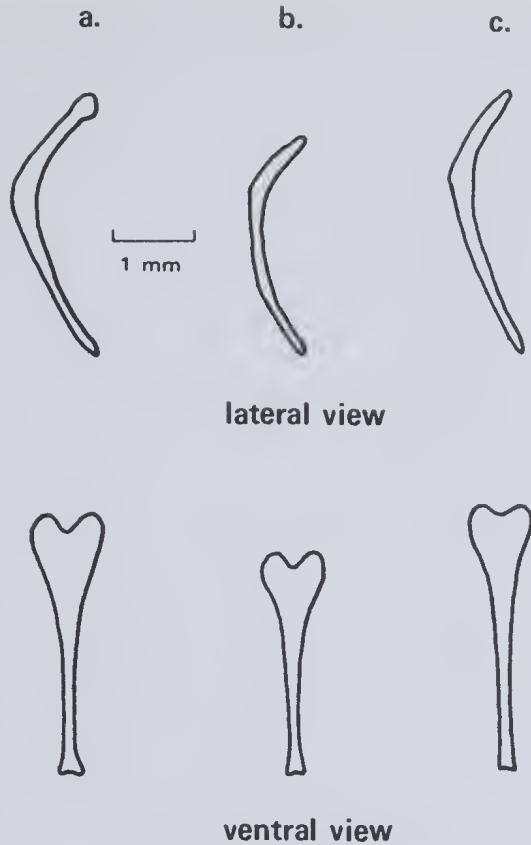


Fig. 1. Baculum, in ventral and lateral view, of (a) *Eptesicus douglasi* (M14557), (b) *Eptesicus pumilus caurinus* (M14013), and (c) *Eptesicus pumilus pumilus* (M14562).

Description

(a) Skull and Dental Characters: although *E. douglasi* is much larger than the *E. pumilus caurinus* collected sympatrically (see measurements, Tables 1 and 2), the general shape of the skull and teeth of the two taxa is very similar. *E. douglasi* does, however, have a narrower interorbital constriction expressed as a proportion of its rostrum (distance from I¹ to the least interorbital constriction) than does *E. pumilus caurinus* (.62-.70 compared to .71-.75).

(b) External Characters: the *E. douglasi* described herein are all preserved in alcohol; no skins were prepared. Fortunately, W.K. Youngson records in his field notes that the colour of *E. douglasi*, M14015, immediately after he shot it, had "distinct yellow-orange mantle and chest, lips and snout orange". These colours and presumably those of the other spirit specimens

(described following Ridgway's 1912, colour code) have faded somewhat and now appear, after careful drying and grooming of the pelage, as a pale orange mantle of fur on head, shoulders and throat, orange buff lips, snout, forearm and foot; fur on ventral and dorsal surfaces tipped with light greyish olive and pale olive buff, respectively, and with a clove brown base; a patch of ivory yellow hair posterior to the arms on the ventral surface; and a black patagium. The colour of the other *E. douglasi* alcohol specimens is similar; they all have a light coloured covering of fur on the head, throat and shoulders, and pale skin on the front of the face, forearm and foot. The light coloration of the face of *E. douglasi* highlights the large 'glandular' pads on the side of the snout giving its face a much less pointed appearance than that of *E. pumilus caurinus*, which lacks large nasal pads.

(c) Baculum: recent studies on bacula of *Eptesicus* in Australia have indicated that their shape may be used as a diagnostic character to distinguish between forms of this genus (J.L. McKean, *pers. comm.*).

Bacula were removed from *E. douglasi* (M3405B, M14016, M14557), *E. pumilus caurinus* from Drysdale River National Park (M14009, M14013), *E. pumilus pumilus* from Middle Creek, East Pilbara, Western Australia (M12666, M12668 and M12671), and Yardie Homestead, North West Cape, Western Australia (M5147 and M14562); and from a specimen from Halls Creek, southeast Kimberley, Western Australia (M6255), which is intermediate in size between *E. pumilus caurinus* and *E. pumilus pumilus*. The bacula of specimens in these taxa are represented in ventral and lateral view in Fig. 1.

The baculum of *E. douglasi* is slightly larger than any of the others examined and differs from the others in that the small horns at the proximal end are more swollen in the lateral view, and the curve of the baculum from the lateral view is more acute. The bacula from the forms of *E. pumilus* examined vary in size but are approximately the same shape.

(d) General: *E. douglasi* is apparently a cave bat. It was mist-netted at the mouth of Tunnel Creek in October 1958, and collected from inside the Tunnel Creek cave in June 1965.

The flight pattern of *E. douglasi* differed from that of *E. pumilus caurinus* in that it kept closer to the cliffs and was more difficult to shoot than the latter species (W.K. Youngson *pers. comm.*).

Female *E. douglasi* were collected from August, June and October. None had obviously enlarged uteri or swollen teats.

Remarks

E. douglasi is a distinct species from *E. pumilus*; it occurs in sympatry with *E. pumilus caurinus* from which it differs markedly in overall size and

colour, and slightly in shape of baculum. However, the differences in cranium, teeth and body form between *E. douglasi* and *E. pumilus caurinus* are no greater than the differences between the other weakly differentiated races of *E. pumilus* recognised by Tate (1942). It is possible then, that *E. darlingtoni* which was relegated to a subspecies by Tate (1942) and Ride (1970), and *E. pumilus vulturnus*, should be elevated to specific status.

Of the subspecies of *E. pumilus* recognised by Tate (1942), *E. pumilus darlingtoni*, although of different colour, appears nearest to *E. douglasi*. Measurements (in mm) taken from the paratype of *E. darlingtoni* (No. 29120) are as follows: greatest length 13.3, zygomatic breadth 8.6, interorbital breadth 3.8, braincase breadth 6.8, braincase depth 4.9, maxillary tooth row 4.9, post palatal length 5.2, palatal breadth 5.7, mandible C-M₃ 5.2, canine breadth 4.1, mastoid breadth 7.8, I¹ - least interorbital constriction 5.3, distance between bullae 1.4, head and body length 46.0, ear length 10.0, tragus length 6.8, radius length 36.2, tibia length 14.7, foot length 7.0.

Although the body measurements of *E. douglasi* listed in Table 2 are from spirit specimens and those from *E. darlingtoni* above are from a skin, they do suggest that the general body shape in these two taxa is similar (the ears of the *E. darlingtoni* specimen appear to have shrunk). Comparison of the skull and dental measurements and shape of these two taxa indicates that in *E. douglasi* the skull is shorter and relatively narrower at the back. It has slightly less inflated bullae and these, relative to the mastoid breadth, are closer together. The anterior margin of the orbit in *E. douglasi* is much more oval in shape than in *E. darlingtoni*, where it projects forward to a sharper angle. Further the rostrum in *E. douglasi* shows a tendency to be slightly longer relative to the greatest length of the skull, than is the case with *E. pumilus caurinus* — whereas Allen (1933) states that the rostrum of *E. darlingtoni* is slightly shorter than in *E. pumilus*.

ACKNOWLEDGEMENTS

Eptesicus douglasi is named after Athol M. and Marion Douglas for their extensive collecting of bats in Western Australia. I am grateful to A.M. Douglas and J.L. McKean for preparing the bacula described in this paper, and to the Director, Queensland Museum, for the loan of the *E. darlingtoni* paratype.

I would also like to thank G.M. Storr, Western Australian Museum, and J.L. McKean, C.S.I.R.O. Wildlife Research, for their advice, and G.M. Storr for reading this manuscript.

Table 1: Skull and Dental Measurements (mm) of *Eptesicus douglasi* and *E. pumilus caurinus*.

No.	<i>E. douglasi</i>		<i>E. pumilus caurinus</i>	
	M	M	M	M
Sex	♂	♂	♂	♂
Locality (Kimberley District)	Orysdale River N.P.	Prince Regent River R.	Orysdale River N.P.	Orysdale River N.P.
Greatest length	12.7	13.0	12.6	12.7
Zygomatic breadth	8.3	8.1	8.2	8.3
Interorbital breadth	3.4	3.5	3.5	3.4
Braincase breadth	6.2	6.1	6.4	6.1
Braincase depth	4.9	5.0	-	4.9
Maxillary tooth row	4.6	4.7	4.7	4.6
Post palatal length	5.0	5.3	5.0	4.9
Palatal breadth	5.5	5.5	5.4	5.3
Mandible C-M3	4.9	5.0	5.0	5.0
Canine breadth	4.0	4.1	4.1	3.9
Mastoid breadth	7.0	7.1	7.2	6.8
1 - least interorbital constriction	5.0	5.3	5.0	5.1
Distance between bullae	1.1	1.0	1.2	1.1

Table 2: Body Measurements (mm) of *Eptesicus douglasi* and *E. pumilus caurinus*. (Measurements taken from fixed specimens.)

No.	<i>E. douglasi</i>		<i>E. pumilus caurinus</i>	
	M	M	M	M
Sex	♂	♂	♂	♂
Locality (Kimberley District)	Orysdale River N.P.	Prince Regent River R.	Orysdale River N.P.	Orysdale River N.P.
Head and body length	40.6	37.8	39.6	37.1
Tail length	-	-	37.1	-
Ear length	11.6	12.5	38.3	11.7
Tragus length	6.0	6.7	11.7	6.1
Radius length	35.6	37.0	36.4	37.6
Tibia length	-	-	14.4	15.3
Foot length	-	-	6.4	6.1

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TWO NEW SPECIES OF PEBBLE CRAB (OXYSTOMATA : LEUCOSIIDAE) FROM WESTERN AUSTRALIA

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and

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ABSTRACT

Leucosia thysanotus sp. nov. from northwest Australia and *Leucisca levigena* sp. nov. from southwest Australia are described. *L. thysanotus* is distinguished from the closely related *L. whitei* Bell by the fringe of hair on the epibranchial angle and the weakly bilobed front. *L. levigena* is only the second species described for the genus which was erected by Macleay for the South African south coast species *L. squalina*.

INTRODUCTION

Since the publication on the Oxystomata and Gymnopleura of Western Australia by Tyndale-Biscoe and George (1962), further collecting, particularly in the shallower waters of the north coast, has been carried out. Two of the most important expeditions were the Crown of Thorns Starfish Survey in the Dampier Archipelago (1972-1974) and the *Dorothea* cruise (1962), which obtained collections between Port Hedland and Brisbane. This paper describes two new species of pebble crab resulting from these efforts. We wish to thank the members of the Commonwealth and Queensland Governments' Crown of Thorns Research Committee and Mr and Mrs W. Goode, owners of *Dorothea* whose support has advanced our knowledge of the State's marine fauna. Illustrations were prepared by Sue Clark.

Measurements of the crabs are midline carapace lengths from rostrum to posterior margin of carapace.

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Leucosia thysanotus sp. nov.

(Figs 1 - 4)

Description

Carapace slightly longer than broad; front prominent, weakly bilobed; hepatic regions broadly raised with 40-60 microscopic granules; epibranchial angles pronounced, margined with a thick fringe of hair above base of arm; upper surface of lateral region with band of pubescence covering small marginal granules; thoracic sinus deep, extending posteriorly to level of last pair of walking legs, without anterior granules; thickened epimeral edge granulate, visible dorsally.

Dorsal inner and outer surfaces of arm of cheliped granular, interspersed with pubescence proximally; ventral surface smooth; dorsal proximal margin of arm with fringe of hair similar in texture and extent to that on epibranchial margin (Figure 3). Dorsal and ventral surfaces of wrist covered with small granules. Ventral margin of hand sharply granular; dorsal margin smooth or microscopically granular. Movable finger crested, with ridge on central inner surface; immovable finger with two feebly granular ridges on inner surface; fingers cross; cutting edge of fingers with hair.

Merus of 2nd to 4th walking legs almost square in section with microscopic granules along some angles. Carpus of 2nd and 3rd walking legs bicarinate; carpus of 5th uncarinate and of 4th uni- or bicarinate.

Abdominal formula of male 1+R+6+T; small projection on penultimate segment of abdomen. Abdominal formula of female 1+R+T.

Male pleopod (Figure 4). Short, stout, slightly curved with bulbous tip. Distal aperture at tip of tooth in centre of bulb surrounded by strong tuft of hair. Shaft bare, untwisted. Ridge straight on inner side of shaft.

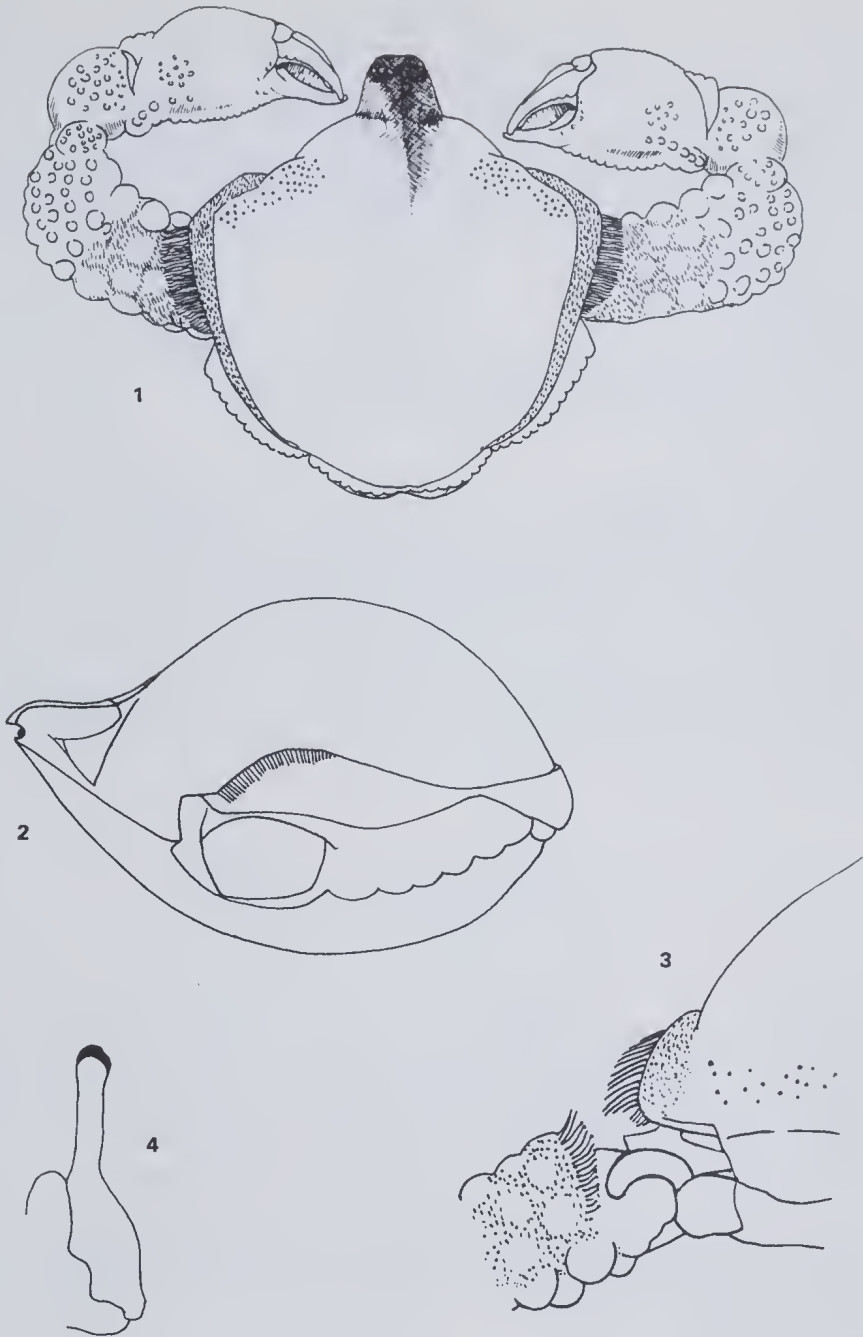
Colour

Carapace marbled with brown, white and orange; paler posteriorly. Front dark brown. Hepatic granules red. Arm of cheliped brown with white granules; hand pale with orange-brown spot on palm, base of fingers orange. Legs white with orange blotches.

Material examined

Holotype.— Adult male (14.1 mm), 22.v.74, dredged 3 m sand, some weed, Western Australian Museum Crown of Thorns Survey, WAM 79-75.

Type locality.— Norbill Bay, Rosemary I., Dampier Archipelago, northwest Australia.



Figures 1 - 4. *Leucosia thysanotus* sp. nov. 1. dorsal view; 2. lateral view; 3. cheliped joint viewed from front showing fringes on arm and on epibranchial angle; 4. 1st pleopod. Holotype male WAM 79-75.

Paratypes.— 3 ♂♂ (13.1 - 13.8 mm) NE side of Rosemary I., Dampier Archipelago, northwest Australia, 4.xi.71, intertidal sand flats, B.R. Wilson *et al.*, WAM 80-75; 1 ♂ (14.7 mm) 1.6 km S of Delambre I., Dampier Archipelago, 30.viii.61, dredged 11 m, B.R. Wilson and G.W. Kendrick, WAM 124-64; 4 ♂♂ (14.4 - 15.9 mm), 2 ♀♀ (16.2 - 16.3 mm), 2 juveniles (13.8 - 14.7 mm), Broome, northwest Australia, 16.x.62, on exposed sand bar opposite town jetty, R.W. George on 'Dorothea', WAM 16-63.

Distribution

Northwest coast of Western Australia living in shallow protected sand flat conditions from Dampier Archipelago to Broome.

Comments

L. thysanotus is similar to *L. whitei* Bell in having the epibranchial angles pronounced, the presence of hepatic granules, the lateral band of pubescence and the projection on the male penultimate abdominal segment. It is easily distinguished however by the nature of the front, the hairiness of the epibranchial angle, the hepatic granules, the dorsal margin of the hand and the carpus of the walking legs; these differences are given in Table 1. The name *thysanotus* (Gr. = fringe) refers to the fringe of hair on the epibranchial angle.

Leucisca levigena sp. nov.

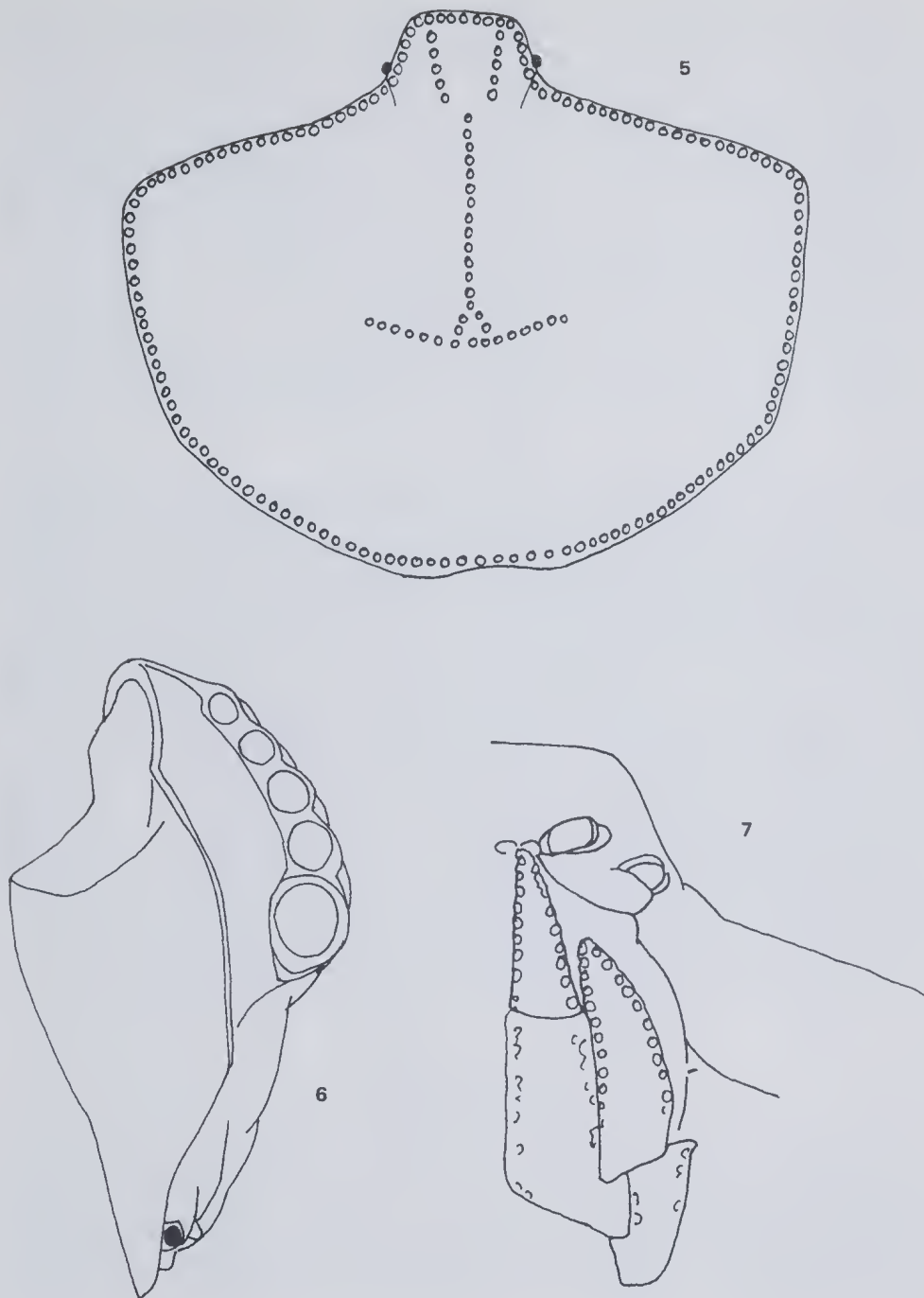
(Figs 5 - 7)

Description

Carapace subcircular with narrow truncate front marked by faint orbital sutures; submarginally depressed; margin faintly beaded; gastric region markedly elevated, outlined posteriorly by a transverse row of low tubercles; a beaded ridge extends forward from gastric elevation to about level of eyes; front concave, bearing two anteriorly diverging ridges.

Ventral surface of front and pterygostomial region smooth, punctate (Figure 7). Thorax smooth with some pits. External maxillipeds mostly smooth, exopod distinctly shorter than endopod and both margined with elevated granules.

Arm of cheliped short, squarish in section, 2/3 length of hand; ventral surface of wrist flattened; hand flattened with fingers twisted away from normal plane; tips of fingers sharply pointed and crossed; cutting edges smooth; surface of cheliped smooth and sparsely pitted.



Figures 5 - 7. *Leucisca levigena* sp. nov. 5. dorsal view; 6. lateral view; 7. pterygostomial region. Holotype female WAM 253-62.

Table 1. Comparison of *Leucosia thysanotus* sp. nov. and *L. whitei* Bell.

	<i>L. thysanotus</i>	<i>L. whitei</i>
Hair on epibranchial angle	Long thick fringe	Short, sparse
Front	Obscurely bilobed	Sharply tridentate
Hepatic region	40-60 microscopic red granules	10-14 obvious white granules
Dorsal margin of hand	Smooth or microscopically granular	Sharply granular
Carpus of 2nd and 3rd walking legs	Bicarinate	Unicarinate
Thoracic sinus anterior margin	Without granules	With granules

Table 2. Comparison of *Leucisca levigata* sp. nov. and *L. squalina* Macleay.

	<i>L. levigata</i> Yanchev ♀ 4.9 mm	<i>L. squalina</i> False Bay ♂ 9.5 mm	<i>L. squalina</i> Natal ♂ 6 mm ♀ 6 mm
Front	Concave	Very slightly convex	Flat
Elevation of gastric region of carapace	Marked	Very slight	Slight
Pterygostomian region	Smooth	Pitted	Marked granules
Thoracic sternum	Smooth	Pits and granules	Marked granules
Beading around margin of carapace	Faint	Marked	Marked

Colour

The preserved female holotype is uniform creamy-white.

Material examined

Holotype.— Adult female (4.9 mm), 1.i.61, 1 m on sheltered side of reef. G.W. Kendrick. WAM 253-62.

Type locality.— Yanchep Reef, Western Australia (31°33' S, 115°37' E).

Distribution

The species is represented by only one specimen from Yanchep on the southern west coast of Australia.

Comments

The present species falls clearly into the genus *Leucisca* Macleay, 1838 which is characterised by the smooth subcircular, depressed carapace with a raised beaded margin, the truncate front and the small deeply set eyes.

L. levigena sp. nov. is the second species recorded for the genus if Barnard's opinion (1950) that only one species occurs on the south coast of Africa is correct. He regards *Carcinaspis marginatus* Stimpson, 1858 and *Leucisca phaenomma* Stebbing, 1920 as synonyms of *Leucisca squalina* Macleay, 1838 and notes some geographical variation in size stating (1950, p.372) 'Natal specimens are smaller (both sexes) than Cape specimens, but otherwise indistinguishable'. However, an examination of specimens at the British Museum (Natural History) by one of us (R.W.G.) suggests that there are some morphological variations (Table 2) in *L. squalina*. This table sets out the distinguishing features of *L. levigena* as well. The name *levigena* (Lat. levis = smooth, gena = cheek) refers to the smooth pterygostomial region.

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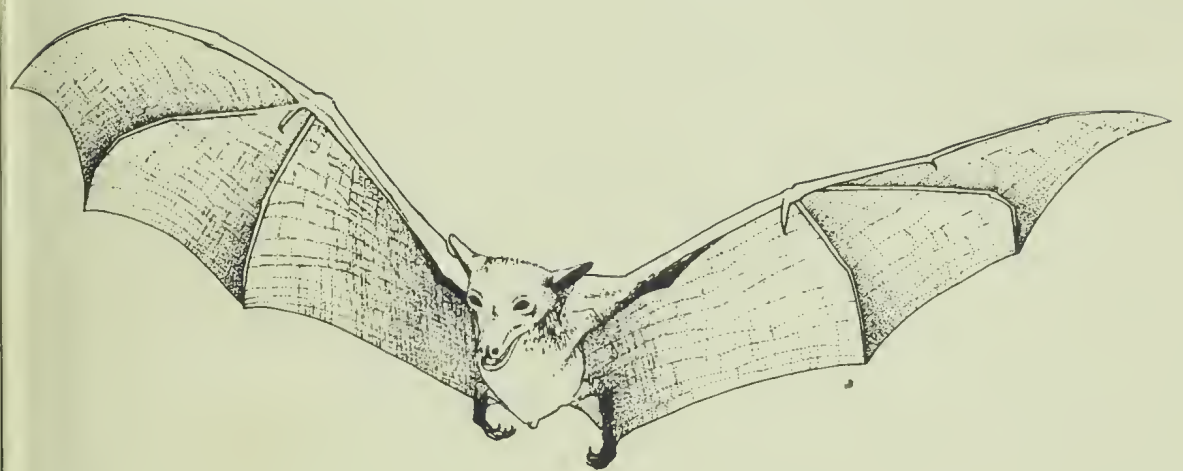
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Cover: Northern Blossom Bat (*Macroglossus lagophilus*) drawn by Allan Muller, Western Australian Museum. This bat feeds on pollen and nectar of mangroves along the Kimberley coastline of Western Australia. It is also found at short distances inland where it is attracted at certain times of the year by other flowering plants, particularly melaleucas.

ISSN 0312—3162

CHEILODACTYLUS RUBROLABIATUS, A NEW SPECIES OF
MORWONG (PISCES: CHEILODACTYLIDAE) FROM WESTERN
AUSTRALIA, WITH A KEY TO THE CHEILODACTYLID
FISHES OF AUSTRALIA.

GERALD R. ALLEN*

and

PHILLIP C. HEEMSTRA†

[Received 10 June 1976. Accepted 20 July 1976. Published 31 December 1976.]

ABSTRACT

Cheilodactylus rubrolabiatus is described from 22 specimens collected off Western Australia between Point Maud and Albany. It is distinguished by a colour pattern consisting of seven oblique dark brown bars and relatively high dorsal fin ray and lateral-line scale counts. In addition a key to the cheilodactylid fishes of Australia and a table giving the allocations of all nominal species of cheilodactylids from Australia and New Zealand are presented.

INTRODUCTION

Our purpose in this paper is to describe a new species of fish that is apparently common in certain areas along the coast of Western Australia. Although we have not attempted a revision of the Australian species of *Cheilodactylus*, a key to the Australian species of Cheilodactylidae is presented — both as an aid in identifying these fishes and as a representation of the affinities of the new species. As a further guide to the taxonomy of these species, we give a list (Table 1) of all nominal species of Australian and New Zealand cheilodactylids, with their allocation to the species we recognise as valid.

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Table 1: Species of Cheilodactylidae described from Australia and New Zealand, with their present allocations

NOMINAL SPECIES	PRESENT ALLOCATION
<i>Sciaenoides abdominalis</i> Richardson, 1843	<i>Nemadactylus macropterus</i>
<i>Chilodactylus allporti</i> Günther, (Sept.) 1872	<i>Cheilodactylus spectabilis</i>
<i>Chilodactylus annularis</i> Castelnau, 1879	<i>Cheilodactylus fuscus</i>
<i>Chilodactylus asper</i> Klunzinger, 1872	<i>Cheilodactylus spectabilis</i>
<i>Cheilodactylus aspersus</i> Richardson, 1850*	? <i>Cheilodactylus monodactylus</i>
<i>Cheilodactylus carponemus</i> Cuvier, 1829	<i>Nemadactylus macropterus</i>
<i>Nemadactylus concinnus</i> Richardson, 1839	<i>Nemadactylus macropterus</i>
<i>Psilocranium coxii</i> Macleay, 1884	<i>Dactylophora nigricans</i>
<i>Chilodactylus douglasii</i> Hector, 1875	<i>Nemadactylus douglasii</i>
<i>Cheilodactylus ephippium</i> McCulloch & Waite, 1916	<i>Cheilodactylus ephippium</i>
<i>Chilodactylus fuscus</i> Castelnau, 1879	<i>Cheilodactylus fuscus</i>
<i>Cheilodactylus gibbosus</i> Richardson, 1841	<i>Cheilodactylus gibbosus</i>
<i>Cichla macropterus</i> Schneider, in Bloch & Schn., 1801	<i>Nemadactylus macropterus</i>
<i>Chilodactylus morwong</i> Ramsay & Ogilby, 1887	<i>Nemadactylus douglasii</i>
<i>Chilodactylus mullhallii</i> Macleay, 1882	<i>Dactylophora nigricans</i>
<i>Chilodactylus nebulosus</i> Klunzinger, 1872	<i>Dactylophora nigricans</i>
<i>Chilodactylus nigrescens</i> Saville-Kent, 1897	<i>nomen nudum</i>
<i>Cheilodactylus nigricans</i> Richardson, 1850	<i>Dactylophora nigricans</i>
<i>Cheilodactylus nigripes</i> Richardson, 1850	<i>Cheilodactylus nigripes</i>
<i>Chilodactylus polyacanthus</i> Ramsay & Ogilby, 1886	<i>nomen nudum</i>
<i>Cheilodactylus rubrofasciatus</i> Castelnau, 1878	<i>Cheilodactylus spectabilis</i>
<i>Dactylophora semimaculata</i> De Vis, 1883	<i>Dactylophora nigricans</i>
<i>Chilodactylus spectabilis</i> Hutton, (Feb.) 1872	<i>Cheilodactylus spectabilis</i>
<i>Zeodrius vestitus</i> Castelnau, 1879	<i>Cheilodactylus gibbosus</i>
<i>Chilodactylus vizonarius</i> Saville-Kent, 1888	<i>Cheilodactylus nigripes</i>

*Richardson's description of *C. aspersus* matches no Australian cheilodactylid. If Hureau (1969) is correct in equating *C. aspersus* and *C. monodactylus* (Carmichael, 1818); then the specimens that Richardson received from Lempriere, which were supposed to have all come from Port Arthur in Tasmania, were augmented with specimens collected elsewhere. An obvious example of a similar occurrence is that of *Oplegnathus conwayi* Richardson, 1840 (cf. Barnard, 1927: 506). Another example from the Lempriere collection may be *Atherina preſbyteroides* Richardson, 1843 which Whitley (1943) was unable to identify with any species of Australian atherinid.

METHODS

Measurements were made with dial calipers to the nearest 0.1 mm. Standard length (SL) is measured from the premaxillary symphysis to the

end of the hypural bones. Snout length does not include the upper jaw; eye diameter is the horizontal diameter of the dermal orbit; interorbital width is the least width of the bony interorbital region; anal fin length is measured from the origin of the fin to the tip of the longest ray; dorsal and anal fin spines are measured from their base, rather than the point where they emerge from the scaly sheath; caudal peduncle length is the distance from the base of the last anal fin ray to the lower end of the caudal fin base.

Lateral-line scale counts do not include any scales posterior to the base of the caudal fin; gill-raker counts are given as upper + lower limb rakers; the last ray of the dorsal and anal fins is usually double (split to its base), but counted as a single ray.

Type-specimens have been deposited at the following institutions: Australian Museum, Sydney (AM); British Museum (Natural History), London (BMNH); C.S.I.R.O. Division of Fisheries and Oceanography, Cronulla, N.S.W. (CSIRO); Rhodes University, Grahamstown, South Africa (RUSI); United States National Museum of Natural History, Smithsonian Institution, Washington, D.C. (USNM); Western Australian Museum, Perth (WAM).

Cheilodactylus rubrolabiatus n. sp.

(Figs 1 and 2; Table 2)

Holotype

WAM P 25225-001, 182 mm SL, collected with spear near boat launching ramp at Woodman's Point, Western Australia (32°08.5' S, 115°45.6' E) in two metres by G.R. Allen on 28 March 1975.

Paratypes

AM I.18854-001, 102 mm SL, collected at east end of Nancy Cove, Rottnest Island, Western Australia on 18 January 1953; BMNH 1975.9.23.10, 200 mm SL, collected with rotenone at Cape Vlaming, Rottnest Island, Western Australia (32°01.5' S, 115°26.7' E) by zoology class, University of Western Australia on 9 March 1963; CSIRO C 2694-2700, 7 specimens, 85-105 mm SL, collected at east end of Nancy Cove, Rottnest Island on 18 January 1953; CSIRO C 2712, 202 mm SL, collected at Strickland Bay, Rottnest Island on 21 January 1954; RUSI 835, 127 mm SL, same data as BMNH 1975.9.23.10; USNM 214831, 157 mm SL, collected at Jervoise Groyne, near Woodman's Point, Western Australia by M. Graham and J. Lucas on 2 March 1963; WAM P 4879, 233 mm SL, collected at Cape

Vlaming, Rottnest Island, Western Australia by Fisheries Department on 9 March 1960; WAM P 5562, 201 mm SL, same data as BMNH 1975.9.23.10; WAM P 5925, 127 mm SL, collected with spear at Triggs Island, near Perth, Western Australia by D. Parker on 7 January 1964; WAM P 10529, 41.0 mm SL, collected about 3.2 km south of Maud's Landing, Western Australia (23°07.5' S, 113°46' E) by N.E. Milward on 6 October 1957; WAM P 22244, 64.5 mm SL, collected at Rottnest Island, Western Australia by E. Hodgekin on 26 February 1972; WAM P 22580, 112 mm SL, collected at Rockingham (approximately 40 km south of Perth), Western Australia by M. Beynan on 10 March 1973; WAM P 25255-003, 2 specimens, 93 & 95 mm SL, collected with rotenone at Cape Clairault, Western Australia (33°41.5' S, 115°00' E) in 1-2 metres by G.R. Allen and J. Scott on 25 April 1975; WAM P 25473-001, 34.8 mm SL, collected with rotenone at whaling station near Albany, Western Australia (35°06' S, 117°57' E) in 1-2 metres by G.R. Allen and R.R. Allen on 13 August 1975.

Diagnosis

Dorsal fin rays usually XVII,30-34; anal fin rays III,8; height of anal fin greater than length of its base; anterior dorsal spines at least twice length of last dorsal spine; lateral-line scales 60-64; juveniles and adults without bony knobs in front of eyes and at front of snout; body generally pale with seven oblique dark bars or blotchy bands; lips of adults bright red in life.

Description

(Counts and proportions of the paratypes, when different from the holotype, are given in parentheses; number of paratypes with a particular count is shown in square brackets.)

Dorsal fin XVII (XVI[2] or XVII[20]), 31 (30[4], 31[7], 32[8], 33[2], 34[1]); anal fin III,8; pectoral fin ii,6,vi; lateral-line scales 60 (60[2], 61[3], 62[6], 63[7], 64[4]); principal caudal fin rays 9 + 8, branched rays 7 + 6; 6 rows of large scales between middle of spinous dorsal fin and lateral line; 13 rows below lateral line to origin of anal fin; gill-rakers 8 + 15 (8[10], 9[12] + 15[10], 16[10], 17[2]); branchiostegal rays 6; vertebrae 34: 14 precaudal + 20 caudal.

Body compressed; upper profile of head and body moderately arched; greatest body depth 2.9 (2.7 to 3.2), head 3.1 (3.1 to 3.3) in standard length; snout 3.1 (2.9 to 3.7), eye diameter 4.4 (3.5 to 4.6), interorbital width 4.9 (4.7 to 5.5), least depth of caudal peduncle 2.8 (2.9 to 3.7), length of caudal peduncle 1.1 (1.0 to 1.2), all in head length.

Origin of dorsal fin above dorsal end of operculum; dorsal spines increasing in length from first to fourth spines; fourth and fifth spines

subequal, remaining spines gradually decreasing in length posteriorly; fifth spine 2.4 (2.0 to 2.8), last spine 3.7 (4.0 to 4.7) in head length; anterior third of soft dorsal fin rays subequal to longest dorsal spine, remaining rays gradually decreasing in length posteriorly; anal fin origin less than pupil width from anus; longest anal spine about 1/3 length of longest anal ray; anal fin length 1.2 (1.2 to 1.4), longest soft ray 1.4 (1.4 to 1.7), last ray 3.7 (3.7 to 4.8), all in head length; six ventral rays of pectoral fin unbranched, thickened, semi-detached; rays four to six, counting from bottom, prolonged slightly past margin of fin; fifth ray longest, 1.0 (1.0 to 1.1) in head length; upper margin of pectoral fin 1.5 (1.5 to 1.8) in head length; pelvic fins relatively short, 1.5 (1.4 to 1.7) in head length; caudal fin emarginate to forked, its length 1.2 (1.1 to 1.4) in head length.

Scales cycloid; scales on head very small, the largest about 1/7 or 1/8 size of largest body scales; cheek scales partially embedded; scales on top of head extending to about level of anterior nostrils; snout, preorbital, lips, chin, branchiostegal membrane, fleshy opercular flap, and dermal ring around eye lacking scales; ventral surface of thorax covered with minute, embedded scales; scaly sheath about equal to pupil diameter in width at base of dorsal and anal fins; sheath comprising two rows of fairly large scales along base of spiny dorsal fin and about three to five rows of smaller, more irregularly arranged scales at base of soft dorsal fin.

A pair of large nostril openings on each side of snout, just in front of eye: anterior nostril opening about twice as long as posterior one, with low fleshy rim and elevated dermal flap anteriorly and posteriorly; anterior flap fringed with about six to eight cirri, posterior flap fringed with about 12 to 15 cirri; pores of lateralis system on head tiny and inconspicuous; no spines on head bones; rear margin of opercle ending in two, widely spaced, blunt points; margin of preopercle entire.

Mouth relatively small; maxilla not quite reaching a vertical at front edge of orbit; lips thick and fleshy; upper jaw slightly protrusile; both jaws with numerous, cardiform teeth in several rows; teeth are embedded in thick fibrous tissue, with only their tips exposed (except for those teeth on outer margin of jaws); height of longest teeth about equal to greatest diameter of posterior nares; vomer and palatines toothless; tongue wide, squarely cut across the front; gill-rakers rather short, about half pupil diameter.

Gas bladder well developed, firmly attached to dorsal surface of body cavity.

Colour of holotype when fresh: head and body generally a very pale tan with seven oblique brown bars on body, the first extending from dorsal

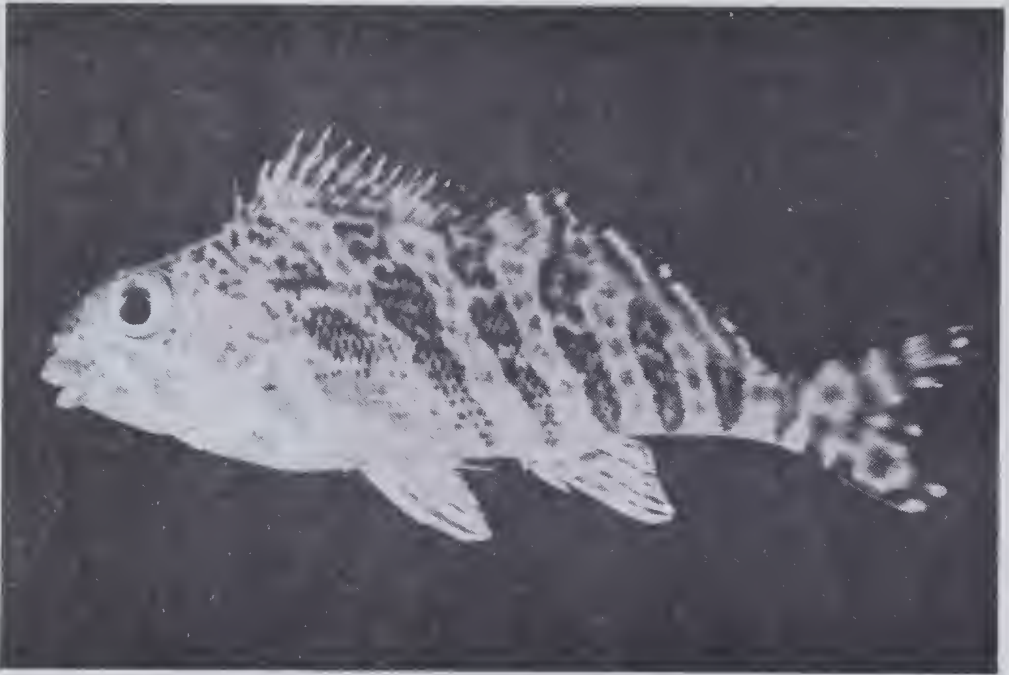


Fig. 1: *Cheilodactylus rubrolabiatus*, paratype, 93.0 mm SL; Cape Clairault, Western Australia.

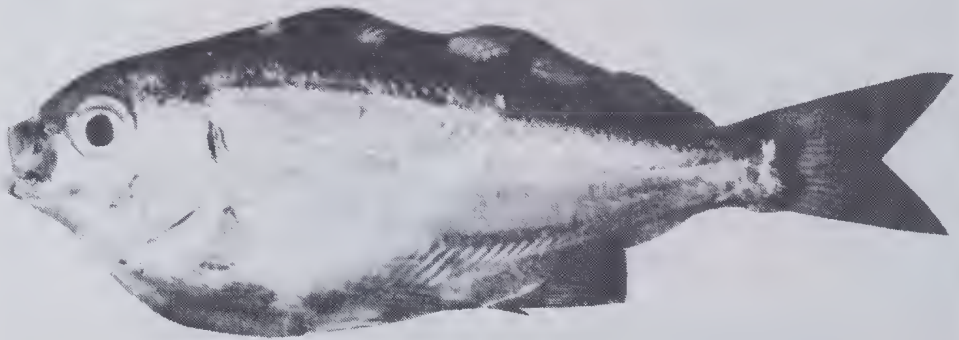


Fig. 2: *Cheilodactylus rubrolabiatus*, paratype, 34.8 mm SL; Albany, Western Australia. (Note: The fins appear much darker than normal because the specimen was originally photographed on a dark background.)

fin origin to pelvic fins, and the last across base of caudal fin; pale interspaces with faint network of blotches and spots giving overall pale golden-brown appearance; head with numerous brown spots, more or less arranged in oblique bands, the first across side of snout to angle of preopercle, the second through eye, and the third on nape; short brown band extending from corner of mouth to anterior part of lower edge of preopercle; lips pink; several brown spots on pectoral fin base and side of thorax; fins pale, covered with brown spots, those of pectoral fins confined to dorsal half of fin. The oblique bands of adults are prominently dark brown, and the lips usually bright red.

The smallest paratype (Fig. 2) was primarily silvery in life, grading to blackish above the lateral line; a series of seven black blotches on dorsal fin and dorsal surface of caudal peduncle.

Colour in 70% ethanol: pattern of holotype and larger paratypes generally similar to fresh colours described above except the pale interspaces on the body are dusky grey-brown, the lips are tan, and the pectoral fins are mostly grey, with a whitish distal margin; pelvic and anal fins mostly dark grey.

The 41.0 mm paratype is primarily tan in preservative, with pale fins; oblique dark bands clearly visible on dorsal fin, but just barely discernible on body; three brown bars across caudal fin. The remaining paratypes clearly exhibit the trend of the bars on the body becoming more distinct and their continuations onto the dorsal fin breaking up into spots, as the fish grows.

Remarks

In general appearance, *C. rubrolabiatus* most closely resembles *C. spectabilis* Hutton of New Zealand, New South Wales, Victoria and Tasmania. The latter species has a similar number of dark bars on the body, but they are more uniform (those of *C. rubrolabiatus* are somewhat blotchy) and the posterior bars are vertical rather than oblique. Also the dorsal and caudal fins of *C. spectabilis* are nearly uniform in colour; whereas those of *C. rubrolabiatus* are pale with dark spots and bands. These two species also differ in meristic characters as indicated in the key below.

In addition to the characters noted in the key below, *C. rubrolabiatus* differs from *C. fuscus* in having 20 (rather than 21) caudal vertebrae. Of the non-Australian species of *Cheilodactylus*, only *C. fasciatus* Lacepède (1803) of South Africa and *C. zonatus* Cuvier in Cuvier and Valenciennes (1830) of China and Japan are at all similar to *C. rubrolabiatus*. The South

Table 2: Measurements (in thousandsths of standard length) of selected type-specimens of *Cheilodactylus rubrolabialis*

DIMENSION	WAM	WAM	CSIRO	CSIRO	CSIRO	WAM	USNM	BMNH	WAM
	P25225-001*	P22244	C2698	C2695	C2694	P5925	214831	1975.9.23.10	P4879
Standard length (mm)	182	64.5	85	94	110.	126.5	156.5	200	233
Greatest body depth	349	322	328	316	309	356	371	340	322
Greatest body width	148	118	139	133	136	154	147	136	139
Head length	291	341	319	313	314	310	313	323	296
Snout length	93	93	101	100	101	103	101	104	86
Upper jaw length	73	78	80	74	84	85	86	82	73
Eye diameter	66	96	87	84	76	77	75	73	64
Interorbital width	59	62	65	62	59	61	65	60	63
Caudal peduncle (least depth)	105	93	92	89	86	99	102	100	101
Caudal peduncle (length)	258	276	282	277	282	292	307	265	275
Spinous dorsal fin base	313	326	312	319	309	320	326	320	309
Soft dorsal fin base	429	357	394	394	391	395	377	410	403
Anal fin base	121	124	125	126	115	126	132	120	120
Length of anal fin	247	248	236	238	227	267	256	250	242
Length of caudal fin	241	248	253	245	236	273	266	258	249
Length of pelvic fin	201	202	200	181	182	206	204	205	208
Longest pectoral fin ray	297	298	282	287	291	308	294	307	300
Longest dorsal fin spine	121	124	127	137	151	147	153	130	131
Last dorsal fin spine	78	**	72	70	73	77	78	78	64
Longest anal fin ray	209	209	212	202	182	213	214	213	197

*Holotype

**Damaged

African species has smaller, more numerous scales, fewer dorsal fin rays, more dorsal spines, and a different pattern of dark bars on the body, (Smith, 1961). *C. zonatus* has fewer lateral-line scales, prominent white spots on the caudal fin and peduncle, black blotch on the upper rear edge of the operculum, and the dark bars on the body are narrower than in *C. rubrolabiatus*, (Lindberg and Krasnyukova, 1969).

C. rubrolabiatus is known from the subtropical coral reefs near Pt Maud (approximately 23° S) southwards to the Albany area. It is common in the Houtman Abrolhos (about 65 km offshore between 28° - 29° S), in the Perth area, and at Geographe Bay (33.5° S). South of the Abrolhos it frequents rocky reefs at depths ranging from surge pools to at least 10 metres. North of the Abrolhos, it is also found in coral reef areas.

The young of *C. rubrolabiatus* appear to initially colonise inshore areas as post-larvae in the distinctive 'paper-fish' stage (Fig. 2). At this stage, they somewhat resemble a nomeid fish: the body is very compressed and silvery, except for some dark markings above the lateral line and at the base of the caudal fin. These post-larvae appear to be more pelagic than the normally benthic adults and older juvenile fish. Similar 'paper-fish' stages have been described and illustrated for *Nemadactylus macropterus* (Vooren, 1973 and Whitley, 1957); for *C. fuscus* and *N. douglasi* (Whitley, 1957); for *Palunolepis grandis* and *P. brachydactylus* (Smith, 1961); and for *C. variegatus* (Nielson, 1963). This distinctive post-larval stage may be characteristic of all cheilodactylids, and thus a useful character to distinguish them from other 'cirrhitiform' fishes.

Juveniles (more than 80 mm SL) look essentially like adults, and both are normally benthic fish, commonly seen 'perched' on rock or coral in the same fashion as the tropical hawkfishes (Cirrhitidae). They feed on benthic invertebrates and algae.

The species is well known to local anglers and spearfishermen, who refer to it as the 'red-lip morwong' or simply 'red-lips'; hence the Latin name *Cheilodactylus rubrolabiatus*.

Although this paper does not purport to be a revisionary work, a definition of the genus *Cheilodactylus* seems called for.

Cheilodactylus Lacepède, 1803

Cheilodactylus Lacepède, 1803:5 (Type-species: *Cheilodactylus fasciatus* Lacepède, 1803, by monotypy).

- Clodactylus* Rafinesque, 1815:88 (Unjustified substitute for *Cheilodactylus* Lacepède, 1803, and therefore taking the same type-species).
- Pteronemus* Hoeven, 1833:247 (Type-species: *Pteronemus cynaedus* Hoeven, [= *C. fasciatus* Lacepède] by subsequent designation of Whitley, 1957).
- Trichopterus* Gray, 1854:162 (Type-species: *Trichopterus indicus* Gray, by monotypy; preoccupied by *Trichopterus* Agassiz, 1845, a fish).
- Chilodactylus* Günther, 1860:78 (Unjustified emendation of *Cheilodactylus* Lacepède, 1803; and therefore taking the same type-species).
- Acantholatris* Gill, 1862:119 (Type-species: *Chaetodon monodactylus* Carmichael, 1818, by original designation).
- Chirodactylus* Gill, 1862:119 (Type-species: *Cheilodactylus antonii* Cuvier and Valenciennes, 1833, by original designation).
- Goniistius* Gill, 1862:120 (Type-species: *Cheilodactylus zonatus* Cuvier, 1830, by original designation).
- Zeodrius* Castelnau, 1879:377 (Type-species: *Zeodrius vestitus* Castelnau, 1879 [= *Cheilodactylus gibbosus* Richardson, 1841], by subsequent designation of Jordan, 1919).
- Morwong* Whitley, 1957:65 (Type-species: *Chilodactylus fuscus* Castelnau, 1879, by original designation).

Diagnosis

Body compressed, oblong, with moderate-sized, cycloid scales. Mouth small, terminal; upper jaw slightly protrusile; lips thick and fleshy in adults; no supramaxilla. Teeth cardiform, in several rows on jaws; none on vomer or palatines. Gill membranes united, free from isthmus. Preopercle entire; opercle ending in two, widely spaced, blunt points. One dorsal fin with 16-19 spines and 23-37 rays. Anal fin with three spines and 8-12 rays; anterior rays much longer than posterior rays. Dorsal and anal fins with scaly sheath along the base. Caudal fin moderately forked, with 13 branched rays. Pectoral fin with 13-15 rays, the lower 4-7 unbranched, thickened, slightly prolonged. Branchiostegal rays six. Gas bladder present. Vertebrae 34 or 35, including hypural centrum.

The currently accepted generic classification of the family Cheilodactylidae (as gleaned from the works of Penrith, 1967; Smith, 1961; Whitley, 1957; and Norman, 1937) is most unsatisfactory. It seems that the genera *Goniistius*, *Acantholatris*, *Chirodactylus*, *Zeodrius*, and *Morwong* were erected solely because their type-species differed in some way from *Cheilodactylus fasciatus*. No attempt was made to assess these differences or demonstrate their greater significance as compared with the intra-generic

differences. In fact, the differences between these various type-species and *C. fasciatus* are no greater than those between *C. fasciatus* and any other species of *Cheilodactylus*. In erecting his genera, Gill (1862) was also led astray by Günther's (1860) erroneous datum of five hundred branchiostegal rays in *C. fasciatus*.

**KEY TO THE AUSTRALIAN SPECIES
OF THE FAMILY CHEILODACTYLIDAE**

- 1a. Anal fin III,14-19; anterior rays not much longer than posterior ones; anal fin base longer than length of longest ray
 2
- 1b. Anal fin III,8-10; anterior rays much longer than posteriors; height of anal fin greater than length of its base
 4
- 2a. Anal fin III,17-19; dorsal fin XVI-XVII,30-31; lateral-line scales 64-68; head and body blue dorsally, paler ventrally, with bright yellow lines around eyes and across snout (Western Australia, South Australia, Victoria and Tasmania)
 *Nemadactylus valenciennesi*
- 2b. Anal fin III,14-17; dorsal fin XVII-XIX, 25-30; lateral-line scales 53-60
 3
- 3a. Anal fin III,14-15; broad black bar across nape from dorsal fin origin to upper edge of operculum; young (<60 mm SL) without black blotch near middle of lateral line (Western Australia, South Australia, Victoria, Tasmania & New South Wales)
 *Nemadactylus macropterus*
- 3b. Anal fin III,16-17; no black bar across nape; young (<60 mm SL) with small black blotch on flanks near middle of lateral line

(Queensland, New South Wales, Victoria, and Tasmania)

... .. *Nemadactylus douglasii*

4a. Dorsal fin spines XVII-XVIII, those near front of fin at least twice length of last spine; cheeks scaly

... .. 5

4b. Dorsal fin XV-XVI,24-26; anterior spines not elevated; cheeks naked; lateral-line scales 45-55 (Western Australia, South Australia, Victoria, Tasmania & New South Wales)

... .. *Dactylophora nigricans*

5a. Dorsal fin XVIII,24-28; lateral-line scales 65-70; head and body pale, with broad dark vertical band from spinous dorsal to pelvic fins; fainter dark bands usually present from soft dorsal to anal fins and on front of head (Western Australia, South Australia, Victoria, and Tasmania)

... .. *Cheilodactylus nigripes*

5b. Dorsal fin XVI-XVIII,26-35; lateral-line scales 48-64

... .. 6

6a. Spinous dorsal fin much elevated anteriorly (4th spine 4 to 5 times length of last spine); body pale with broad oblique dark bands: the longest runs from middle dorsal spines, along base of fin to peduncle and lower lobe of caudal fin; a second band goes from dorsal fin origin to belly; a V-shaped band runs from lower edge of orbit to pectoral fin base, thence up to join its fellow on nape; two dark bands cross interorbital, and a third crosses snout; soft dorsal fin and upper lobe of caudal fin yellow (Western Australia, New South Wales and Queensland)

... .. *Cheilodactylus gibbosus*

6b. Spinous dorsal fin not much elevated anteriorly (4th spine only about twice length of last

- spine); colour not as above
 7
- 7a. Dorsal fin rays 26-27; lateral-line scales 48-54; head and body pale, with 6 to 8 vertical dark brown bars, the last encircling caudal peduncle, the first across interorbital area (New South Wales, Victoria, and Tasmania)
 *Cheilodactylus spectabilis*
- 7b. Dorsal fin rays 30-34; lateral-line scales 60-64
 8
- 8a. Body generally reddish-brown, paler ventrally; adults with two prominent bony knobs in front of eyes and another at front of snout; anal fin rays 9 (8 in only 1 of 10 specimens counted) (South Australia, Victoria, New South Wales, and Queensland)
 *Cheilodactylus fuscus*
- 8b. Body pale with seven oblique dark bars or blotchy bands: first across nape and last at base of caudal fin; anal fin rays 8 (Western Australia)
 *Cheilodactylus rubrolabiatus* n. sp.

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A PRELIMINARY EXAMINATION OF EUTHECOSOMATOUS PTEROPODS OFF THE CENTRAL COAST OF WESTERN AUSTRALIA

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ABSTRACT

Twenty-one species of euthecosomatous pteropods were collected in plankton tows and dredge hauls made off the western coast of Western Australia. All species except *Limacina helicina* were tropical. *Limacina trochiformis* and *L. inflata* were the most abundant species in both the plankton and the sediment. Small individuals dominated the populations of both species.

INTRODUCTION

Euthecosomatous pteropods are a very poorly known group of opisthobranch gastropods. In contrast to the vast majority of marine gastropods, euthecosomes are holoplanktonic; they deposit free-floating egg masses from which veligers hatch and develop into free-swimming adults without ever touching the bottom. The group is highly modified for planktonic existence in several ways; the shell is reduced and the animals have a small body size; the foot is modified into a pair of swimming wings, or parapodia; all species are ciliary mucous feeders; and reproduction is highly specialised. Euthecosomes are the animals whose shells form the pteropod oozes found in some areas of the ocean floor.

Euthecosome species are widely distributed in temperature zones. The tropical species are found over the warm water areas of the Atlantic, Pacific, and Indian Oceans. Broad distributional patterns of the various species are known, but distribution in localised areas is largely unstudied. Recent work in the Atlantic Ocean has shown two genera — *Limacina* (*Spiratella*) and *Creseis* to be more important numerically than has been previously thought (Wells, 1976). This is because the small individuals of

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these genera readily slip through the large meshed nets used by most investigators (Wells, 1973).

Euthecosome distributions in the Indian Ocean are not as well known as in the two larger oceans. Tesch (1948) showed the broad distributional patterns of a number of the most common species based on the Dana collections and on records made by merchant ships. Frontier (1963) made a detailed study of the distribution of euthecosomes in several areas of the northwestern Indian Ocean: the Arabian Sea, Persian Gulf, and Gulf of Aden.

The availability of ship time on dredging cruises of the MV *Sprightly* in February 1976 and the HMAS *Diamantina* in March 1976 offered an opportunity for a preliminary examination of euthecosomatous pteropods off the central west coast of Western Australia.

MATERIALS AND METHODS

Two oblique plankton hauls were made at night on 15 February 1976 at Sprightly Station 1M (30°21'S; 114°38'E) with a $\frac{3}{4}$ m diameter open plankton net equipped with #20 (80 μ) nylon mesh. Tows were made from 150 m to the surface in an area where the water depth was 165 m. After the net was lost further tows were made at the same station with a 50 cm square open net equipped with a mesh of approximately #8 (200 μ) nylon. The station was revisited on 20 February 1976 and oblique hauls were made during daylight hours with the #8 net. A bathythermographic record was made at this station on 20 February.

Plankton samples were initially preserved in 10% formalin buffered with borax. Upon returning to shore hexamethylene tetramine was substituted as the buffer. The entire #20 tows were examined for euthecosomes and all euthecosome species were identified and counted. Maximum shell diameter of all individuals of *Limacina inflata* and maximum shell length of *L. trochiformis* were measured with a microscope equipped with an ocular micrometer. The #8 samples were searched for species not present in the #20 tows.

As part of the general dredging programme sediment samples were made at Station 1M with a pipe dredge; this and all other sediment samples were preserved in 10% formalin buffered with borax. On shore the sediment sample from Station 1M was subsampled and all euthecosomes identified and counted. Again all available individuals of *Limacina inflata* and *L. trochiformis* were measured. Sediment samples from the other 'Sprightly' stations were searched for species not found at Station 1M.

The *Diamantina* cruise made three transects along the continental slope at depths of 150 to 400 fathoms. The transects were made at latitudes 31°00', 31°30' and 32°00'S between longitudes 114°46' and 115°12'E. Large numbers of empty euthecosome shells were collected from the sediment during the dredging operations conducted from 15 to 17 March 1976. The shells were identified and several species not collected on the *Sprightly* were found.

RESULTS

The bathythermograph slide from *Sprightly* Station 1M showed a surface water temperature of 23.0°C. The upper layer was homogeneous to depth of 70 m, where the temperature was still 22.5°C. Below 70 m the temperature declined rapidly to 20.0°C at 95 m. There was very little variation below the thermocline; the temperature at 140 m, the maximum depth measured, was 19.0°C.

Table 1: Relative abundances of euthecosomatous pteropods in the plankton and sediments at 'Sprightly' Station 1M (30°21'S; 114°38'E) off Western Australia in February 1976.

	Plankton %	Sediment %	Sediments from other Stations
<i>Cavolinia gibbosa</i> (d'Orbigny, 1836)	-	-	Present
<i>Cavolinia inflexa</i> (Lesueur, 1813)	4.3	1.2	Present
<i>Cavolinia longirostris</i> (Blainville, 1821)	-	-	Present
<i>Cavolinia tridentata</i> (Niebuhr, 1775)	-	-	Present
<i>Cavolinia uncinata</i> (Rang, 1829)	-	-	Present
<i>Clio balantium</i> (Rang, 1834)	-	-	Present
<i>Clio cuspidata</i> (Bosc, 1802)	-	-	Present
<i>Clio pyramidata</i> (Linnaeus, 1767)	2.8	2.1	Present
<i>Creseis acicula</i> (Rang, 1828)	2.4	0.8	Present
<i>Creseis virgula conica</i> (Rang, 1828)	1.0	1.6	Present
<i>Creseis virgula virgula</i> (Rang, 1828)	0.4	0.4	Present
<i>Cuvierina columnella</i> (Rang, 1827)	0.2	0.2	Present
<i>Diacria quadridentata</i> (Blainville, 1821)	1.2	0.2	Present
<i>Diacria trispinosa</i> (Blainville, 1821)	0.4	1.0	Present
<i>Hyalocylix striata</i> (Rang, 1828)	0.2	0.0	Absent
<i>Limacina bulimoides</i> (d'Orbigny, 1836)	0.8	1.0	Present
<i>Limacina helicina</i> (Phipps, 1774)	0.2	0.0	Absent
<i>Limacina inflata</i> (d'Orbigny, 1836)	31.6	38.4	Present
<i>Limacina lesueuri</i> (d'Orbigny, 1836)	0.6	0.8	Present
<i>Limacina trochiformis</i> (d'Orbigny, 1836)	52.5	51.5	Present
<i>Styliola subula</i> (Quoy and Gaimard, 1827)	1.4	1.2	Present
Total	100.0	100.4	
n	514	510	

Plankton samples

Fifteen species and subspecies of euthecosomes were collected in the plankton at Station 1M (Table 1). The most abundant species were *Limacina trochiformis*, with 52.5% of all euthecosome individuals collected, and *L. inflata*, with 31.6%. In all, the 5 species of *Limacina* collected comprised 85.7% of all the whole euthecosome catch. The remaining 10 species and subspecies of other genera were present only in small numbers. This is particularly true of the 3 species and subspecies of *Creseis*¹, which together constituted only 3.8% of the total euthecosome numbers.

The size frequency histogram of *Limacina trochiformis* collected in the plankton is shown on Fig. 1. *Limacina trochiformis* collected off Western Australia ranged from 0.10 to 1.16 mm in shell length; the mean size was 0.33 ± 0.20 mm. Most individuals (56.9%) were veligers 0.16 to 0.24 mm in shell length. Individuals of *L. inflata* ranged from 0.08 to 1.00 mm in shell diameter; the mean shell diameter was 0.19 ± 0.06 mm.

Sediment samples

Limacina trochiformis was also the most abundant species in the sediment samples (Table 1). The percentage of individuals of this species (51.5%) in the euthecosome count of the sediment sample is very close to the 52.5% recorded in the plankton. *Limacina inflata* was relatively more abundant in the sediment (38.4%) than in the plankton (31.6%). The relative abundance of the genus *Limacina* as a whole was greater in the sediment (91.7%) than in the plankton (85.7%), due entirely to the higher proportion of *L. inflata* in the sediment. All other species were represented by small numbers of individuals in the sediments, giving similar relative abundance to those exhibited in the overlying water column. Specimens of three species and subspecies of *Creseis* composed 2.8% of all euthecosomes collected in the sediments.

Empty shells of 6 species not found in the plankton were recorded from the complimentary dredge samples. They were *Cavolinia gibbosa*, *Ca. longirostris*, *Ca. tridentata*, *Ca. uncinata*, *Clio balantium*, and *C. cuspidata*.

The size frequency histogram of *Limacina trochiformis* collected in the sediment is also shown on Fig. 1. The mean of the shell length was 0.31 ± 0.08 mm. This was not statistically different (t-test, 0.05 confidence level) from the mean of 0.33 mm recorded in the plankton. Unbroken large shells of *L. trochiformis* were absent in the sediment. Several fragments of adult shells were found, but their total length could not be determined.

¹The taxonomic positions of *Creseis virgula virgula* and *C. virgula conica* are uncertain. This paper follows the classification suggested by Chen and Bé (1964).

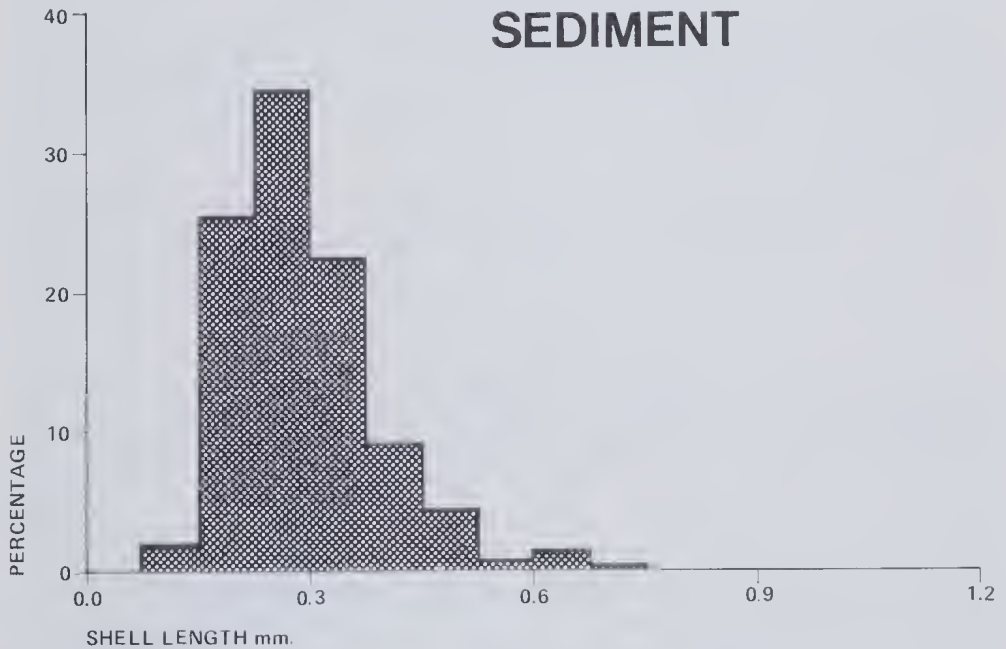
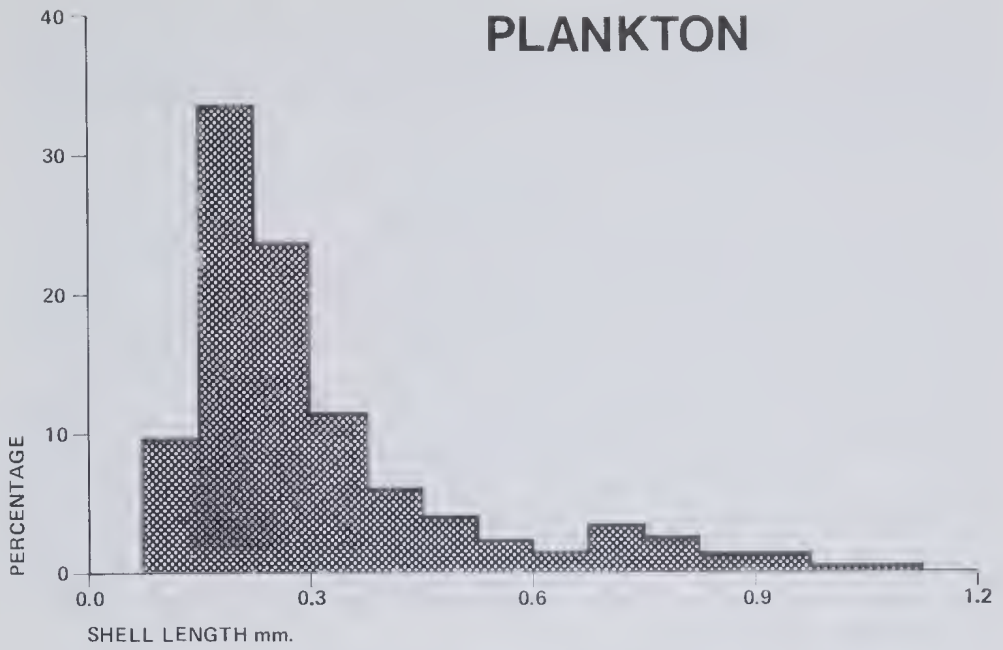


Fig. 1: Size-frequency histograms of *Limacina trochiformis* collected in the plankton and sediment at 'Sprightly' Station 1M (30°21'S; 114°38'E) off Western Australia in February 1976.

The mean diameter of *L. inflata* in the sediment was 0.36 ± 0.15 mm, significantly larger than in the plankton (t-test, 0.05 confidence level). The largest *L. inflata* found was an empty shell 1.52 mm in diameter taken from the sediment samples.

DISCUSSION

The most recent distributional maps (van der Spoel, 1967) have a paucity of data on species distributions along the west coast of Western Australia. The present data extend the known ranges of most of the species for several hundred miles eastward to the Western Australian coast. Van der Spoel (1967) reported only *Limacina helicina* and *Clio pyramidata* in the waters off South Australia. He was apparently unaware of the report by Cotton (1959) on the molluscs of South Australia which listed 9 additional species: *Cavolinia longirostris*, *C. inflexa*, *C. tridentata*, *Diacria trispinosa*, *Clio balantium*, *Creseis virgula*, *Limacina bulimoides*, *L. inflata*, and *Styliola subula*. Cotton (1959) actually lists *Cavolinia telemus* Linnaeus, 1758, but the correct designation of this species is *Cavolinia tridentata* (Niebuhr, 1775) (van der Spoel, 1967).

The isolated individual of *Limacina helicina* collected during this study off central Western Australia is the only cold water species recorded in this area. Rochfort (1967) described a West Australian Current flowing northward during the summer months. It is probable that the *L. helicina* was brought north by the West Australian Current to a latitude outside the normal range of the species.

The plankton samples were spread over a period of only 5 days, and thus might not accurately reflect the relative abundances of the various species over a year. The most abundant species, *Limacina trochiformis*, is known to be particularly prone to variations in seasonal abundance (Wells, 1976). However euthecosome shells deposited in shallow sediments have been shown to accurately reflect the composition of living species in the overlying water column (Chen, 1964; Wells, 1975). Since shells deposited in the sediment represent a much longer time period, the sediment samples made off Western Australia offer a more reliable picture of the long term relative abundances of euthecosome species. Both the plankton and sediment samples show the tropical nature of the euthecosomatous pteropod fauna off the west coast of Western Australia. The relative proportions of species in the two were similar. *Limacina trochiformis* was 52.5% of all individuals collected in the plankton and 51.5% in the sediment. *Limacina inflata* was the second most numerous species in both provinces. In all, the 5 species of *Limacina* comprised 85.7% of all euthecosomes in the plankton and 91.7% in the sediment.

Although mesh size of the net is the most important factor in adequately sampling small species of euthecosomes (Wells, 1973), the only comparative quantitative data with an 80 μ mesh was collected off Barbados, West Indies (Wells, 1976). In two years of sampling off Barbados the genus *Limacina* constituted 70.7% of the numbers of all euthecosomes collected; it was also the dominant genus off Western Australia. Individuals of the three species and subspecies of *Creseis* formed 27.3% of the euthecosomes collected off Barbados, but were only 3.8% of the catch numbers off Western Australia. The fact that members of the genus *Creseis* numbered only 2.8% of the shells in the sediment indicates that the relative paucity of this genus in the plankton was not a short term phenomenon. Though no figures for 80 μ mesh are available for other areas of the Indian Ocean, Frontier (1963) showed *Creseis* to be abundant in collections made with larger meshed nets in the Arabian Sea and Gulf of Aden, but not in the Persian Gulf. The reasons for the rarity of *Creseis* off Western Australia are not known, and it would be interesting to know whether the genus is similarly rare in other parts of the Indian Ocean.

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FURTHER OBSERVATIONS ON REPRODUCTION IN THE COMMON SHEATH-TAILED BAT, *TAPHOZOUS GEORGIANUS* THOMAS, 1915 IN WESTERN AUSTRALIA, WITH NOTES ON THE GULAR POUCH.

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ABSTRACT

Reproductive cycles of adult *T. georgianus* from the south Murchison area are similar to those of this species from more northern localities reported in Kitchener (1973).

Over its range in Western Australia female *T. georgianus* are thought to be monoestrous. There appears to be a brief anoestrus during mid autumn to mid winter before females assume reduced activity in reproductive organs. The depth of the gular pouch in adult males is correlated with testicular activity and enlargement of accessory glands.

INTRODUCTION

Aspects of the reproduction of *Taphozous georgianus* have been described from histological preparations of Museum specimens collected principally from the Pilbara and Kimberley districts of Western Australia (Kitchener 1973). From that study it appears that *T. georgianus* females are monotocous with young born from October through to February; only the right ovary is functional and pregnancies occur only in the right horn. They are considered monoestrous. Sperm are not stored in the reproductive tract of females. In males spermatogenesis appears to occur throughout the year; testes descend to scrotal sacs in summer and ascend abdominally in autumn, winter, and spring.

Although changes have been observed in aspects of reproduction within species of Australian bats at different localities (Dwyer 1968, 1970; Douglas 1967, and Kitchener 1975), Kitchener (1973) observed no such changes in *T. georgianus* from the Kimberley, with its reliable summer

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rainfall, and the Pilbara, which has a markedly different climate of unreliable rainfall in all seasons. In late 1972 a population of *T. georgianus* was discovered at Tallering Peak, 28°06'S, 115°38'E. This is the most southern known population of this species in Western Australia (400 km north east of Perth). Further, the climate at Tallering Peak, which is on the boundary of Gaffney's (1970) Southern Region of reliable winter rainfall and Central Region of unreliable rainfall, is different from other Western Australian localities from which *T. georgianus* had been previously collected. Because reproduction of *T. georgianus* at Tallering Peak may differ from that previously recorded (Kitchener 1973), a collection was made throughout 1973 at this locality, and during June of that year from Murgoo (27°22'S, 116°25'E).

This collection of fresh specimens of *T. georgianus* from the south Murchison area should provide a more detailed description of their reproduction and allow comparison with the previous study (Kitchener 1973), which was based on specimens collected opportunistically from many localities during the preceding fifteen years.

Taphozous georgianus has a glandular area beneath the throat (Ride 1970). This gland is visible in adults of both sexes from Tallering Peak and Murgoo but is only pouched in males. It may be that it is involved in agonistic or mating behaviour because glandular areas on several other species of bats appear to play a role during such behaviour by disseminating an olfactory signal. For example, Pearson *et al.* (1952) record that the very glandular snout of *Corynorhinus rafinesquei* (Lesson) is rubbed over females of that species during precopulatory behaviour, apparently to induce submission. Bradbury and Emmons (1974) have observed male *Saccopteryx bilineata* (Temminck) voluntarily open the muscular orifice of their wing gland and then sharply shake their wings (in an action they refer to as *salting*) during territorial displays against females, and during interactions within their territories with females.

This paper also reports on the possible function of the gland in male *T. georgianus* by comparing development of the gular pouch with male reproductive condition.

MATERIALS AND METHODS

This study is based principally on a collection from Tallering Peak of 25 adult females, 3 attached young, and 19 adult males. They were collected by mist netting and shooting with .22 dust shot, from an exploratory tunnel for iron ore more than 50 m long. However, because they were not seen at Tallering Peak during June 1973, 3 adult females and 4 adult males

were collected during that month at Murgoo from a lateritic breakaway. Table 1 shows the number of adult *T. georgianus* from each month used in this study and their date of collection. All specimens have been accessed into the Western Australian Museum collection and have the numbers M 10115-30, M 10191-2, M 10239-42, M 10244-6, M 10673-88, M 10693-8, M 10938-9(A & B), M 10940, M 11030-1, M 12715-7, M 12719.

Table 1: Number of adult *T. georgianus* collected at Tallering Peak during 1973, and date of collection. Numbers in brackets indicate those examined histologically.

Date	Adult Males	Adult Females
13 January	1 (1)	1 (1)
21 April	6 (6)	9 (7)
14 May	0	2 (2)
* 3 June	4 (4)	3 (2)
12 August	9 (8)	7 (4)
1 October	3 (3)	3 (0)
15 December	0	3 (3)

*Collected at Murgoo

All specimens were fixed in 10% formalin and preserved in 75% alcohol. Adult condition was judged from absence of swelling of digital joints and general size. Forearm lengths of adult males and adult females ranged from 64.3 to 70.3 mm, and 66.1 to 71.3 mm respectively. Table 1 also shows number of specimens from each monthly sample selected for histological preparation; no October females were thus selected because their condition was obvious — they were carrying moderately large fetuses; juveniles were not included in this aspect of the study. In addition to those shown in Table 1, histological preparations were made of ovaries of 4 females with enlarged teats collected at Tallering Peak on 13 January 1975.

Reproductive organs were placed in Bouin's fluid after formalin. Sections were stained in Erlich's haemotoxylin and counterstained in eosin. With females, sections were cut from vagina, corpus uteri, uterine horns, ovaries, and occasionally uterine glands. With males, sections were cut from testis, the head, body and tail of epididymis, vas deferens, vesicula seminalis, prostate, and bladder. All sections were cut at 10 μ m and every twentieth section was retained, except for ovaries where every tenth section was retained.

Measurements from histological preparations were recorded as follows: diameters of seminiferous tubules for each male by averaging measurements of 30 tubules; the diameters of each tubule is an average of the length of its longest axis through cross section and length of axis at right angles to this. The diameter of nuclei of interstitial cells of each individual is an average of 30 measurements. Size of male accessory glands and uterine horn endometrium is the maximum width measured from sections; because only every twentieth section was retained, some of these measurements could be slightly less than their actual width. Diameters of corpora lutea and ovarian follicles were measured as nearly as possible through their centres and are the average of a measurement through the long axis and another at right angles to this. Counts and measurements were taken only from secondary follicles which have more than two layers of follicle cells.

Depth of gular pouch is an average of two measurements recorded with a probe from the bottom of the pouch to the opposite corners formed by the lip of pouch with throat.

OBSERVATIONS

(a) Male reproduction.

(1) Spermatogenic cycle.

As shown in Table 1, adult males were captured in January, April, June, August, and October. An indication of male reproductive condition throughout the year was given by these specimens and this information is summarized in Figs 1 and 2. The first of these figures indicates that in all monthly samples males were found with active testes, that is with developed sperm in seminiferous tubules, or with numerous early to late spermatid stages. Further, in all these samples (only one male from January) there were some males with inactive testes, that is with spermatid stages lacking or infrequent. Males with few or no sperm in testes had no sperm in the reproductive tract, suggesting that sperm were not stored in tubes or accessory glands during cessation of spermatogenesis.

The observation that there was no interstitial tissue in testes of adult male *T. georgianus* (Kitchener 1973) was mistaken; this was clearly observed in the present study.

Figs 1 and 2, in addition to indicating testicular activity in monthly samples, show the diameter of seminiferous tubules (Fig. 1a), and interstitial cell nuclei (1b), maximum width of prostate (2a), vesicula seminalis (2b),

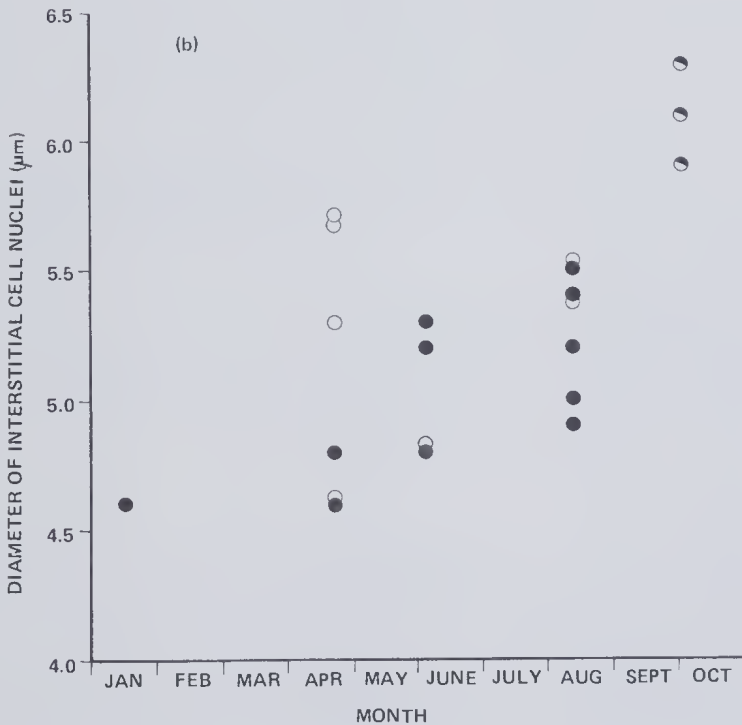
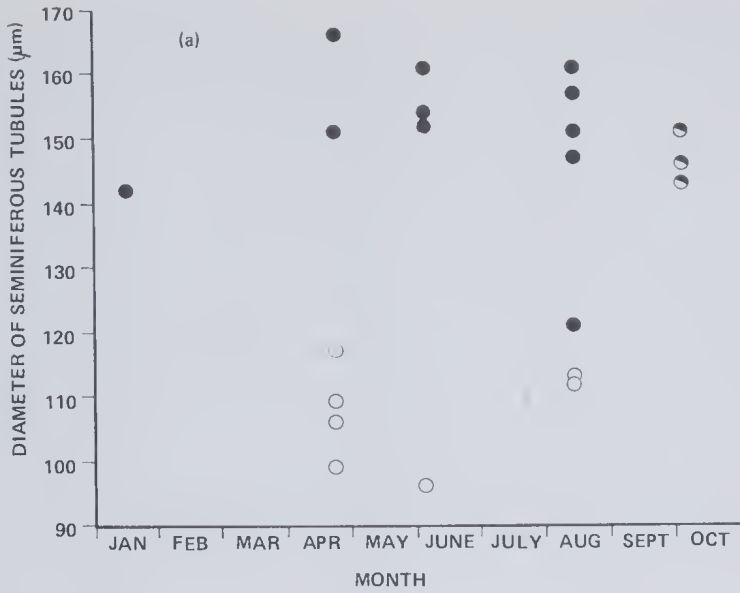


Fig. 1: Testicular activity of adult male *T. georgianus* from Tallering Peak in monthly samples collected during 1973. (a) diameter of seminiferous tubules, (b) diameter of interstitial cell nuclei. Males with spermatozoa (●), numerous early to late spermatid stages (◐), and absence of spermatids or presence of only occasional spermatid stages (○) are indicated.

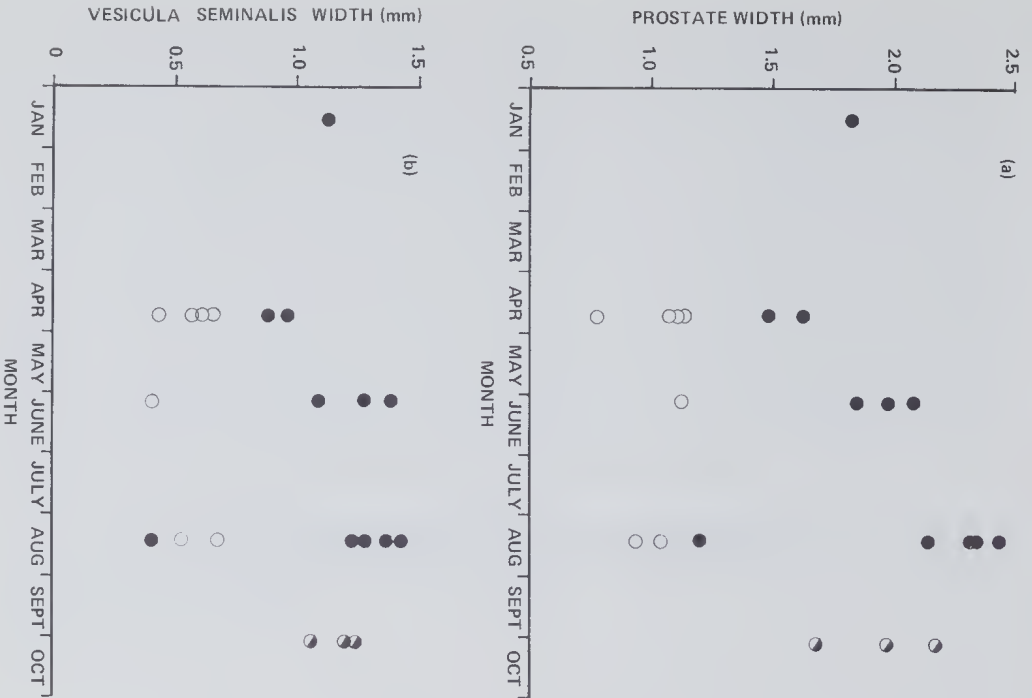


Fig. 2: Width of accessory glands in adult male *T. georgianus* from Tallinging Peak in monthly samples collected during 1973. (a) prostate, (b) vesicula seminalis and (c) ampulla of Henle. Males with spermatozoa (●), numerous early to late spermatid stages (◐), and absence of spermatids or presence of only occasional spermatid stages (○) are indicated.

and ampulla of Henle (2c), in each month. From Figs 1a and 2a-c, it is apparent that males with spermatazoa or early to late spermatid stages in testes have considerably larger seminiferous tubules than those with inactive testes. The exception is the single autumn specimen which is thought to have declining testicular activity. Further, accessory glands of males with active testes tend to be smallest in April and increase in size in June and August. It is likely that in the field population accessory glands of males from October onward would further enlarge as their testes become more active. From Fig. 1b there appears to be a trend for interstitial cells to increase from January through to October. However, there is in each monthly sample an indication that interstitial cells are larger in inactive testes than they are in active testes, possibly suggesting imminent commencement of spermatogenesis in inactive testes. Certainly, with the exception of the male collected in June which has only spermatogonia and Sertoli cells, inactive testes have numerous spermatogonia and primary spermatocytes, and some have early spermatid stages.

Although males were not collected at Tallering Peak during early summer it is thought that they are reproductively active at that time. This is suggested by the collection of a female at this locality on 13 January 1973 which had a developing corpus luteum of diameter 110 μm , and a small blastocyst of diameter c. 1.1 mm in the horn. This pregnancy was presumably from a very recent copulation because there is no evidence in this or the previous study of sperm storage in females or delayed blastocyst development.

The position of the testes of male *T. georgianus* in this study suggests a similar seasonal pattern as noted in Kitchener (1973). At Tallering Peak and Murgoo, testes were located inguinally in April and June, abdominally in August and October, and in the scrotum only in January.

(2) Gular pouch.

The pouch at the posterior part of the glandular area of male *T. georgianus*, shown in Fig. 3, varies considerably in its depth. It is, then, of interest to record that in males with active testes the average depth of this pouch is 3.9 mm which is very significantly greater than its average depth in males with inactive testes of 3.0 mm (Student T test: $t = 13.8$, $df. = 20$, $p < .001$). These statistics include a male (M 10681) in which the histological preparation is poor but nevertheless adequate to recognise numerous sperm in tubules. This male is not referred to elsewhere in this study. From Fig. 4 and Table 2 it is seen that development of the pouch is closely correlated with enlargement of seminiferous tubules and accessory glands.



Fig. 3: Ventral surface of throat region of male *Taphozous georgianus* (M 10683) from Tallinging Peak showing the glandular area with posterior facing pouch. X 4.

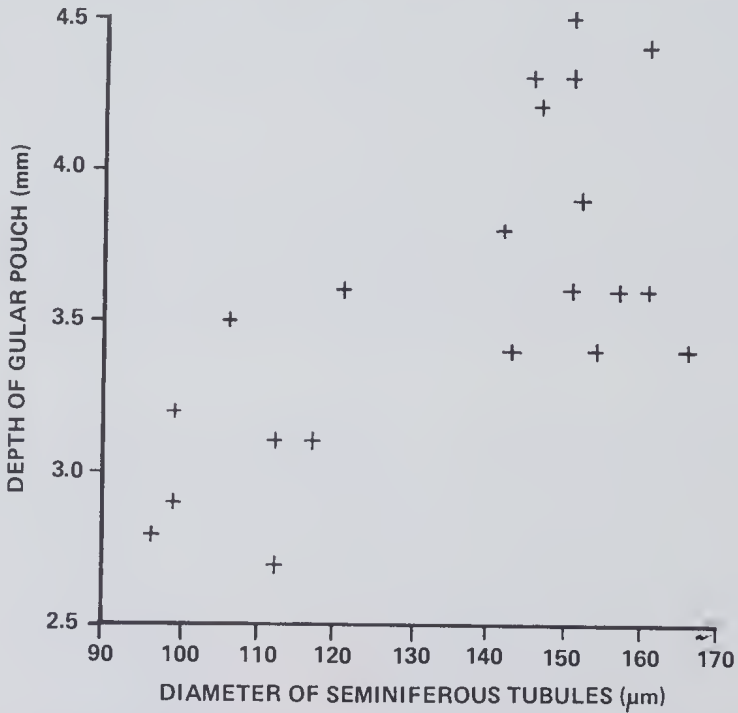


Fig. 4: Relationship between depth of gular pouch and diameter of seminiferous tubules in male *T. georgianus* from Tallinging Peak during 1973.

Table 2: Correlation coefficients between depth of gular pouch of adult males at Talling Peak (and Murgoo) and diameter of seminiferous tubules, and maximum width of accessory reproductive organs.

	r	d.f.	p	significance
seminiferous tubules	0.762	19	$p < .001$	+++
vesicula seminalis	0.735	19	$p < .001$	+++
prostate	0.702	19	$p < .001$	+++
ampulla of Henle	0.695	19	$p < .001$	+++

(b) Female reproduction.

(1) Period of births.

At Talling Peak females are monotocous but of the twelve females in which the pregnant horn could be recognised, two showed evidence of recent pregnancy in the left horn from the left ovary. These two females, which were lactating when caught on 21 April, had only recently given birth; they had swollen uteri and left ovaries with large corpora lutea 120 and 190 μm in diameter respectively.

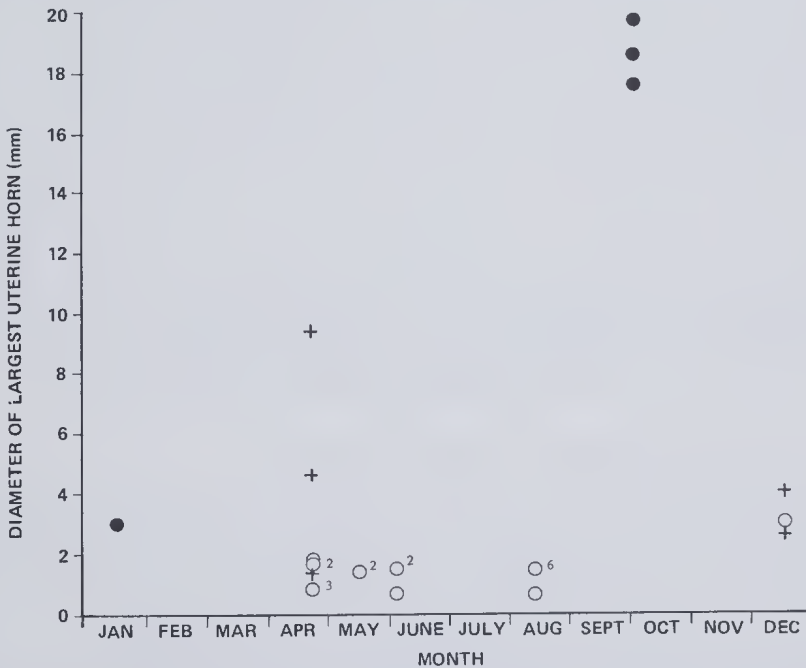


Fig. 5: Maximum diameter of largest uterine horn of pregnant (●), non pregnant (○), and lactating (+) *T. georgianus* from Talling Peak, and date of capture during 1973.

An indication of the period of births for this species at Tallering Peak can be obtained from Fig. 5 which records date of capture of adult females, maximum diameter of largest horn and whether or not they were pregnant or lactating when collected. Three females collected in early October were pregnant and had uterine horns 17.5 to 18.7 mm in diameter. At term the uterine horn has a diameter of about 33 mm (Kitchener 1973). Two females collected in mid December were lactating and had relatively involuted horns; one had no luteal tissue in either ovary, the other had a small degenerating corpus luteum 51 μm across. These females probably gave birth in late November or early December, one to three weeks prior to their capture. Another female was in early pregnancy in January, and on 21 April three females were collected still lactating and these had recently given birth; a young with attached umbilical cord was collected with these April females.

These observations suggest that births occur between late November and late April.

(2) Lactation.

Of the females used in the histological study, two collected in April and two in December were lactating. The April females had large deteriorating corpora lutea of 610 and 970 μm diameter in left ovaries, and one of the December females had a small corpus luteum 260 μm across in the right ovary. Ovaries with a corpus luteum had only small follicles, none of which was tri-laminar; contralateral ovaries had numerous (12-31) secondary follicles, some vesicular; the largest was 326 μm in diameter. Several bi-, tri- and quadri-ovular follicles were also present. The lactating female with ovaries lacking luteal tissue had numerous primary follicles but only a few moderate sized secondary follicles. Their uterine horns were swollen and full of detritus from the breakdown of endometrium, blood vessels, and tissue resulting from pregnancy and parturition. Their vaginal tracts were lined by 2-4 layers of cuboidal epithelium with many leucocytes.

(3) "Relative quiescence" to early pro-oestrus.

These females, collected from April, May, June and August, are diagnosed by their reduced endometrium which averages 185 μm (100-260 μm) in thickness, and lack of stratification or cornification of vaginal epithelium. The term 'relative quiescence' is applied here because some of these females had an endometrium that was proliferating (mitotic figures were common) and had ovaries which, with one exception, had 6 to 54 secondary follicles with vesicles, some of which were well developed and range in maximum diameter from 245 to 383 μm . Only one female, collected in April, had no

large follicles in the right ovary and apart from a single large vesicular follicle 428 μm in diameter, this was the situation in its left ovary. Only one of these females lacked numerous atretic follicles throughout; this is a May specimen which had small secondary follicles without developed vesicles. The vaginal epithelium varies from 2 to 4 layers of cuboidal epithelium to 2 to 3 layers of stratified epithelium. Leucocytes were frequent amongst the cuboidal epithelium.

(4) Pro-oestrus.

This condition was found in two females, one from June and the other from August. It was diagnosed by the proliferation of the endometrium to a thickness of 230-310 μm , and stratification with some cornification of vaginal epithelium. Right ovaries of the two specimens had 19 and 21 moderate sized secondary follicles with a mean diameter of 240-265 μm (122-326 μm). Numerous atretic follicles occurred throughout both ovaries.

(5) Oestrus.

This condition is observed in two females, one collected in August, the other December. It is diagnosed by continuing cornification of vaginal epithelium, increased proliferation of endometrium to a thickness of 310-400 μm , and the presence of 16 to 42 moderate sized vesicular follicles, with mean diameter of 231 and 251 μm , including several very large follicles of 408 and 536 μm diameter in the right ovaries. The largest of these follicles was atretic; numerous small atretic follicles occurred throughout both ovaries.

DISCUSSION

Females at Tallering Peak gave birth to young over a five month period between late November and late April suggesting that the period of births at this locality is similar to that recorded previously at more northerly localities in Western Australia (Kitchener 1973).

It was suggested in the previous study of this species (Kitchener 1973) that females with small uterine horns during the period late autumn to early winter were in anoestrus, and that the absence of any truly reproductively quiescent females at that time reflected the nature of the collection and not the probable reproductive cycle of individuals. However, in the present study only one female, collected almost at the completion of its lactation, approached anoestrus and most of the females collected in autumn and winter (April, May, June and August) showed only reduced activity in the reproductive tract and ovaries. These observations, coupled with those of

the earlier study, suggest that the mid autumn and winter period for females is one of reduced activity of reproductive organs, but not one of total inactivity.

Observations on the reproduction of males collected from Tallering Peak are consistent with the conclusions of the earlier study (Kitchener 1973), namely that some have active spermatogenesis throughout the year. However, in several of the monthly samples from Tallering Peak, males were collected with inactive testes and small accessory glands. Further, these males had larger interstitial cell nuclei than males with active testes and enlarged accessory glands. If size of interstitial cell nuclei measured from histological preparations reflects levels of androgen production (although according to Racey and Tam (1974) this is contentious), then males with inactive testes may soon commence spermatogenesis and those with active testes may soon cease production of sperm. It is interesting that although males appear to be fertile all year, sperm were not recorded from the reproductive tract of females during this study, and from only one female in the previous study.

In examining the possibility that the glandular area beneath the throat in male *T. georgianus* plays a role in their social (particularly mating) behaviour, it has been presumed that the degree of development of the pouched part of this glandular area reflects the level of activity of the gland. This being so it would appear that its activity is closely influenced by levels of androgens because increase in its depth is correlated with testicular activity and closely parallels enlargement of seminiferous tubules and accessory glands.

Bradbury and Emmons (1974) stated that the development of the wing gland in *Saccopteryx bilineata* has 'some bearing on maturational processes', and that at 2½ months of age the glands of males are small and similar to adult females in development, while at 6 months of age the glands of the majority of males are fully developed. Similarly it is possible that the size of the gland in these *T. georgianus* relate to nothing more than their sexual maturity. This is not, however, thought to be the case because males used in this study were adult in that they were fully grown and lacked swelling of digital joints. Further, the four males with the deepest gular pouch were amongst those with the least tooth wear and presumably, then, amongst the most recently adult. In conclusion, it is felt that the glandular area in *T. georgianus* males is influenced by their reproductive condition and probably plays some role in male social behaviour.

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A REVIEW OF THE FISH GENUS NEOODAX (ODACIDAE) OF WESTERN AUSTRALIA WITH DESCRIPTION OF A CLOSELY ALLIED NEW GENUS AND SPECIES

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ABSTRACT

The Western Australian Odacidae are reviewed. The family is comprised of ten species belonging to six genera. Of these *Odax*, consisting of the monotypic species *Odax pullus*, was not collected from this state; *Olisthops*, consisting of the distinctive species *Olisthops cyanomelas*, was not examined, and the related *Heteroscarus* and *Siphonognathus*, which are sometimes placed in separate families, are included in the key but not described in the text. The genera *Haletta* and *Sheardichthys* have been included in *Neoodax* as they are not outside the variability of this group, and a new genus is described to include odacids with canines and deeply notched dorsal fins.

Two species, *Neoodax beddomei* and *Neoodax attenuatus*, previously known from two specimens from Tasmania are described and figured. These two species with *Neoodax balteatus* are greatly extended in distribution. *Neoodax frenatus* is relegated to the synonymy of *Neoodax radiatus*. *Parodax caninis*, new species, is described from six specimens collected between Carnac and Rottnest Islands, Western Australia. It is separated from other odacids by the presence of canines, four pairs in the upper jaw and one pair in the lower jaw, a deeply notched dorsal, compressed snout, and 45 pored lateral line scales. Apart from the endemic *Parodax caninis* all Western Australian species have a southern Australian distribution.

INTRODUCTION

The family Odacidae contains six genera, including the following five which are monotypic: *Odax* Cuvier, 1829; *Olisthops* Richardson, 1850; *Heteroscarus* Castelnau, 1872; *Siphonognathus* Richardson, 1858; and *Parodax* described herein. The remaining species are included in *Neoodax* (sometimes mis-spelt *Neodax*) Castelnau, 1875. The members of the family are generally small fishes which inhabit shallow coastal seas of southern Australia and New

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Zealand. The group is well represented in Western Australia where all the species occur except *Odax pullus* (Bloch & Schneider 1801). Although Whitley (1948) included it in his checklist, the occurrence of this species outside New Zealand is doubtful.

Dr John R. Paxton of the Australian Museum, Sydney is currently studying the generic classification of the Odacidae.

There is some doubt regarding the inclusion of *Heteroscarus acroptilus* (Richardson, 1846) and *Siphonognathus argyrophanes* Richardson, 1858. The remaining species not treated in this paper, *Olisthops cyanomelas* Richardson, 1850, appears to be closely allied to *Odax*, but is distinct on the basis of less scales in the lateral line and the absence of scales on the head.

All measurements were taken with needle point calipers to the nearest 0.1 millimetre (mm). Most of the measurements are self-explanatory. Body depth refers to the maximum depth; head length is measured from the posterior-most border of the opercular flap; standard length (SL) is measured from the tip of the upper jaw to the base of the caudal fin. The lateral line count includes all lateral line scales with pores. A summary of the counts for the dorsal fin rays and tubed lateral-line scales is presented in Tables 1 and 2.

Type specimens of *Parodax caninis* have been deposited at the Western Australian Museum, Perth (WAM); and the Australian Museum, Sydney (AMS).

KEY TO THE SPECIES OF WESTERN AUSTRALIAN ODACIDAE

- 1a. Pelvic fin absent; lateral line count about 100; thin filament attached to the anterior most edge of the upper lip; body elongated (Western Australia, South Australia, Victoria) *Siphonognathus argyrophanes*
- 1b. Pelvic fin present; lateral line count less than 90; no filaments on the lips; body moderately compressed to elongate 2
- 2a. Jaws with canine teeth; dorsal fin deeply notched at soft dorsal junction; snout compressed and pointed (Western Australia) *Parodax caninis*

- 2b. Jaws without canine teeth; dorsal fin notch present or absent; snout blunt to elongated
 3
- 3a. Pored lateral line scales 30 to 32; spinous dorsal rays XV; first three dorsal spines produced in male (Western Australia, South Australia, New South Wales)
 *Heteroscarus acroptilus*
- 3b. Pored lateral line scales 36 or more; only first dorsal spine produced or elongate spines absent
 4
- 4a. Snout blunt; dorsal moderately notched at soft dorsal junction; head mostly naked; pored lateral line scales 48 to 50; caudal fin emarginate, outer rays may be produced (Western Australia, South Australia, Victoria, New South Wales, Tasmania, Queensland)
 *Olisthops cyanomelas*
- 4b. Snout pointed; dorsal fin without notch or only slightly notched at soft dorsal junction; head with scales on operculum; pored lateral line scales more than 50 or less than 47; caudal fin rounded or lanceolate
 5
- 5a. Pored lateral line scales 56 to 63; margin of preoperculum serrated (less obvious in larger specimens); caudal fin rounded (Western Australia, South Australia, Victoria, Tasmania, New South Wales)
 *Neoodax semifasciatus*
- 5b. Pored lateral line scales less than 50; margin of preoperculum serrated or entire; caudal fin rounded or lanceolate
 6
- 6a. Pored lateral line scales 36 to 39; margin of preoperculum serrated; caudal fin rounded, dorsal spines XIV to XVI (Western Australia,

- South Australia, Victoria, Tasmania, New South Wales)
 *Neoodax balteatus*
- 6b. Pored lateral line scales 40 to 45; margin of preoperculum entire; caudal fin lanceolate; dorsal spines XVII to XXI
 7
- 7a. Snout triangular, 2.5 to 2.9 in head length; caudal fin without a conspicuous black spot; first dorsal spine and first pelvic ray may be greatly produced (Western Australia, South Australia, Tasmania)
 *Neoodax radiatus*
- 7b. Snout rounded or elongate, less or greater than 2.5 to 2.9 in head length; caudal fin with a conspicuous black spot; no dorsal or pelvic rays produced
 8
- 8a. Snout short, 3.2 to 4.2 in head length; head relatively short, its length 3.9 to 4.3 in standard length (Western Australia, Tasmania)
 *Neoodax attenuatus*
- 8b. Snout compressed and elongated, 1.8 to 1.9 in head length; head relatively elongate, 2.7 to 2.9 in standard length (Western Australia, Tasmania)
 *Neoodax beddomei*

Genus *Neoodax* Castelnau

Neoodax Castelnau (1875) Vict. Off. Rec. Philad. Exhibition 1875:37 (type species *Neoodax waterhousii* (= *N. balteatus*) by original designation).

Halletta Whitley (1947) Aust. Zool. 11:146 (type species *Odax semifasciatus* by original designation).

Sheardichthys Whitley (1947) Aust. Zool. 11:146 (type species *Neoodax radiatus* by original designation).

Diagnosis

Dorsal rays XIV to XXI, 10 to 14; anal rays III, 10 to 12; pectoral rays 12 to 14; pelvic rays I, 4; branched caudal rays 10; body moderately slender to elongate, the depth 5.0 to 11.0 in standard length; head length 3.0 to 4.0 in standard length; snout short to elongate; mouth small, terminal; lips moderately fleshy; teeth fused except for a narrow gap dividing the upper row of teeth; operculum scaled; preoperculum sometimes naked; no scales on fins except basally on caudal; body scales cycloid; lateral line continuous with 36 to 64 pored scales; margin of preoperculum entire or serrated; gill membranes broadly attached to isthmus; gill rakers short and triangular, 10 to 12 on first branchial arch.

Colour in alcohol generally brown dorsally and lighter on the ventral half; one to several dark bands frequently present on head; fins translucent, occasionally with banding; caudal sometimes with dark spot; base of dorsal fin sometimes with black longitudinal band.

Colour in life variable but usually green or brown (occasionally red), frequently with blue lines on head and fins in adults; juveniles with red spots on ventral half of body and with transparent fins.

Remarks

Neoodax was established by Castelnau to include *Odax* species with 'a serrated operculum and soft vertical fins'. Since then most authors have included all Australian odacids in this genus except *Olisthops cyanomelas* and *Neoodax semifasciatus*.

Whitley (1947) placed *N. semifasciatus* in *Haletta* distinguishing it on the base of 'having more than 50 . . . transverse rows of scales . . . preoperculum entire, the caudal fin rounded . . .'. However the magnitude of these differences seems relatively unimportant at the generic level. Therefore I prefer to include *Haletta* as a junior synonym of *Neoodax*.

Neoodax species are typically inhabitants of the shallow coastal marine angiosperm communities. In the case of *Neoodax radiatus* and *Neoodax balteatus* they are the dominant fish species in this habitat in W.A.

Neoodax semifasciatus and *Neoodax balteatus* are known to occur in all southern states of Australia. *Neoodax radiatus* is reported as rare throughout its distribution while *Neoodax attenuatus* and *Neoodax beddomei* have only been reported previously from Tasmania.

Neoodax balteatus Valenciennes

(Fig. 1; Tables 1 & 2)

Odax balteatus Valenciennes (1839:303) (Type locality ? Tasmania).
Günther (1862:241) (Port Arthur, Tasmania; Port Jackson, New South
Wales); Macleay (1881:106) (Tasmania; Port Jackson, New South Wales).

Odax algensis Richardson (1840:26) (Port Arthur, Tasmania); Richardson
(1849:148) (Port Arthur, Tasmania).

Odax obscurus Castelnau (1872:154) (Melbourne, Victoria); Macleay
(1881:108) (Port Phillip, Victoria).

Neoodax waterhousii Castelnau (1875:37) (Adelaide, South Australia);
McCulloch (1929:324) (South Australia).

Odax waterhousii.— Macleay (1881:109) (South Australia).

Odax brunneus Macleay (1881:109) (Port Jackson, New South Wales).

Neoodax balteatus.— McCulloch (1922:100) (Port Jackson, New South
Wales); Lord & Scott (1926:12,76) (Tasmania). Whitley (1929:58)
(Jordan 'River', Tasmania); McCulloch (1929:324) (New South Wales,
Tasmania, Victoria); Scott (1966:100) (Buckingham, Tasmania).

Neoodax obscurus.— McCulloch (1922:100); McCulloch (1929:324) (New
South Wales, Victoria).



Fig. 1: *Neoodax balteatus*, 69 mm SL, Cockburn Sound, Western Australia.

Diagnosis

Dorsal rays XV to XVI, 12 to 14; anal rays III, 11 to 12; pectoral rays 12 to 14; pelvic rays I, 4; branched rays in caudal fin, 10; lateral line scales 37 to 38; preoperculum serrated; body depth 4.5 to 5.7 in SL; head length 3.0 to 3.2 in SL; snout 2.5 to 3.5 in head length; eye 1.2 to 1.6 in snout length; interorbital width 1.2 to 1.7 in snout length; dorsal fin base 1.8 to 2.0 in SL; anal fin base 4.3 to 4.7 in SL; pelvic fin length 2.4 to 3.0 in head length; pectoral fin length 2.0 to 2.8 in head length; first dorsal spine 1.2 to 2.3 in snout, remaining spines about equal in length; first anal spine 2.0 to 4.0 in snout length, about half the length of second spine which is less than the third spine; first pelvic ray not greatly extended; caudal fin truncate to slightly rounded.

Colour in alcohol: brown dorsally, separated from the lighter ventral half by a dark band, passing above the upper lip through the ventral half of the eye to the caudal (this band may be absent); small dark patches over the body except between lower jaw and anal fin; fins either colourless or with some dark spots.

Colour of live specimens: basically green or brown, occasionally grey. In green and brown specimens a dark band passes from the tip of the snout, above the lips, and ends at the caudal fin base (in darker specimens this may be obscured); in green specimens the dorsal, anal and caudal fins green, the remainder colourless; fins on brown specimens colourless. Grey specimens may have a dark longitudinal band on middle of sides; ventrally whitish-silver with scales edged in grey; dorsal fin with alternating bands of red, brown and white (larger specimens may have red and blue bands which fade posteriorly); caudal orange basally or with red and brown vertical bands; larger specimens sometimes with red and blue bands on the anal and ventral fin and a series of blue or orange lines on the head, three to six on the snout, some continuing onto the operculum.

Remarks

The types of *N. algensis* were examined by Günther (1862) and found to be identical with *N. balteatus*. Whitley (1964) also relegated *N. obscurus* and *N. waterhousii* to junior synonyms of *N. balteatus*.

The description of *O. brunneus* included scale counts of 30 but on re-examination of the holotype, McCulloch (1922) found counts of 38-39 and concluded that the specimen was *N. balteatus*.

The holotype of *N. balteatus* - MNHN 2190, 80 mm SL, was examined at the Muséum National d'Histoire Naturelle, Paris, on behalf of the author by

Table 1: Fin ray counts for species of *Neodax* and *Parodax*.

	Dorsal Spines										Dorsal Rays				
	XIV	XV	XVI	XVII	XVIII	IXX	XX	XXI	10	11	11	12	13	14	15
<i>Neodax semifasciatus</i>					11	12	1				1	6	12	4	
<i>N. radiatus</i>						6	12	7	1	4	11	11			
<i>N. beddomei</i>						1	3				2	2			
<i>N. attenuatus</i>							1	1		2					
<i>N. balteatus</i>	1	11	14							1	19	4	2		
<i>Parodax caninis</i>		4	2								2	4			

Table 2: Lateral line scale counts of *Neodax* and *Parodax*

	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	
<i>Neodax semifasciatus</i>																					4	4	2	3	3	3		4		
<i>N. radiatus</i>						5	10	12	6																					
<i>N. beddomei</i>						1	2	1																						
<i>N. attenuatus</i>						1		1																						
<i>N. balteatus</i>	2	3	11	1																										
<i>Parodax caninis</i>										6	3	2																		

G.R. Allen. It was collected by Péron. There are no collecting data but as McCulloch (1929) suggests, the locality was probably Tasmania.

N. balteatus occurs from southwest Australia to New South Wales. In Western Australia it is an inhabitant of seagrass beds at depths between 3 to 10 metres. The stomach and gut contents of 19 specimens, 46 mm to 90 mm SL, contained mainly crustaceans (largely shrimps and amphipods) and small molluscs.

Material examined

34 specimens, 37-122 mm SL.

Western Australia

Cockburn Sound — WAM P25258, 2, 57-69 mm; WAM p25350, 2, 67-70 mm; WAM P25257-003, 2, 43-64 mm; WAM P25358-001, 1, 70 mm; WAM P22192, 1, 99 mm; WAM P22193, 1, 93 mm; WAM P295, 2, 78 mm.

Carnac Island — WAM P21561, 1, 99 mm; WAM 25355-001, 1, 61 mm; WAM P21560, 6, 49-74 mm.

Oyster Harbour — WAM P25356-001, 1, 71 mm; WAM P25357-001, 1, 59 mm; WAM P21761, 1, 50 mm.

South Australia

No data — AMS B228, 3, 102-112 mm.

Tasmania

Hobart — AMS I14206, 7, 37-77 mm; WAM P25359-001, 1, 41 mm.

New South Wales

Sydney — AMS I16799-016, 1, 75 mm.

Neoodax attenuatus Ogilby

(Fig. 2; Tables 1 & 2)

Oodax attenuatus Ogilby (1897:83) (Type locality, Tasmania).

Neoodax attenuatus.— McCulloch (1929:324) (Tasmania); Scott (1974:280, fig. 2, p.282) (Promise Bay, Glamorgan, Tasmania).

Diagnosis

Dorsal rays IXX to XX, 14; anal rays III, 8 to 9; pectoral rays 12 to 13; pelvic rays I, 4; branched rays in caudal fin 10; lateral line scales 40 to 42;

preoperculum entire; body depth 9.9 to 10.8 in standard length; head length 3.9 to 4.3 in standard length; snout 3.2 to 4.2 in head length; eye 0.8 to 1.1 in snout length; interorbital width 1.0 to 1.1 in snout length; dorsal fin base 1.7 to 1.8 in standard length; anal fin base 1.7 to 2.4 in head length; pelvic fin length 2.7 to 3.5 in head length; pectoral fin length 2.0 to 2.7 in head length; first dorsal spine 1.0 in snout, the rest about equal; first anal spine, being 0.9 in the snout, one third the second spine which is less than half the third spine; first pelvic ray not greatly produced; caudal fin lanceolate.

Colour in alcohol: brown dorsally, fading to yellow below; snout brown dorsally, becoming darker on interorbital; nape lighter; caudal fin pale except for a prominent black spot on upper portion, upper and lower margin of fin black basally and also outer edge of middle caudal rays black; remaining fins colourless.

The basic colour of fresh specimens is red-brown with a prominent black spot on the caudal fin.

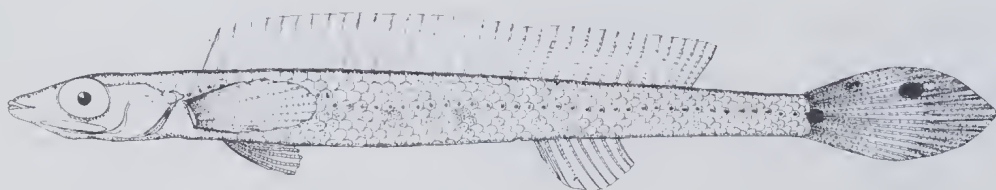


Fig. 2: *Neoodax attenuatus*, 75 mm SL, (from Scott, 1974).

Remarks

The type of this species was originally lodged in the Tasmanian Museum, Hobart (Ogilby, 1897), but was not included in the recent list (Andrews, 1971) of fish types from there. Only one other specimen is known from the literature (Scott, 1974). It was taken in Tasmania, but apparently was not deposited in a museum collection and has not been examined by the author.

This species was previously known only from Tasmania.

The two specimens listed below were caught by beam trawl in a bed of the marine angiosperm *Posidonia australis*. In spite of extensive trawling in

this habitat no further specimens have been obtained. Thus, the species is either rare in Western Australia or normally occurs in a different habitat.

Material examined

2 specimens, 47-69 mm SL.

Western Australia

Geographe Bay — WAM P21553, 1, 47 mm; WAM P21554, 1, 69 mm.

Neoodax beddomei Johnston

(Fig. 3; Tables 1 & 2)

Odax beddomei Johnston (1885:231) (Type locality, Derwent River, Tasmania); Ogilby (1897:84) (Tasmania).

Neoodax beddomei.— Lord & Scott (1924:12,76) (Tasmania); Scott (1969:163, fig. 1a,b,c, p.169) (between Flinders and Cape Barren Islands, Tasmania).

Siphonognathus beddomei.— McCulloch (1929:325) (Tasmania); Whitley (1929:59, pl. IV, fig. 6) (Tasmania).



Fig. 3: *Neoodax beddomei*, 98 mm SL, Carnac Island, Western Australia.

Diagnosis

Dorsal rays XVIII to XIX, 11 to 12; anal rays III, 11 to 12; pectoral rays 12 to 14; pelvic rays I, 4; branched rays in caudal fin, 10; lateral line scales 40 to 42; preoperculum entire; body depth 9.6 to 10.4 in standard length; head length 2.7 to 2.9 in standard length; snout elongated 1.8 to 1.9 in head length; eye 3.1 to 3.8 in snout length; interorbital width 3.3 to 4.5 in

snout length; dorsal fin base 2.1 to 2.3 in standard length; anal fin base 8.5 to 9.8 in standard length; pelvic fin length 2.8 to 3.5 in head length; pectoral fin length 3.1 to 3.4 in head length; first dorsal spine 4.4 to 5.4 in head length, just shorter than second and third spine but longer than 14th to 16th spine; thus forming a shallow notch; posterior dorsal rays the longest; first anal spine less than half first dorsal spine and a third of second anal spine which is less than the third anal spine; first pelvic spine less than second and third; caudal fin lanceolate.

Colour in alcohol: light green dorsally, ventral pale brown becoming lighter on both snout and tail; dark lines sometimes present on snout and operculum; small black spot on upper portion of caudal fin, remaining fins colourless.

Colour in life: dark green dorsally with ventral half pale brown to yellow; a series of dark bands radiating from snout, one extending to lower edge of eye, another to upper anterior edge of eye, and another series of three mid-dorsally between snout tip and interorbital; two rows of small spots originating at eye and passing along body to base of caudal fin, lower row not continuous, ending at preoperculum and re-commencing as a faint row along the posterior half of the body. Dorsal fin greenish-yellow, with red patches basally and distally on membranous portion; anal, pelvic, pectoral, and posterior dorsal fin rays reddish; caudal fin with conspicuous black spot on three uppermost branched rays, remainder of fin red, lighter posteriorly.

Remarks

This species has been variously placed in the Odacidae and Siphonognathidae by previous authors, but as Scott (1969) points out, the absence of ventral fins in the original description and in Johnston's drawing of the type (Whitley, 1929, pl. IV, fig. 6) is probably an oversight.

The type was deposited in the Tasmanian Museum, Hobart, but appears to have been lost (Lord & Scott, 1924). Andrews (1971) does not include this species on the list of types for the same institution. Only one other specimen was previously reported (Scott, 1969), but apparently it was not deposited in a museum collection.

This species was previously known only from Tasmania.

N. beddomei is associated with patches of weed, principally marine angiosperms, which occur in small clumps (less than 6 m diameter) in sand amongst limestone reefs (depth 10-12 metres). The species swims above the weed in small groups (usually of three to five individuals of varying sizes). They quickly seek shelter in the weeds if disturbed.

Material examined

4 specimens, 53-98 mm SL.

Western Australia

Carnac Island — WAM P25224-002, 2, 53-98 mm; WAM P25297-005, 1, 90 mm.

Canal Rocks — WAM P25150-001, 1, 90 mm.

Neoodax radiatus (Quoy & Gaimard)

(Fig. 4; Tables 1 & 2)

Malacanthus radiatus Quoy & Gaimard (1835:717, pl. XIX, fig. 2) (Type locality, King Georges Sound, Western Australia).

Cheilio lineatus Valenciennes (1839:354) (King Georges Sound, Western Australia).

Odax lineatus Richardson.— (1848:133, pl. LX, fig. 1-5) (King Georges Sound, Western Australia).

Odax frenatus Günther (1862:241) (Fremantle Gage Roads, Swan River, Western Australia); Castelnau (1873:72) (South Australia); Macleay (1881:107) (Western Australia).

Odax radiatus.— Günther (1862:242) (Fremantle, Western Australia); Castelnau (1873:71) (South Australia); Macleay (1881:108) (Port Phillip, Victoria).



Fig. 4: *Neoodax radiatus*, 120 mm SL, Cockburn Sound, Western Australia.

Odax pusillus Castelnau (1873:72) (South Australia); Macleay (1881:108) (South Australia).

Neoodax pusillus.— McCulloch (1929:323).

Neoodax radiatus.— Scott (1962:282) (South Australia, Western Australia); Scott (1964:97) (Tasmania); Scott (1966:100) (Tasmania).

Neoodax frenatus.— Scott (1962:282) (South Australia, Western Australia); Scott (1966:100) (Tasmania); Scott, Glover & Southcott (1974:314) (South Australia, Western Australia).

Neoodax (Sheardichthys) radiatus.— Whitley (1947:146).

Diagnosis

Dorsal rays XVIII to XX, 10 to 12; anal rays III, 9 to 11; pectoral rays, 12 to 13, ventral rays I, 4; branched rays in caudal fin, 10; lateral line scales 41 to 43; preoperculum not serrated; body depth 5.7 to 7.0 in standard length; head length 3.2 to 3.6 in standard length; snout 2.5 to 2.9 in head length; eye 1.5 to 2.1 in snout length; interorbital width 1.5 to 2.0 in snout length; dorsal fin base 1.7 to 2.0 in standard length; and fin base 5.0 to 6.7 in standard length; pelvic fin length 2.0 to 2.6 in head length for specimens below 120 mm SL; specimens above this size pelvic length is up to 1.2 in head length; pectoral fin 2.3 to 2.8 in head length; in specimens over 120 mm SL, the first dorsal spine is greatly produced, up to 1.6 in head length, the second is less than first and greater than third and following spines; in specimens below 120 mm SL the first dorsal spine is less or equal to the second and other spines; in specimens above 120 mm SL the first pelvic ray is greatly produced to 1.2 in head length, the second pelvic ray just greater than or equal to the pelvic spine; in specimens below 120 mm SL the first pelvic ray is not greatly extended; first anal spine is half the second which is just less than the third; caudal fin lanceolate.

Colour of juveniles and females in alcohol: dark dorsally, paler below, with some dark patches on ventral half; dark band from snout passing through eye and fading on operculum; fins colourless except caudal which may be tinged with dark brown. Males exhibit the same basic colour pattern with the following additions: a series of lines with darkened margins on head; dorsal fin with prominent longitudinal dark band basally between 6th to 13th rays, membranes on anterior half of fin with series of dusky bands fading posteriorly; pectoral and anal fins colourless; pelvic and caudal fins sometimes dusky between rays.

Colour of females and juveniles in life: green or brown with a dark band extending from the upper lip, through the eye, and fading on the operculum. Juveniles are generally green, brown or red dorsally, whitish ventrally, with

red spots, particularly under the head; fins colourless; a dark band sometimes extending from snout to operculum.

Colour of males in life: dark green dorsally becoming lighter to yellow ventrally; a series of faint blue lines and grey, brown and green blotches on dorsal half of body; ventral portion of body with six blue lines; head dark green with series of light green lines; membrane between first two dorsal spines brown; anterior portion (to about 10th ray) of soft dorsal fin with alternating blue and yellow longitudinal bands; broad blackish streak bordered above with orange at base of 8th to 16th dorsal rays; posterior portion of dorsal translucent; caudal fin yellow with blue lines from body extending onto basal part; pectoral fin translucent; pelvic fins yellow with membrane between first and second rays dusky; anal fin mostly yellow, pink posteriorly with 2 or 3 blue longitudinal lines extending to about sixth ray.

Remarks

Neoodax radiatus was described on the basis of a drawing done during the voyage of the *Astrolabe* (mid 1820s). The potential type was apparently lost or destroyed. The drawing of this species by Richardson (1848) is frequently reproduced (Scott, 1962; Scott, Glover & Southcott, 1974) but contains several inadequacies, particularly with reference to the lower number of scales on the lateral line.

This species shows marked sexual dimorphism. The colourful male is readily distinguished by the black band at the base of the 8th to 16th dorsal ray. The first dorsal and second pelvic fin ray are produced, sometimes equalling the head length in the case of the pelvic. The less colourful female form was considered to be a separate species, *N. frenatus*, by Günther (1862) and later authors.

N. radiatus occurs from Western Australia to Tasmania.

This species is principally found in beds of seagrass in 3 to 10 metres depth. The stomach and gut contents of 20 specimens, 53 mm to 130 mm SL, contained mostly crustaceans (mainly shrimps and amphipods) and molluscs.

Material examined

88 specimens, 34-135 mm SL.

Western Australia

Carnac Island — WAM P25341-001, 1, 77 mm; WAM P25297-001, 12, 34-111 mm; WAM P5890, 21, 64-85 mm; WAM P25343-009, 1, 130 mm.

Rockingham, Cockburn Sound — WAM P25257-001, 164 mm; WAM P25365, 1, 98 mm; WAM P25258-008, 3, 68-128 mm.

Geographe Bay — WAM P25259-001, 29, 16-85 mm; WAM P20926, 7, 56-102 mm; WAM P25364-001, 1, 121 mm; WAM P20934, 1, 121 mm; WAM P25362-001, 1, 100 mm.

King Georges Sound — WAM P25361-001, 1, 91 mm; WAM P24842, 1, 125 mm; WAM P5637, 2, 128-132 mm; WAM P25360-001, 1, 135 mm.

Cottesloe, Perth — WAM P823, 1, 110 mm.

Warnbro Sound — WAM P23260, 1, 107 mm.

Yallingup — WAM P4960, 1, 116 mm.

No data — WAM P25362-001, 1, 116 m.

South Australia

Investigator Strait — AMS I12388, 1, 121 mm; AMS I12387, 1, 121 mm; AMS I12389, 1, 103 mm; AMS I12390, 1, 74 mm.

Neoodax semifasciatus

(Fig. 5; Tables 1 & 2)

Odax semifasciatus Valenciennes (1839:299. pl. CCCCVII) (Type locality, Indian Ocean ?); Günther (1862:241) (no locality); Macleay (1881:107) (Port Jackson, New South Wales).

Odax richardsonii Günther (1862:241 & 509) (Port Jackson, Hobson's Bay, New South Wales); Castelnau (1873:72) (South Australia); Macleay (1881:107) (Port Phillip, Victoria); Waite (1900:211) (Swan River,

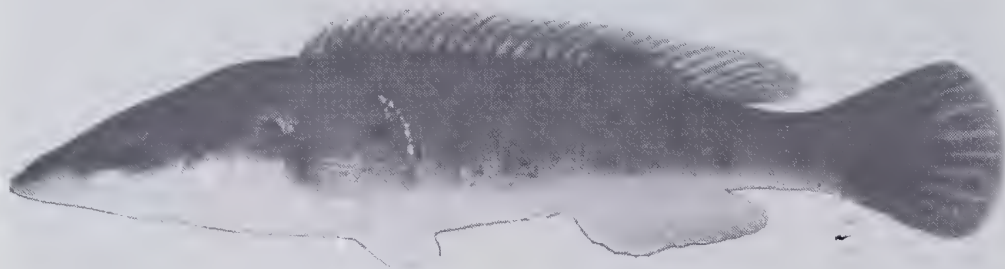


Fig. 5: *Neoodax semifasciatus*, 243 mm SL, Geographe Bay, Western Australia.

Perth, Western Australia); Waite (1905:71) (Houtman's Abrolhos, Western Australia).

Odx hyrtlui Steindachner (1866:464, pl. V, fig. 4) (Port Jackson, New South Wales).

Neodax semifasciatus.— McCulloch (1929:323) (Tasmania, New South Wales, Victoria, Western Australia, South Australia).

Haletta semifasciatus.— Whitley (1946:146) (Western Australia); Scott (1962:281, unnumbered fig.) (South Australia); Scott (1966:102) (Dorset, Devon, Tasmania); Scott, Glover & Southcott (1974:313) (Western Australia, South Australia, Victoria, New South Wales, & Tasmania).

Diagnosis

Dorsal rays XVII to XVIII, 12 to 14; anal rays III, 10 to 12; pectoral rays 14 to 15; pelvic rays I, 4; branched rays in caudal fin, 10; lateral line scales 53 to 63; preoperculum serrated, obscured in some adults; body depth 5.0 to 6.0 in standard length; head length 2.9 to 3.4 in standard length; snout 2.3 to 3.0 in head length; eye 2.2 to 2.7 in snout length; interorbital width 1.8 to 2.6 in snout length; dorsal fin base 1.8 to 2.1 in standard length; anal fin base 5.1 to 6.0 in standard length; pelvic fin 2.3 to 3.0 in head length; pectoral fin 1.9 to 2.4 in head length; first dorsal spine 2.2 to 3.4 in snout length, the rest about equal; longest ray, twenty sixth, 1.0 to 2.0 in snout length; first anal spine 5.0 to 7.0 in snout length, less than a third of second, which is less than the third; first pelvic ray not greatly produced; caudal fin truncate to rounded.

Colour in alcohol: dark dorsally with six to seven dark bars extending onto lighter ventral region; head sometimes with narrow lines, especially around eye except on upper dorsal edge; fins translucent except a few individuals with dark band on dorsal fin base.

One specimen, 226 mm SL, male, showed some colour retention in alcohol: dark dorsally with seven dark bars extending into ventral region; lateral side of head with irregular green lines with dark borders, lines fade ventrally; snout to interorbital dark brown; dorsal fin with alternating green and brown bands, one black band on mid-dorsal fin base; anal fin with alternating green and brown bands; caudal fin green; pectoral and pelvic fins translucent.

Colour in life: basically blue-green, dark dorsally with six to seven vertical bands fading ventrally; side of body with orange scales; head dark dorsally, white ventrally, blue and orange lines on cheek, operculum blue, upper lip dusky, lower pale; dorsal fin with orange and blue horizontal

lines, 7 to 8 in all; dark blotch from last spine to 7th ray sometimes present; anal fin with blue and orange horizontal lines, 4 to 5 in all, membrane grey distally; caudal fin with blue background with orange markings, grey distally; pectoral fin translucent, rays light orange; pelvic fin translucent, rays light orange.

The juveniles of *N. semifasciatus* (approx. 37 to 110 mm SL) are similar in appearance to *N. balteatus*, but are readily distinguished by the presence of faint vertical bands and an obvious blue spot surrounding the vent.

Remarks

The holotype — MNHN 2191, 209 mm SL, was examined at the Muséum National d'Histoire Naturelle, Paris on behalf of the author by G.R. Allen.

This is the largest member of the genus and appears to be distributed throughout the coastal waters of southern Australia. It frequents weed beds as a juvenile and occasionally as an adult. Specific adult habits and food preferences are not known.

Material examined

26 specimens, 37-264 mm SL.

Western Australia

Cockburn Sound — WAM P25378-001, 1, 81 mm; WAM P11, 2, 121-168 mm; WAM P4694, 2, 175-215 mm.

Fremantle — WAM P2226, 1, 216 mm; WAM P3698, 1, 264 mm; WAM P3699, 1, 256 mm; WAM P3700, 1, 226 mm.

Scarborough, Perth — WAM P3190, 1, 222 mm.

Geographe Bay — WAM P21009, 1, 37 mm.

Hardy Inlet — WAM P25275-005, 1, 125 mm; WAM P24403, 3, 111-117 mm.

King Georges Sound — WAM P4557, 1, 214 mm; WAM P5031, 3, 215-250 mm; WAM P5636, 2, 181-251 mm; WAM P20189, 1, 237 mm.

No data — WAM P25379-001, 1, 193 mm; WAM P25393-001, 1, 113 mm.

South Australia

Investigator Straits — AMS I12385, 1, 228 mm; AMS I12386, 1, 222 mm.

Genus *Parodax* new genus

Diagnosis

Dorsal fin deeply notched, rays XV to XVI, 12 to 13; anal rays III, 10 to 11; pectoral rays 12; pelvic rays I, 4; branched caudal rays 10; lateral line scales 45, continuous, one pored scale beyond base of caudal fin; gill rakers on first branchial arch 10; gill membranes broadly attached to isthmus; body with cycloid scales; head naked except for an occasional two scales on preoperculum; no scales on fins except for sheath at caudal fin base; head with numerous pores; posterior nostril at upper anterior edge of eye; a pupil length to anterior nostril, tubed with posterior flap; mouth small and terminal; lips moderately fleshy; upper jaw with two rows of teeth which fuse basally; inner row fused, individual teeth still visible, forming small points on fused plate; outer row of four canines: three lateral pairs, posterior most smallest, anterior most largest; single anterior pair directed forward; lower jaw with fused row of teeth plus a separate anterior pair of canines; body elongate, depth 6.0 to 8.0 in standard length; head length 2.6 to 2.9 in standard length; snout long and compressed, its length 2.3 to 2.6 in head length.

Colour in alcohol: brown dorsally, ventral half lighter, but with some dark scales; fins grey or with transparent patches; some specimens with dark irregular spot on distal membranes of posterior dorsal spines.

Colour in life variable but basically green or red; fins with transparent patches and dark spot sometimes present on distal membranes of posterior dorsal spines.

Type species *Parodax caninis*.

Remarks

This genus is readily distinguished from other odacids on the basis of dentition. In addition to the normal fused teeth of the upper and lower jaws there are supplementary canines. The deeply notched dorsal fins and elongate, compressed snout are also distinctive.

Parodax caninis new species

(Fig. 6; Table 3)

Holotype: WAM P25346-002, 73.6 mm SL, Fremantle, between Carnac Island and Gage Roads, 21 metres, triangle dredge, J.K. Scott on the R.V. *Flinders*, June 30, 1975.

Table 3: Measurements of type specimens of *Parodax caninis* (in thousandths of the standard length).

	HOLOTYPE		PARATYPES				
	P25346-002	P25251-019	P25252-009	AMS118627-001	P25343-010	P25498-001	
Standard length (mm)	73.6	72.5	59.4	52.0	47.7	79.9	
Depth of body	132	166	153	167	141	153	
Head length	347	364	359	375	377	374	
Snout length	145	159	148	146	138	179	
Eye diameter	69	70	74	78	84	76	
Bony interorbital width	64	83	66	83	80	76	
Length of mouth	65	107	88	73	80	100	
Least depth of caudal peduncle	64	84	71	85	69	76	
Length of caudal peduncle	182	146	146	148	178	138	
Snout to origin of dorsal fin	345	372	360	367	377	375	
Snout to origin of anal fin	666	663	635	669	694	D*	
Length of caudal fin	191	154	172	192	197	213	
Length of pectoral fin	111	132	113	123	96	113	
Length of pelvic fin	112	118	101	165	98	249	
Length of first dorsal spine	87	74	77	86	128	124	
Length of longest dorsal spine (3rd)	115	86	94	96	132	189	
Length of shortest dorsal spine (11th)	32	28	30	19	34	66	
Length of longest dorsal ray	91	82	72	85	90	98	
Length of first anal spine	48	28	29	29	63	50	
Length of second anal spine	68	57	59	58	86	65	
Length of third anal spine	81	75	81	75	90	66	
Length of dorsal fin base	501	500	473	478	490	D*	
Length of anal fin base	179	180	185	175	174	190	
Length of pelvic spine	99	63	74	75	90	75	
Length of first pelvic ray	118	94	99	98	90	249	

D* = damaged



Fig. 6: *Parodax caninis*, 73.6 mm SL, holotype, Carnac Island, Western Australia.

Paratypes: WAM P25251-019, 72.5 mm SL, Rottnest Island, off south coast, 6 metres, spear, G.R. Allen, April 9, 1975; WAM P25252-009, 59.4 mm SL, Carnac Island, 8 metres, spear, G.R. Allen, April 6, 1975; WAM P25343-010, 47.7 mm SL, Fremantle, Gage Roads, 33 metres, triangle dredge, C. Bryce and L. Marsh on the R.V. *Flinders*, June 24, 1975; AMS I. 18627-001, 52.0 mm SL, Rottnest Island, off south coast, 6 metres, spear, G.R. Allen, April 9, 1975; WAM P25498-001, 79.9 mm SL, Rottnest Island, 3 km off S.E. coast, 15 metres, spear, J.B. Hutchins, December 24, 1975.

Description

(See also Table 3.) Dorsal rays XV to XVI, 12 to 13; anal rays III, 10 to 11; pectoral rays 12; pelvic rays I, 4; branched caudal rays 10, total caudal rays 18 to 21; pored lateral line scales 45 to base of caudal fin (one pored scale beyond base); gill rakers, short, triangular, 10 on first branchial arch.

Body elongate, the depth 6.0 to 7.6 in standard length; head length 2.6 to 2.9 in standard length; snout moderately long and pointed, 2.3 to 2.6 in head length; eye diameter 1.7 to 2.5 in snout length; interorbital space flat, the bony width 1.8 to 2.2 in snout length; least depth of caudal peduncle 1.7 to 2.2 in snout length.

Origin of dorsal fin slightly posterior to pectoral base; first dorsal spine 1.1 to 2.1 in snout length, just shorter than second spine; third, fourth and fifth rays longest and about equal; length of following dorsal spines decreasing to eleventh spine (4.1 to 5.7 in snout length), then remaining spines gradually increasing in length; first dorsal ray longest (just greater

than last dorsal spine), following rays decreasing slightly in length to sixth ray then increasing to tenth ray and finally decreasing to last ray; origin of anal fin below last dorsal spine; first anal spine greater than one half second anal spine which is less than the third spine; first anal rays longest, remaining rays decreasing in length posteriorly; dorsal and anal rays branched distally; pectoral fin rounded, its length 2.7 to 3.9 in head length, the tip reaching a vertical below fourth dorsal spine; pelvic fin length 2.9 to 3.8 in head length, its origin just posterior and below pectoral base; length of pelvic spine equal to second pelvic ray or slightly less than length of first pelvic ray.

Head and body scales cycloid; head naked except for an occasional two scales on preoperculum and two or three scale rows on operculum; lateral line continuous; no scales on fins except for sheath at caudal fin base; four longitudinal scale rows from first dorsal ray origin to lateral line; eight longitudinal scale rows from third anal ray origin to lateral line.

Upper jaw with two rows of teeth which fuse basally; inner row fused, individual teeth still visible, forming small conical points on the fused plate; outer row of four canines: three lateral pairs, posterior most smallest, anterior most largest; single anterior pair directed forward; lower jaw with fused row of teeth plus an outer separate pair of canines.

Head with numerous pores; a pair of small nostrils on each side of snout; posterior nostrils at upper anterior edge of eye; a pupil length to anterior nostrils, tubed with a small posterior flap; mouth small and terminal; lips moderately fleshy; preoperculum entire.

Colour of holotype in alcohol: light green with small dark spots on dorsal half; interorbital space with fine dark lines; dorsal fin grey with dark spot on distal portion of eighth to ninth spine; other fins grey. Colour of paratypes in alcohol identical except for the absence of dark spot on dorsal fin.

Colour in life: body green, becoming lighter ventrally; some darker green patches along lateral line, on caudal peduncle and at caudal fin base; head green-brown; snout and dorsal half of operculum with blue spots; ventral surface of head with irregular brown spots; lips pink; dorsal fin mainly green, membranes transparent on base of sixth to eighth spine and also tenth to twelfth spine, also red about base of ninth, thirteenth, fourteenth spine and from about sixth ray to the last ray; distal portion of last seven rays transparent; black spot present on upper membranes of eighth and ninth spine of dorsal fin of holotype; anal fin green to eighth ray, posterior portion transparent with red base; caudal fin green with red blotches on either side of middle; pelvic fins green; pectoral fins transparent.

The live pattern of a 47.7 mm SL paratype differed from the other types. The colours were as follows: body pink, becoming lighter ventrally;

side with silver band, extending from lower edge of eye to pectoral base, then continuing to caudal peduncle; dorsal portion of head red-brown with white spots; ventral region of head white with red spots; lips pink; indistinct red spots between pectoral and anal fins; small blue spots just above lateral line; base of dorsal fin red to fifth spine, remainder transparent; membranes on distal part of dorsal fin grey with red edges; anal fin red, grey distally; base of caudal fin red, remainder of fin with three areas of grey separated by white; pelvic fin grey with red patches, edges red; pectoral fins transparent.

One paratype, 79.9 mm SL, male, also differed and had the following colouration: body brown-green dorsally, yellow-green ventrally with a black patch on the ventral half of body from the start of anal fin to the caudal fin; body with four horizontal white lines with dark borders; dorsal portion of head green-brown, ventral portion of head yellow-green with two white lines with dark borders on snout, four white lines with dark borders on cheek and operculum continuous with lines on body; lips pink; dorsal fin yellow-green basally in spinous portion and posterior portion; red distally on spinous portion; first dorsal membrane blue with red and yellow spots encircled by black; from sixth dorsal spine to notch, orange spots border the basal side of a conspicuous black blotch; posterior half of fin with three horizontal blue lines edged in red; anal fin dusky-green, becoming yellow posteriorly, also with three horizontal blue lines fading posteriorly; caudal fin red-green with numerous small blue spots, dorsal and ventral tips dusky green; pelvic fin yellow-green basally, dusky green with black margins on rays; pectoral fin translucent, rays red.

Remarks

This species generally lives in association with seagrasses or algae on or between patches of reef. The six known specimens were captured at depths ranging from 6 to 33 metres.

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European types were examined by Dr G.R. Allen. Examples of *Odax pullus* were sent for comparison by Mr J. Moreland, Curator of Fishes at the National Museum of New Zealand. Dr G.R. Allen and Mr J.B. Hutchins supplied photos of all species. I would like to thank Mrs E. Rusterholts and Mrs L. Handley for typing the manuscript.

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THE HYPOPIAL NYMPHS OF THE GENUS *MARSUPIOPUS* FAIN,
1968 (ACARINA: ASTIGMATA) INCLUDING FOUR NEW TAXA

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and

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ABSTRACT

3 new species and 1 new subspecies of hypopi of the genus *Marsupiolopus* Fain, 1968 (Glycyphagidae) are described from Australian mammals.

All these species were embedded in the hair follicles, except one which was found in the superficial layers of the skin and had produced thickening of the epidermis and hyperkeratosis.

INTRODUCTION

The hair follicles of numerous mammals harbour heteromorphic deutonymphs (=hypopi) belonging to various groups of mites (Fain, 1969).

All the hypopi that infest the hair follicles of Australian mammals belong to two genera: *Marsupiolopus* Fain, 1968 and *Alabidopus* Fain, 1967.

Until now, the genus *Marsupiolopus* was represented by only 3 species, all from Australia: *Marsupiolopus trichosuri* Fain, 1968, from *Trichosurus vulpecula*; *M. leporilli* Fain, 1969, from *Leporillus jonesi*; and *M. michaeli* Fain, 1969, from *Mesembriomys gouldi*.

The first species of this genus was discovered in a marsupial, hence the name *Marsupiolopus*, but later it appeared that Murinae also were infested with these hypopi.

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Recently the junior author discovered numerous specimens of this kind of hypopi in various Australian mammals preserved in alcohol in different museums. Among this material we found 3 new species and 1 new subspecies of hypopi of the genus *Marsupiopus*. They are described here.

These new species do not correspond exactly with the original definition of the genus. In *M. antechinus* sp. n. and *M. acrobates* sp. n. there is a distinct sejugal furrow, and a small anus is present inside the genital ring. We propose therefore to emend the scope of the genus *Marsupiopus* in order to include these new characters.

The genus *Marsupiopus* is known only from the hypopial stage. The life cycle is still unknown. All these hypopi live in the hair follicles, except one species (*M. myrmecobius*) which lives like most of the Sarcoptidae, in the corneous layers of the skin, especially in the hairless regions of the ears.

The genus *Marsupiopus* is the type genus of the subfamily Marsupiopinae Fain, 1968, which has been included in the Glycyphagidae Berlese, 1887, by Fain, 1968.

KEY TO SPECIES AND SUBSPECIES OF THE GENUS *MARSUPIOPUS* (HYPOPI)

- | | | |
|----|--|---|
| 1. | Femora I-II with a short thick spine... .. | 2 |
| | Femora I-II with a fine seta | 5 |
| 2. | Apical half of tarsi I-II with two thick spines
... .. <i>M. michaeli</i> Fain, 1969 | |
| | Apical half of tarsi I-II either with only thin
setae or with one small ventral spine | 3 |
| 3. | Tibia I-II with 1 seta and 1 spine. Posterior
region of hysterosoma with a small dorsal
shield much wider than long. Solenidia alpha
distinctly separated. Idiosoma rounded anter-
iorly. Pregenital longitudinal sclerite well
developed... .. | 4 |
| | Tibia I-II with 2 spines. Hysteroma without
dorsal shield. Solenidia alpha close together.
Idiosoma ending anteriorly as a narrow cone.
Pregenital sclerite very poorly developed
... .. <i>M. trichosuri</i> Fain, 1968 | |

4. Tarsal claws I-II as long as their pretarsi
 *M. leporilli leporilli*
 Tarsal claws I-II distinctly longer than their
 pretarsi
 *M. leporilli pseudomys* ssp. nov.
5. Genital ring longer than wide. Sejugal furrow
 absent. Dorsal surface with a long punctate
 shield
 *M. myrmecobius* sp. nov.
 Genital ring wider than long. Sejugal furrow
 present. Dorsal shield either absent or much
 reduced 6
6. Body 260-280 μ long. Distance alpha-alpha
 16 μ . Tarsi I 2.5 times longer than its maxi-
 mum width. Posterior spines of tibiae and
 genua I-II strong and equal
 *M. antechinus* sp. nov.
 Body 190-210 μ long. Distance alpha-alpha
 6-8 μ . Tarsi I 1.4 times longer than its maxi-
 mum width. Posterior spine of genua I-II much
 smaller than corresponding spine of tibiae I-II
 *M. acrobates* sp. nov.

1. *Marsupiosus leporilli* Fain, 1969

This species has been described from *Leporillus jonesi*, South Australia.

We have found this species in two new hosts. As these specimens are slightly different from the typical series we separate them as a new subspecies.

Marsupiopus leporilli pseudomys ssp. nov.

This new subspecies is distinguished from the typical series by the size of the claws I-II which are distinctly longer than their pretarsi. Besides, the cuticle is less sclerotised than in *M. l. leporilli*. It is to be noted that there are 2 small punctate areas laterally at the level of coxae III. These areas are also present in *M. l. leporilli*. Holotype hypopus 295 μ long and 166 μ wide. Average for 10 paratypes: 311 μ long (288-336 μ) and 154 μ wide (154-182 μ).

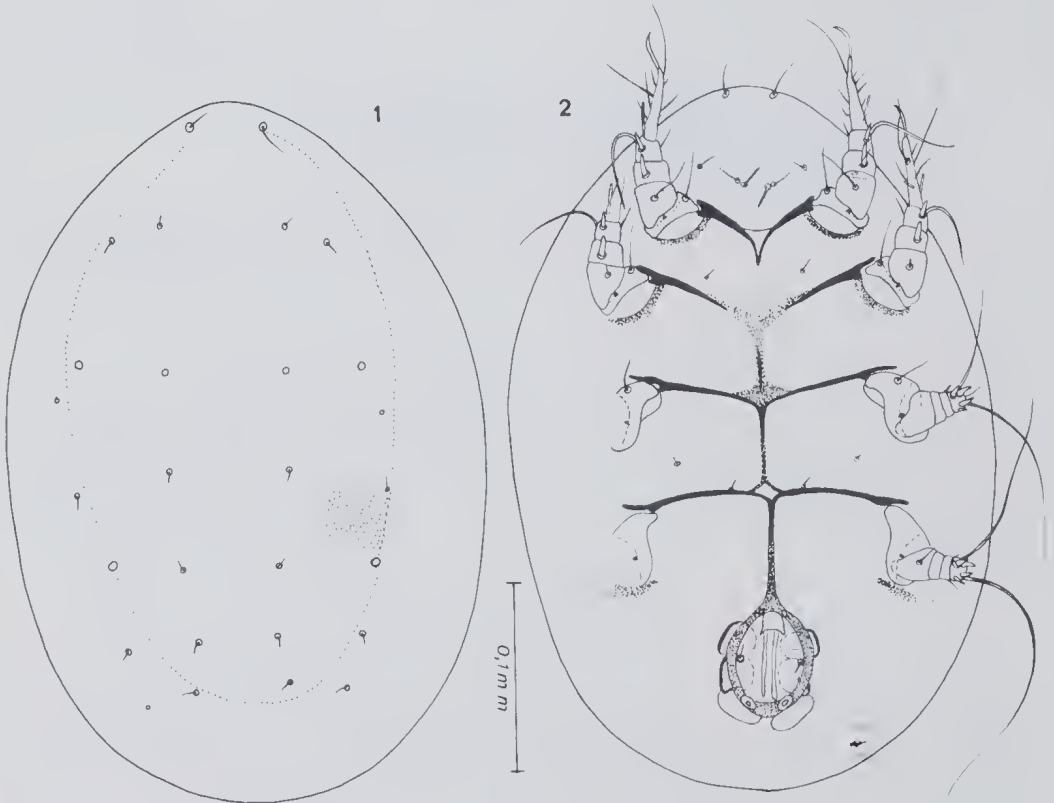
Hosts and localities

On *Pseudomys hermannsburgensis*, Hermannsburg, Central Australia, 1910 (holotype and 40 paratypes). The mites were embedded in the hair-follicles. Host specimen in the Senckenberg Museum, Frankfurt.

On *Rattus fuscipes*, Australia, 1869 (10 paratypes) (Coll. F.S. Lukoschus). Host specimen in the Rijksmuseum, Leiden. 5 paratypes in the Natural History Museum, Leiden; other paratypes in the Western Australian Museum, Perth, and in the collections of the authors.

2. *Marsupiopus myrmecobius* sp. nov.

This species is clearly distinguished from the 3 previously described species by the genital ring being longer than wide (cf. wider than long in the other 3 species), the presence of a simple hair on the femora I-II, and the great length of the tarsal claws I and II. In addition it is distinguished from *M. michaeli* Fain by the absence of a spine on tarsi I-II.



Figs 1-2: *Marsupiopus myrmecobius* sp. n. Hypopus (holotype). Dorsum (fig. 1) and venter (fig. 2).

Hypopus (Fig. 1-5): Holotype 360μ long and 240μ wide. Average for 10 paratypes: 355μ long (336 - 374μ) and 237μ wide (221 - 250μ). Dorsal surface with a punctate shield covering most of the median region of the dorsum. This shield lacking in lateral and posterior regions of the dorsum. Sejugal furrow absent. Epimera I fused into V. Genital ring longer than wide and bearing membranous prolongation backwards. A small anus is present. Pregenital sclerite fused to epimera IV. Palposoma indistinct. Solenidia alpha narrow, close to one pair of simple setae, the other pair of setae situated more laterally. Tarsus I much longer (27μ) than wide (7μ). Claws I-II 18μ long, longer than the pretarsi. Femora I-II with a thin seta.

Host and locality:

On *Myrmecobius fasciatus*, Katoomba, N.S.W., Australia, 2.V.1906. The mites were enclosed in the corneous layers of the skin, especially the hairless region of the ears. They had produced thickening of the epidermis and hyperkeratosis. Host specimen (No. 12240) in the Senckenberg Museum, Frankfurt (holotype and 40 paratypes). Holotype and 13 paratypes in the Senckenberg Museum, Frankfurt; other paratypes in the Western Australian Museum, Perth, and in the collections of the authors.

3. *Marsupiopopus antechinus* sp. nov.

In this new species the femora I-II bear simple setae, as in *M. myrmecobius*. It is distinguished from this species by the presence of a distinct sejugal furrow, and by the genital ring being wider than long.

Hypopus (Fig. 6-10): Holotype 260μ long and 175μ wide. Dorsum with a small punctate area in the posterior region. A distinct sejugal furrow present. Epimera I fused into a Y. Palposoma distinct, bearing 2 solenidia and 4 simple setae. Pregenital sclerite formed of two narrow longitudinal lines. Genital ring wider than long with slight lateral prolongations directed forwards. Femora I-II with setae simple. Tibiae and genua I-II with strong spines. Tarsi I-II 21μ long and 8μ wide. Claws I-II 9μ long, distinctly longer than the pretarsi.

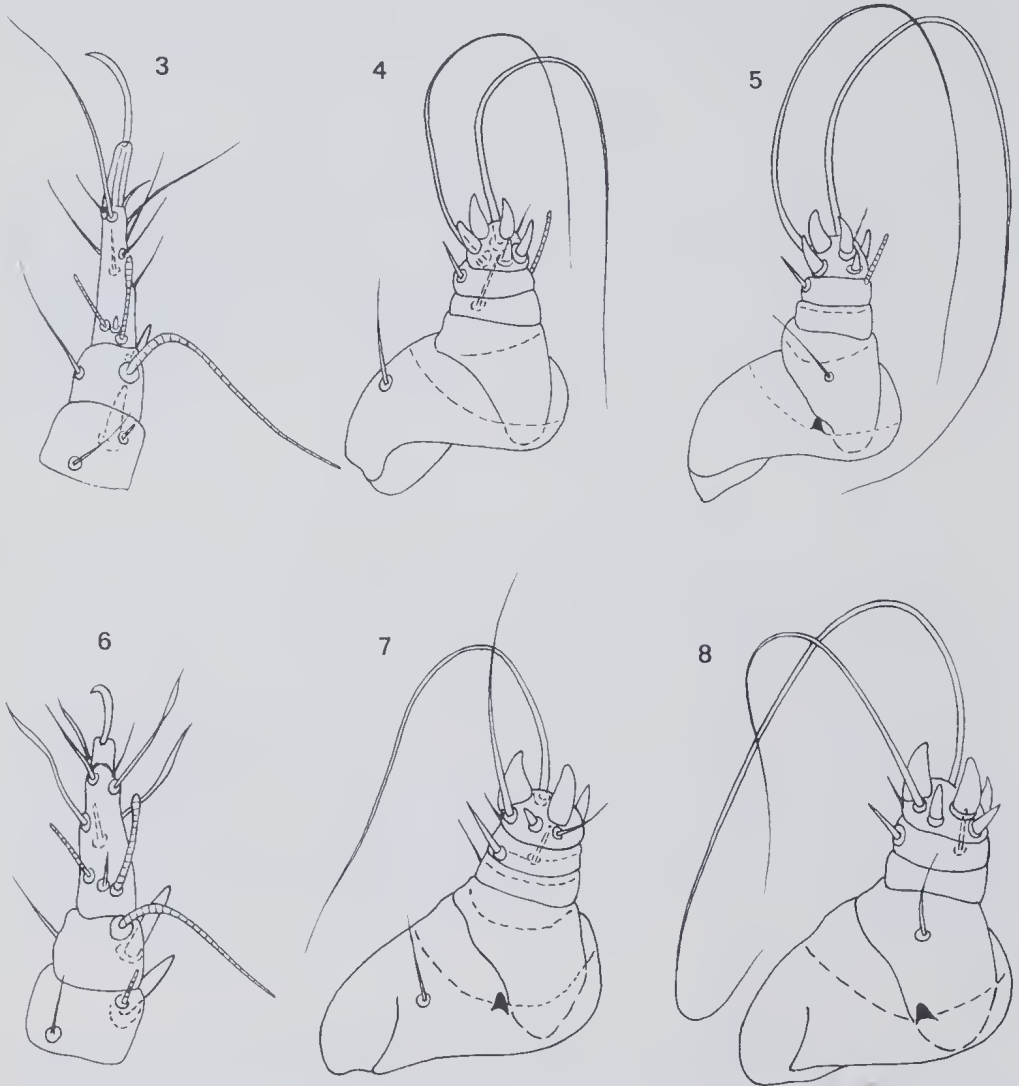
Host and localities

From the hair follicles of *Antechinus flavipes*, Australia, March 1884. Host specimen in the Museum of Leiden, Netherlands (holotype and 1 paratype).

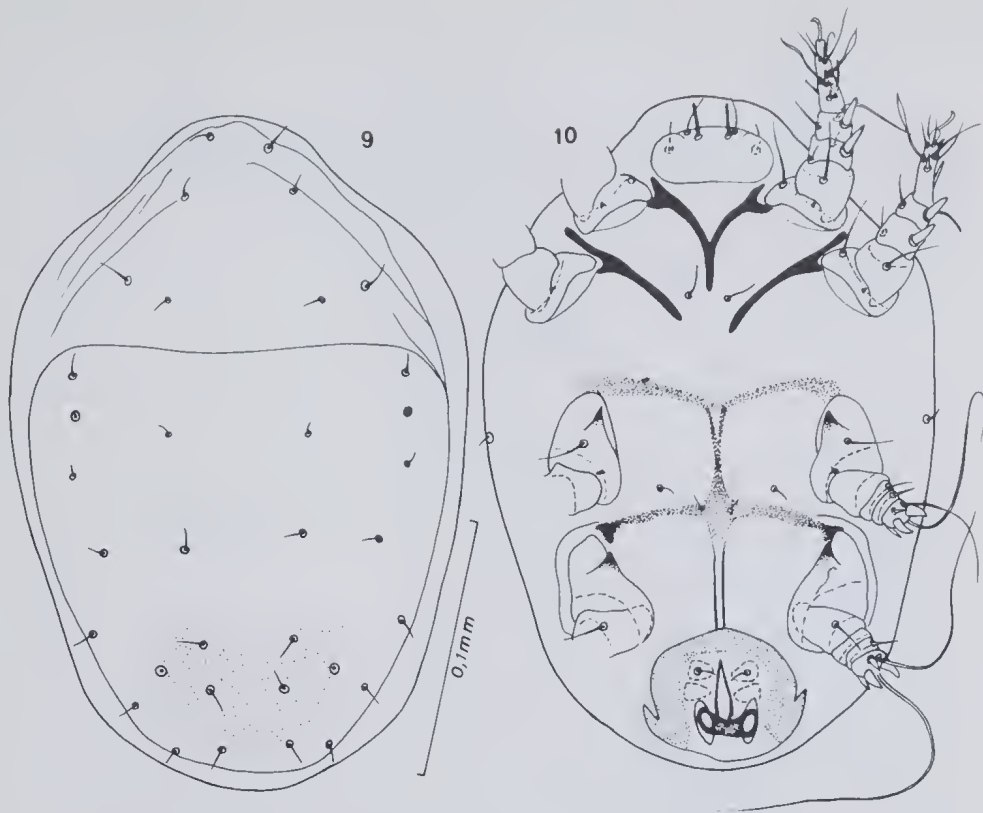
From the same host, Wandanian, N.S.W. (4 paratypes); Atherton Tableland, Queensland, 30.VII.1921 (2 paratypes); Ebor, N.S.W., 5.II.1921 (6 paratypes); Milton, N.S.W., 20.VII.1920 (1 paratype). These specimens

were collected from mammals in the Smithsonian Museum, Washington, by the junior author.

Holotype in the Rijksmuseum, Leiden, Netherlands. Paratypes in the Western Australian Museum, Perth, in the U.S. National Museum, Washington, and in the collections of the authors.



Figs 3-8: *Marsupiopus myrmecobius* sp. n. Hypopus (holotype). Tarsus, tibia and genu I dorsally (fig. 3). Leg III (fig. 4) and IV (fig. 5). *Marsupiopus antechinus* sp. n. Hypopus (holotype). Tarsus, tibia and genu I dorsally (fig. 6). Leg III (fig. 7) and IV (fig. 8).

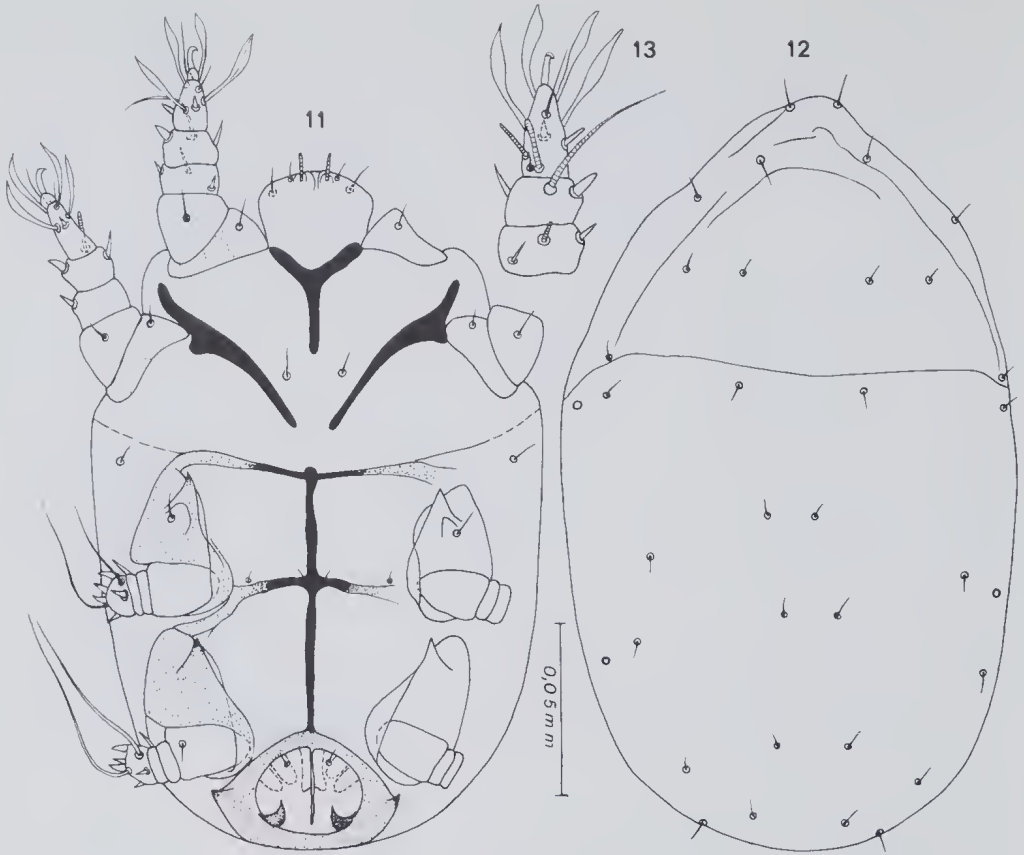


Figs 9-10: *Marsupiopus antechinus* sp. n. Hypopus (holotype). Dorsum (fig. 9) and venter (fig. 10).

4. *Marsupiopus acrobates* sp. nov.

This species has a distinct sejugal furrow as in *M. antechinus*. It differs from this species by the much smaller size of the body, the broader tarsi I-II, and the unequal size of the spines on tibiae and genua I-II.

Hypopus (Fig. 11-13): Holotype 195μ long, 120μ wide. In 3 paratypes the length is 210μ , 190μ and 195μ . Sejugal furrow well developed. In the anterior part of the dorsum there are several irregular transverse grooves. Palposoma well developed, rounded, with alpha solenidia short (5μ) and close together (distance alpha-alpha 7μ) and 2 pairs of short hairs. Pregonital median sclerite strongly sclerotised. Pregonital ring wider than long, with 2 globulous setae bifid apically. Tarsus I 13μ long and 8.5μ maximum width; tarsus II a little longer (15μ) and narrower (7.5μ). Claws I-II 7.5μ long. Tibiae and genua I-II with 1 narrow setae and 1 spine, the spine of the tibia being 2 to 3 times thicker than that of the genu.



Figs 11-13: *Marsupiopus acrobates* sp. n. Hypopus (holotype). Venter (fig. 11) and dorsum (fig. 12). Tarsus, tibia and genu I dorsally (fig. 13).

Host and locality

On *Acrobates pygmaeus*, Armidale, N.S.W., Australia. The mites were embedded in the hair follicles. Host specimen (No. 221347; collected by C.M. Hoy, 1916) in the Smithsonian Museum (holotype and 8 paratypes). Holotype and 3 paratypes in the U.S. National Museum, Washington; other paratypes in the Western Australian Museum, and in the collections of the authors.

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BENTHIC FAUNAL CHANGES IN A SEASONAL ESTUARY OF SOUTH-WESTERN AUSTRALIA

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ABSTRACT

The estuary of the Swan River is located in a region of Mediterranean-type climate and experiences contrasting hydrologic conditions from summer to winter. Consequently few species of benthic fauna are able to live there continuously. Data on the occurrence and distribution of benthic fauna over the period 1952-1975 are presented in relation to hydrologic conditions. Distributions within the estuary during and after a two-year period of reduced winter flooding are compared.

INTRODUCTION

The Swan Estuary receives discharge from one of the larger catchment basins of south-western Australia, referred to by Bettenay and Mulcahy (1972) as the Avon System. Most of this System drains the modified agricultural land of the eastern, central and southern wheatbelt, but the western part includes substantially unmodified forest tracts of the Darling Range. The estuary forms the central landscape feature of the Perth Metropolitan Region. Recent district maps of the surface geology have been prepared by Low and Lake (1970) and physiographic and hydrologic aspects of the estuary have been described by Somerville (1921), Aourousseau and

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Budge (1921), Jutson (1950), Rochford (1951), Spencer (1956), Churchill (1959) and Wilson (1968, 1969).

A two-part division of the Swan Estuary was adopted by Spencer (1956) and Wilson (1968), who envisaged an upper and lower estuary, above and below Heirisson Island. This study suggests that, as a biotope, the estuary divides appropriately into three parts (fig. 1). The Upper Estuary, above Heirisson Island, corresponding to those of Spencer and Wilson, has the character of a tidal river with a meandering channel of fluvial aspect. The banks are chiefly alluvium, although quartz dune sands are present in places below Guildford. The bed substratum grades from coarse, mainly quartz sand in the upper reaches to dark grey mud downstream. Water depths range from less than 2 metres above Middle Swan to about 6 metres near Maylands. The Canning Arm from Salter Point to Riverton Weir resembles the Upper Estuary of the Swan in its hydrology but has extensive shallow mud and sand flats.

The Middle Estuary, of delta-basin form, extends from Heirisson Island to Blackwall Reach, occupying a wide, drowned valley with extensive shallows in Perth Water and a deep central basin with marginal sand flats in Melville Water. The banks are composed of Pleistocene quartz sands of low relief and discontinuous, more elevated deposits of aeolian calcarenite, the so-called "Coastal Limestone". The Middle Estuary deepens seaward from about 1 metre in parts of Perth Water, to a maximum of 21 m in Mosman Bay. Marginal flats and spits are sandy and support extensive growths of the seagrass *Halophila ovalis*. This plant does not extend into the Upper Estuary. The basin substratum consists of a fine, dark grey mud. In addition, extensive fossil shell beds of Middle Holocene age occur in much of Perth and Melville Waters (Reath, 1925; Serventy, 1955). Combined dredging and foreshore reclamation have greatly modified many areas of both Upper and Middle Estuaries.

The Lower Estuary, from Blackwall Reach to Fremantle Harbour, is an inlet occupying a narrow, winding channel that has been incised through a prominent ridge of Coastal Limestone, forming cliffs which in some places extend below sea level. In contrast to the Middle Estuary, the Lower Estuary shallows seaward from about 16 m near Chidley Point to 5 m or less upstream from the Fremantle road bridges. Here, an extensive sand sill occurs, restricting the flow of both tidal and flood water. The harbour at the mouth of the estuary has been dredged to a depth of 11 m. Substrates range from a fine, dark grey mud in the Blackwall Reach channel to coarse shell and pebble beds in the Rocky Bay channel; elsewhere sand flats and sills predominate. *Halophila ovalis* and *Zostera mucronata*, both seagrasses, occur in shallow areas.

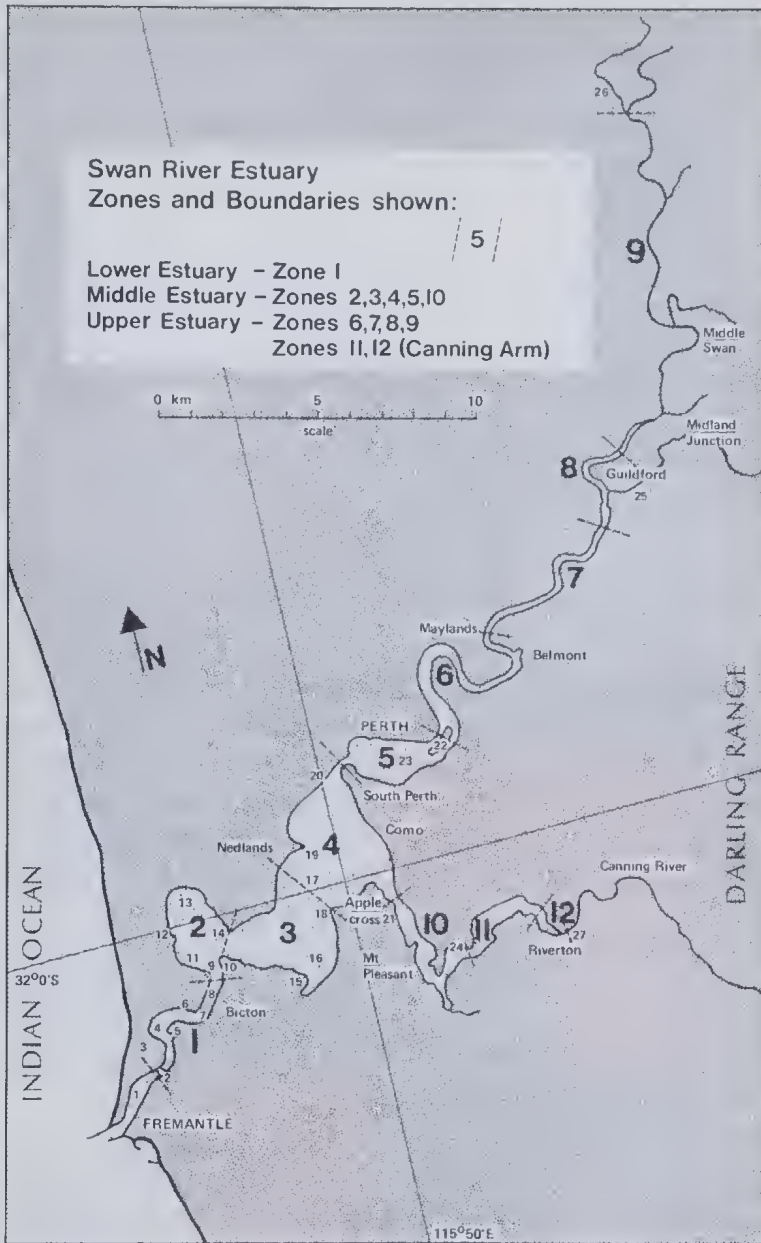


Fig. 1. Swan River Estuary, localities.

1. Fremantle Harbour. *Lower Estuary*. 2. Fremantle bridges. 3. North Fremantle. 4. Rocky Bay. 5. Preston Point. 6. Minim Cove. 7. Point Roe. 8. Blackwall Reach. *Middle Estuary*. 9. Chidley Point. 10. Point Walter. 11. Mosman Bay. 12. Peppermint Grove. 13. Freshwater Bay. 14. Point Resolution. 15. Point Waylen. 16. Lucky Bay. 17. Melville Water. 18. Point Dundas. 19. Pelican Point. 20. Swan Brewery. 21. Canning Bridge. 22. Heirisson Island (Causeway). 23. Perth Water. 24. Salter Point. *Upper Estuary*. 25. Helena River. 26. Ellen Brook. 27. Riverton Weir.

Spencer (1956) has described an annual hydrologic cycle in the Swan Estuary. The two phases of this cycle contrast markedly and are a result of the contrasting summer drought and heavy winter rainfall of the Mediterranean-type regional climate. River discharge ceases during the summer, when the Lower and Middle Estuaries become a virtual arm of the sea. Marine water circulation, induced by a weak tidal oscillation, which may be negated or augmented in effect by changes of barometric pressure, characterises the summer-autumn phase. During winter, river discharge resumes, diminishing or even eliminating tidal influence and introducing comparatively fresh, turbid water into the estuary. A substantial fall in chlorinity, cooling, stratification, light penetration and some de-oxygenation of deep water are among the consequences of this change of phase. These conditions persist until a slackening river discharge in the spring allows marine influences to be reasserted. The Lower Estuary is the last to be affected by the river discharge and the first to which marine influences are restored. Conversely, the Upper Estuary is first to receive floodwater and the last to be penetrated by marine water in summer.

In addition to the two-phase annual cycle, the Swan Estuary experiences widely varying hydrologic conditions from one year to another depending on rainfall and the volume and pattern of river runoff. During the wet years 1963-65 surface water of the Middle Estuary was fresh (<5‰ S.) for four to five months each winter (Bhuiyan, 1966; Wilson, 1968). On the other hand during 1969 salinity was never less than 20‰ and during the winters of 1970-72 it was probably less than 10‰ for only 4 to 6 weeks (E.P.H., unpublished data). The winter of 1973 was moderately wet and salinity was between 5 and 10‰ for about four months. There are no hydrologic data for 1959, but the rainfall record indicates that winter salinities were probably relatively high in that and the three following years. We have used winter rainfall (May to October) for Perth as a convenient, relative measure of the degree of winter river discharge (fig. 2).

Past faunal studies of the Swan Estuary (Thiele, 1930; Thompson, 1946; Serventy, 1955; Wilson, 1964, 1968, 1969; Lucas, 1968, 1971; Lucas and Hodgkin, 1970) have revealed a low species diversity of benthic fauna. This paper presents further results of collections and observations from the Swan Estuary in relation to hydrologic fluctuations over the past 20 years. The information is presented in two parts. Part 1 deals with Western Australian Museum records of the benthic fauna and Part 2 considers distributions of benthic species during two summers, one after a series of dry winters with low rainfall and the other after a wet winter of above average rainfall. Most of the data concern molluscs; other groups, such as polychaetes, crustaceans, echinoderms and coelenterates have been studied less consistently.

For the taxonomy of tapetinine bivalves, Lamy (1922) and Fischer-Piette and Métivier (1971) have been followed; for oysters, Stenzel (1971); for Pinnidae, Rosewater (1961); for *Proxichione*, Darragh (1965) and for other bivalves, Part N of the Treatise on Invertebrate Paleontology has been used as a guide.

Part 1. Museum records

The records of molluscs, echinoderms and coelenterates presented below are drawn from the collections of the Western Australian Museum. With the exception of a few earlier records, they are the results of collecting by many persons, including the present writers, since the early 1950s. Further supplementary data are provided in Part 2 of this paper.

Collecting was most intensive in the more accessible, marginal habitats. Sand flats were sampled by sieving and rocky areas were examined intertidally and in the shallow sub-littoral; rocks were turned over and crevices and borings searched. Submerged wood was similarly investigated, particularly in the Upper Estuary. Areas of algal growth, sea grass and rushes were sampled directly and by sieving and dredging. The deeper basins and channels were collected with a towed dredge, the recovery (pebbles, sand and mud) being sieved and sorted mainly in the boat; sorting of some finer substrates was completed under magnification in the laboratory. Most collecting activity took place in the summer-autumn period, but a proportion was carried out at other times of the year.

The sectional (i.e., Upper, Middle or Lower) faunas of the estuary were each divided into continuous and temporary resident species. Continuous status was accepted in cases where living specimens had been collected or observed regularly throughout the year and the maturity of individuals indicated prolonged residence in the locality. A few species, known only from specimens collected dead, were also assessed as continuous residents. These were obtained in fresh condition (e.g., containing soft tissue remnants or having a fresh periostracum) and usually by deep water dredging. Such species are deep substrate burrowers and the failure to collect living examples may be a consequence of inadequate sampling techniques.

A species was assessed as a temporary inhabitant of a zone if records, living or dead, were sporadic or if evidence of mature specimens regularly present in the area was lacking. Future dredging in the deeper parts of the estuary may reveal that some burrowing species regarded as temporary residents are actually continuous and *vice versa*; this applies mainly to some records from the Lower Estuary. All occurrences are based on positive records; inferred distributions have not been included in the tables of results.

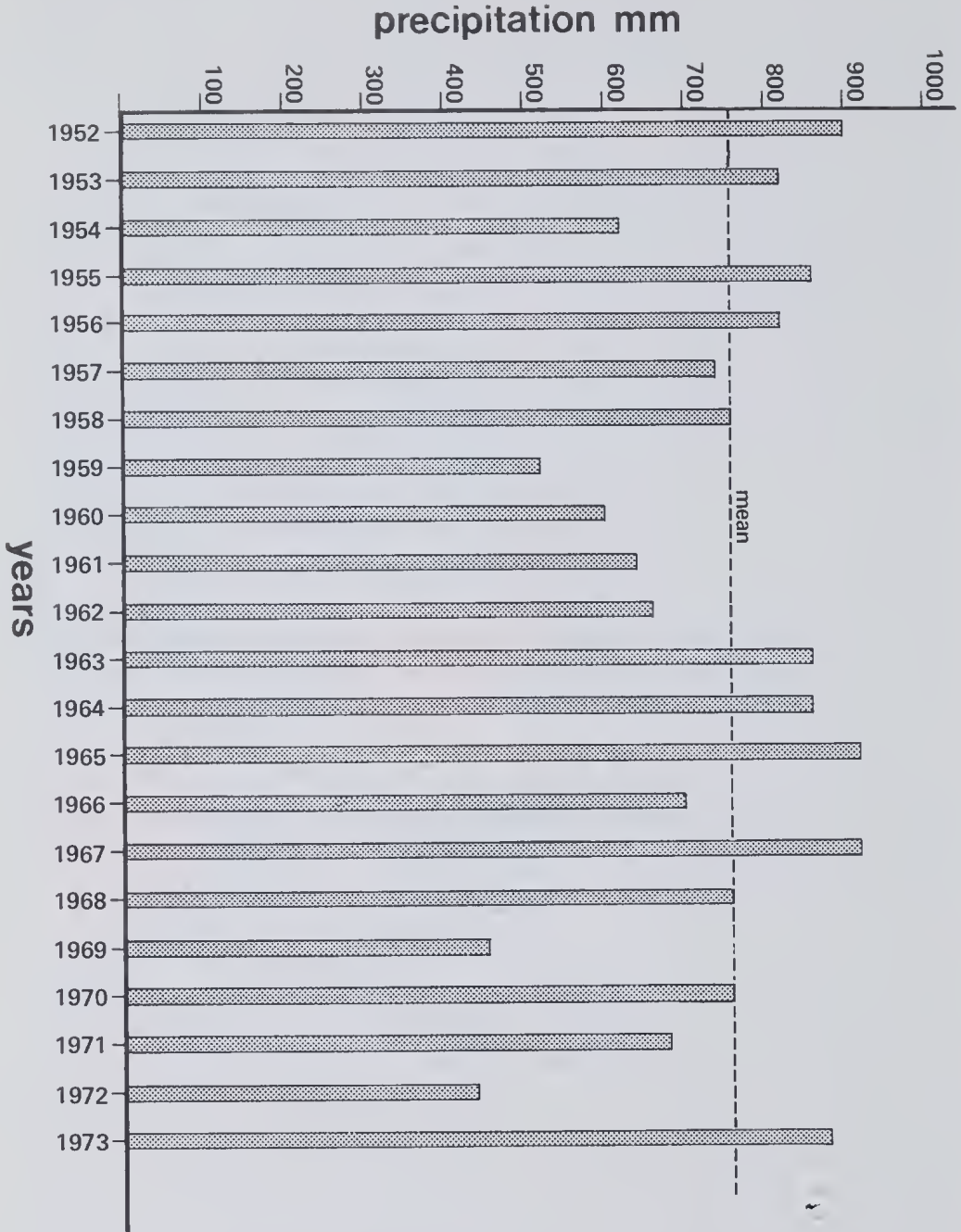


Fig. 2. Total precipitation (mm) at Perth for the six wettest months, May to October inclusive, 1952 to 1973. Mean is for the hundred years 1876 to 1975.

Results. Table 1 lists the benthic fauna according to the presence or absence of each species on a continuous or temporary basis in each of the three sections of the estuary. A local marine presence for each species is also indicated where appropriate, based on Museum collection data. The table is followed by a more detailed discussion of the habitat and other field observations of most species.

Table 1. Distributions of benthic molluscs, echinoderms and coelenterates within the Swan Estuary; marine occurrences of species are given where available. A cross (+) in the columns for estuarine records indicates that one or more live-collected specimens are known. An asterisk (*) indicates that the record is based on dead material.

SPECIES	Marine records (W.A.)	Lower Estuary		Middle Estuary		Upper Estuary	
		Temp.	Cont.	Temp.	Cont.	Temp.	Cont.
MOLLUSCA							
AMPHINEURA							
Acanthochitonidae							
1. <i>Acanthochiton</i> sp.		+					
Lepidopleuridae							
2. Lepidopleurid, genus uncertain		+					
BIVALVIA							
Solemyidae							
3. <i>Solemya (Solemyarina) australis</i> Lamarck	+			*			
Mytilidae							
4. " <i>Amygdalum</i> " <i>glaberrimum</i> (Dunker)	+	+					
5. <i>Brachidontes</i> sp. cf. <i>B. variabilis</i> Krauss	+	+					
6. <i>Musculus paulucciae</i> (Crosse)	+	+					
7. <i>Musculus</i> sp. cf. <i>M. nanulus</i> Thiele		+					
8. <i>Mytilus edulis planulatus</i> (Lamarck)	+		+	+			
9. <i>Xenostrobus pulex</i> (Lamarck)	+		+				
10. <i>Xenostrobus securis</i> (Lamarck)		+			+		+
Pinnidae							
11. <i>Pinna bicolor</i> Gmelin	+	*		*			
Pteriidae							
12. <i>Pinctada fucata</i> (Gould)	+	+					
Malleidae							
13. <i>Malleus meridianus</i> Cotton	+		+				

Table 1 Continued

SPECIES	Marine records (W.A.)	Lower Estuary		Middle Estuary		Upper Estuary	
		Temp.	Cont.	Temp.	Cont.	Temp.	Cont.
Pectinidae							
14. <i>Chlamys asperrimus</i> (Lamarck)	+	*		*			
Anomiidae							
15. <i>Anomia descripta</i> Iredale	+		+	*			
Ostreidae							
16. <i>Saccostrea cucullata</i> (Born)	+	+		*			
Lucinidae							
17. <i>Cavatidens perplexa</i> (Cotton and Godfrey)	+	+					
18. <i>Wallucina assimilis</i> (Angas)	+	*		*			
19. <i>Wallucina</i> sp.	+	*		+			
20. <i>Epicodakia</i> sp.	+	*					
Ungulinidae							
21. <i>Felaniella (Zemysia)</i> sp.		+					
Chamidae							
22. <i>Chama ruderalis</i> Lamarck	+		+				
Erycinidae							
23. <i>Arthritica semen</i> (Menke)		*			+	+	
Kelliidae							
24. <i>Kellia australis</i> (Lamarck)	+	+					
25. <i>Marikellia</i> sp.		+					
Leptonidae							
26. <i>Lepton</i> sp.		+					
Montacutidae							
27. <i>Mysella</i> sp.		*					
Carditidae							
28. <i>Megacardita incrassata</i> (Sowerby)	+		+				
Cardiidae							
29. <i>Laevicardium (Fulvia) apertum</i> (Bruguiere)	+	+		*			
Mactridae							
30. <i>Mactra (Electromactra) antecedens</i> (Iredale)	+	+		*			
31. <i>Spisula (Notospisula) trigonella</i> (Lamarck)	+		+		+	*	
32. <i>Mesodesma angusta</i> Reeve	+	+					
Cultellidae							
33. <i>Phaxas (Ensiculus) cultellus</i> (Linnaeus)	+		+	*			

Table 1 Continued

SPECIES	Marine records (W.A.)	Lower Estuary		Middle Estuary		Upper Estuary	
		Temp.	Cont.	Temp.	Cont.	Temp.	Cont.
Tellinidae							
34. <i>Tellina</i> (<i>Macomona</i>) <i>deltoidalis</i> Lamarck	+		+		+	*	
35. <i>Tellina</i> (<i>Pharaonella</i>) <i>perna</i> Spengler	+	*					
36. <i>Tellina</i> (<i>Pinguitellina</i>) sp.	+		+				
37. <i>Tellina</i> (<i>Teilinangulus</i>) sp.	+	+					
38. <i>Tellina</i> sp.	+	*					
Psammobiidae							
39. <i>Sanguinolaria</i> (<i>Psammotellina</i>) <i>biradiata</i> (Wood)	+		+				
Semelidae							
40. <i>Theora</i> (<i>Endopleura</i>) <i>lubrica</i> Gould	+				+		
Veneridae							
41. <i>Chioneryx cardioides</i> (Lamarck)	+	+		*			
42. <i>Circe sulcata</i> Gray	+	*		*			
43. <i>Dosinia</i> (<i>Pectunculus</i>) <i>sculpta</i> (Hanley)	+	*					
44. <i>Gomphina undulosa</i> (Lamarck)	+	+					
45. <i>Paphia</i> (<i>Callistotapes</i>) <i>crassisulca</i> (Lamarck)	+		+				
46. <i>Irus</i> (<i>Irus</i>) <i>carditoides</i> (Lamarck)	+	+					
47. <i>Irus</i> (<i>Irus</i>) <i>crenata</i> (Lamarck)	+		+	+			
48. <i>Irus</i> (<i>Notirus</i>) <i>iridescens</i> (Tate)	+	+					
49. <i>Proxichione laqueata</i> (Sowerby)	+	*					
50. <i>Venerupis anomala</i> (Lamarck)	+	+					
Petricoliidae							
51. <i>Petricola</i> (<i>Velargilla</i>) sp.	+	*					
Hiatellidae							
52. <i>Hiatella australis</i> (Lamarck)	+	+					
Lyonsiidae							
53. <i>Anticorbula amara</i> (Laseron)		*			+		+
GASTROPODA							
Acmaeidae							
54. <i>Acmaea</i> (<i>Notoacmea</i>) <i>onychitis</i> (Menke)	+	+					

Table 1 Continued

SPECIES	Marine records (W.A.)	Lower Estuary		Middle Estuary		Upper Estuary	
		Temp.	Cont.	Temp.	Cont.	Temp.	Cont.
Trochidae							
55. <i>Monilea callifera</i> (Lamarck)	+	*					
Cyclostrematidae							
56. <i>Elachorbis tatei</i> (Angas)	+	*					
Littorinidae							
57. <i>Bembicium melanostomum</i> (Gmelin)	+		+				
58. <i>Littorina (Austrolittorina) unifasciata</i> Gray	+	+					
Hydrobiidae							
59. <i>Hydrococcus graniformis</i> Thiele	rare - see text	last recorded about 1840					
60. <i>Potamopyrgus</i> sp.		*					+
61. <i>Tatea preissi</i> (Philippi)		*			+		+
Assimineidae							
62. <i>Assiminea</i> sp.							+
Tornidae							
63. <i>Teinostoma</i> sp.		*					
64. <i>Vitrinella</i> sp.		*					
Rissoidae							
65. <i>Alvinia (Linemera)</i> sp.		*					
66. <i>Ovirissoa nitidula</i> (Thiele)	+	+					
Thiaridae							
67. <i>Plotiopsis australis</i> (I. & H.C. Lea)							+
Potamididae							
68. <i>Batillaria (Velacumantus) australis</i> (Quoy & Gaimard)	+		+		+		
Diastomatidae							
69. <i>Obtortio</i> sp.	+	+					
Cerithiidae							
70. <i>Alaba fragilis</i> (Thiele)	+		+				
71. <i>Alaba pusilla</i> (Thiele)	+	*					
72. <i>Diala lauta</i> (A. Adams)	+	*					
Epitoniidae							
73. <i>Epitonium</i> sp. cf. <i>E. imperiale</i> (Sowerby)	+	+					
Muricidae							
74. <i>Trophon (Bedeva) paivae</i> Crosse	+		+	+			

Table 1 Continued

	Marine records (W.A.)	Lower Estuary		Middle Estuary		Upper Estuary	
		Temp.	Cont.	Temp.	Cont.	Temp.	Cont.
Columbellidae							
75. <i>Milrella (Denlimirella) lincolnensis</i> (Reeve)	+	*					
76. <i>Zafra vercoi</i> (Thiele)	+	+					
Nassariidae							
77. <i>Nassarius burchardi</i> (Philippi)	+		+		+	*	
78. <i>Nassarius pauperatus</i> (Lamarck)	+		+		+		
79. <i>Nassarius pauperus</i> (Gould)	+		+				
80. <i>Nassarius pyrrhus</i> (Menke)	+	+					
Pyramidellidae							
81. ? <i>Aclis</i> sp.		+					
82. <i>Syrnola bifasciata</i> (Tenison Woods)		+					
83. <i>Turbonilla (Pyrgiscus) fusca</i> (A. Adams)	+	*					
Bullidae							
84. <i>Bulla tenuissima</i> Sowerby	+	+					
Athyidae							
85. <i>Liloa brevis</i> (Quoy & Gaimard)	+	+					
Akeridae							
86. <i>Akera soluta</i> (Gmelin)	+	+					
Scaphandridae							
87. <i>Acleocina</i> sp. cf. <i>A. canaligradala</i> Ludbrook		+					
88. <i>Adanneslia arachis</i> (Quoy & Gaimard)	+	+					
89. <i>Roxania hordeacea</i> (A. Adams)		*					
Philinidae							
90. <i>Philine angasi</i> (Crosse & Fischer)	+		+	*			
91. <i>Philine</i> sp.			+	+			
Aglajidae							
92. <i>Aglajid</i> , cf. <i>Nakamigawaia</i> sp.		+					
Aplysiidae							
93. <i>Aplysia angasi</i> Crosse & Fischer	+	+					
94. <i>Aplysia</i> sp.	recorded in Part 2						
Elysiidae							
95. <i>Elysia australis</i> (Quoy & Gaimard)	+	+					

Table 1 Continued

	Marine records (W.A.)	Lower Estuary		Middle Estuary		Upper Estuary	
		Temp.	Cont.	Temp.	Cont.	Temp.	Cont.
Siphonariidae							
96. <i>Siphonaria baconi</i> Reeve	+	+					
97. <i>Siphonaria luzonica</i> Reeve	+	+					
ECHINODERMATA							
ECHINOIDEA							
Temnopleuridae							
98. <i>Temnopleurus michaelsoni</i> (Döderlein)	+		+				
Laganidae							
99. <i>Peronella lesueri</i> Loveniidae	+	+		+			
100. <i>Breynia australasiae</i> (Leach)		+			*		
STELLEROIDEA							
Astropectinidae							
101. <i>Astropecten triseriatus</i> Muller & Troschel	+	+					
Oreasteridae							
102. <i>Anthenea australiae</i> Döderlein	+	+					
Ophiactidae							
<i>Ophiactis</i> sp. cf.			+				
<i>O. acosmeta</i> H.L. Clark							
Amphiuridae							
104. <i>Amphipholis squamata</i> (Della Chiaje)	+		+				
105. <i>Amphiura</i> sp. cf. <i>A. constricta</i> Lyman			+				
COELENTERATA							
ANTHOZOA							
Veretillidae							
106. Seapen, unidentified Rhizangiidae	+		+				
107. <i>Culicia</i> sp. cf. <i>C. tenella</i> Hoffmeister	+	+					
Stoichaetidae							
108. <i>Radianthus concinnata</i> Lager	+	+					

Remarks on individual species

The two amphineuran species are known only from channel dredgings around Rocky Bay. All specimens are small and uncommon.

Mytilus edulis planulatus. A large colony lived on the piles of the old Fremantle railway bridge until its demolition in 1966; subsequently this

species has been recorded living upstream to Bicton, and from 1970 to the winter of 1973, temporarily in the Middle Estuary upstream to Pelican Point (E.P. Hodgkin, unpublished data). This species was common on pilings at Pelican Point during the summers of 1960-64 but was severely affected by the winter floods (Wilson, 1964: 73-4).

Brachidontes sp. cf. *B. variabilis*. At Rocky Bay, recently-dead juveniles were common on intertidal rocks in Dec. 1960 and were living there also in Mar. 1973. Each record follows a dry winter.

"*Amygdalum*" *glaberrimum*. A mature, living specimen was dredged from a sand-flat, now removed, upstream from the old Fremantle railway bridge in Dec. 1964; juveniles were living on the Rocky Bay sand flat in Jan. 1973.

Xenostrobus securis were collected from the Lower Estuary in a recently-dead condition at Preston Point in Dec. 1964 and living at Minim Cove in Jan. 1974. Wet winters preceded both of these records. Occurrences in the Lower Estuary appear to be sporadic and those in the downstream part of the Middle Estuary probably have been temporary. The species is a continuous inhabitant in the upstream part of the Middle Estuary and in the Upper Estuary to about Midland Junction and Riverton, forming mat-like colonies on submerged objects such as piles, logs and rocks. There are no marine records of the species from Western Australia. Adults are tolerant to a wide range of salinities but fertilisation and larval development can occur only within a limited salinity range (Wilson, 1968). This evidently precludes establishment of colonies in either the sea or in the uppermost extremities of the estuary. The related *X. pulex* also occurs in the Lower Estuary and care is needed in distinguishing between the two species. *X. securis* is doubtless that species collected at Perth and Canning River in 1905 by the Hamburg Expedition and listed as *Modiolus pulex* by Thiele (1930).

X. pulex. Mature specimens that appear to have lived through a winter were occasionally found intertidally on rocky substrates downstream from Blackwall Reach.

Pinna bicolor. Empty shells, some in fresh condition, were collected from the Rocky Bay channel in 1960, 1973 and 1974 and from Freshwater Bay in 1962. All are small and appear to represent temporary colonisations.

Malleus meridianus and *Chama ruderalis*. Mature specimens of both species have been found regularly in channel dredgings downstream from Pt Roe.

Pinctada fucata. A well-grown living specimen was dredged from Rocky Bay in June 1962.

Anomia descripta. Mature living specimens were common at Rocky Bay in the channel and on deeper sand flats and less frequently attached to rocks in the shallow sub-littoral. Some articulated valves, one with attached muscle tissue, were washed ashore at Perth Water (South Perth) in Apr. 1970 and may represent a temporary incursion into the Middle Estuary following the dry winter of 1969.

Saccostrea cucullata. This rock oyster was not uncommon in the littoral and sub-littoral around Rocky Bay and occasionally upstream to Freshwater Bay. All individuals and colonies are small and appear to have been short-lived.

Wallucina assimilis. Fresh valves of this species, including articulated pairs, were present in dredged sandy substrates of the Lower Estuary in January of 1973 and 1974. No living record has been obtained. *W. assimilis* appears to be less common than the following species, which is distinguished by a more robust, rounded shell with stronger concentric sculpture.

Wallucina sp. Articulated pairs of valves were common in dredged sandy substrates of the Lower Estuary between Jan. 1973 and Mar. 1974. A single living specimen was dredged from Melville Water near Pt Walter in Jan. 1963. This record follows a dry winter.

Arthritica semen. This minute clam was abundant on sand flats of the Middle Estuary and ranged into the lower reaches of the Upper Estuary. Occurrences in the Lower Estuary were sporadic; there are no marine records from Western Australia. Ashman (1969) indicates that this species tolerates salinities ranging from normal sea water to 2‰ S.

Megacardita incrassata occurs living in the deeper parts of Rocky Bay and in the Blackwall Reach channel. Specimens are of mature size and suggest a continuous population.

Mactra (Electromactra) antecedens was a common species living on the Rocky Bay sand flat in Feb. 1960 and Jan. 1961 but was not observed again until Dec. 1973. These records follow dry winters.

Spisula (Notospisula) trigonella. The sudden appearance of this species in the Swan Estuary around 1964 was recorded by Wilson and Kendrick (1968). Since then, it has become a continuous and conspicuous inhabitant of the sand flats in the Lower and Middle Estuaries; it is also present in the deeper basins and channels of the Middle Estuary. In periods of reduced river discharge, this species expands temporarily upstream to Belmont and Riverton. Western Australian marine records are rare.

Phaxas (Ensiculus) cultellus. Though never common, recently-dead, articulated shells of this species are regularly found in dredgings from the Lower Estuary, suggesting that a continuous population may be present. Recently-dead specimens from Melville Water near Pt Walter in the summer

of 1962-63 are believed to represent a temporary incursion into the Middle Estuary similar to that of *Laevicardium apertum* in the same period. A mature, living specimen was collected at North Fremantle in Jan. 1974.

Tellina (Macomona) deltoidalis was commonly found living on the Rocky Bay sand flat in Feb. 1960 and Jan. 1961 and since then has been collected regularly, either living or in a recently-dead condition, from the sand flats of the Lower Estuary, where it appears to be a continuous resident. Other records, living and recently dead, from Pt Waylen, May 1953, Heirisson Island, May 1953 and Pt Walter spit, Apr. 1960, suggest that it invades the Middle Estuary in the summer but does not regularly survive the winter phase of the hydrologic cycle. A single old valve from Belmont, Oct. 1966, indicates a temporary extension into the Upper Estuary, probably following an interval of reduced river discharge. It is occasionally collected in the sea near Fremantle.

Tellina (Pharaonella) perna. A dead, articulated juvenile shell from the Rocky Bay sand flat in the summer of 1959-60 appears to represent a temporary incursion into the Lower Estuary as a result of the dry winter of 1959.

Tellina (Pinguitellina) sp. Mature, living specimens were collected from the Rocky Bay channel and sand flat in Jan. 1974, following the normal winter rainfall of 1973.

Tellina sp. This is a pink, thin-shelled tellin of undetermined subgenus; recently-dead valves, some articulated, were collected from the channel of the Lower Estuary in 1973 and 1974.

Sanguinolaria (Psammotellina) biradiata. Several live records and other recently-dead specimens collected from Preston Point and North Fremantle over 1971-73 indicate a continuous population in the Lower Estuary. This species burrows deeply into the substrate and is not readily collected alive.

Theora (Endopleura) lubrica. Live specimens were dredged from mud in 4 m at Lucky Bay, Feb. 1973 and Mar. 1974 and from Freshwater Bay in Mar. 1974. It was abundant on each occasion and appears to be well established in the basin and channel areas of the Middle Estuary. The only other record of this species known to us from Western Australia is from a beach near Rockingham, May 1971. It appears that the species may be a recent addition to the benthos of the Swan Estuary, comparable with *Spisula (Notospisula) trigonella* discussed previously. *T. (E.) lubrica* has recently been reported for the first time from places as far apart as California (Seapy, 1974) and New Zealand (Powell, 1974) and appears to have expanded considerably beyond its previously-known range along the Pacific coast of Asia (Kuroda *et al.*, 1971 : 447).

Proxichione laqueata. A recently-dead single juvenile valve was found in Jan. 1961 and a large single valve in poor condition was dredged in Jan. 1973. Both specimens were collected at Rocky Bay.

Dosinia (Pectunculus) sculpta. Recently-dead, articulated pairs of valves were common on the Rocky Bay sand flat in the summer of 1960-61 and may have lived during the dry winter of 1959. Numerous other recently-dead specimens have been collected from around Rocky Bay since then but no living specimen is yet known. The only local marine record known to us is an articulated pair of valves in fresh condition collected at Rockingham in 1940; the species is common at Shark Bay and other northern localities.

Circe sulcata. As with the preceding, there are several records of this species, comprising recently-dead, articulated shells from the Lower Estuary over the period 1960-75, but no living specimen has yet been obtained. Some recently-dead, articulated specimens were also dredged from Melville Water near Pt Walter in Oct. 1962 and Jan. 1963. This species was collected in 1905 by the Hamburg Expedition in Freshwater Bay and listed by Thiele (1930) as *Circe lentiformis* sp. nov. The Thiele type is of fresh appearance and may have been collected living (R. Kilius, pers. comm.).

Paphia (Callistotapes) crassisulca. Recently-dead articulated specimens, some of mature size, were dredged from the deeper parts of Rocky Bay in Jan. 1973, Jan. and Mar. 1974. A living juvenile was obtained in Mar. 1974.

Irus (Irus) crenata was common throughout the Lower Estuary living on sand flats, in rock cavities and in channel beds. Shells from rock cavities tend to be of irregular shape. Living records from Pt Dundas, Dec. 1972 and Applecross, Nov. 1972 suggest a temporary occupation of the lower part of the Middle Estuary following the previous dry winter. Other non-living records from Canning Bridge and the Causeway, both 1961, point to temporary settlement further upstream when conditions are favourable.

Irus (Irus) carditoides and *Irus (Notirus) iridescens* were collected alive from the Rocky Bay sand flat in the summer of 1959-60, while *Venerupis anomala* was also living there then and in the following summer. An empty, articulated shell of *Petricola (Velargilla)* sp. was collected from the same place in Jan. 1961. These records follow the dry winters of 1959-60; none of the species has since been re-collected from the estuary.

Anticorbula amara. This appears to be the species collected at Guildford in 1905 by the Hamburg Expedition and listed by Thiele (1930) as *Modiolus (Fluviolanatus) subtortus* (Dunker). Lower Estuary records are infrequent and the species appears to be temporary there. *A. amara* can live at marine salinities (E.P.H., unpublished data) but there are no known marine occurrences from Western Australia. The species is continuous in the

Middle and Upper Estuaries and collecting in recent years has established that it inhabits the Swan-Avon River upstream to beyond York. This non-estuarine population appears to have become established over the past 50 years and its establishment coincides with pronounced hydrologic changes, mainly increased salinity, in the Avon River (Kendrick, 1976). Such changes have been attributed to the clearing of land for agriculture (Peck and Hurlle, 1973). The species lives attached by byssal threads to submerged, firm substrates, large sand grains and aquatic plants.

An assortment of gastropods, *Acmaea (Notoacmea) onychitis*, *Littorina (Austrolittorina) unifasciata*, *Epitonium* sp. cf. *E. imperiale*, *Siphonaria luzonica* and *S. baconi*, were all collected alive from the Rocky Bay-Preston area in the summer of 1973-74. *A. (N.) onychitis* (empty shells in growth position) was also found at Preston Pt in Dec. 1960. These records all follow dry winters.

Bembicium melanostomum is common on intertidal rocks from Blackwall Reach downstream. In Western Australia, this species is mainly confined to estuaries, although a small marine population occurs on the south side of Woodman Point near Fremantle. Thompson (1946) recorded a "*Trochus* sp." in abundance along the littoral of Freshwater Bay. The identity of this species is uncertain but it may have been *B. melanostomum*, which has a trochiform shell. If so, there appears to have been a contraction of range downstream within the last 30 years.

Tatea preissi was first collected by Preiss from the Swan Estuary about 1840 and described by Menke (1843) under the preoccupied name *Paludina acuta*. Our earliest subsequent records are dead shells from Peppermint Grove, 1927 and from Bicton and Belmont, 1956. It was found living among mat colonies of *Xenostrobus securis* at the Causeway, Nov. 1969 and was common, living on intertidal rocks at Pt Walter, Pt Dundas and Peppermint Grove, Apr. 1970. This species appears to be a continuous inhabitant of the intertidal of the Middle Estuary and upstream to about Guildford; no marine or fluviatile records are known from Western Australia.

Hydrococcus graniformis was initially collected by Preiss around 1840 from "among white quartz sand on the bank of the Swan River" (Smith, 1882). Menke (1843) described these specimens under the preoccupied name *Paludina granum*. Thiele (1928) re-named and further described the Preiss-Menke specimens, adding details of the anatomy, indicating that they were collected alive. In all probability, they originated (together with Preiss' specimens of *Arthritica semen*), from a marginal sand flat of Melville Water in the Middle Estuary. Since the initial discovery, no living specimen of *H. graniformis* has been recorded from the Swan. Observations of the

species in other estuaries of south-western Australia (e.g., Leschenault, Hardy and Nornalup Inlets) show that the preferred habitat is on shallow sand flats. In the Middle Estuary of the Swan, this habitat has been considerably modified over recent decades by extensive dredging and shore reclamation. Empty shells of *H. graniformis*, none of fresh appearance, are common in fine substrates of the Lower and Middle Estuaries. They do not appear to have lived recently and it appears not unlikely that the species is now extinct in the Swan. There are no fluviatile or marine records from south-western Australia but the species is common in parts of Shark Bay; its listing as a freshwater element by McMichael (1967) is incorrect.

Potamopyrgus sp. Old shells of this species have been occasionally found in fine substrates from the Rocky Bay area but only recently (Mar. 1975) have living specimens been found. These were located in the Canning Arm at Riverton on sand flats and among rushes of a largely unmodified area. The species inhabits other estuaries in south-western Australia but there are no wholly marine or fluviatile records.

Assiminea sp. Living specimens were found together with *Potamopyrgus* sp. amongst rushes in the Canning Arm, Riverton, March 1975. Both of these species may have been overlooked previously because of their now-restricted habitat, which has been progressively eliminated by dredging and reclamation.

Plotiopsis australis is the only mollusc species of freshwater affinity known to occur in the estuary. It can survive salinities up to 25‰ (Blackwell, 1969) and is common in the Upper Estuary above Guildford. The species occurs in rivers of northern Western Australia, south to the Swan-Avon.

Batillaria (Velacumantus) australis. Since 1960, this species has been collected regularly from the Lower Estuary and the lower part of the Middle Estuary, where it occurs in abundance. Empty shells from the Canning at Mt Pleasant, Apr. 1972 and living specimens from Canning Bridge, Dec. 1972 suggest temporary range extensions upstream following periods of reduced river discharge.

Alaba fragilis was common living on a weed-grown part of the Rocky Bay sand flat in Jan. 1973 (following the dry winter of 1972), but living specimens were rare at the same station one year later. Freshly-dead specimens were obtained in the same general area in 1956 and 1963. The type material was collected at Freshwater Bay (Thiele, 1930).

Trophon (Bedeva) paivae. Common on the sand flats, rocky shores and channel throughout the Lower Estuary. Freshly-dead shells and occasional living specimens have been found in Freshwater Bay and Melville Water near Pt Walter.

Zafra vercoi and ?*Aclis* sp. were both common species living on the Rocky Bay sand flat in Jan. 1973 but only empty shells of each species were collected at the same station in Jan. and Mar. 1974. Evidently the species became established in the Lower Estuary following the dry winter of 1972 but could not survive the winter of 1973.

Nassarius pauperatus. Mature specimens, both living and recently-dead, have occasionally been found on the sand flats of the Lower Estuary; living specimens have also been collected at Pt Resolution, Mar. 1969, and Pelican Pt, Mar. 1973. Smith (1975) has established that 12 to 18 months are required for this species to reach maturity. It appears therefore that specimens collected would have survived at least one winter in either the Middle or Lower Estuaries.

Nassarius burchardi is a continuous inhabitant of sand flats and deeper areas throughout the Lower and Middle Estuaries, where it is one of the most abundant gastropods. Empty shells from Belmont, Dec. 1970, suggest a temporary move into the Upper Estuary, perhaps following the dry winter of 1969. Over the period 1972-74, *N. burchardi* was killed during the winters in shallow waters at the upper limits of range, but was able to survive in deeper, more saline waters in the same general area (Smith, 1975). From the Swan, the species is known only since about 1965, when the initial records were made. It was not observed during intensive collecting of the Rocky Bay-Pt Walter area in 1959-63, although the much rarer *N. pauperatus* was collected twice in that period. The first appearance and subsequent massive proliferation of *N. burchardi*, a scavenger, coincided with the establishment of *Spisula (Notospisula) trigonella* in the estuary (Wilson and Kendrick, 1968). The two species have a similar distribution within the estuary and the bivalve may be an important food resource for the snail.

Nassarius pauperus. Living and freshly-dead specimens of mature size dredged from the channel of the Lower Estuary on four occasions over 1973-74 suggest a continuous population there.

Philine angasi. Records of living specimens from the Blackwall Reach channel (Jan. 1963, Nov. 1969) and the Rocky Bay sand flat (Jan. 1974) suggest that a continuous population inhabits the Lower Estuary.

Philine sp. was collected from the Rocky Bay sand flat (Jan. 1973, Jan. and Mar. 1974) and in Lucky Bay (Mar. 1974). These are the only known records for the species, which is believed to be undescribed (R. Burn, pers. comm.).

Akera soluta was found living on the Rocky Bay sand flat in Jan. 1974 and may be only temporary in the Lower Estuary.

Temnopleurus michaelsoni. This echinoid was dredged alive from the Rocky Bay channel in Dec. 1962, Jan. 1963 (from field notes, G.W.K.) and in Jan. 1973; also collected alive from rocks in the sublittoral at Bicton, Apr. 1974.

Breyntia australasiae. A freshly-dead test of adult size, devoid of spines but with some of the fragile anal plates intact, was collected at Lucky Bay in Nov. 1961, following the dry winters of 1959-60.

Peronella lesueurii. The first of two records comprises four juveniles, all bearing spines and evidently collected alive. They were collected by members of the Natural History Society (forerunner of the Royal Society of Western Australia) apparently in Dec. 1908 during a dredging excursion between Perth and Chidley Point. A live juvenile of this species was trawled from 8-10 fathoms in Blackwall Reach, June 1962, following a sequence of dry winters.

The ophiuroids *Amphiura* sp., *Ophiactis* sp. and *Amphipholis squamata* were dredged from the Lower Estuary channel below Pt Roe in Jan. 1973 and Mar. 1974.

Astropecten triseriatus was dredged from 7-10 m in Blackwall Reach, July 1970, and was collected in less than 1 m of water on sand at Bicton, Feb. 1971. *Anthenea australis* was collected at Mosman Bay in Jan. 1974 and at Bicton in Apr. 1974. These few starfish records probably represent temporary incursions into the lower parts of the estuary.

The anemone *Radianthus concinnata* was dredged from 4-8 m on the western slope of the Rocky Bay sand bank in Jan. 1973.

Culicia sp. cf. *C. tenella*. A living colony of this small, semi-colonial, ahermatypic coral was dredged from a shingle substrate in the channel of the Lower Estuary near Minim Cove in Mar. 1974. It is indistinguishable in size of colony and growth form from samples of the same species from Garden Island off Fremantle (L.M. Marsh, personal communication, Oct. 1975).

Part 2. Littoral surveys during the summers of 1972-73 and 1973-74.

Surveys of benthic fauna around the margins of the Swan Estuary were carried out by P.N. Chalmer from Dec. 1972 to Feb. 1973 and during Nov.-Dec. 1973. The first survey followed a period in which three of the four preceding winters had been relatively dry (fig. 2) and winter salinities had remained relatively high (see Introduction). The subsequent winter of 1973 was comparatively wet and the surface salinity in the Middle Estuary was no more than 5‰ for the 6-8 weeks during August-September.

On both surveys, the margins of the estuary within a water depth of one metre were collected. Rocks, logs, piles and beds of sea grass (*Zostera mucronata*, *Halophila ovalis*) were examined; substrates were washed through a 1 mm sieve. Specimens were identified and recorded on site and most were released. Some of the less common species were deposited in the Western Australian Museum. Common species only are recorded here.

Results. The Lower, Middle and Upper Estuaries were subdivided into 12 zones (fig. 1) to permit a more detailed presentation and analysis of results. Species distributions according to zones on each survey together with habitat preferences are shown in Table 2.

Distributions of four mollusc species, *Sanguinolaria* (*Psammotellina*) *biradiata*, *Bembicium melanostomum*, *Plotiopsis australis* and *Aplysia* sp. were unchanged on the two surveys. These species occurred at either the upper or lower extremities of the estuary, the parts of greatest hydrologic stability. Four other species, *Xenostrobus securis*, *Arthritica semen*, *Tatea preissi*, and *Anticorbula amara*, which are usually associated with the Middle and Upper Estuaries, had extended their ranges downstream, the first three as far as Rocky Bay, by the second survey.

The ranges of the other molluscs, *Mytilus edulis planulatus*, *Spisula* (*Notospisula*) *trigonella*, *Irus* (*Irus*) *crenata*, *Batillaria* (*Velacumantus*) *australis*, *Nassarius burchardi*, *Tellina* (*Macomona*) *deltoidalis* and *Trophon* (*Bedeua*) *paivae*, had contracted downstream by the second survey; on that occasion, only recently-dead shells were found at the previous summer's upstream range limits. The second survey further showed that the first five of these seven species were represented at their upstream limits only by newly-settled juveniles, which had evidently been dispersed as larvae from a downstream source in the estuary. For example, the upstream limit of adult *Mytilus* was at Rocky Bay in the Lower Estuary (zone 1), but newly-settled juveniles were located as far upstream as Nedlands in the Middle Estuary (zone 4). Similarly, on the first survey it was noted that *S. (N.) trigonella* and *N. burchardi* were represented at their upstream limits by juveniles which apparently had extended their ranges upstream as planktonic larvae.

The crab *Halicarcinus bedfordi* maintained its range between the surveys, although it was less common on the second occasion. This species was abundant amongst the sea grass *Halophila ovalis*, the leaves of which died back during the winter of 1973, and the reduced numbers of the crab are considered to be a direct response to the temporary decline of the *Halophila* beds. If so, then the reduced numbers of *H. bedfordi* would have been only an indirect consequence of the winter river discharge. The congener,

TABLE 2

Records of common benthic fauna living in shallow marginal habitats around the Swan Estuary. For each species, the upper, continuous line shows the distribution observed during the summer of 1972-73, following several dry winters. The lower, broken line shows the distribution observed in the summer of 1973-74, following a winter of above-average rainfall. Zonal boundaries are shown in fig. 1. Asterisks denote "not sampled".

	ZONES												HABITATS	
	LWR. EST.	MIDDLE ESTUARY					UPPER ESTUARY							
	1	2	3	4	5	10	6	7	8	9	11	12		
MOLLUSCA														
1. <i>Mytilus edulis planulatus</i>														Attached to rocks, jetty piles.
2. <i>Xenostrobus securis</i>														Attached to rocks, logs, jetty piles.
3. <i>Arthritica semen</i>														In sandy to muddy substrates.
4. <i>Spisula (Notoispisula) trigonella</i>														In sandy to muddy substrates.
5. <i>Tellina (Macomona) deltoidalis</i>														In sandy to muddy substrates.
6. <i>Sanguinolaria (Psammetelina) biradiata</i>														Deeply buried in sandy substrates.
7. <i>Irus (Irus) crenata</i>														In sand, mud or rock crevices.
8. <i>Anticorbula amara</i>														Attached to plants, rocks, logs, sand grains.
9. <i>Bembicium melanosotomum</i>														On rocks, intertidal.
10. <i>Talea preissi</i>														On rocks, logs, among rushes.
11. <i>Platopsis australis</i>														On sandy to muddy substrates.
12. <i>Batillaria (Velacumantus) australis</i>														On or within sandy to muddy substrates.
13. <i>Trophon (Bedeva) patuae</i>														On rocks or sandy to muddy substrates.
14. <i>Nassarius burcharadi</i>														On or within sandy to muddy substrates.
15. <i>Aplysia</i> sp.														On submerged rocks.
CRUSTACEA														
16. <i>Hallicarcinus australis</i> (Haswell)														Under rocks, logs.
17. <i>Hallicarcinus bedfordi</i> Montgomery														On rocks, jetty piles or in sea grass.
18. <i>Balanus</i> sp.														Attached to piles, rocks, etc.
POLYCHAETA														
19. <i>Mercierella enigmatica</i> Fauvel														Tubes on jetty piles, logs, rocks.
20. <i>Austratonereis ehlersi</i> (Augener)														In coarse, sandy substrates.
21. <i>Marphysa sanguinea</i> (Montagu)														In sandy to muddy substrates.
22. <i>Ceratonereis erythracensis</i> (Fauvel)						*								In sandy to muddy substrates.
23. <i>Haploscoloplos kerguelensis</i> (McIntosh)						*								In sandy to muddy substrates.
24. <i>Diopatra</i> sp.														In sandy to muddy substrates.

H. australis, extended its range downstream a little during the 1973 winter, but this does not seem to be a direct response to salinity changes, in view of the wide tolerances of the species established by Lucas and Hodgkin (1970).

The range of the estuarine barnacle, *Balanus* sp., contracted downstream between the two surveys.

Of the polychaetes studied, only the range of *Ceratonereis erythraeensis* changed between the two summers, expanding upstream. We consider that the distribution of *Mercierella enigmatica* probably remained unchanged between the two summers, despite gaps in the collection records.

Discussion

Though incomplete in many respects, the data presented herein are relatively comprehensive for molluscs, and for this reason the discussion and conclusions will be based largely on molluscan evidence. We recognize that there is an element of uncertainty and subjectivity in some of our assessments of the status of individual species, but nevertheless consider that the information obtained enables some generalizations to be made about the Swan Estuary and its fauna and will assist future studies on environmental and faunal trends.

In all, 97 mollusc species have been recognised as inhabitants, either continuous or temporary, of the Swan Estuary. Within this highly diverse aggregate, four broad groupings may be recognised. These are:

- (i) species of marine affinity, with no more than temporary or sporadic estuarine representation — 64 species (66%);
- (ii) species of marine affinity, with more or less continuous estuarine representation — 25 species (26%);
- (iii) species of exclusively estuarine affinity, having neither marine nor freshwater representation — about seven species (7%); and
- (iv) species of freshwater affinity, with limited estuarine and no marine representation — one species (1%).

Species of marine affinity, both continuous and temporary, dominate the mollusc fauna of the Lower Estuary (equivalent to zone 1 on table 2) and in most cases do not extend further upstream. Of the 25 species considered to live continuously in the Lower Estuary, no more than about six seem to be able also to live continuously in the Middle Estuary and only four of these appear to have made temporary incursions in the Upper Estuary during sustained periods of low river discharge. The group is therefore characterised by drastic attenuation above the Lower Estuary; significantly, all of the six species which live continuously in the Middle

Estuary, i.e., *Spisula (Notospisula) trigonella*, *Tellina (Macomona) deltoidalis*, *Theora (Endopleura) lubrica*, *Batillaria (Velacumantus) australis*, *Nassarius pauperatus* and *N. burchardi*, are much more abundant in this and other estuaries than in normal marine environments. This subgroup of six species stands apart from the others in the fauna in exhibiting a preference for estuarine living, while retaining the ability to inhabit the sea. The presence in the Lower Estuary of such a diversity of marine molluscs (89 species), together with eight echinoderms, an alcyonarian and a scleractinian as either continuous or temporary inhabitants, demonstrates the distinctiveness of the Lower Estuary as defined here and justifies the three-part biotopic subdivision of the Swan Estuary.

The seven exclusively estuarine species are *Xenostrobus securis*, *Arthritica semen*, *Anticorbula amara*, *Tatea preissi*, *Potamopyrgus* sp., *Assimineia* sp. and *Hydrococcus graniformis*. These characterise the Middle and Upper Estuaries; the first four are believed to range temporarily into the Lower Estuary in the wake of strong winter flooding. *Potamopyrgus* sp. and *Assimineia* sp., are known only from the Upper Estuary and *H. graniformis* has not been recorded alive from the Swan since about 1840. Despite its presence in the Avon River, *A. amara* is included in this grouping of wholly estuarine species because we consider that this reflects the original relationships of the species in the estuary prior to changes in the hydrology of the Swan-Avon, caused by agricultural practices since the turn of the century. Elsewhere in south-western Australia, the species inhabits estuaries but apparently avoids freshwater tributaries.

The only truly freshwater element, the snail *Plotiopsis australis*, is confined to the higher reaches of the Swan Arm, where it is the sole gastropod.

Over the period covered by our studies, there is evidence that three mollusc species have become established within the Lower and/or Middle Estuaries of the Swan. These are *Spisula (Notospisula) trigonella*, *Nassarius burchardi* and *Theora (Endopleura) lubrica*; earliest estuarine records are Dec. 1964, Dec. 1965 and Feb. 1973 respectively. We interpret the appearance of these species in the Swan as consequences of transient marine migrations, which by virtue of pre-adaptation to local estuarine conditions, were able to successfully occupy otherwise vacant niches. Conversely, there is reason to suspect that one species, *Hydrococcus graniformis*, has become extinct in the Swan within historic time.

The patterns of response to annual, cyclic environmental changes that are evident from two littoral surveys, one after a series of winters of low rainfall

and relatively high estuarine salinity, the other after a wet winter with a relatively low estuarine salinity are:

- (i) the ranges of non-marine species contracted upstream in a period of relatively dry winters and advanced downstream after the next wet winter;
- (ii) conversely, the ranges of species of marine affinity extended upstream during a period of dry winters but these extensions did not withstand the next wet winter; and
- (iii) by early summer, the larvae of most marine species had successfully recolonised those parts of the estuary upstream where all adults had perished during the previous winter flood.

Conclusions

The Swan Estuary is divisible into three parts on the basis of the distribution of the benthic fauna, particularly the molluscs. The Lower Estuary contains the greatest number of species. Most of these also live in adjacent marine waters and many are believed to invade the Lower Estuary seasonally as planktonic larvae; other marine species inhabit the Lower Estuary more or less continuously and, when conditions permit, invade the Middle and, less often, the Upper Estuaries. Ten mollusc species live continuously in the Middle Estuary, and are uncommon in or absent from the local marine environment. One freshwater species only occurs in the Upper Estuary.

The composition and distribution of the benthic fauna change seasonally, annually and over longer periods. There is a tendency for species ranges to shift upstream in summer and during prolonged dry periods and to shift downstream during the freshwater winter flood. The number of species inhabiting the estuary increases temporarily during summer and over periods of one or more dry winters, when higher estuarine salinities enable marine species to enter the estuary and move upstream. Superimposed on these short-term fluctuations are faunal trends of longer duration, involving the acquisition and loss of species of continuous status within the fauna.

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