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Cover: A photographic representation (by John Chambel-Gaspar, Western Australian Museum) of a cast of the skull of a Pleistocene Australian found at Keilor, Victoria.

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FIVE PROBABLE HYBRID BUTTERFLYFISHES OF THE GENUS *CHAETODON* FROM THE CENTRAL AND WESTERN PACIFIC

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ABSTRACT

The following five cases of probable hybridisation in marine butterflyfishes (genus *Chaetodon*) are reported: *C. auriga* x *C. ephippium* (Tuamotu Archipelago), *C. ephippium* x *C. semeion* (Marshall Islands), *C. kleini* x *C. unimaculatus* (Marshall Islands), *C. miliaris* x *C. tinkeri* (Hawaiian Islands), and *C. aureofasciatus* x *C. rainfordi* (Great Barrier Reef). Comparisons between the presumed hybrids and their respective parent species are presented, and each trio is illustrated. In addition, a discussion of possible conditions responsible for hybridisation in chaetodontids is included.

INTRODUCTION

Relatively few marine fishes have been reported as hybrids; of 212 fish hybrids listed by Slastenenko (1957), only 30 were inhabitants of the sea. The same preponderance of freshwater hybrids over marine is apparent in the review by Schwartz (1972) of the hybrid fishes of the world. In the present paper data are given for five presumed hybrids of the marine butterflyfish genus *Chaetodon* (family Chaetodontidae). In addition, the junior authors have observed (but not collected) probable hybrid crosses between *C. ornatissimus* — *C. meyeri* and *C. pelewensis* — *C. punctatofasciatus* at Palau, New Britain, and the northern Great Barrier Reef.

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Chaetodontids have not been reported previously as hybrids, although this phenomenon has been documented in the closely related angelfishes (Pomacanthidae). Longley (*in* Longley and Hildebrand, 1941) suspected that the angelfish, *Holacanthus townsendi* of the Caribbean Sea, is a cross between *H. ciliaris* and *H. isabelita* (now regarded as *H. bermudensis* — see Bailey *et al.* 1970: 77-78), and Feddern (1968) confirmed this. Though often classified in the Chaetodontidae by previous authors, there is now firm evidence for granting the angelfishes separate family status (see Freihofer, 1963 and Burgess, 1974a).

Hybridisation in marine fishes obviously does not lend itself to the close scrutiny offered by certain freshwater fish hybrids. Moreover, as Randall (1956) pointed out, the overwhelming majority of freshwater hybrids is reflected not only from our greater knowledge of freshwater fishes (particularly American and European species) and greater opportunity for sampling populations of freshwater habitats, but probably also from an actual lower percentage of hybrids in the sea. Unlike freshwater hybrids, which can often be either experimentally reared or collected in numbers, reports of hybrid fishes in the sea are frequently based on a single chance sighting; the investigator is very fortunate if a hybrid specimen is collected or photographed.

To those who might criticise the limited data herein in documenting hybridisation in the Chaetodontidae, we wish to point out the great amount of time and effort that was necessary to obtain the hybrid specimens and make the pertinent observations. The authors of the present work are experienced SCUBA and skin divers. It is estimated that we collectively spend over 1000 hours per year underwater. We have maintained this level of diving for the past decade, dividing our time over a vast area of the tropical Indo-Pacific and Atlantic. In the former region we have visited most of the major island groups of Polynesia, Micronesia, and Melanesia. Also we have dived at Japan, Ryukyu Islands, Taiwan, Hong Kong, Philippine Islands, Molucca Islands, Java, Australia, Sri Lanka (Ceylon), Maldive Islands, Mafia Island (off Tanzania), Mauritius, Reunion, and the Red Sea. During much of our time underwater butterflyfishes have been a focal point of interest. Randall and Allen have made a special effort to collect and observe chaetodontids at the request of W.E. Burgess who is currently preparing a taxonomic monograph of the family. Randall (1975) and Randall and Caldwell (1973) described four new species of butterflyfishes, and Allen named *Chaetodon burgessi* in conjunction with W.A. Starck (1973). Steene has been greatly involved with these fishes for the past three years and has recently completed a manuscript dealing with chaetodontids and pomacanthids which will be published as a popular book.

In addition to our investigations of chaetodontid fishes we have drawn upon the experience and collecting ability of other divers. The butterflyfishes are among the most conspicuous families of fishes inhabiting coral reefs, and the group is well known to both laymen and scientists. Because these fishes are so colourful and their patterns so distinctive, a variant is apt to attract attention.

Comparisons were made of meristic data and selected proportional measurements of the five hybrids of which we have specimens with eight examples of each of the parent species. These data are presented in Tables 1-5. Many of the selected characters which appear in these tables do not specifically bear on the hybrid nature of the fishes. However, we have included them to show that the presumed hybrids generally possess meristics and morphometrics which are either identical or within the range of the presumed parental species, thus reinforcing the suspected relationship. Body depth was taken as the greatest depth from the base of the dorsal spines. Head length was measured from the front of the upper jaw to the posterior end of the opercular membrane. The interorbital width is the bony width above the centre of the eyes. The depth of the caudal peduncle is the least depth.

The *C. aureofasciatus* x *C. rainfordi* hybrid is deposited at the Western Australian Museum, Perth (WAM). The other hybrids are at the Bernice P. Bishop Museum, Honolulu (BPBM).

CHAETODON AURIGA x *CHAETODON EPHIPPIUM*

On November 17, 1956 the senior author speared a butterflyfish at a depth of 4 m on a patch reef in the lagoon of the atoll of Takaroa, Tuamotu Archipelago (14°30′S; 145°W). This specimen (Fig. 1) was intermediate in colour and caudal fin shape to *C. auriga* Forsskål and *C. ephippium*. We conclude that it probably represents a hybrid of these two species (shown in Figs 2 and 3), both of which were common at Takaroa. In most respects the colour is intermediate to the parent species. When fresh the colours of the presumed hybrid were as follows: ground colour white with large dusky area of yellowish cast on posterior portion of back; caudal peduncle and caudal fin light yellow with triangular extension of this colour onto upper and lower parts of fin; posterior portion of dorsal fin orange-yellow with a curved extension of this colour into large dusky area of the back; trace of a black spot anteriorly on outer part of soft portion of dorsal fin (*auriga* generally has a well developed spot here; *ephippium* has none); black bar below eye (absent on adults of *ephippium*, very broad in *auriga*), and short, narrower bar above, becoming progressively diffuse and finally disappearing on nape; snout, ventral part of head, pelvic fins, and anal fin light yellowish. The hybrid lacked the two sets of diagonal dark lines which are set at right angles on the body of *auriga.* It also lacked the narrow purplish stripes found on the ventral half of the body, as well as the deep blue band along the upper edge of the gill opening, and the dark purplish line which runs from above the pectoral base to the base of the fifth dorsal spine; all these features, on the contrary, are present in *ephippium.*

The caudal fin of the hybrid is truncate and intermediate to the parent species. Adult *C. auriga* possess a slightly rounded (truncate if not fully spread) caudal fin, whereas that of *C. ephippium* is emarginate, the caudal concavity 2 to 6.5% of the standard length. Randall (1956) noted an intermediate caudal shape in the hybrid surgeonfish *Acanthurus achilles* x *A. glaucopareius.*

Fig. 1: *Chaetodon auriga* x *C. ephippium,* 138 mm SL, Takaroa, Tuamotu Archipelago.

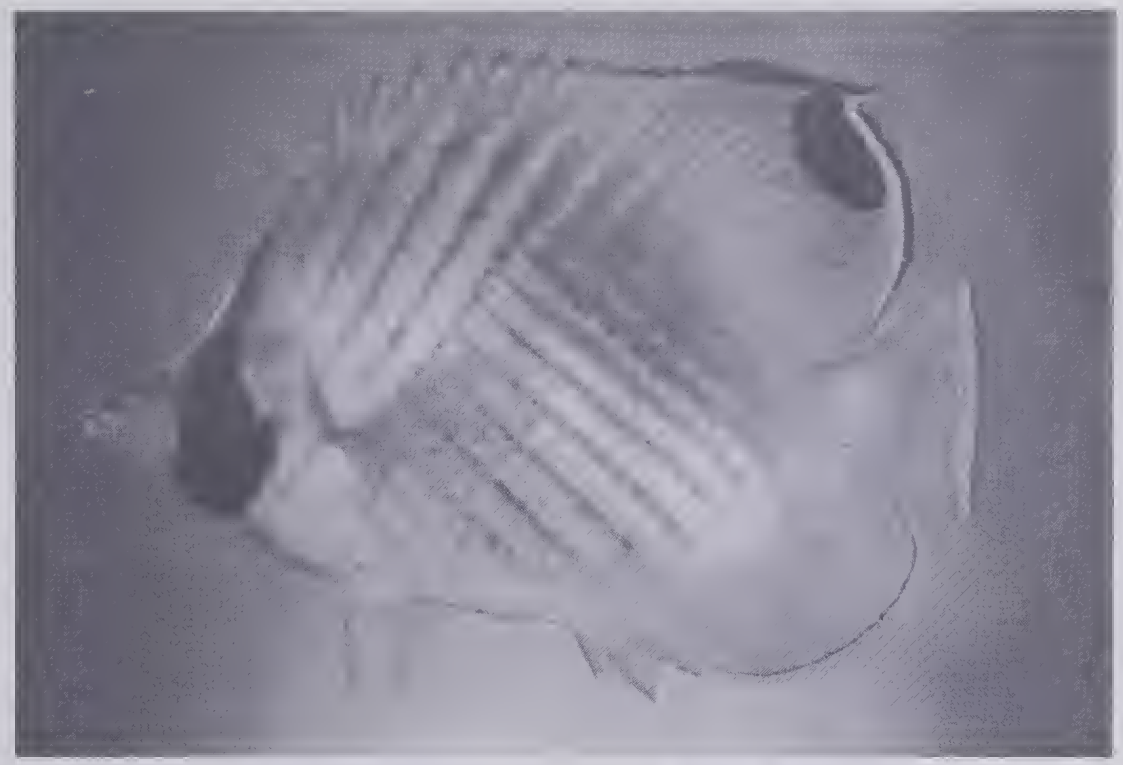

Fig. 2: *Chaetodon auriga*, 145 mm SL, Tahiti, Society Islands.

Fig. 3: *Chaetodon ephippium*, 146 mm SL, Oahu, Hawaiian Islands.

Selected counts and measurements of the presumed hybrid are compared with the parent species in Table 1. All the attributes of the hybrid which appear in this table are within the ranges of *auriga* and *ephippium*. The parent species are closely related, as indicated by the data of Table 1. Both have the same general body shape with a moderately produced snout and a filament extending from the anterior soft portion of the dorsal fin. Also sharing the same body and fin configuration are *C. semeion* Bleeker and *C. xanthocephalus* Bennett. Previous authors have grouped these species in the subgenus *Rhabdophorus* Swainson. Hybrid crosses between any of these could be expected. Burgess (1974b) described and illustrated a potential cross between *C. ephippium* and *C. xanthocephalus* from Sri Lanka.

The register number of the hybrid is BPBM 19065.

TABLE 1

Comparison of counts and measurements of *Chaetodon auriga*, *C. auriga* x *C. ephippium* (indicated as hybrid), and *C. ephippium*. Measurements expressed as percentage of the standard length.

	Chaetodon auriga	Hybrid	*Chaetodon ephippium*
Dorsal rays	XIII,23-25	XIII,24	XIII,23-25
Anal rays	III,20-22	III,21	III,21-23
Pectoral rays	16	16	16
Lateral-line scales	33-36	34	33-36
Gill rakers	17-20	16	15-17
Standard length (mm)	117-168	139	108-169
Depth of body	57.2-62.7	59.8	58.0-62.6
Head length	30.9-34.8	33.7	29.6-32.5
Snout length	12.2-15.0	13.8	10.7-13.1
Orbit diameter	7.3-8.7	8.0	7.4-8.2
Interorbital width	9.3-10.0	9.2	9.1-10.1
Depth of caudal peduncle	10.4-11.6	10.6	10.4-11.8
First dorsal spine	7.9-9.1	8.8	7.3-10.3
Pectoral fin length	24.6-26.9	24.4	23.1-25.7
Pelvic fin length	23.1-25.3	23.7	21.7-23.7

CHAETODON EPHIPPIUM x *CHAETODON SEMEION*

On March 15, 1972 Mr and Mrs Nathan A. Bartlett of Kwajalein, Marshall Islands observed a strange butterflyfish on a patch reef in the southern part of the lagoon (8°43′52.1″N; 167°43′30.5″E) which they did not recognise. Mr Bartlett took an excellent underwater colour photograph of the fish, which he brought to the Bishop Museum for identification nearly two years later. It is reproduced herein as Fig. 4. The live coloration of the fish was as follows: ground colour of body and fins yellowish; snout, lower part of head, thorax, and base of pectoral fins yellow-orange; caudal fin yellow-orange basally and on upper and lower edges, remainder of fin primarily hyaline; conspicuous, large comma-shaped area of black on upper part of posterior portion of back, extending onto dorsal fin; this marking preceded by an area of pale yellow grading to white centrally; prominent black ocular bar, becoming bright blue on upper part of head; forehead and interorbital largely bright blue. The large black posterior spot is suggestive of *C. ephippium* and the blue on the head indicates a relationship to *C. semeion.* Both of these species occur at Kwajalein, though the latter is relatively rare. On the basis of the photograph we suspected the fish represented a cross between these two species, in spite of the absence of the purplish or blue bands on the ventral half of *ephippium* (Fig. 3) and dark dots on the body of *semeion* (Fig. 5). Mr Bartlett was asked if he would try to collect the fish and on April 21, 1974 he succeeded in spearing it at a depth of 5 m, approximately 25 m from the location where it was originally sighted and photographed. On a previous occasion, after the fish was first sighted in 1972, the Bartletts observed it about 55 m from the location of the first sighting, at which time it was paired with *C. semeion.* The Bartletts and other divers alerted by them have not seen any other butterflyfishes of this colour form at Kwajalein in spite of numerous hours of underwater observation and photography.

The specimen was presented to the Bishop Museum (BPBM 17363). Counts and measurements were taken and compared with equivalent data for eight specimens of *C. ephippium* and *C. semeion* (Table 2). All the counts and measurements for this fish fall within the range of these two species. As in the previous case, the colour is not exactly intermediate in all respects. However, the overall yellowish colour is intermediate to the light grey of *ephippium* and the orange of *semeion.* In addition, the large black zone on the upper back is intermediate in size to the black dorsal band of *semeion* and the huge black area on the upper back of *ephippium*; it is not rimmed on the ventral margin with a pale band as in *ephippium* except for the anterior patch of pale yellow. There is no trace of the black band at the base of the soft portion of the anal fin of *semeion.* The narrow black bar below the eye is intermediate to the broad black bar of *semeion* and

Fig. 4: *Chaetodon ephippium* x *C. semeion*, 124 mm SL, Kwajalein, Marshall Islands.

Fig. 5: *Chaetodon semeion*, 151 mm SL, Tetiaroa, Society Islands.

the absence of this marking on adult *ephippium*; above the eye the black bar is also intermediate to that of the probable parents. The blue of the upper part of the bar and on the forehead is, as previously mentioned, typical of *semeion*.

A possibility exists that this fish represents an undescribed species closely allied to both *ephippium* and *semeion*. It seems far more likely, however, that it is a hybrid of the two.

TABLE 2

Comparison of counts and measurements of *Chaetodon ephippium*, *C. ephippium* x *C. semeion* (indicated as hybrid), and *C. semeion*. Measurements expressed as percentage of the standard length.

	Chaetodon ephippium	Hybrid	*Chaetodon semeion*
Dorsal rays	XIII,23-25	XIII,25	XIV,25-26
Anal rays	III,21-23	III,21	III,21.23
Pectoral rays	16	16	16
Lateral-line scales	33-36	34	32.34
Gill rakers	15-17	17	15-17
Standard length (mm)	108-169	124	116-165
Depth of body	58.0-62.6	59.5	56.3-60.5
Head length	29.6-32.5	33.6	29.8-34.5
Snout length	10.7-13.1	13.7	10.6-14.4
Orbit diameter	7.4-8.2	8.1	6.7-8.7
Interorbital width	9.1-10.1	9.3	9.3-10.3
Depth of caudal peduncle	10.4-11.8	10.3	9.8-10.9
First dorsal spine	7.3-10.3	9.4	8.5-10.3
Pectoral fin length	23.1-25.7	24.6	23.0-24.6
Pelvic fin length	21.7-23.7	22.5	21.6-23.4

CHAETODON KLEINI x *CHAETODON UNIMACULATUS*

During the northern summer of 1970 one of us (GRA) observed an unusual butterflyfish near the wreck of a cement ship at the edge of the deep passage of Enewetak Atoll to the west of Bogen Islet (11°26′N; 162°22′E). This individual was clearly intermediate to *C. kleini* Bloch and *C. unimaculatus* (Bloch). Illustrations of these two species are presented as Figs 7 and 8 respectively. At Enewetak *C. kleini* usually occurs in water greater than 20 m, whereas *unimaculatus* tends to prefer shallower depths (usually less than 10 m). The intermediate fish was a member of an aggregation of about 12 *kleini* which roamed over a steep reef slope at depths ranging from about 14 to 25 m. It was seen on several dives over a period of 1½ months, always within 50 m of the same location. It was finally speared on August 3, 1970 and photographed (Fig. 6). The specimen is now deposited at the Bishop Museum (BPBM 11377).

Fig. 6: *Chaetodon kleini* x *C. unimaculatus*, 92 mm SL, Enewetak, Marshall Islands.

The counts and measurements of the presumed hybrid are compared with those of eight specimens of *kleini* and *unimaculatus* (three of each collected in the same area as the hybrid) in Table 3. The data for the hybrid are either within the ranges or intermediate to those of *kleini* and *unimaculatus*.

The colour pattern of the probable hybrid is essentially a compromise between those of the suspected parents. Some characters are intermediate, and others favour one species or the other. If we ignore the dark markings, the overall colour is very similar to *kleini*: generally brownish-yellow, the centres of the scales pale tan, thus forming spots (which are larger anteriorly on the body). The diffuse blackish bar in the middle of the body is more suggestive of *kleini*, but its darker colour probably represents an effect from the black spot of *unimaculatus*. The black bar across the caudal peduncle, which is continuous into the dorsal fin above and anal fin below, is derived from *unimaculatus* but its restriction in the fins and diffuse nature seem to be of *kleini* origin. The broad bold eye bar and blackish pelvic fins typify *unimaculatus*. There is no broad, diffuse dusky bar anteriorly on the body which is characteristic of *kleini*. On the upper anterior body there are narrow, near-vertical dark bands due to dusky posterior edges on the scales, a pattern which is suggestive of *unimaculatus*; however, these bands are more conspicuous on the latter species and continue ventrally where they are abruptly deflected posteriorly, forming a chevron-like pattern.

C. kleini and *C. unimaculatus* do not appear to be as similar morphologically as the parent species of the potential hybrids previously discussed. Nevertheless, Weber and de Beaufort (1936) grouped them in the same subgenus, *Lepidochaetodon* Bleeker.

TABLE 3

Comparison of counts and measurements of *Chaetodon kleini*, *C. kleini* x *C. unimaculatus* (indicated as hybrid), and *C. unimaculatus*. Measurements expressed as percentage of the standard length.

	Chaetodon kleini	Hybrid	*Chaetodon unimaculatus*
Dorsal rays	XIII,21-22	XIII,22	XIII,22-24
Anal rays	III,18-19	III,19	III,19-20
Pectoral rays	15-16	15	15-16
Lateral-line scales	34-40	40	40-43
Gill rakers	21-23	22	17-21
Standard length (mm)	82-105	92	89-101
Depth of body	54.0-62.2	61.8	58.5-64.0
Head length	27.5-29.9	29.0	31.3-34.2
Snout length	8.2-9.4	10.9	11.1-12.6
Orbit diameter	8.0-10.4	9.5	9.2-12.2
Interorbital width	9.0-10.6	10.4	11.0-12.2
Depth of caudal peduncle	8.8-10.3	9.7	9.8-10.6
First dorsal spine	6.4-8.1	6.8	7.5-8.6
Last dorsal spine	19.9-22.6	22.3	20.8-22.7
Third anal spine	20.3-23.3	22.8	20.5-24.0
Pectoral fin length	24.0-26.9	26.2	26.0-28.2
Pelvic fin length	23.7-26.7	25.8	23.8-27.0

Fig. 7: *Chaetodon kleini*, 75 mm SL, Palau Islands.

Fig. 8: *Chaetodon unimaculatus*, 103 mm SL, Bora Bora, Society Islands.

CHAETODON MILIARIS x *CHAETODON TINKERI*

In the summer of 1973 a butterflyfish about three inches long with a colour pattern and shape intermediate to *C. miliaris* Quoy and Gaimard and *C. tinkeri* Schultz was captured in 12 m off Nanakuli, Oahu by Daniel Coughlin, who was then working as an aquarium fish collector for Coral Fish Hawaii. Mr Coughlin took a colour photograph (reproduced in black and white as Fig. 9) of this specimen, but unfortunately the fish was subsequently discarded. A comparison of this photograph with Figs 11 and 12 of *C. miliaris* and *C. tinkeri* respectively, seems to indicate that the specimen was a hybrid of these two species. The ground colour of the presumed hybrid in the photograph is white with a faint yellowish cast, shading to yellow on the dorsal and anal fins, thus intermediate to the deep yellow of *miliaris* and the white of *tinkeri*. The black area posteriorly on the body and on the soft portion of the dorsal fin is clearly intermediate in size to the corresponding black areas of the suspected parents. The faint dark spots on the body are slightly more evident on the hybrid than on *tinkeri*, but notably less so on *miliaris*; also they are not in such regular vertical rows as on *miliaris*. The ocular bar of *miliaris* is black and that of *tinkeri* is yellow; the bar of the hybrid is dusky orange.

Fig. 9: *Chaetodon miliaris* x *C. tinkeri*, about 60 mm SL, Oahu, Hawaiian Islands.

Fig. 10: *Chaetodon miliaris* x *C. tinkeri*, 40.5 mm SL, Oahu, Hawaiian Islands.

Fig. 11: *Chaetodon miliaris*, 124 mm SL, Hawaii, Hawaiian Islands.

Another noteworthy distinction between *C. miliaris* and *C. tinkeri* which is evident from the illustrations is the high spinous in contrast to the low soft portion of the dorsal fin of the latter in comparison to the former. The dorsal fin of the hybrid is intermediate in this respect.

In August, 1976 Dan Coughlin and Dennis Yamaguchi each captured a juvenile (40.5 and 41.3 mm SL) of the same hybrid in 8 and 18 m off Makua, Oahu. These were brought frozen to the senior author by Anthony Nahacky. A colour photo was taken of the smaller of the two which is reproduced herein in black and white as **Fig. 10.** These specimens have been deposited in the Bishop Museum under number BPBM 20458.

Fig. 12: *Chaetodon tinkeri,* 115 mm SL, Oahu, Hawaiian Islands.

Counts and measurements were made of the two hybrids and compared with data from the parent species (Table 4). The only count showing a clear distinction between the parent species is the number of anal soft rays. As may be noted in the table, both hybrids are exactly intermediate in having 18 anal rays. The measurement data are not so readily compared because of the small size of the hybrids and the lack of specimens of the parent species of this size. Nevertheless, all of the measurements of the hybrid except interorbital width and orbit diameter fall within the range of the parent species; the relatively large eye of the hybrids, at least, would be expected from such diminutive specimens. The proportional measurement with the greatest difference between *miliaris* and *tinkeri* is the length of the longest dorsal spine. In this the hybrids are strikingly intermediate. In having a low soft portion of the dorsal fin they favour *tinkeri.*

TABLE 4

Comparison of counts and measurements of *Chaetodon miliaris, C. miliaris* x *C. tinkeri* (indicated as hybrids), and *C. tinkeri.* Measurements expressed as percentage of the standard length.

	Chaetodon miliaris	Hybrids	*Chaetodon tinkeri*
Dorsal rays	XIII,21-23[1]	XIII,22	XIII,20-22[1]
Anal rays	III,19-21	III,18	III,16-17
Pectoral rays	15-16	15-16	15-16
Lateral-line scales	35-40	37-38	36-40
Gill rakers	17-19	18	16-19
Standard length (mm)	45.3-98	40.5-41.3	49.6-107
Depth of body	57-62.2	58.2-61.7	61.2-66.7
Head length	28.8-35.4	34.5-35.4	29-34.9
Snout length	9.7-12.4	11.8-12.1	10.9-12.1
Orbit diameter	9.7-12.1	14.3-16	9.9-12.7
Interorbital width	9.2-11	10.3-12.1	9.6-10.1
Depth of caudal peduncle	9.8-11	10.2-10.6	10.1-11.7
First dorsal spine	7.4-9.7	10.8[2]	8.9-11.9
Longest dorsal spine	21.4-25.7	28.9-29.8	30.3-34.9
Eleventh dorsal ray	19-21.9	16.3-16.7	15.0-18.7
Pectoral fin length	24.7-29.1	27.4-29.9	27.3-31.7
Pelvic fin length	26.4-35.2	31.3-35.8	30.5-36.2

[1] One of 15 individuals of *C. miliaris* has XIV dorsal spines, and Schultz (1951) reported one of his three type specimens of *C. tinkeri* with XIV dorsal spines.

[2] First dorsal spine of one hybrid aberrant.

Both *C. miliaris* and *C. tinkeri* are endemic to Hawaii. The former is the most common butterflyfish in the islands. It occurs over a considerable depth range which extends from shallow inshore waters to at least 200 m; submarine observations have revealed that it is one of the most abundant shorefishes penetrating deeper waters. *C. tinkeri* is strictly a deep-water form, having seldom been sighted in less than 40 m. It is often encountered in pairs, whereas *miliaris* occurs either singly or in aggregation. *C. miliaris* feeds mainly on zooplankton and has also been observed to 'clean' other fishes. *C. tinkeri* feeds on a variety of planktonic and benthic organisms, and partly for this reason does well in aquariums in contrast to species of *Chaetodon* which are more specialised in their feeding, many of which are restricted to browsing on coral polyps.

C. miliaris is also known to hybridise with *C. multicinctus* Garrett, another common species which is endemic to Hawaii. Two cases of this cross will be reported separately by Warren E. Burgess.

CHAETODON AUREOFASCIATUS x *CHAETODON RAINFORDI*

On November 20, 1973 one of us (RCS) encountered an apparent hybrid of *C. aureofasciatus* Macleay and *C. rainfordi* (McCulloch) at Decapolis Reef, about 24 km southwest of Lizard Island, Great Barrier Reef (approximately 13°51′S; 145°15′E). The fish was observed for about two hours. It was in the company of two *C. aureofasciatus*, both about twice the size of the presumed hybrid. In spite of its inferior size the hybrid seemed to dominate the trio, leading the way while foraging and acting the most aggressive towards other fishes which were encountered during this activity. This agonistic behaviour consisted of the characteristic *Chaetodon* habit of erecting the dorsal spines and tilting the head downwards, thus presenting the spines to the opposition. Both *C. aureofasciatus* and *C. rainfordi* were common on Decapolis Reef. At the end of the observation period the hybrid was photographed (Fig. 13) and then collected by concussion with a .303 powerhead.

Counts and measurements of the probable hybrid are compared with those of *C. aureofasciatus* and *C. rainfordi* in Table 5. These data for the hybrid fall within the ranges given for the parent species. *C. aureofasciatus* and *C. rainfordi* are very closely related, differing primarily in colour pattern. Their geographical distribution is confined to the northern Australia-Arafura Sea region; *C. rainfordi* has a limited distribution which is mainly restricted to the Great Barrier Reef.

Fig. 13: *Chaetodon aureofasciatus* x *C. rainfordi*, 51 mm SL, Decapolis Reef, Great Barrier Reef.

TABLE 5

Comparison of counts and measurements of *Chaetodon aureofasciatus*, *C. aureofasciatus* x *C. rainfordi* (indicated as hybrid), and *C. rainfordi*. Measurements expressed as percentage of the standard length.

	Chaetodon aureofasciatus	Hybrid	*Chaetodon rainfordi*
Dorsal rays	XI,21-22	XI,21	XI,21-22
Anal rays	III,18-19	III,18	17-18
Pectoral rays	15-16	16	15
Lateral-line scales	31-36	36	32-37
Gill rakers*	14-21	14	15-19
Standard length (mm)	40-92	51	42-70
Depth of body	74.3-80.3	71.0	70.6-80.3
Head length	29.3-37.0	34.7	32.9-37.7
Snout length	9.2-12.5	10.3	11.1-13.0
Orbit diameter	9.8-13.3	12.8	11.8-13.2
Interorbital width	10.2-13.3	12.0	11.1-13.0
Depth of caudal peduncle	12.0-13.3	12.0	12.1-13.8
First dorsal spine	8.6-11.3	9.3	8.7-11.8
Pectoral fin length	27.8-31.1	29.2	28.7-33.6
Pelvic fin length	32.9-36.3	37.1	35.0-40.3

*Gill raker counts for the upper portion of the first branchial arch of *C. aureofasciatus* are extremely variable. There is an apparent increase in the number of elements with increasing growth.

Fig. 14: *Chaetodon aureofasciatus*, 53 mm SL, Wistari Reef, Great Barrier Reef.

The live coloration of the potential hybrid was as follows: ground colour pale greyish-white with this colour extending over most of the dorsal fin; snout, distal portion of dorsal fin, caudal base, and pelvic and anal fins yellow; two faint bars on middle of sides, mostly grey but grading to yellowish on ventral half; ocular bar bright orange below eye, dusky orange above eye with pale margins; a narrow bar extending from base of about fourth or fifth dorsal spine, passing through pectoral base and extending to abdomen, this bar mainly orange, but dorsal third grey; a similar but fainter bar behind eye, extending onto thorax. This coloration, although not exactly intermediate, represents a compromise condition between *C. aureofasciatus* (Fig. 14) and *C. rainfordi* (Fig. 15). This is particularly true with reference to the alternating white and grey bars on the middle of the sides; these are much more prominent in *C. rainfordi*, and entirely absent in *C. aureofasciatus*. However, the bars lack the dusky orange margins which are characteristic of *rainfordi*. The somewhat ovate, pale rimmed spot on the caudal peduncle of the hybrid is derived from the *rainfordi* parent, although it is far less prominent in the suspected hybrid; again it represents a compromise condition as this marking is absent in adult *aureofasciatus*. Juveniles of the latter species exhibit a dark bar across the peduncle.

The specimen is now deposited at the Western Australian Museum (WAM P25103-001). The bars have faded in preservative (70% ethanol) and it closely resembles *C. aureofasciatus*.

Fig. 15: *Chaetodon rainfordi*, approximately 110 mm SL, off Cairns, Great Barrier Reef.

DISCUSSION

One aspect regarding the hybridisation of chaetodontid fishes which merits further discussion involves the circumstances under which it might occur and its possible adaptive significance. Reese (1975) studied the social behaviour and related ecology of chaetodontid fishes. He divided various species into three groups according to social relationships: (A) those occurring as solitary individuals; (B) those occurring in conspecific pairs; and (C) those occurring in groups containing either conspecific or interspecific members. He also noted that a given species might be classed in one category at one locality and another category at a different location. He established 95% confidence limits for 19 species occurring at Enewetak Atoll (Marshall Islands), Heron Island (Great Barrier Reef), and Johnston Island (Central Pacific). As an example from his data at Enewetak, one could be 95% confident of seeing *C. auriga* in pairs approximately 73% of the times when observed.

Five of our presumed parental species (*auriga*, *ephippium*, *unimaculatus*, *aureofasciatus*, and *rainfordi*) were classed by Reese as being either solitary or occurring in pairs. *C. kleini*, *C. semeion*, and *C. tinkeri* were not studied by him, but we have frequently seen these species either alone or in conspecific pairs. The remaining parental species, *C. miliaris*, exhibits a relatively wide range of social behaviour, but is frequently seen in large aggregations. In addition, we have previously mentioned the occurrence of probable crosses involving *C. ornatissimus* (with *C. meyeri*) and *C. punctatofasciatus* (with *C. pelewensis*), which are also mentioned by Reese as pair-forming species.

On the basis of the evidence presented in the previous paragraph it is apparent that the suspected hybridisation potential is greater in chaetodontids which are normally solitary or which form pairs, in contrast to aggregating species. If suitable mates are in short supply, we would expect the solitary fish to seek an individual of a closely related species for reproduction. This seems to be the case, for example, for the hybrid surgeonfish *Acanthurus achilles* x *A. glaucopareius* on the Kona coast of the island of Hawaii where this hybrid may on rare occasions be seen. *A. achilles* is abundant at this locality whereas the closely related *glaucopareius* is uncommon. The same situation pertains to certain chaetodontids we have observed. One has to swim literally 'miles' in order to encounter an individual of *Chaetodon semeion* in the Marshall Islands or *C. adiergastos* at Northwest Cape and the Dampier Archipelago of Western Australia.

Unfortunately there is little information about the reproductive habits of chaetodontids, and it is not known whether breeding occurs in pairs or aggregations, or both, depending on species. We suspect, however, that pair-forming species spawn as pairs as we have never seen breeding aggregations. These aggregations are conspicuous for certain other common diurnal reef fishes, such as labrids, scarids, and acanthurids, during reproductive periods.

Reese differentiated between weakly and strongly pairing species. Chaetodontids such as *C. ephippium* and *C. unimaculatus*, whose 95% confidence limits for pairing ranged between 65-83% of the total individuals observed, were regarded as being strongly paired. On the contrary, *C. reticulatus* was considered as a weakly paired species with 57% of the individuals observed occurring in this condition. Reese mentioned that mixed pairs or threesomes were occasionally encountered and were usually composed of fishes belonging to a strongly paired species. Reese stated, 'apparently when a fish of a strongly paired species became separated [sometimes only temporarily] it attempted to establish a pair with another fish [different species of chaetodontid]. The second fish presumably was in the same situation and motivational state, and therefore both fish responded appropriately to one another.' It seems to us that this type of behaviour might certainly set the stage for interbreeding.

Reese found that adult pairs of chaetodontid fish were usually composed of members of the opposite sex. He did not, however, discuss the phenomenon of pairing in relation to growth. We have noted that juveniles of some species swim in pairs. It would be fruitful to conduct long-term studies of pairing to assess the degree of permanence of bonds formed at an early age. If there is some semblance of permanence in the pairing by butterflyfishes, the death of one member of the pair, as by predation, would seem to enhance the possibility of hybridisation.

In addition to certain social conditions, an obvious prerequisite for hybridisation in chaetodontids is a close phylogenetic relationship between the interbreeding species. The probable hybrid between *C. miliaris* and *C. tinkeri* is the only cross we have studied involving members of different subgenera. In nearly every case the presumed parents possess strikingly similar morphology, although colour patterns may be very different.

The psittaciform birds (parrots) might be regarded as the terrestrial counterpart of the butterflyfishes, exhibiting a multitude of dazzling colour patterns and being distributed primarily in the tropics. The species inhabiting Australia are among the most ecologically diverse and have been well documented. Hybridisation in Australian parrots is widespread both in captivity and in the wild. Of the 52 species reported by Forshaw (1969) all but 16 are known to form hybrids. Most of the interbreeding occurs between closely related forms, but in a few cases members of different genera have been involved.

ADDENDUM

Just prior to publication a letter was received from Dr Leighton Taylor, Director of the Waikiki Aquarium (Honolulu, U.S.A.) with a photograph of a probable hybrid of *C. auriga* x *C. lunula* (Lacépède). The fish is approximately 130 mm SL and is still alive and on display at the aquarium. It was collected by G. Daigle of Pacific Tropical Fish Inc. near Kona, Hawaii in 8-10 m depth. The probable hybrid appeared to be paired off with a normal *C. lunula* and they were travelling with a mixed aggregation of 6-8 *C. lunula* and a pair of *C. auriga*. We have been aware for the past three years of an identical hybrid collected by Mr J. Braun of Perth at North West Cape, Western Australia. The fish is still alive (approximately 125 mm SL) in an aquarium and it was not until Dr Taylor's letter arrived that we became aware that *C. lunula* was involved in this cross. The general colour pattern is similar to that of *C. auriga*, but *lunula* characters include a large dusky area posteriorly on the upper back, a broad white band behind the black ocular bar, slanting dark lines most prominent on the lower sides (which cross the chevron lines inherited from the *auriga* parent at right angles), and a black margin on the dorsal fin. There is a weak spot at the middle of the tail base which represents a compromise between the prominent black spot on *lunula* and the complete absence of this mark in *auriga*.

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We are indebted to Nathan A. and Patricia Bartlett of Kwajalein, Marshall Islands for providing both the specimen and photograph of *C. ephippium* x *C. semeion* and to Anthony Nahacky, Daniel Coughlin, and Dennis Yamaguchi for the photograph and two juvenile specimens of *C. miliaris* x *C. tinkeri*. Thanks are also due to Philip Helfrich, former Director of the Mid-Pacific Marine Laboratory, and the U.S. Energy, Research and Development Administration for the opportunity to collect *C. kleini* x *C. unimaculatus* at Enewetak Atoll. John R. Paxton and Douglass F. Hoese

of the Australian Museum, Sydney kindly sent us loan specimens of *C. rainfordi.* Finally, we thank Connie Allen for preparation of the typescript.

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THE STATUS OF *GAMBUSIA AFFINIS* (BAIRD & GIRARD) IN SOUTH-WESTERN AUSTRALIA

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In a recently-published book on the native and introduced freshwater fishes of Australia (Lake 1971), no mention is made of the occurrence of *Gambusia affinis* (Baird & Girard) in Western Australia, although the wide distribution of this introduced pest in the Eastern States is acknowledged.

The truth is different, for actually *Gambusia* has been established in Western Australia for many years. Understandably, however, naturalists and zoologists are usually more interested in native fauna than in introduced exotic species and that is why in zoological literature little has been published on *Gambusia* in Western Australia. Whitley (1948) did not mention the species, but in the same year it was recorded from Lake Leschenaultia by Shipway (1948), who observed that in April 1948: 'No native fishes were found, the lake apparently containing only English Perch (*Perca fluviatilis*) and *Gambusia affinis*'. In later volumes of the *Western Australian Naturalist* I have traced four more references to *Gambusia affinis*, and perhaps it reflects the contempt in which this little fish is held that, although it has been recorded five times in five different volumes, its name is found in the index of only two. In chronological sequence the records are: Hyde Park Lake, Perth, where: 'An exotic fish, *Gambusia affinis*, has been introduced and no native fishes have been seen there' (Irene Shipway 1950, reporting on a visit made in 1949); Lake Cooloongup or White Lake (Robinson 1951); Ellendale Pool, Greenough River (Watson 1958) and Benger Swamp (Sedgwick 1973). In addition, the species is listed for Western Australia by Main and Edward (1968), but without particulars.

My own notes on *Gambusia* are incomplete as I also despised it, but I can add the following localities: Garden Island (February 1959), Walyunga

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Pool, Swan River near Upper Swan (April 1960), pool in Greenough River near crossing of Geraldton-Mullewa road (December 1962), dam on Brookton road near 27 mile post, Canning River drainage (January 1963), Blackwood River at Sue Bridge (April 1968), Margaret River near the town of the same name (repeatedly in 1968, 1974, 1975), lake near Darkan (October 1968), Pallinup River at bridge of the new road from Albany to Jerramungup (November 1968), Abba River, Wonnerup (March 1975), Ellen Brook between Yallingup and Margaret River (March 1975, not present in 1968), and Narrogin (April 1975).

Information received from Mr Scott of the Zoology Department, University of Western Australia, is that in his institute samples are present as follows: Warren River (May 1964), Beaufort Inlet (October 1971), Murray River near Quindanning (February 1971, March 1972), Williams River, Williams (April 1972, April 1973), Narrogin (April 1973), bed of Avon River, York (May 1973), Lake Leschenaultia (1974), Gogerug Lake (December 1974), Collie River at crossing of South West Highway (October 1975), lakes Banganup, Joondalup, Jandabup and swamps nearby (October 1975), Wooroloo Brook at Gidgegannup (October 1975), small creek on S. end of Garden Island (October 1975).

In the collection of the Western Australian Museum, Dr Allen (*in litt.*, 15.10.1975) was unable to locate a single *Gambusia* specimen; he added: 'About eight months ago we had a big re-organization of the collection. Because of critical lack of storage space many of our uncatalogued *Gambusia* holdings were discarded'. Better proof that museum authorities hold the species in no high esteem could scarcely be provided. In fairness it should be stated, however, that there must also be catalogued specimens, but that in connection with the re-organization these are at the moment not accessible. Later, Dr Allen (*in litt.*, 20.4.1976) informed me that he had found a sample of *Gambusia* in the collection from Hutt River (October 1966), which is important as the northernmost locality from where the species is known in Western Australia.

Undoubtedly, the above list of localities is very incomplete, but the information at present available is enough to show that *Gambusia* is distributed throughout the south-west of the State, from the Hutt River to the Pallinup River, and that it has infested several major river systems: Greenough, Swan, Margaret and Blackwood Rivers.

The genus *Gambusia* is by no means well known systematically and new species are still being described. The specimens examined agree with the description of *G. affinis* given by Rosen & Bailey (1963) and at present there is no evidence that other species occur in Western Australia.

An attempt was made to find out more about the introduction of *Gambusia affinis* in Western Australia. The introduction in Australia as a whole has not been particularly well-documented, but what is known was summarized by Wilson (1960). It appears that the first liberations in Australia took place at Brisbane in 1925 and in New South Wales from 1926 onwards. In Western Australia the first liberation was made in 1934, when an amateur pisciculturist, who mercifully remains anonymous, released specimens in irrigation ditches at Nedlands. Later, introductions were made to other areas around Perth, apparently by health authorities, and in 1940 to Broome (does it still occur there?). Wilson's information on introductions to Western Australia was received from D.J.R. Snow, at the time Commissioner of Public Health.

In striking contrast to the high praise bestowed on *Gambusia affinis* by many health authorities (see Wilson 1960), is the verdict of ichthyologists. Whitley (1951) declared it to be: 'a general pest' and added some bitter words about its influence on native fish, and Lake (1971) observed: 'The mosquito fish was purposely introduced earlier this century . . . in the mistaken belief that they would control mosquitos. I believe that their effect on mosquitos has been negligible'.

Although they did not state it clearly, the remarks made by Shipway, quoted above, imply that there is a relation between the presence of *Gambusia* and the absence of native fishes. Later, in a newspaper article, Shipway (1959) was much more outspoken. I have also come to expect that in localities where *Gambusia* is plentiful, native fishes are scarce. In some places, such as the Abba River, we found *Gambusia* together with Pigmy Perch, *Nannoperca vittata*, and both species were common. In the Pallinup River, in slightly brackish water, it was associated with Atherinidae, *Galaxias* sp. [1]) and *Lizagobius olorum*.

[1] This *Galaxias* cannot be identified with any species of its genus hitherto recorded from Western Australia. In 1968 I found it common or even plentiful in the Pallinup, West and Jerdacuttup Rivers, all rivers draining to the south. Originally I was inclined to identify these specimens with *G. maculatus* = *G. attenuatus*, but they differ in proportions (the fins are smaller), and some specimens that were X-rayed showed only 52-53 vertebrae, which seems very low for non land-locked populations of *G. maculatus* (*cf.* McDowall 1972). The problem of the identity of this *Galaxias* is not relevant to the matter here discussed and will be dealt with elsewhere.

I am not aware that much research has been done in Australia on the influence of *Gambusia* on other fishes, and certainly nothing has been done in Western Australia, although mention should be made of an unpublished thesis by Griffiths (see references), a work I have been unable to consult. In other parts of the world there is, however, ample evidence of the damage it can do. To quote from Myers (1965a): 'Almost everywhere that *Gambusia* has been introduced, it has gradually wiped out most or all of the smaller native mosquito-destroying species'. Menon (1976) referred to several pertinent cases of damage that have been recorded in Indian literature. The unique native freshwater fish-fauna of south-western Australia would, because of its very limited range, be particularly vulnerable, especially as the expansion of *Gambusia* occurs simultaneously with land-clearing and increasing pollution of the remaining freshwater. At present the range of *Gambusia* already encompasses the ranges of all the more interesting native species; the main and perhaps the only chance of survival of the latter would be in fast-running streams, which is a habitat not attractive to *Gambusia*.

It will be noted that although generally speaking there is much understanding in the State of the danger of indiscriminate introductions, public services like local health councils could apparently make introductions of a great ecological impact without referring to, let alone consulting, the Department of Fisheries and Wildlife or any zoologist. Evidently there is still a great deal of ignorance of the statutory requirement that exists in prohibiting the import of live fish into Western Australia, except under licence.

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From the text it will be clear how much I owe to Dr G.R. Allen and in particular to Mr J.K. Scott. In addition I have to thank Mr H.B. Shugg, Secretary of the Department of Fisheries and Wildlife, who made a search in the files of his department, and helped me with information and with literature references. His researches confirmed that his department was not involved in (indeed, was entirely ignorant of) the introduction of *Gambusia*.

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TYPE SPECIMENS IN THE DEPARTMENT OF MOLLUSCS, WESTERN AUSTRALIAN MUSEUM

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INTRODUCTION

The mollusc collection of the Western Australian Museum is the repository of type specimens of 157 species of recent molluscs. The majority of the species are gastropods which fall essentially into two categories: the pre-1940 collections of land snails described by Iredale and species named since 1960. Although the collection emphasizes Western Australian species there are some paratypes from other parts of the world. Most notable among these is a collection of 8 North and South American species of the pulmonate family Bulimulidae which were obtained on exchange from Dr Alan Solem of the Field Museum of Natural History, Chicago, U.S.A., in 1974.

The list is in taxonomic order by classes and families (orders in the Opisthobranchia). Within each family species are listed in alphabetical order as they were originally described. The scientific name and authority for the species are given; then the type of specimen in the collection, WAM catalogue number, number of specimens, collection locality (type locality where the specimens came from various areas), the reference to the original description and remarks. The last category includes changes in nomenclature made by later authors.

The type collection was established by Dr B.R. Wilson and Mrs S.M. Slack-Smith. I am indebted to them and to Mrs H. Merrifield for a great deal of assistance in compiling this list.

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PHYLUM MOLLUSCA

CLASS AMPHINEURA

Family Ischnochitonidae

Stenochiton longicymba historia Iredale and Hull, 1924
Holotype: WAM 11657
Number of specimens: 1
Locality: King George Sound, W.A.
Reference: *Aust. Zool.* 3: 285, plate 36, figure 8
Remarks: Iredale and Hull (1927) recognised this as a synonym of *Stenochiton cymodocealis* Ashby, 1918.

Stenochiton pilsbryanus dilatus Iredale and Hull, 1924
Holotype: WAM 11658
Number of specimens: 1
Locality: Lucky Bay, 40km east of Esperance, W.A.
Reference: *Aust. Zool.* 3: 287, plate 36, figure 11.

Family Lepidopleuridae

Lepidopleurus glauerti Ashby, 1929
Holotype: WAM 12876
Paratype: WAM 12875
Number of specimens: 2
Locality: Rottnest Island, W.A.
Reference: *J. Roy. Soc. West. Aust.* 15: 50-51, figures 14-16.

Family Loricidae

Kopionella tasmanica Ashby, 1920
Paratype: WAM 9772
Number of specimens: 1
Locality: D'Entrecasteaux Channel, Tasmania
Reference: *Trans. Roy. Soc. South Aust.* 44: 268, plate 11, figures 1a-c.
Remarks: Regarded as a synonym of *Kopionella matthewsi* Iredale, 1910, by Iredale and Hull (1927).

Lorica paucipustulosa Hull, 1923
Holotype: WAM 11659
Number of specimens: 1
Locality: Rabbit Island, King George Sound, W.A.
Reference: *Aust. Zool.* 3: 197, plate 27, figure 3.

Family Acanthochitonidae

Acanthochiton (Notoplax) subviridis Torr, 1911
Cotype: WAM 5811
Number of specimens: 1
Locality: Albany, W.A.
Reference: *Trans. Roy. Soc. South Aust.* 25: 104, plate 25, figures 3a-f.

Acanthochiton spongalis glauerti Ashby, 1923
Holotype: WAM 10399
Number of specimens: 1
Locality: Cottesloe, Perth, W.A.
Reference: *J. Roy. Soc. West. Aust.* **10**: 14, plate i, figure 2
Remarks: Iredale and Hull (1927) considered this a synonym of *Notoplax glauerti* (Ashby, 1923).

Autochiton virgatus exaggeratus Iredale and Hull, 1924
Holotype: WAM 11656
Number of specimens: 1
Locality: Albany Harbour, King George Sound, W.A.
Reference: *Aust. Zool.* 3: 284.

Glyptelasma matthewsi occidentalis Iredale and Hull, 1925
Holotype: WAM 11660
Number of specimens: 1
Locality: Middleton Beach, King George Sound, W.A.
Reference: *Aust. Zool.* 4: 95, plate 11, figures 18 and 20

Notoplax rottnestensis Ashby, 1929
Holotype: WAM 12885
Paratypes: WAM 12880 to 12884
Number of specimens: 6
Locality: Bathurst Point, Rottnest Island, W.A.
Reference: *J. Roy. Soc. West. Aust.* 15: 47-49, figures 10-13.

Family Cryptoplacidae

Cryptoplax striata occidentalis Iredale and Hull, 1925
Holotype: WAM 11661
Number of specimens: 1
Locality: Quarantine Station, Albany, W.A.
Reference: *Aust. Zool.* 4: 106.

Family Chitonidae

Squamopleura carteri Iredale and Hull, 1926
Holotype: WAM 11662
Number of specimens: 1
Locality: Point Cloates, W.A.
Reference: *Aust. Zool.* 4: 260, plate 37, figures 18, 20 and 28.

CLASS GASTROPODA

SUBCLASS PROSOBRANCHIA

Family Phasianellidae

Leptothyra fugitiva Hedley, 1911
Cotypes: WAM 7586
Number of specimens: 4
Locality: 180 m depth, 64 km south of Cape Wiles, S.A.
Reference: Report on the Mollusca obtained by the F.I.S. *Endeavour* chiefly off Cape Wiles, South Australia. Part 1. Zoological results of the fishing expedition carried out by the F.I.S. *Endeavour* 1909-1910, part 2: 102-103, plate 18, figures 18-20.
Remarks: Abbott (1974) regarded *Lepthothyra* as a synonym of *Homalopoma.*

Family Littorinidae

Nodilittorina australis (Gray, 1826)
Neotype: WAM 292-70
Number of specimens: 1
Locality: South Mole, Fremantle, W.A.

Reference: *Indo-Pacific Mollusca* 2 (11): 485-487, plates 325, 373 and 374
Remarks: Rosewater considered the type specimens of Gray to be lost and designated the neotype under ICZN Article 75, 196.

Family Hydrobiidae

Hydrorissoa hospitalis Brandt, 1968
Paratypes: WAM 365-71
Number of specimens: 5
Locality: Mekong River at Khong, Laos
Reference: *Arch. Moll.* 98: 244-245, plates 9 and 32.

Pachydrobia bavayi Brand, 1970
Paratypes: WAM 368-71
Number of specimens: 3
Locality: Mekong River at Kratie, Cambodia
Reference: *Arch. Moll.* **100**: 192-193, plate 13, figure 11.

Family Truncatellidae

Coxiella molesta Iredale, 1943
Syntypes: WAM 51-57
Number of specimens: 6
Locality: Port Phillip, Victoria
Reference: *Aust. Zool.* **10**: 211.

Coxiella glabra Macpherson, 1957
Holotype: WAM 370-72
Number of specimens: 1
Locality: Morawa, W.A.
Reference: *West. Aust. Nat.* 5 (7): 199.

Coxiella glauerti Macpherson, 1957
Holotype: WAM 258-48
Number of specimens: 1
Locality: Israelite Bay, W.A.
Reference: *West. Aust. Nat.* 5 (7): 194-195, figure 2

Coxielladda exposita Iredale, 1943
Syntypes: WAM 52-57
Number of specimens: 8
Locality: Cranbrook, inland from Albany, W.A.
Reference: *Aust. Zool.* **10**: 211

Family Bulimidae

Gabbia australis suspecta Iredale, 1944
Paratypes: WAM 2229-69
Number of specimens: 23
Locality: Armiolmle, N.S.W.
Reference: *Aust. Nat.* 11: 116.
Remarks: Wenz (1938) classified *Gabbia* as a subgenus of *Bulimus.*

Hydrobioides gracilis Brandt, 1968
Paratypes: WAM 366-71
Number of specimens: 8
Locality: Mekong River at Bamdan, Thailand
Reference: *Arch. Moll.* 98: 242-243, plate 9
Remarks: Wenz (1938) classified *Hydrobioides* as a subgenus of *Bulimus.*

Family Rissoidae

Rissoa lockyeri Hedley, 1911
Cotypes: WAM 7587
Number of specimens: 3
Locality: 180 m depth, 64 km south of Cape Wiles, S.A.
Reference: Report on the Mollusca obtained by the F.I.S. *Endeavour* chiefly off Cape Wiles, South Australia. Part 1. Zoological results of the fishing expedition carried out by the F.I.S. *Endeavour* 1909-1910, part 2: 103, plate 18, figure 22.

Rissoa verconiana Hedley, 1911
Cotypes: WAM 7590
Number of specimens: 3
Locality: 180 m depth, 65 km south of Cape Wiles, S.A.
Reference: Report on the Mollusca obtained by the F.I.S. *Endeavour* chiefly off Cape Wiles, South Australia. Part 1. Zoological results of the fishing expedition carried out by the F.I.S. *Endeavour* 1909-1910, part 2: 89-114, plates 17-20.

Family Assimineidae

Assiminea microscopea Brandt, 1968
Paratypes: WAM 367-67
Number of specimens: 49

Locality: Glaeng Harbour, Rayon Province, Thailand
Reference: *Arch. Moll.* 98: 263, plates 10 and 50

Family Turritellidae

Archimediella dirkhartogensis Garrard, 1972

Holotype:	WAM 834-70	
Paratypes:	WAM N4388	WAM 143-69
	WAM 121-69	WAM 145-69
	WAM 123-69	WAM 346-69
	WAM 124-69	WAM 835-70
	WAM 134-69	WAM 836-70
	WAM 135-69	WAM 837-70
	WAM 139-69	WAM 838-70
	WAM 141-69	WAM 190-71
	WAM 142-69	

Locality: 73 m depth, north of Dirk Hartog Island, Shark Bay, W.A.
Reference: *J. malac. Soc. Aust.* 2 (3): 273, plate 26, figure 1.

Calcospira (Acutospira) yarramundi Garrard, 1972
Paratypes: WAM 231-72
Number of specimens: 3
Locality: 114-123 m depth, northwest of Cape Moreton, Queensland
Reference: *J. malac. Soc Aust.* 2 (3): 298, plate 27, figure 10.

Colpospira (Colpospira) bundilla Garrard, 1972
Paratypes: WAM 234-72
Number of specimens: 3
Locality: 114 to 123 m depth, northeast of Cape Moreton, Queensland
Reference: *J. malac. Soc. Aust.* 2 (3): 278, plate 26, figure 17.

Colpospira (Colpospira) moretonensis Garrard, 1972
Paratypes: WAM 232-72
Number of specimens: 2
Locality: 76 m depth off Moreton Bay, Queensland.
Reference: *J. malac. Soc. Aust.* 2 (3): 286, plate 26, figure 13.

Colpospira (Colpospira) translucida Garrard, 1972
Paratype: WAM 230-72
Number of specimens: 1
Locality: 79 to 140 m depth, southwest of Eucla, W.A.
Reference: *J. malac. Soc. Aust.* 2 (3): 288, plate 26, figure 16.

Colpospira (Colpospira) wollumbi Garrard, 1972
Paratypes: WAM 233-72
Number of specimens: 3
Locality: 114 to 123 m depth, northeast of Cape Moreton, Queensland.
Reference: *J. malac. Soc. Aust.* 2 (3): 289, plate 27, figure 1.

Haustator (Kurosioia) leeuwinsis Garrard, 1972
Paratype: WAM 146-71
Number of specimens: 1
Locality: 126 to 130 m depth, west of Dongara, W.A.
Reference: *J. malac. Soc. Aust.* 2 (3): 319-320, plate 29, figure 6.

Family Cerithiidae

Diala polyaulax Tomlin, 1923
Paratypes: WAM 25-73
Number of specimens: 2
Locality: South Coast, Isipingo, Natal
Reference: *J. Conch.* 17: 49, figure 3.

Pseudovertagus peroni Wilson, 1975
Holotype: WAM 324-73
Number of specimens: 1
Locality: Point Peron, W.A.
Reference: *Rec. West. Aust. Mus.* 3 (4): 327-334, plate 1, figures 1-4.

Family Cerithiopsidae

Cerithiopsis dannevigi Hedley, 1911
Cotype: WAM 7589
Number of specimens: 1
Locality: 180 m depth, 64 km south of Cape Wiles, S.A.
Reference: Report on the Mollusca obtained by the F.I.S. *Endeavour* chiefly off Cape Wiles, South Australia. Part 1. Zoological results of the fishing expedition carried out by F.I.S. *Endeavour* 1909-1910, part 2: 109, plate 19, figures 26 and 27

Family Strombidae

Strombus wilsoni Abbott, 1968
Paratypes: WAM 838-66
WAM 840-66
WAM 851-66

Number of specimens: 4
Locality: Dampier Archipelago, W.A.
Reference: *Indo-Pacific Mollusca* 6 (7): 455, plate 328, figures 1-3.

Family Cypraeidae

Cribraria chinensis whitworthi C. Cate, 1964
Holotype: WAM 33-64
Number of specimens: 1
Locality: Vlaming Head, North West Cape, W.A.
Reference: *Veliger* 7 (1): 20-21, plate 5, figures 2a and 2b.
Remarks: Wilson and Gillett (1971) referred this subspecies to the genus *Cypraea.*

Cypraea kingae Rehder and Wilson, 1975
Paratypes: WAM 220-222, 224-69
Number of specimens: 4 + 2 radulae
Locality: Pitcairn Island
Reference: *Smithsonian Contr. Zool.* 203: 2-6, figures 1-3.

Cypraea (Lycina) leviathan gedlingae C. Cate, 1968
Holotype: WAM 334-67
Number of specimens: 1
Locality: Five Mile Beach, North West Cape, W.A.
Reference: *Veliger* 10 (3): 227, plate 26, figure 28.

Cypraea mauiensis Burgess, 1967
Paratypes: WAM 2585-67
Number of specimens: 2
Locality: Olawalu, Maui, Hawaii
Reference: *Nautilus* 81.

Mauritia arabica brunnescens C. Cate, 1964
Holotype: WAM 32-64
Number of specimens: 1
Locality: Broome, W.A.
Reference: *Veliger* 7 (1): 24-26, plate 5, figures 3a and 3b.
Remarks: Wilson and Gillett (1971) referred this subspecies to the genus *Cypraea* and did not feel subspecies differentiation was warranted.

Palmadusta saulae crakei C. Cate, 1968
Holotype: WAM 1321-67
Number of specimens: 1

Locality: Quondong, 56 km north of Broome, W.A.
Reference: *Veliger* 10 (3): 212-232, plates 21-34, 5 maps
Remarks: Wilson and Gillett (1971) referred this subspecies to the genus *Cypraea.*

Zoila friendii jeaniana C. Cate, 1968
Holotype: WAM 1320-67
Number of specimens: 1
Locality: Koks Island, off Carnarvon, W.A.
Reference: *Veliger* 10 (3): 212-232, plates 21-34.
Remarks: Wilson and Gillett (1971) regarded *Zoila* as a subgenus of *Cypraea* and they expressed the opinion that the "subspecies" name should not be used. It is a synonym of *C. friendii friendii.*

Family Amphiperatidae

Globovula cottesloensis C. Cate, 1973
Holotype: WAM 69-70
Number of specimens: 1
Locality: Cottesloe Beach, Perth, W.A.
Reference: *Veliger* 15 (Supplement): 23, figure 42.

Globovula spatiosa C. Cate, 1973
Holotype: WAM 68-70
Number of specimens: 1
Locality: Red Bluff, 128 km north of Carnarvon, W.A.
Reference: *Veliger* 15 (Supplement): 22, figure 40.

Margovula aboriginea C. Cate, 1973
Holotype: WAM 67-70
Number of specimens: 1
Locality: Geralia, Exmouth Gulf, W.A.
Reference: *Veliger* 15 (Supplement): 20, figure 34.

Xandarovula figgisae C. Cate, 1973
Holotype: WAM 1454-70
Number of specimens: 1
Locality: North West Cape, W.A.
Reference: *Veliger* 15 (Supplement): 36, figure 70.

Family Cassidae

Cassidea stadialis Hedley, 1914
Cotypes: WAM 8786

Number of specimens: 2
Locality: 90 to 180 m depth near Cape Howe, S.A.
Reference: Report on the Mollusca obtained by the F.I.S. *Endeavour* chiefly off Cape Wiles, South Australia 2 (2): 72-73, plate 10, figure 4.

Phalium whitworthi Abbott, 1968
Paratypes: WAM 5115-68
WAM 130-66
Number of specimens: 2
Locality: West Wallaby Island, Houtmans Abrolhos, W.A.
Reference: *Indo-Pacific Mollusca* 2 (9): 179-181, plates 165-168.

Family Muricidae

Chicoreus venustulus Rehder and Wilson, 1975
Paratypes: WAM 138, 139, 140, 142, 143-72
WAM 385 to 395-72
Number of specimens: 18 + soft parts
Locality: 65-70 m depth southwest of Tahuata Island, Marquesas
Reference: *Smithsonian Contr. Zool.* 203: 7-10, figures 4 and 5.

Dermomurex (Viator) antonius Vokes, 1974
Holotype: WAM 3646-67
Paratype: WAM 2834-67
Number of specimens: 2
Locality: Shell Island, Dampier Archipelago, W.A.
Reference: *J. malac. Soc. Aust.* 3 (1): 4, plate 1, figures 1 and 2.

Haustellum (Tritonohaustellum) wilsoni Old and d'Attilio, 1971
Holotype: WAM N3981
Paratypes: WAM N2148 WAM N3955
WAM N2641 WAM N5366
WAM N2987 WAM N5367
Number of specimens: 7
Locality: Off Jurien Bay, W.A.
Reference: *Veliger* 13 (4): 316-318, figures 1-3.

Pterynotus (Pterochelus) westralis Ponder and Wilson, 1973
Holotype: WAM 438-72
Paratypes: WAM 439-72; WAM 440-72
Number of specimens: 4
Locality: 144 to 162 m depth, northwest of Rottnest Island, W.A.
Reference: *J. malac. Soc. Aust.* 2 (4): 395-399, plate 39, figures 1-3.

Family Pyrenidae

Anachis (Costoanachis) fayae Keen, 1971
Paratypes: WAM 371-72
Number of specimens: 2
Locality: Playa Caracol, Nuevo Guaymas, Sonara, Mexico
Reference: *Seashells of Tropical West America*, 2nd edition, Stanford Univ. Press, p. 579.

Family Fasciolariidae

Fusinus galatheae bountyi Rehder and Wilson, 1975
Paratype: WAM 135-72
Number of specimens: 1 + radula + soft parts
Locality: Pitcairn Island
Reference: *Smithsonian Contr. Zool.* 203: 10-13, figures 6 and 7.

Family Mitridae

Mitra (Nebularia) sowerbyi kingae Cernohorsky, 1972
Holotype: WAM 1222-76
Number of specimens: 1
Locality: 34 to 40 m depth, off the east coast of Wasir Island, West Wokam, Aru Island, Moluccas, Indonesia
Reference: *Rec. Auckland Inst. and Mus.* 9: 195-196, figures 1, 2 and 6

Pterygia barrywilsoni J.M. Cate, 1968
Holotype: WAM 334-68
Number of specimens: 1
Locality: Nightcliffe, Darwin, N.T.
Reference: *Veliger* 11 (2): 86, plate 11, figures 2a and 2b
Remarks: Cernohorsky (pers. comm. to B.R. Wilson, 1969) regarded this as a synonym of *Scabricola nympha* (Reeve, 1845).

Pterygia gilbertsoni J.M. Cate, 1968
Holotype: WAM 1129-67
Number of specimens: 1
Locality: 8 km west of the northwest end of Rottnest Island, W.A.
Reference: *Veliger* 11 (2): 85-86, plate 11, figures 1a-d.

Scabricola (Scabricola) backae Cernohorsky, 1973
Holotype: WAM 14-72
Paratypes: WAM 233-70; 14-72; 472-72

Number of specimens: 6
Locality: *Rec. Auckland Inst. and Mus.* **10**: 133-135, figures 1-5.

Scabricola (Swainsonia) ocellata ekerae Cernohorsky, 1973
Holotype: WAM 5014-68
Paratypes: WAM 5014-68
WAM 228-70
Number of specimens: 6
Locality: Southwest of Pt. Cloates, W.A.
Reference: *Rec. Auckland Inst. and Mus.* **10**: 135-137, figures 6-11.

Vexillum (Pusia) hansenae Cernohorsky, 1973
Holotype: WAM 13-72
Paratypes: WAM N3569
WAM 13-72
Number of specimens: 10
Locality: Sarge Bay, Augusta, W.A.
Reference: *Rec. Auckland Inst. and Mus.* **10**: 138, figures 13-16.

Vexillum (Pusia) marrowi Cernohorsky, 1973
Holotype: WAM N408

Paratypes:	WAM 1585	WAM 4457
	WAM 1757	WAM 1112-67
	WAM 2591	WAM 150 to 152-70
	WAM 2827	WAM 171-70
	WAM 3569	WAM 230-70
	WAM 4159	WAM 238-70
	WAM 246-70	WAM 349-70

Number of specimens: 71
Type locality: Yanchep reef flat, Yanchep, W.A.
Reference: *Rec. Auckland Inst. and Mus.* **10**: 140-142, figures 19-23.

Vexillum sitangkaianum J.M. Cate, 1968
Holotype: WAM 1230-67
Paratypes: WAM 1230-67
Number of specimens: 14
Locality: 16 to 23 m depth, south lagoon, Sibutu, Sulu Archipelago
Reference: *Veliger* 11 (2): 86-87, plate 11, figures 3a and 3b
Remarks: Cernohorsky (pers. comm. to B.R. Wilson 1969) regarded this as a synonym of *Vexillum vulpecula* (Linneus, 1758)

Family Harpidae

Austroharpa loisae Rehder, 1973
Holotype: WAM 1784-69
Paratype: WAM 31-64
Number of specimens: 2
Locality: 126 m depth, northwest of Rottnest Island, W.A.
Reference: *Indo-Pacific Mollusca* 3 (16): 264-265, plate 237, figures 3a and b

Austroharpa wilsoni Rehder, 1973
Holotype: WAM 36-70
Paratypes: WAM 125-63
WAM 35-70
WAM 151-72
Number of specimens: 5
Locality: 180 to 185 m depth, northwest of Rottnest Island, W.A.
Reference: *Indo-Pacific Mollusca* 3 (16): 267-268, plate 237, figures 1 and 2

Family Volutidae

Amoria dampieria Weaver, 1960
Paratypes: WAM 5866
WAM 16-61
Number of specimens: 2
Locality: Off Delambre Island, Dampier Archipelago, W.A.
Reference: *Hawaiian Shell News* 8 (12): 1, 3, figures 5-7.
Remarks: These specimens are listed in the article as "additional paratypes" and thus are really not types at all

Amoria diamantina Wilson, 1972
Holotype: WAM 142-64
Paratypes: WAM N4331, WAM N4356, WAM N4454, WAM 133-64, WAM 141-64, WAM 144-64, WAM 147-64, WAM 148-64, WAM 4685-68, WAM 626-71, WAM 663-71, WAM 664-71, WAM 665-71, WAM 666-71
Number of specimens: 22

Locality: 144 to 149 m depth, southwest of Rottnest Island, W.A.
Reference: *J. malac. Soc. Aust.* 2 (3): 340-345, plate 31, figures 1-4.

Notopeplum annulatum Wilson, 1972
Holotype: WAM 132-64
Paratypes: WAM 134-64; WAM 472-71
Number of specimens: 3
Locality: 135 to 140 m depth, west of Rottnest Island, W.A.
Reference: *J. malac. Soc. Aust.* 2 (3): 354-358, plate 33, figures 1 and 2, page 357 figures a, b, d, f, g, h

Notovoluta baconi Wilson, 1972
Holotype: WAM 1565-70
Paratype: WAM 41-60
Number of specimens: 2
Locality: 126 to 144 m depth, west of Wedge Island, W.A.
Reference: *J. malac. Soc. Aust.* 2 (3): 352-353, figures 1-3.

Volutoconus capricorneus Wilson, 1972
Holotype: WAM 146-64
Paratype: WAM 774-71
Number of specimens: 2
Locality: 128 m depth, west of Pt. Cloates, W.A.
Reference: *J. malac. Soc. Aust.* 2 (3): 346-347, plate 31, figures 9-12.

Family Cancellariidae

Cancellaria (Merica) melanostoma westralis Garrard, 1975
Holotype: WAM 697-74
Number of specimens: 1
Locality: Turtle Bay, North West Cape, W.A.
Reference: *Rec. Aust. Mus.* 30: 5-6, plate 1, figures 2 and 3.

Cancellaria (Sydaphera) panamuna Garrard, 1973
Holotype: WAM 551-71
Number of specimens: 1
Locality: 137 m depth, 32 km northwest of Anchor Island, off Onslow, W.A.
Reference: *Rec. Aust. Mus.* 30: 14-15, plate 2, figure 7.

Fusiaphera dampierensis Garrard, 1975
Holotype: WAM 550-71
Paratype: WAM 434-72
Number of specimens: 2

Locality: 11 to 13 km north of Delambre Island, Dampier Archipelago, W.A.
Reference: *Rec. Aust. Mus.* 30: 117-18, plate 2, figure 8.

Trigonostoma (Trigonophera) diamantina Garrard, 1975
Holotype: WAM 90-72
Paratype: WAM 437-72
Number of specimens: 2
Locality: 201 to 228 m depth, northwest of Bunbury, W.A.
Reference: *Rec. Aust. Mus.* 30: 22-23, plate 3, figure 4.

Family Conidae

Conus marielae Rehder and Wilson, 1975
Paratypes: WAM 317 to 321-73
Number of specimens: 5
Locality: One half mile off Baie Motu-Hee, Nuka Hiva, Marquesas Islands
Reference: *Smithsonian Contr. Zool.* 203: 14-16, figure 10.

Family Terebridae

Duplicaria (Duplicaria) crakei Burch, 1965
Paratypes: WAM 2675-67
Number of specimens: 2
Locality: Cable Beach, Broome, W.A.
Reference: *Veliger* 7 (4): 245-247, plate 31, figure 1.

Terebra jacquelinae Bratcher and Burch, 1970
Paratype: WAM 367-72
Number of specimens: 1
Locality: Academy Bay, Santa Cruz Island, Galapagos Islands, Equador.
Reference: *Los Angeles County Mus. Contr. Sci.* 188: 2-5, figures 3 and 4

SUBCLASS OPISTHOBRANCHIA

Order Pyramidelloida

Pseudoskenella depressa Ponder, 1973
Paratypes: WAM 425-73

Number of specimens: 2
Locality: Long Reef, Collaroy, N.S.W.
Reference: *Malacol. Rev.* 6: 119-123, figures 1-8.

Order Cephalaspidea

Ringicula meridionalis Hedley, 1911
Syntypes: WAM 7588
Number of specimens: 3
Locality: 180 m depth, 64 km south of Cape Wiles, S.A.
Reference: Report on the Mollusca obtained by the F.I.S. *Endeavour* chiefly off Cape Wiles, South Australia. Part 1. Zoological results of the fishing expedition carried out by the F.I.S. *Endeavour* 1901-1910, Part 2: 112-113, plate 20, figure 38.

Order Nudibranchia

Astraeolis westralis Burn, 1966
Holotype: WAM 180-64
Paratypes: WAM 106-65
Number of specimens: 3
Locality: Rottnest Island, W.A.
Reference: *J. malac. Soc. Aust.* 1 (9): 31-32, figures 11-14.

Nossis westralis Burn, 1964
Holotype: WAM 61-64
Number of specimens: 1
Locality: Nicol Bay, north of Roebourne, W.A.
Reference: *J. malac. Soc. Aust.* 1 (8): 11-12, figures 1-5

SUBCLASS PULMONATA

Family Chondrinidae

Australbinula complexa Iredale, 1939
Holotype: WAM 22-40
Paratypes: WAM 22-40
Number of specimens: 8
Locality: Nangeenan via Merredin, W.A.

Reference: *Rec. West. Aust. Mus.* 2 (1): 7-8, plate 1, figure 7.
Remarks: Classified in the genus *Gastrocopta*, subgenus *Australbinula*, by Wenz and Zilch, 1959-60.

Australbinula helmsiana Iredale, 1939
Paratypes: WAM 21-40
Number of specimens: 6
Locality: Forrest River, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 8, plate 1, figure 2.
Remarks: Classified in the genus *Gastrocopta*, subgenus *Australbinula*, by Wenz and Zilch, 1959-60.

Family Helicinidae

Helicina walkeri Smith, 1894
Paratype: WAM 20-40
Number of specimens: 1
Locality: Bavelin Island, W.A.
Reference: *Proc. malac. Soc. Lond.* 1: 99, plate 7, figure 26.
Remarks: Iredale (1939) classified this species in the genus *Pleuropoma.*

Family Pupillidae

Omegapilla occidentalis Iredale, 1939
Syntypes: WAM 12981-12988, 12992, 12993
Number of specimens: 10
Locality: Rottnest Island, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 12, plate 1, figure 10.
Remarks: Classified in the genus *Pupilla*, subgenus *Omegapilla*, by Wenz and Zilch, 1959-60.

Themapupa anapacifica Iredale, 1939
Paratypes: WAM 23-40
Number of specimens: 3
Locality: Forrest River, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 11-12, plate 1, figure 9.
Remarks: Classified in the genus *Pupoides*, subgenus *Themapupa*, by Wenz and Zilch, 1959-60.

Themapupa beltiana asserta Iredale, 1939
Paratypes: WAM 92 to 99-34
Number of specimens: 8

Locality: Nangeenan via Merredin, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 11, plate 1, figure 3.
Remarks: Classified in the genus *Pupoides*, subgenus *Themapupa*, by Wenz and Zilch, 1959-60.

Themapupa beltiana contexta Iredale, 1939
Paratypes: WAM 883
Number of specimens: 3
Locality: Cardanumbi, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 11, plate 1, figure 6.
Remarks: Classified in the genus *Pupoides*, subgenus *Themapupa*, by Wenz and Zilch, 1959-60.

Themapupa dirupta Iredale, 1939
Paratype: WAM 24-40
Number of specimens: 1
Locality: Napier Range, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 11, plate 1, figure 8.

Family Succineidae

Austrosuccinea contenta isolata Iredale, 1939
Paratypes: WAM 839 to 845-31
Number of specimens: 7
Locality: Rottnest Island, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 13.

Family Punctidae

Westralaoma aprica Iredale, 1939
Paratype: WAM 40-40
Number of specimens: 1
Locality: Nangeenan via Merredin, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 38, plate 3, figure 9.

Westralaoma expicta Iredale, 1939
Paratype: WAM 42-40
Number of specimens: 1
Locality: Nangeenan via Merredin, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 37-38, plate 3, figure 4.

Family Dipnelicidae

Annoselix dolosa Iredale, 1939
Paratypes: WAM 43-40
Number of specimens: 3
Locality: Deep River, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 39, plate 1, figures 24 and 27

Family Charopidae

Epinicium restifer Iredale, 1939
Paratypes: WAM 13732
Number of specimens: 36
Locality: Serpentine, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 43, plate 1, figure 26.

Epinicium restifer firmatum Iredale, 1939
Holotype: WAM 13115
Number of specimens: 1
Locality: Peppermint Grove, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 43

Pernagera lena Iredale, 1939
Paratypes: WAM 45-50
Number of specimens: 3
Locality: Bow River, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 40, plate 3, figure 3.

Family Bulimulidae

Bothriembryon balteolus Iredale, 1939
Lectotype: WAM 9876
Paratypes: WAM 8877, 15339, 15341 to 15351
Number of specimens: 15
Localities: Esperance mallee belt, 80 km south of Norseman, Salmon Gums, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 21-22, plate 2, figure 9.

Bothriembryon bradshawi Iredale, 1939
Paratypes: WAM 13109, WAM 1028-76
Number of specimens: 5

Locality: Tambellup, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 24, plate 2, figure 14.

Bothriembryon distinctus Iredale, 1939
Paratypes: WAM 8873
Number of specimens: 7
Locality: Cardanumbi, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 36, plate 2, figure 43.

Bothriembryon esperantia Iredale, 1939
Paratypes: WAM 13427 to 13430
Number of specimens: 4
Locality: Esperance, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 21, plate 2, figure 8.

Bothriembryon fuscus Thiele, 1930
Paratypes: WAM 1015-76
Number of specimens: 6
Locality: Deep River, Nornalup Inlet, W.A.
Reference: *Fauna South-West Australia.* 5 (8): 588, plate 7, figure 8.

Bothriembryon glauerti Iredale, 1939
Holotype: WAM 10127
Paratypes: WAM 10127
Number of specimens: 3
Locality: Stirling Ranges, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 29, plate 2, figure 24.

Bothriembryon iruineanus Iredale, 1939
Paratypes: WAM 1027-76
Number of specimens: 3
Locality: Cape Naturaliste, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 29, plate 2, figure 15.

Bothriembryon jacksoni Iredale, 1939
Paratypes: WAM 1023-76
Number of specimens: 3
Locality: West of Nornalup Inlet, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 31, plate 2, figure 30.

Bothriembryon leeuwinensis eventus Iredale, 1939
Paratypes: WAM 271 to 275
Number of specimens: 8
Locality: Margaret River, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 25, plate 2, figure 18.

Bothriembryon notatus Iredale, 1939
Paratypes: WAM 11624
Number of specimens: 19
Locality: Pallinup River, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 31, plate 2, figure 29.

Bothriembryon perditus Iredale, 1939
Paratypes: WAM 35 to 40
Number of specimens: 7
Locality: 112 km east of Israelite Bay, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 32, plate 2, figure 32.

Bothriembryon perobesus Iredale, 1939
Holotype: WAM 10217
Number of specimens: 1
Locality: Mouth of Moore River, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 28, plate 2, figure 22.

Bothriembryon praecelsus Iredale, 1939
Holotype: WAM 9321
Number of specimens: 1
Locality: Kellerberrin, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 22, plate 2, figure 11.

Bothriembryon rhodostomus grantianus Iredale, 1939
Paratypes: WAM 1025-75
Number of specimens: 4
Locality: Charlie Island, Esperance, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 21

Bothriembryon rhodostomus hullianus Iredale, 1939
Paratypes: WAM 1026-76
Number of specimens: 4
Locality: Gunton Island, Recherche Archipelago, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 20

Bothriembryon rhodostomus perspectus Iredale, 1939
Paratypes: WAM 1029-76
Number of specimens: 2
Locality: Woody Island, Recherche Archipelago, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 21

Bothriembryon rhodostomus wrightianus Iredale, 1939
Paratypes: WAM 1014-76
Number of specimens: 5

Locality: Rabbit Island, Recherche Archipelago, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 21

Bothriembryon serpentinus Iredale, 1939
Paratypes: WAM 12115 to 12174
Number of specimens: 60
Locality: Serpentine Falls, Darling Range, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 22, plate 2, figure 10.

Bulimulus (Lissoacme) rudistriatus Haas, 1955
Paratypes: WAM 692-74
Number of specimens: 4
Locality: Hacienda Palmira, Andahuaylas, Apurimac, Peru
Reference: *Fieldiana: Zool.* 37: 318-319, figure 64.

Bulimulus (Peronaeus) acme Haas, 1955
Paratypes: WAM 689-74
Number of specimens: 3
Locality: Altura de la Hacienda de Mozobamba, Ongoy, Andahuaylas, Peru
Reference: *Fieldiana: Zool.* 37: 325-326, figure 68

Bulimulus (Peronaeus) extensus Haas, 1955
Paratypes: WAM 688-74
Number of specimens: 5
Locality: Hacienda Palmira, Andanuaylas, Apurimac, Peru
Reference: *Fieldiana: Zool.* 37: 323-324, figure 67

Bulimulus (Peronaeus) pyrigidium Haas, 1955
Paratypes: WAM 685-74
Number of specimens: 4
Locality: Hacienda Moyamba, Orgoy, Andanuaylas, Apurimac, Peru
Reference: *Fieldiana: Zool.* 37: 321-322, figure 66.

Bulimulus (Rhabdotus) dealbatus pasonis Pilsbry, 1902
Paratype: WAM 687-74
Number of specimens: 1
Locality: Franklin Mountain, El Paso, Texas
Reference: *Nautilus* 16: 32

Bulimulus (Scutalus) longitudinalis Haas, 1955
Paratypes: WAM 684-74
Number of specimens: 6
Locality: Polanco, Tambo, San Miguel, Ayachuca, Peru
Reference: *Fieldiana: Zool.* 37: 316-317, figure 63.

Drymaeus (Drymaeus) schmidti Haas, 1955
Paratypes: WAM 691-74
Number of specimens: 5
Locality: Ccachubamba, Marcapata, Cuzco, Peru
Reference: *Fieldiana: Zool.* 37: 314-315, figure 62.

Notopetraceus platychielus Haas, 1955
Paratypes: WAM 690-74
Number of specimens: 5
Locality: Hacienda Pajonal, Ocros Cangallo Ayacucho, Peru
Reference: *Fieldiana: Zool.* 37: 311-313, figures 60 and 61.

Family Camaenidae

Amplirhagada novelta Iredale, 1939
Paratype: WAM 3994
Number of specimens: 1
Locality: Drysdale River, Napier/Broome Bay, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 67-68, plate 5, figure 12.

Chloritis micromphala Gude, 1907
Paratypes: WAM 48-40
Number of specimens: 2
Locality: Barrier Range, W.A.
Reference: *Proc. malac. Soc. Lond.* 7: 231, plate 21, figure 6.
Remarks: Iredale (1939) classified this species in the genus *Kimboraga.*

Helix derbyi Cox, 1892
Paratypes: WAM 52-40
Number of specimens: 4
Locality: Napier Range, W.A.
Reference: *Proc. Linn. Soc. N.S.W. Ser. 2;* 6: 566, plate 20, figures 4 and 5
Remarks: Iredale (1939) classified this species in the genus *Westraltrachia.*

Helix (Gonostoona) baudinensis Smith, 1893
Paratype: WAM 50-40
Number of specimens: 1
Locality: Baudin Island, W.A.
Reference: *The Conchologist* 2: 97
Remarks: Iredale (1939) classified this species in the genus *Baudinella.*

Helix (Hadra) oscarensis Cox, 1892
Paratype: WAM 63-40
Number of specimens: 1

Locality: Oscar Range, W.A.
Reference: *Proc. Linn. Soc. N.S.W. Ser. 2*, 6: 565, plate 20, figures 6 and 7
Remarks: Iredale (1939) classified this species in the genus *Rhagada.*

Parrhagada commoda Iredale, 1939
Paratypes: WAM 66-40
Number of specimens: 2
Locality: Napier Range, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 64, plate 4, figure 19.

Parrhagada delecta Iredale, 1939
Paratypes: WAM 65-40
Number of specimens: 4
Locality: Napier Range, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 64, plate 4, figure 22.

Parrhagada ferrosa Iredale, 1939
Paratypes: WAM 67-40
Number of specimens: 2
Locality: Barker Gorge, Napier Range, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 65, plate 4, figure 21.

Pleuroxia abstans Iredale, 1939
Paratypes: WAM 833 to 841-32
Number of specimens: 9
Locality: Murchison House, Gantheaume Bay, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 56-57, plate 3, figure 22.
Remarks: Classified in the genus *Angasella* by Wenz and Zilch, 1959-60.

Pleuroxia oligopleura numba Iredale, 1939
Holotype: WAM 8881
Number of specimens: 1
Locality: Cardanumbie, west of Eyre, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 56, plate 3, figure 28.
Remarks: Classified in the genus *Angasella* by Wenz and Zilch, 1959-60.

Pleuroxia polypleura elfina Iredale, 1939
Holotype: WAM 8880
Paratypes: WAM 8880
Number of specimens: 6
Locality: Newman Rocks, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 55, plate 3, figure 27.
Remarks: Recognised as *Angasella cyrtopleura* Tate, 1879, by Wenz and Zilch, 1959-60.

Rhagada convicta tambra Iredale, 1939
Holotype: WAM 221-32
Number of specimens: 1
Locality: Tambrey Station, Fortescue River, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 61-62, plate 4, figure 12.

Rhagada gatta Iredale, 1939
Paratype: WAM 59-40
Number of specimens: 1
Locality: Napier Range, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 60-61, plate 4, figure 5.

Rhagada mimika Iredale, 1939
Paratype: WAM 60-40
Number of specimens: 1
Locality: Napier Range, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 61, plate 4, figure 4.

Rhagada oscarensis Cox, 1892
Paratypes: WAM 64-40
Number of specimens: 3
Locality: Oscar Range, W.A.
Reference: *Proc. Linn. Soc. N.S.W. Ser. 2*, 6: 565, plate 20, figures 6 and 7

Rhagada sutra Iredale, 1939
Paratype: WAM 62-40
Number of specimens: 1
Locality: Napier Range, W.A.
References: *Rec. West. Aust. Mus.* 2 (1): 61, plate 4, figure 9.

Sinumelon datum Iredale, 1939
Holotype: WAM 8878
Paratypes: WAM 8878
Number of specimens: 3
Locality: Eucla, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 53, plate 3, figure 18.
Remarks: Classified in the genus *Thersites*, subgenus *Sinumelon*, by Wenz and Zilch, 1959-60.

Sinumelon lennum mutcum Iredale, 1939
Holotype: WAM 8879
Number of specimens: 1
Locality: Madura, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 54, plate 3, figure 21.

Remarks: Classified in the genus *Thersites*, subgenus *Sinumelon*, by Wenz and Zilch, 1959-60.

Sinumelon vagente Iredale, 1939
Holotype: WAM 10944
Paratype: WAM 10944
Number of specimens: 2
Locality: Mount Singleton, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 54, plate 3, figure 24.
Remarks: Classified in the genus *Thersites*, subgenus *Sinumelon*, by Wenz and Zilch, 1959-60.

Tenuigada ignara Iredale, 1939
Paratypes: WAM 70-40
Number of specimens: 3
Locality: Napier Range, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 68, plate 5, figure 13.

Tenuigada percita Iredale, 1939
Paratypes: WAM 69-40
Number of specimens: 2
Locality: Napier Range, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 68, plate 5, figure 14.

Thersites woodwardi Fulton, 1902
Cotypes: WAM 734-77
Number of specimens: 2
Locality: Northwest W.A.
Reference: *Proc. malac. Soc. Lond.* 5: 33
Remarks: Iredale (1939) classified this species in the genus *Parrhagada.*

Torresitrachia monticola Iredale, 1939
Paratype: WAM 49-40
Number of specimens: 1
Locality: Napier Range, W.A.
Reference: *Rec. West. Aust. Mus.* 2 (1): 48-49, plate 3, figure 13.

Trachia froggatti Ancey, 1898
Paratype: WAM 51-40
Number of specimens: 1
Locality: Oscar Range, W.A.
Reference: *Proc. Linn. Soc. N.S.W.* 22: 774, plate 36, figure 2.
Remarks: Iredale (1939) classified this species in the genus *Westraltrachia.*

Trachia monogramma Ancey, 1898
Paratype: WAM 56-40
Number of specimens: 1
Locality: Oscar Range, W.A.
Reference: *Proc. Linn. Soc. N.S.W.* 22: 775, plate 36, figure 3.

Trachia orthocheila Ancey, 1898
Paratypes: WAM 53-40
Number of specimens: 5
Locality: Oscar Range, W.A.
Reference: *Proc. Linn. Soc. N.S.W.* 22: 774, plate 36, figure 4.
Remarks: Iredale (1939) classified this species in the genus *Westraltrachia.*

CLASS BIVALVIA

Family Mytilidae

Fluviolanatus amarus Laseron, 1956
Paratypes: WAM 2227-67
Number of specimens: 4
Locality: Woogoolga, N.S.W.
Reference: *Aust. Zool.* 12 (3): 274, figures 46-49.
Remarks: Transferred to the genus *Modiolus* by Macpherson and Gabriel (1962) but it is not a mytilid (Wilson, pers. comm., 1977).

Modiolaria perstriata Hedley, 1906
Cotypes: WAM 2228-69
Number of specimens: 3
Locality: 29-36 m depth off Masthead Island, Queensland.
Reference: *Proc. Linn. Soc. N.S.W.* 31: 472, plates 36-38.
Remarks: Macpherson and Gabriel (1962) transferred this species to the genus *Lanistina.*

Family Lyonsiidae

Guiandesma sinuosa Morrison, 1943
Paratype: WAM 1176-67
Number of specimens: 1

Locality: Kartabo, British Guiana (Guyana)
Reference: *Nautilus* 57 (2): 46-52, plate 8.
Remarks: The genus *Guiandesma* was regarded as a synonym of *Ostomya* by Moore (1969).

CLASS CEPHALOPODA

Family Sepiidae

Sepia iruingae Meyer, 1909
Holotype: WAM 4203
Number of specimens: 1
Locality: Warnbro Sound, Safety Bay, W.A.
Reference: *Fauna Sudwest-Aust.* 2 (19): 333, figures 7-10.

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MORPHOMETRICS OF WESTERN AUSTRALIAN ABORIGINAL SKULLS

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and

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ABSTRACT

A sample of 105 crania and 53 mandibles from Aboriginal Western Australians has been studied by univariate and multivariate techniques. Fifty cranial dimensions, 22 derived indices and 18 mandibular measurements were analysed for sexual dimorphism and regional differences. Comparisons were also made with data from similar studies of samples from Western Australia and coastal New South Wales.

Most of the measurements and indices studied showed significant sexual dimorphism and hence, for further analysis, the sexes were analysed separately. The material was subdivided on broad linguistic criteria. Canonical analysis indicated clinal variation in the 3 coastal samples, with the single inland sample markedly divergent. The main discriminating features have been analysed.

A generalised distance analysis of the 4 Western Australian and 3 coastal New South Wales samples revealed an interesting pattern. The northern samples of the 2 States were most similar, and the central and southern samples showed progressively higher D^2 values from their own State northern sample and also from the opposite State equivalent. Such a set of relationships would seem to indicate an initial northern Australian colonisation by a single stock followed by migration down the east and west coasts.

INTRODUCTION

Starting in the 19th century (e.g. summary by Turner, 1884) a large number of metrical studies have been made of Australian Aboriginal skulls and

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interest continues (e.g. Howells, 1970; Brown, 1973). In most of the earlier studies, the samples of skulls analysed from the various parts of Australia were small, but more recently, some substantial samples from the eastern States have been analysed (e.g. Freedman, 1964; Giles, 1976). However, in all of the metrical studies so far made the number of specimens from Western Australia, which in area comprises just under one third of the continent, has never exceeded 30. Of the many previous studies only two have dealt specifically with Western Australia. Woodward (1901) examined 16 crania using 16 measurements and indices, while Bourne and Mulcahy (1935) published cranial indices for 30 unsexed crania. Apart from these two reports, reference to Western Australian crania has been restricted to small numbers (8-17) which were studied as parts of Australia-wide analyses (e.g. Morant, 1927; Hrdlicka, 1928; Wagner, 1937). With regard to non-metrical cranial studies, Kellock and Parsons (1970) studied 73 unsexed Western Australian crania by multivariate analysis.

The long settlement of Western Australia by the Australian Aborigines has recently been confirmed by excavations at Devil's Lair in the extreme south west of Western Australia. The cave has been radiocarbon dated as a human occupation site back to 24,600 ± 800 yrs B.P. (Dortch and Merrilees, 1973). This considerable antiquity, coupled with the very substantial area of Western Australia (close to 1 mil. sq. mls), makes Aboriginal skeletal material from this State very important for studies of the origin, variation and the much debated entry and migration routes of the Australian Aborigines.

The specific aim of the present study was to fully describe metrically 105 crania and 53 associated mandibles from Western Australia. The material was studied by uni- and multivariate analysis, as a whole and in subsections, males and females always being treated separately. Comparisons were also made to some of the previously described series of Aboriginal crania from Western Australia (Morant, 1927; Hrdlicka, 1928; Wagner, 1937) and also from coastal New South Wales (Freedman, 1964).

MATERIALS

The sample of Western Australian skulls analysed included: 84 crania and 41 mandibles from the Western Australian Museum, Perth; 17 crania and 9 mandibles from the South Australian Museum, Adelaide; and 4 crania and 3 mandibles from the Department of Anatomy and Human Biology, University of Western Australia, Perth. The material was generally in good condition, with the exception of the zygomatic arch, which was often damaged or lost — generally only unilaterally; also, many teeth were missing, usually due to post-mortem loss. Post-cranial material was available in only a few cases and, of these, only four included appropriate parts (pelves and femora) for confirmatory sex determination. The localities of the specimens used are shown in Fig. 1.

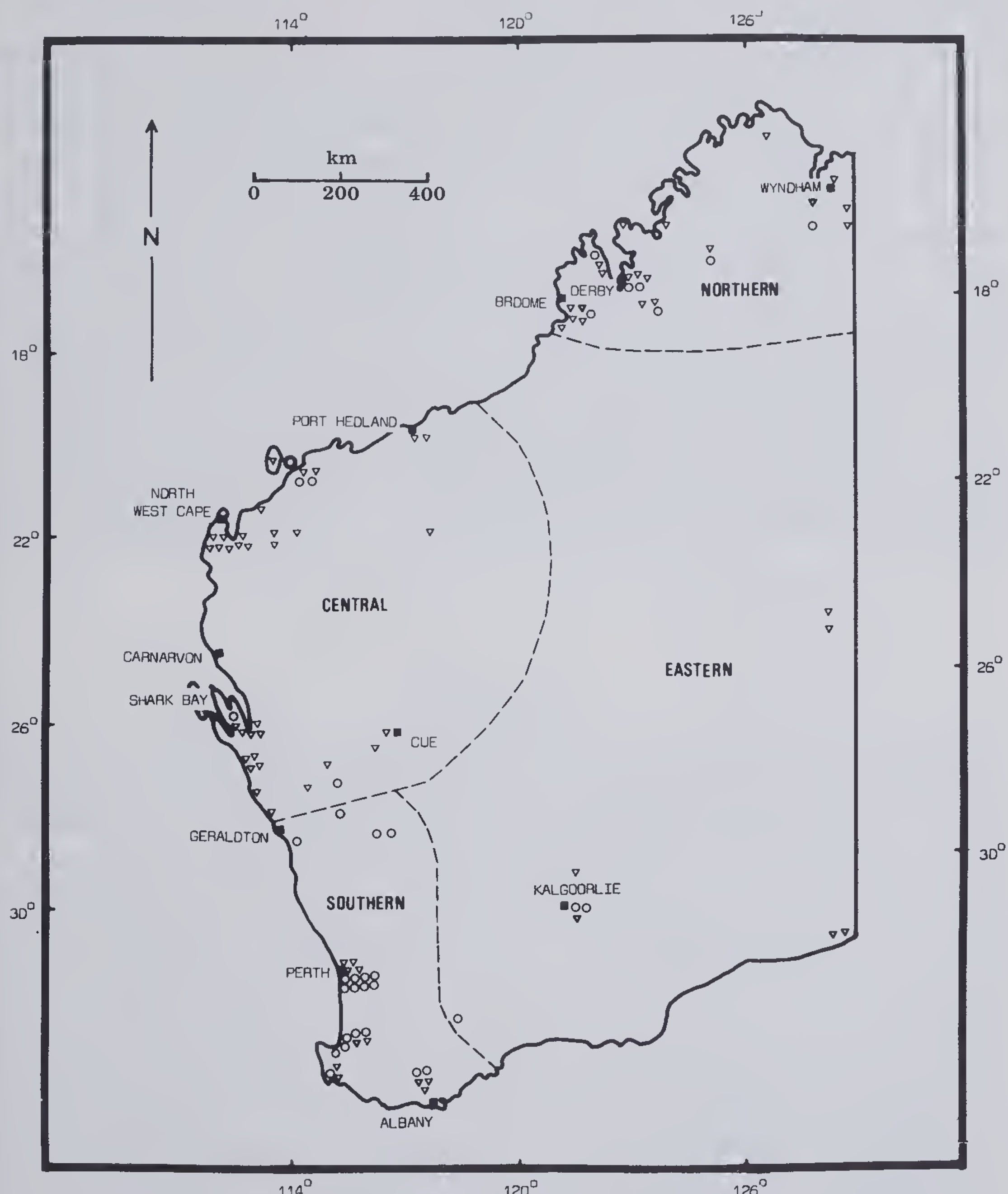

Fig. 1: Map of Western Australia giving the localities of the skulls studied, and the boundaries of the samples analysed. ▽ = males; o = females.

Because the material used was derived from museum collections several problems must be noted. Most of the specimens were recovered from chance discoveries of burials which had been exposed either by weathering or during building excavations. Thus, all of the specimens had to be carefully examined and assessed as Aboriginal, mainly on overall morphological appearance, but also on the records relating to the find. The recorded location of each specimen had also to be accepted in plotting the distribution of the material in Fig. 1. These records have mainly relied upon the original finder recalling, often quite some time later, precisely where, when and with what associated material the specimen was found, and then someone recording the information. Errors in both of these steps may have occurred. A further problem was that the material was assumed to be of recent origin but may in fact range over a quite considerable time span. No radiometric or other dates were available for any of the material used in this study. Finally, as Gill (1968) has noted, p. 213, "there is a selection factor in the preservation of human crania whereby the stronger ones will tend to be preserved and the weaker ones destroyed". This, plus any initial selection for burial, may constitute further possible sources of bias when postulating this sample as representing the recent Aboriginal population of Western Australia. However, similar strictures probably apply to all excavated Australian Aboriginal skull samples.

METHODS

Initially 77 of the crania were sexed by the method developed by Larnach and Freedman (1964). The results are shown in Table 1. In the remaining 28 crania one or more of the features used in the technique was damaged or missing. For these crania the sex was decided by substituting first male and then female mean values for those missing. By this method, confirmed by a detailed study of overall cranial form, it was possible to confidently determine the sex of all of the crania in this group. In the four crania with post-cranial material appropriate for sexing, the subpubic angle, the shape of the sciatic notch, the size of the femoral head and the angle of the femoral neck were examined (Davivongs, 1963). The three crania marked with a plus sign in Table 1 had their sexes confirmed by the post-cranial material. For one specimen (589 — marked with an "X") post-cranial sexing (female) did not confirm cranial sex determination (male). On cranial sexing the value found for this specimen was 12, the lowest male value for the technique. After a full re-assessment, it was decided that the specimen was best regarded as a

Table 1: Scores for 77 Aboriginal crania of known provenance from Western Australia using the 7 character sexing method of Larnach and Freedman (1964).

7	8	9	10	11	12	13	14	15	16	17	18	19	20
									248				
									1348				
				FEMALE	MALE		244		3976				
							1149		4968				
							6071	233	8907				
							10318	234	8965^{+}				
				247			12055	838	15504				
				KAR.2			16002	3978	16343^{+}		241		
			666	5860			16053	8964	22692		243		
	235		4969	9550			16256	11333	22693		10247		
	242		22687	15347		585	16980	13196	22836	656	K		
	9582		22737	15815^{+}		839	25425	22690	25422	16259	15505		
	9988		25423	22689	589^{x}	5107	25475	22691	25569	16261	N.W.C.		231
4686	15349	38698	25521	25424	9987	8540	38699	22835	KAR.1	25474	25619	5884	25471

+ Confirmed by post-cranial skeleton

x Post-cranial skeleton female

female for this study. As a check on the Larnach and Freedman (1964) sexing technique, several crania on either side of the sectioning point, i.e. 11 (female) or 12 (male), were sexed using the discriminant function number 3 of Giles and Elliott (1963). The sectioning point for the discriminant was taken from Larnach and Freedman (1964). In each case (including 589) the assigned sex agreed with the sex determination by the Larnach and Freedman technique.

For purposes of analysis, the Western Australian material was first studied as a group and then subdivided into 4 regional samples (Fig. 1: northern, central, southern and eastern), mainly on the basis of linguistic features. Capell (1956) has divided the Australian Aborigines into two broad linguistic subgroups. Those using prefixing languages are found in the northern one-eighth of the continent, whilst those using suffixing languages are spread over the remaining seven-eights of the continent. In Western Australia the prefixing group extends southward to the Western Desert. This region forms the northern sample of this study. The remainder of Western Australia is populated basically by Aboriginals using a suffixing type of language. However, within this group Capell (1956) has demonstrated varying word order structures. The Western Desert, forming the eastern sample, has an elastic word order which differentiates it from the more restricted word order found along the coastal region. The coastal subdivision between the central and southern group (just north of Geraldton) was somewhat arbitrarily decided upon after consideration of more minor linguistic and other features.

For the available material the above subdivisions would appear to produce the most likely social groupings of the individuals whose skulls have been measured. However, to test for finer micro-evolutionary variations, the northern and central samples were further subdivided into seven subsamples. For descriptive purposes these may conveniently be considered as located around (Fig. 1): Wyndham, Derby and Broome (= northern); and Port Hedland, North West Cape, Shark Bay and Cue (= central).

In the present study 50 cranial and 18 mandibular measurements were made. This rather large number was taken in order to make the data comparable with those studies with which it was intended to compare the material. From the cranial measurements 22 indices and ratios were calculated, several of these (e.g. chord/arc) being specifically aimed at describing bone shapes. The measurements and indices used are mainly from Martin and Saller (1957), Howells (1973), Thorne (1976), and Freedman and Wood (1977). Measurements were made with standard anthropometric instruments and were recorded to the nearest millimetre, except in the case of small measurements (e.g. orbit and foramen magnum) which were recorded to the nearest 0.1 mm. For the mandibular dimensions most of the measurements were made with a mandibulometer. For accurate and comparable measurements we believe the use of this instrument is essential.

To examine observer variation in recording measurements 6 crania were selected at random and measured on two separate occasions. The method of analysis of observer variation used followed Brown (1973). Mean differences and standard errors of the mean differences for the 6 pairs of each measurement were calculated and, from these, 't' values were computed. Of the 50 measurements recorded for the cranium only two were significant at the 5% level of probability; both of these, mastoid height and bi-stephanion, presented technical difficulties because of the variable position of the landmarks used.

The univariate statistics for the cranial and mandibular measurements and indices were computed on the Cyber 72 computer of the University of Western Australia, using the Statistical Package for Social Sciences (S.P.S.S.) Program (Nie, Bent and Hull, 1970). Results are presented, or/and discussed, separately for males and females, for each of the samples studied. In each case the number (N), the mean ($\overline{X}$), standard deviation (S.D.), coefficient of variation (C.V.) and observed range (O.R.) was computed. In addition 't' test values for male-female comparisons were calculated.

To compare and contrast the various Western Australian subgroups the data were also analysed by multivariate techniques. The male samples were studied using all 50 cranial measurements and also in parts, i.e. face, vault and base separately. The male cranial indices and the mandibular dimensions were also examined by multivariate methods. In addition, the 4 male Western Australian samples were compared with 3 male coastal samples from New South Wales (Freedman, 1964). Because of the small numbers and uneven distribution of the female material, the only multivariate analysis made was a 15 variable study of the crania. The programme used on the Cyber 72 computer was MULVAR, kindly provided by N.A. Campbell, Mathematics and Statistics Division, Commonwealth Scientific and Industrial Research Organisation, Perth.

The two multivariate techniques utilised were canonical variate analysis and Mahalanobis generalised distance (Blackith and Reyment, 1971). Canonical variate analysis uses standardised and orthogonal variables to maximise the ratio of between to within population variance. It thus maximises the effect of those variables, or combinations of variables, leading to interpopulation differences, relative to the within population variation. The second multivariate statistic, Mahalanobis generalised distance, may be considered to be the distance between the canonical variate means, as measured in multidimensional space. It thus takes into consideration interdependence and expresses the standardised distance between population means in a single measure, the D^2 value. The principles and methodology of these techniques are described in detail in the reference cited.

RESULTS

(1) Univariate analyses

The basic statistics of the 50 measurements for the Western Australian crania are listed separately for males and females in Table 2. Inspection of the data and coefficients of kurtosis and skewness (calculated but not included) suggest that most of the measurements were normally distributed.

The most important exceptions to normality of distribution, in both males and females, are in the small cranial dimensions involving the opisthocranion and inion. Both of these points are variable in their location, and opisthocranion may even be found at more than one point. The coefficients of variation for measurements involving these points are high, and this is especially so for both sexes in the case of lambda — opisthocranion (male, 37.54%; female 33.76%). The only other markedly high coefficients of variation in both sexes are palatal height (male, 18.55%; female 17.37%) and, to a lesser extent, mastoid height (male, 11.90%; female 11.55%). Palatal height variation probably stems from the tendency for torus or trough formation at the intermaxillary suture; for mastoid height there is difficulty in ensuring consistency in the selection of the uppermost point which should be on the Frankfurt Plane. Nasion — nasospinale (male, 11.70%; female, 10.50%) tends also to have a high coefficient of variation due to some difficulty in locating the inferior point for the measurement.

The male-female 't' test comparison is significant at the 5% level in all but one instance (foramen magnum breadth). Further, in only two instances (bi-infratemporal breadth and lambda-opisthocranion) is the probability level not below the 0.1% level.

The statistics of the 22 cranial indices for the Western Australian males and females are listed in Table 3. Three indices in both males and females are extremely variable and hence have very high coefficients of variation. These are: supra-orbital breadth/bi-frontosphenoidale (male 62.82%; female, 56.30%), supra-orbital breadth/bi-frontotemporale (male, 35.76%; female, 40.21%) and bi-malar breadth (male, 34.60%; female, 35.73%). In addition, the coefficient of variation for the nasal index in both sexes is also somewhat large (male, 15.00%; female, 15.10%). Males and females differ significantly (5% level) in 20/22 indices. Except in two instances, orbital and gnathic indices, the 't' test probability levels are all less than 1% and 16 of these are at less than the 0.1% level.

Table 4 lists the basic statistics for the 18 measurements of the male and female Western Australian mandibles. A number of coefficients of variation are on the high side and this is especially so in both sexes for sigmoid notch depth (male — 13.58%; female — 18.78%) and corpus breadth (male — 12.88%; female — 13.87%). The male corpus height (16.95%) and the female symphyseal breadth (15.91%) are likewise high. All male-female 't' test comparisons for mandibular dimensions are significant at greater than the 0.1% level.

The basic statistics of the 4 male Western Australian samples, for the 15 measurements used in the multivariate analyses comparing these samples with those from coastal New South Wales (Freedman, 1964), are tabulated in Table 5. Table 6 includes the statistics for some other important highly weighted measurements (and derived indices) found in the 4 sample Western Australian canonical analysis. These two sets of univariate statistics will be discussed together with the multivariate data.

(2) Multivariate analyses

(A) Canonical variate analysis

(a) Whole cranium, 50 variables, 4 male Western Australian samples

Table 7 lists the mean scores on the 3 canonical variates for the 4 samples and also the canonical roots and percentages of the variance accounted for by each of the variates. The mean scores on the first 2 variates are plotted in Fig. 2.

Separation between all 4 samples is achieved on the 3 variates. The first variate, which accounts for almost 50% of the variance, separates the northern and southern samples widely, with the eastern and central samples lying close together about midway between them. The second and third variates each account for close to a quarter of the variance. The second variate separates the eastern from the 3 coastal samples; the third variate groups the central and eastern samples and separates them progressively more from the northern and southern samples, respectively.

Table 2: Basic statistics of the male and female Western Australian Aboriginal cranial measurements (in mm).

Group and statistic	Max. cran. length	Max. cran. br.	Basi-breg. ht.	Nas.-opis. thion	Bas.-prosth.	Bas.-nasion	Fr.ma. orbi-auric.	Nas.-prosth.	Lambd.-opis. cran.	Lambd.-inion	Inion-opis. thion	Opist.-opis. cran.	Bas.-spheno. bas.
MALE													
N	68	67	64	65	52	58	63	57	69	70	67	66	58
$\overline{X}$	187.23	131.16	131.23	134.77	103.23	101.07	72.86	68.67	25.16	55.69	52.40	79.14	22.95
S.D.	6.27	4.81	5.37	4.59	4.79	4.87	8.50	5.24	9.45	7.22	5.81	7.69	2.50
C.V. (%)	3.35	3.67	4.09	3.41	4.64	4.82	11.67	7.63	37.54	12.97	11.08	9.71	10.90
O.R.	169-202	117-143	121-144	125-148	95-119	91-116	62-133	60-87	9-55	34-73	36-67	60-98	14-28
FEMALE													
N	32	32	32	31	24	30	30	26	33	33	31	31	29
$\overline{X}$	177.03	129.94	127.87	127.35	97.42	96.50	68.67	64.69	28.94	55.15	51.71	76.07	21.35
S.D.	6.73	5.15	6.07	5.70	8.73	8.35	4.64	5.68	9.77	9.72	5.87	7.42	1.45
C.V. (%)	3.80	3.97	4.75	4.47	8.96	8.65	6.76	8.79	33.76	17.63	11.36	9.75	6.77
O.R.	163-191	120-143	115-139	106-141	62-107	76-129	60-79	53-75	10-54	28-77	36-63	59-89	19-25
SEX. DIM.													
't' test*	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	x	xx	xxx	xxx	xxx

* Significance: xxx, $P<0.001$; xx, $P<0.01$; x, $P<0.05$; N.S., not significant

Table 2 (continued)

Group and statistic	Bi-malar br.	Bi-zygom.	Bi-zygion	Bi-auric.	Bi-mast. tips	Bi-infra temp.	Bi-fr.ma. orb.	Bi-ecto chonc.	Bi-coron.	Bi-steph.	Supra orbit. br.	Bi-fronto. temp.	Bi-fronto. sphen.
MALE													
N	55	59	59	62	62	56	60	56	59	62	66	64	51
$\overline{X}$	117.80	92.39	134.76	118.45	97.21	67.25	102.12	99.68	110.58	104.55	109.88	98.34	100.63
S.D.	5.57	5.60	5.03	4.81	4.38	4.07	4.03	3.34	4.48	7.62	4.15	5.68	5.21
C.V. (%)	4.73	6.05	3.73	4.06	4.51	6.06	3.95	3.35	4.06	7.29	3.77	5.78	5.17
O.R.	105-134	80-107	120-150	106-131	88-111	55-77	94-115	93-110	98-124	77-120	100-121	87-115	86-110
FEMALE													
N	23	25	24	31	31	29	26	24	27	27	31	32	27
$\overline{X}$	109.43	87.84	124.29	113.13	94.71	64.41	95.73	94.63	109.59	104.07	102.81	92.25	97.26
S.D.	7.00	5.19	6.49	5.65	5.89	3.68	3.13	2.95	5.23	5.90	4.10	3.01	4.74
C.V. (%)	6.39	5.91	5.22	5.00	6.22	5.71	3.27	3.11	4.77	5.66	3.99	3.26	4.87
O.R.	98-125	80-103	112-140	104-127	86-110	56-72	89-102	89-101	101-119	91-115	95-111	85-97	91-111
SEX. DIM.													
't' test*	xxx	xxx	xxx	xxx	xxx	x	xxx	xxx	xxx	xxx	xxx	xxx	xxx

* Significance: xxx, $P<0.001$; xx, $P<0.01$; x, $P<0.05$; N.S., not significant

Table 2 (continued)

Group and statistic	Bi-aster.	Bi-basi. occip.	Nas.-naso spin.	Nasal br.	Orbit. br.	Orbit. ht.	Inter-orbit. br.	For. magn. length	For. magn. br.	Max.-alv. length	Max.-alv. br.	Palat. ht.	Mast. ht.
MALE													
N	67	58	57	60	58	58	63	58	61	58	58	57	63
$\overline{X}$	107.31	21.43	49.37	27.98	40.43	33.47	21.89	35.09	29.79	60.03	65.62	14.40	30.59
S.D.	4.57	2.10	5.78	2.73	2.79	2.85	2.07	1.99	2.43	3.38	3.57	2.67	3.64
C.V. (%)	4.26	9.66	11.70	9.78	6.90	8.52	9.47	5.66	8.15	5.63	5.45	18.55	11.90
O.R.	97-117	17-32	42-77	23.40-38.50	30.00-44.10	28.50-43.90	18-28	30.90-39.20	24.00-38.50	51-69	57-76	9-21	24-42
FEMALE													
N	33	30	28	29	27	27	32	29	30	28	28	26	31
$\overline{X}$	104.27	19.77	46.14	25.68	39.29	32.33	20.22	33.63	29.81	55.57	62.07	12.27	25.32
S.D.	6.05	2.50	4.84	1.84	3.27	3.19	1.56	2.01	2.72	4.88	3.35	2.13	2.93
C.V. (%)	5.81	12.65	10.50	7.17	8.33	9.85	7.72	5.98	9.13	8.78	5.41	17.34	11.55
O.R.	94-122	11-24	40-59	21.3-29.7	32.20-48.80	25.90-38.20	17-23	29.90-40.20	24.80-39.30	44-63	55-69	9-17	20-33
SEX. DIM.													
't' test*	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx

* Significance: xxx, $P<0.001$; xx, $P<0.01$; x, $P<0.05$; N.S., not significant

Table 2 (continued)

Group and statistic	Nas.-breg. chord	Nas.-breg. arc	Nas.-breg. subt.	Breg.-lambd. chord	Breg.-lambd. arc	Lamb.-opisth. chord	Lamb.-opisth. arc	Bi-por. chord	Bi-por. arc	Por.-breg. chord	Por.-breg. arc
MALE											
N	69	69	67	70	70	68	67	62	62	68	68
$\overline{X}$	112.30	128.33	24.90	115.60	128.39	93.66	115.25	112.58	298.82	125.53	150.77
S.D.	5.14	6.82	2.59	5.14	6.76	5.38	7.05	4.82	11.09	4.98	6.40
C.V. (%)	4.58	5.31	10.40	4.45	5.26	5.74	6.12	4.28	3.71	3.97	4.25
O.R.	99-124	113-145	20-31	104-128	114-144	82-105	100-138	102-128	268-325	113-137	135-168
FEMALE											
N	34	34	34	33	33	31	31	32	31	32	32
$\overline{X}$	106.56	123.27	25.82	109.12	121.76	94.74	116.35	108.81	293.84	121.87	147.59
S.D.	4.52	5.94	2.69	6.73	9.28	5.69	10.04	5.19	9.91	4.48	6.06
C.V. (%)	4.24	4.82	10.42	6.17	7.62	6.01	8.63	4.77	3.37	3.67	4.11
O.R.	95-116	109-138	21-34	97-126	105-147	85-108	99-144	103-124	273-322	113-130	134-163
SEX. DIM.											
't' test*	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx

* Significance: xxx, $P<0.001$; xx, $P<0.01$; x, $P<0.05$; N.S., not significant

Table 3: Basic statistics of the male and female Western Australian Aboriginal cranial indices and ratios.

Group and statistic	Br./ leng.	Ht./ leng.	Ht./ br.	Cran. mod.	Upper facial	Gnath.	Nasal	Orbital	Maxil. alv.	Palatal	For. magn.
MALE											
N	63	61	61	60	53	49	56	57	56	55	56
$\overline{X}$	70.11	70.51	100.74	149.68	50.70	102.21	58.36	82.29	109.37	39.37	85.24
S.D.	2.89	2.81	4.74	4.45	3.17	4.58	8.81	7.67	5.84	3.72	7.59
C.V. (%)	4.13	4.00	4.71	2.97	6.25	4.48	15.00	9.32	5.34	9.44	8.91
O.R.	64.64-76.33	63.78-78.61	90.91-115.75	138.00-158.00	44.53-61.27	90.52-112.12	36.96-87.32	70.31-111.94	96.55-122.13	32.94-51.80	68.62-106.93
FEMALE											
N	29	30	30	29	22	23	27	26	25	26	29
$\overline{X}$	73.52	72.18	97.94	145.35	52.19	101.96	57.24	81.83	113.08	34.36	88.89
S.D.	2.94	3.07	5.80	4.34	5.45	4.30	8.65	6.71	9.81	4.45	9.17
C.V. (%)	4.00	4.25	5.93	2.98	10.44	4.22	15.10	8.19	8.67	12.94	10.31
O.R.	67.76-79.14	66.84-78.31	87.97-109.84	135.67-154.33	43.80-69.68	92.08-110.53	38.10-79.60	68.24-91.60	97.96-140.77	27.13-41.82	69.90-116.62
SEX. DIM.											
't' test*	xxx	xxx	xxx	xxx	xxx	N.S.	xx	N.S.	xxx	xxx	xxx

* Significance: xxx, $P<0.001$; xx, $P<0.01$; x, $P<0.05$; N.S., not significant

Table 3 (continued)

Group and statistic	Nas.-breg. ch/arc	Front. curv.	Breg.-lambda ch/arc	Lamb.-opisth. ch/arc	Bi-porion ch/arc	Nasion-opisth. arc	Nasion-opisth. ch/arc	Por.-breg. ch/arc	Sup.orb. br.-[1] bi. fr.temp.	Sup.orb. br.-[1] bi. fr.sphen.	Malar eversion[2]
MALE											
N	68	65	69	67	61	65	63	67	63	50	52
$\overline{X}$	87.61	22.03	90.11	81.32	38.03	371.12	36.27	83.55	11.46	8.60	15.25
S.D.	2.49	1.75	2.27	3.00	2.91	12.03	1.44	2.26	4.10	5.40	5.28
C.V. (%)	2.84	7.95	2.52	3.68	7.66	3.24	3.97	2.71	35.76	62.82	34.60
O.R.	79.84-97.39	18.58-25.66	79.84-97.39	72.73-88.18	36.62-54.63	338-397	32.72-39.05	75.00-89.86	2-19	0-21	0-23
FEMALE											
N	33	33	32	30	30	30	30	31	30	26	22
$\overline{X}$	86.76	24.52	89.64	81.59	36.93	360.90	35.28	82.84	10.33	6.04	13.27
S.D.	2.98	3.00	3.81	2.74	1.42	14.01	1.69	2.12	4.15	3.40	4.74
C.V. (%)	3.43	12.25	4.25	3.36	3.85	3.88	4.79	2.56	40.21	56.30	35.73
O.R.	81.60-97.70	19.83-36.56	71.43-94.74	73.13-85.86	33.77-40.39	317-393	29.78-38.49	78.23-86.30	2-19	0-16	4-23
SEX. DIM.											
't' test*	xxx	xxx	xxx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xxx

* Significance: xxx, $P<0.001$; xx, $P<0.01$; x, $P<0.05$; N.S., not significant

1 = *minus*

2 = Fronto-malar orbitale — auriculare *minus* bi-malar breadth

Table 4: Basic statistics for the male and female Western Australian Aboriginal mandibular measurements (in mm).

Group and statistic	Mandib. length	Cor. proj. ht.	Cond. proj. ht.	Gonial angle (degrees)	Corp. proj. length	Ram. proj. ht.	Bicon. br.	Bigon. br.	Symph. ht.
MALE									
N	34	34	33	35	34	33	27	33	34
$\overline{X}$	109.15	62.41	54.27	121.60	80.77	59.82	113.85	97.91	33.56
S.D.	5.54	4.31	6.15	7.21	5.97	4.30	5.63	6.23	3.72
C.V. (%)	5.07	6.90	11.32	5.93	7.39	7.20	4.95	6.36	11.08
O.R.	96-125	55-71	43-66	105-136	71-95	51-67	95-122	87-106	26-40
FEMALE									
N	16	15	16	17	17	16	15	17	17
$\overline{X}$	102.94	55.47	47.56	124.59	75.47	53.69	110.73	91.53	29.82
S.D.	6.31	5.94	5.54	6.24	5.36	5.39	5.37	7.71	3.26
C.V. (%)	6.13	10.71	11.64	5.01	7.11	10.04	4.85	8.43	10.95
O.R.	93-117	47-72	41-61	111-135	68-86	45-66	102-120	82-113	23-37
SEX. DIM.									
't' test*	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx

* Significance: xxx, $P<0.001$; xx, $P<0.01$; x, $P<0.05$; N.S., not significant

Table 4 (continued)

Group and statistic	Symph. br.	Corp. ht.	Corp. br.	Ramus ht.	Ram. max. br.	Ram. min. br.	Mand. ant. br.	P_1-M_2 chord	Sigm. notch depth
MALE									
N	36	35	36	34	33	35	34	35	32
$\overline{X}$	14.44	29.51	16.44	64.94	41.82	33.09	46.21	28.26	12.37
S.D.	1.28	5.00	2.12	3.89	3.12	3.72	2.52	2.12	1.68
C.V. (%)	8.83	16.95	12.88	5.99	7.45	11.25	5.45	7.50	13.58
O.R.	13-17	23-49	11-23	57-73	36-46	27-46	40-52	23-33	9-15
FEMALE									
N	17	17	17	16	15	17	17	17	15
$\overline{X}$	13.29	25.77	15.53	60.31	38.47	29.53	44.23	27.12	10.73
S.D.	2.11	2.75	2.15	5.89	3.98	3.81	3.09	2.74	2.01
C.V. (%)	15.91	10.68	13.87	9.76	10.35	12.90	6.99	10.09	18.78
O.R.	10-18	22-32	12-21	52-71	33-47	24-37	41-52	20-32	7-15
SEX. DIM.									
't' test*	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx

* Significance: xxx, $P<0.001$; xx, $P<0.01$; x, $P<0.05$; N.S., not significant

Table 5: Basic statistics (in mm) of four Western Australian male cranial samples, for 15 of the measurements used in the comparison with New South Wales male crania.

Group and statistic	Max. cran. length	Max. cran. br.	Basi breg. ht.	Bas.-prosth.	Bas.-nasion	Bi-zygom.	Supra orbit. br.	Bi-fronto. temp.	Nas.-pros.	Nas.-naso. spin.	Max-alv. br.	Nasal br.	Orb. br.	Orb. ht.	Inter-orbit.
NORTHERN															
N	22	21	20	19	19	19	22	21	20	19	19	20	19	19	20
$\overline{X}$	187.82	130.95	132.45	102.63	102.05	91.11	110.23	98.33	68.00	48.84	65.53	28.06	40.88	34.36	21.60
S.D.	6.37	5.12	5.22	4.89	4.75	5.53	3.99	5.53	5.10	3.48	4.38	3.41	2.92	3.30	1.85
CENTRAL															
N	30	29	28	22	24	27	29	28	25	26	26	26	26	26	28
$\overline{X}$	187.37	131.31	129.61	104.59	100.71	93.11	109.62	97.96	70.40	51.15	66.23	28.31	40.09	33.66	21.71
S.D.	7.41	4.98	5.38	4.63	5.24	6.06	4.72	6.09	5.74	7.40	3.22	2.66	3.11	2.73	1.94
SOUTHERN															
N	10	11	10	5	9	7	9	9	6	6	7	8	7	7	9
$\overline{X}$	186.30	132.82	133.50	102.60	102.56	93.14	109.22	101.11	66.33	47.33	65.57	26.70	39.84	31.16	22.78
S.D.	3.71	3.31	6.01	3.85	3.81	5.31	3.71	5.71	2.07	2.58	2.76	1.36	1.63	1.31	2.49
EASTERN															
N	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
$\overline{X}$	186.00	128.17	131.00	100.67	97.17	92.33	110.83	96.00	66.00	45.33	63.33	27.93	41.20	32.57	22.33
S.D.	2.76	4.79	2.61	5.32	3.54	4.27	2.64	3.35	3.79	2.81	2.73	1.73	1.97	1.63	2.81

Table 6: Basic statistics (in mm) of four Western Australian male cranial samples, for the most highly weighted variables from the cranial canonical analyses, plus 4 indices discussed in the text.

Group and statistic	Breg.-lambd. chord	Breg.-lambd. arc	Porion-breg. chord	Porion-breg. arc	Lambd.-opisth. chord	Lambd.-opisth. arc	Lambd.-inion	Inion-opisth.	Bi-fronto sphen.	Bi-malar br.	Bi-coron.	Bi-steph.	Bi-zygion
NORTHERN													
N	22	22	21	21	22	22	22	21	19	18	20	20	19
$\overline{X}$	115.64	128.32	126.67	151.24	93.50	115.64	55.23	52.67	101.00	118.11	110.55	104.05	135.32
S.D.	5.69	7.75	5.76	7.44	5.91	7.58	7.89	5.50	4.88	5.90	4.06	8.19	5.73
CENTRAL													
N	31	31	31	31	29	28	31	29	21	25	25	26	26
$\overline{X}$	115.27	127.74	124.90	150.29	93.69	115.57	57.13	51.35	102.29	118.12	111.36	104.50	135.42
S.D.	4.75	5.94	4.92	5.81	5.01	7.61	5.89	5.81	4.76	5.56	5.31	7.88	5.03
SOUTHERN													
N	11	11	10	10	11	11	11	11	6	7	9	11	8
$\overline{X}$	114.82	129.00	125.70	153.10	96.09	116.55	56.00	53.18	98.33	114.57	110.67	105.73	132.87
S.D.	5.46	7.95	4.81	7.08	4.93	4.30	6.77	5.95	3.98	3.87	2.50	7.98	3.68
EASTERN													
N	6	6	6	6	6	6	6	6	5	5	5	5	6
$\overline{X}$	118.83	130.83	124.50	147.67	89.67	110.00	49.38	55.17	95.00	119.60	106.60	104.20	132.67
S.D.	4.45	5.35	2.07	3.27	4.41	5.21	9.81	6.85	6.00	6.27	2.88	3.83	3.93

Table 6 (continued)

Group and statistic	Nas.-breg. chord	Nas.-breg. arc	Bi-auric.	Bi-porion chord	Bi-porion arc	Nas.-breg. subt.	Mast. ht.	Nas.-opis. thion.	Bi-basi. occip.	Breg.-lambd. ch./arc	Porion-breg. ch./arc	Lambd.-opisth. ch./arc	Nas.-breg. ch./arc
NORTHERN													
N	21	21	19	19	19	21	19	21	19	22	21	22	21
$\overline{X}$	113.33	128.67	117.63	113.11	299.26	24.33	29.26	136.00	21.21	90.12	83.83	80.53	87.71
S.D.	5.57	7.25	5.87	5.89	12.19	2.73	2.64	5.59	1.62	1.94	2.56	2.89	2.74
CENTRAL													
N	31	31	28	29	29	29	29	28	25	30	30	28	30
$\overline{X}$	112.13	128.00	119.00	112.24	298.38	24.96	31.72	134.43	21.68	90.16	83.34	81.44	87.76
S.D.	5.11	7.13	4.68	4.82	10.68	2.60	3.85	4.18	2.67	2.22	1.99	3.05	1.52
SOUTHERN													
N	11	11	9	8	8	11	10	11	8	11	10	11	11
$\overline{X}$	112.82	128.82	118.33	111.50	303.37	24.82	30.30	134.73	21.63	89.53	83.14	82.47	88.48
S.D.	3.34	6.65	4.18	3.51	12.83	2.32	4.64	4.05	1.51	3.33	2.58	3.61	3.34
EASTERN													
N	6	6	6	6	6	6	5	6	6	6	6	6	6
$\overline{X}$	108.67	128.00	118.67	114.00	293.50	26.67	29.60	132.33	20.83	90.85	84.34	81.52	84.88
S.D.	5.92	5.21	2.73	2.37	4.42	2.25	1.52	3.20	0.98	1.53	2.12	1.17	2.53

Table 7: Canonical variate means for four Western Australian male samples, using 50 cranial variables.

Samples	Canonical Variate Means		
	C.V. 1	C.V. 2	C.V. 3
Northern	4.747	11.922	10.114
Central	-0.086	13.789	13.781
Southern	-5.470	12.905	7.349
Eastern	-1.009	5.430	13.048
Canonical root:	11.983	7.131	5.564
% of variance accounted for:	48.6	28.9	22.5

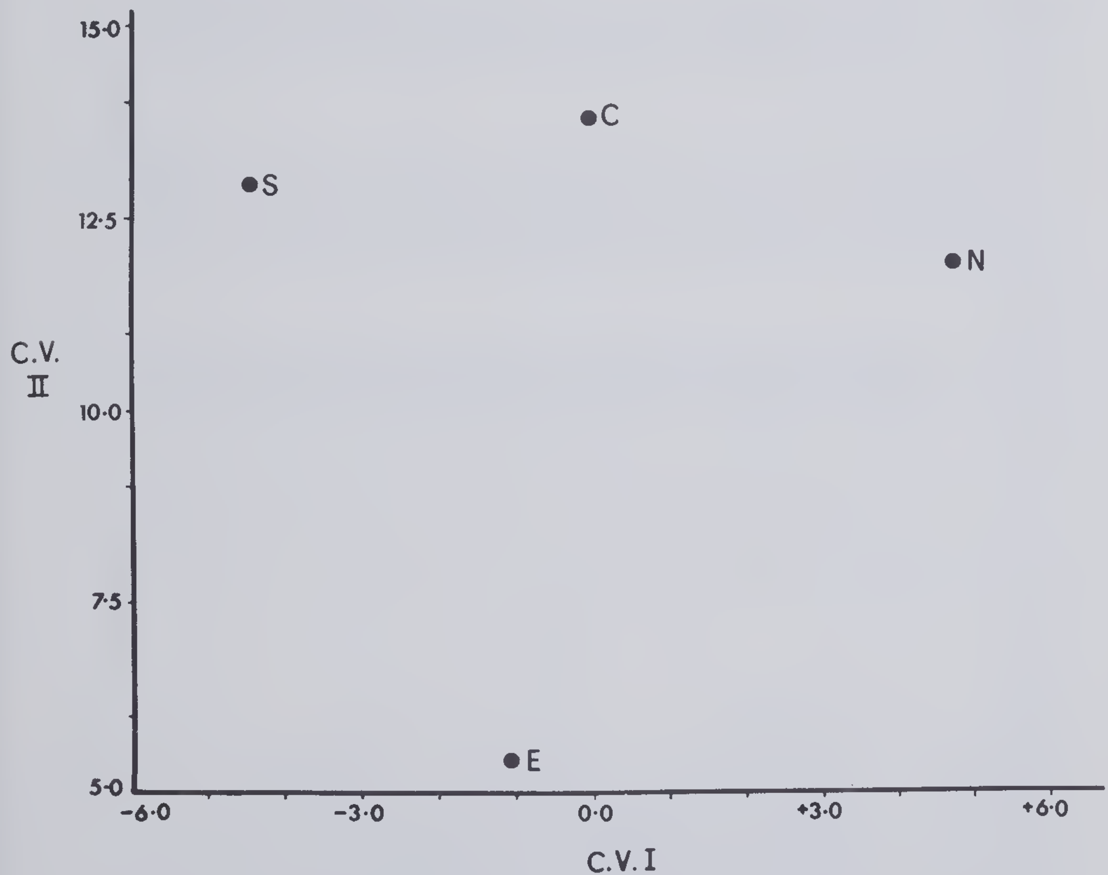

Fig. 2: Plot of canonical variate 1 means against canonical variate 2 means for the 4 Western Australian male cranial samples, using 50 variables.

Table 8: Canonical variate analysis of four Western Australian male cranial samples, using 50 cranial variables.

	Unweighted			Weighted		
	Variate I	Variate II	Variate III	Variate I	Variate II	Variate III
Maximum cranial length	-0.066	0.113	0.035	-0.412	0.698	0.220
Maximum cranial breadth	-0.182	-0.111	-0.583	-0.902	-0.549	-2.896
Basi-bregmatic height	0.127	-0.589	-0.131	0.632	-2.788	-0.652
Nasion-opisthion	0.326	-0.435	-0.454	1.446	-1.923	-2.012
Basion-prosthion	-0.531	0.093	0.201	-2.549	0.445	0.966
Basion-nasion	-0.087	0.454	-0.087	-0.041	2.143	-0.411
Fronto-malar orbitale auriculare	-0.176	-0.176	0.145	-0.660	-0.627	0.517
Nasion-prosthion	0.297	-0.198	0.057	1.459	-0.974	0.281
Lambda-opisthocranion	0.034	-0.069	-0.088	0.360	-0.620	-0.254
Lambda-inion	-0.389	-0.235	-0.082	-2.927	-1.768	-0.616
Inion-opisthion	-0.446	-0.082	0.015	-2.799	-0.514	0.097
Opisthion-opisthocranion	-0.006	0.006	0.039	-0.881	0.048	0.287
Basion-sphenobasion	-0.240	0.240	0.224	-0.711	0.640	0.597
Bi-malar breadth	0.034	-0.034	-0.075	2.536	-0.190	-0.423
Bi-zygomaxillare	-0.038	-0.238	-0.213	-0.215	-1.329	-1.181
Bi-zygion	-0.402	0.405	0.257	-1.991	2.005	1.274

Table 8 (continued)

	Unweighted			Weighted		
	Variate I	Variate II	Variate III	Variate I	Variate II	Variate III
Bi-auriculare	0.399	−0.664	−0.154	0.198	−3.293	−0.763
Bi-mastoid	0.175	0.175	−0.190	0.388	0.786	−0.854
Bi-infratemporale	0.007	0.007	0.309	0.897	0.031	1.292
Bi-frontomalar orbitale	−0.222	−0.222	−0.310	−0.087	−0.961	−1.345
Bi-ectoconchion	−0.265	0.190	0.136	−0.919	0.659	0.472
Bi-coronalia	−0.258	0.258	−0.340	−1.224	1.098	−1.445
Bi-stephanion	−0.007	−0.007	0.246	−1.239	−0.052	1.626
Supra-orbital breadth	−0.130	−0.289	0.480	−0.566	−1.261	2.093
Bi-frontotemporale	0.312	−0.258	0.099	1.844	−1.527	0.589
Bi-frontosphenoidale	0.623	0.060	0.284	2.949	0.285	1.345
Bi-asterion	−0.015	0.089	0.043	−0.067	0.396	0.188
Bi-basioccipital	0.371	0.371	−0.731	0.779	0.837	−1.651
Nasion-nasospinale	−0.127	0.025	0.210	−0.718	0.143	1.185
Nasal breadth	0.313	−0.126	−0.008	0.897	−0.362	−0.024
Orbital breadth	−0.309	0.087	−0.180	−0.093	0.262	−0.543
Orbital height	0.466	0.015	0.172	1.372	0.046	0.507
Interorbital breadth	0.423	0.099	0.358	0.905	0.213	0.766
Foramen magnum length	−0.089	−0.119	0.527	−0.183	−0.246	1.091

Table 8 (continued)

	Unweighted			Weighted		
	Variate I	Variate II	Variate III	Variate I	Variate II	Variate III
Foramen magnum breadth	-0.314	0.352	0.399	-0.756	0.848	0.962
Maxillo-alveolar length	0.284	0.183	0.444	0.777	0.502	1.215
Maxillo-alveolar breadth	-0.115	0.120	-0.350	-0.432	0.452	-1.311
Palatal height	0.367	-0.258	0.254	0.959	-0.673	0.664
Mastoid height	-0.557	0.557	0.429	-1.713	1.852	1.427
Nasion-bregma chord	-0.018	0.371	0.892	-0.092	1.849	0.444
Nasion-bregma arc	0.139	-0.287	0.102	0.959	-1.983	0.702
Nasion-bregma subtense	-0.405	0.465	0.161	-1.024	1.350	0.467
Bregma-lambda chord	-0.473	-0.097	-0.313	-2.506	-0.515	-1.659
Bregma-lambda arc	0.039	-0.210	0.225	2.820	-1.498	1.602
Lambda-opisthion chord	-0.183	0.311	-0.038	-0.921	1.564	-0.191
Lambda-opisthion arc	0.699	0.014	-0.034	4.963	0.097	-0.238
Bi-porion chord	0.084	0.257	0.273	0.360	1.096	1.164
Bi-porion arc	0.024	0.018	-0.145	0.262	0.192	-1.570
Porion-bregma chord	0.320	0.210	-0.005	1.569	1.028	-0.027
Porion-bregma arc	-0.233	0.310	0.150	-1.534	2.235	0.988

The unweighted and weighted coefficients for the 3 variates are listed in Table 8. For the 50 variables studied there are over 20 positive and over 20 negative coefficients in each of the 3 variates. From this one would conclude that, in each case, shape rather than size differences are the most significant features in the discrimination.

For the first canonical variate (Table 8) the weighted coefficients imply that major contrasts exist between the positively weighted lambda-opisthion arc (+ 4.963), bi-frontosphenoidale (+ 2.949), bregma-lambda arc (+ 2.820), bi-malar breadth (+ 2.536) and bi-frontotemporale (+ 1.844) and the negatively weighted lambda-inion (- 2.927), inion-opisthion (- 2.799), basion-prosthion (- 2.549), bregma-lambda chord (- 2.506) and bi-zygion (- 1.991). From these coefficients the major contrasts appear to be in the posterior part of the cranial vault and, to a lesser extent, in variations between cranial breadth measurements.

The canonical variate and univariate data, viewed together, reveal interesting variations in the parietal bone. The first canonical variate high values and opposite signs of the bregma-lambda chord (+ 2.820) and arc (- 2.506) reflect significant antero-posterior curvature differences between this bone in the 4 samples. Referring to the univariate statistics in Table 6, it can be seen that the southern population has a relatively long arc and short chord measurement, making the parietal bone more rounded; the eastern sample has the longest arc and chord measurements, but the relatively longer chord measurement results in a less rounded parietal. Further, the coefficients of the porion-bregma chord (+ 1.569) and arc (- 1.534) indicate important sample differences in the mesio-lateral curvatures of the parietal bone. The univariate statistics (Table 6) show the southern sample to have the relatively longest arc measurement, with the chord/arc index increasing progressively from southern to central to northern to eastern. Thus, the southern sample has an overall antero-posteriorly and mesio-laterally rounder parietal bone, whereas in the eastern sample it is relatively flatter in both directions; the northern and central sample shapes are intermediate.

The contrasting on the first canonical variate (Table 8) between lambda-opisthion chord (+ 4.960) and lambda-opisthion arc (- 0.921) suggests both size and shape variation in the occipital bone. On univariate statistics (Table 6) the southern sample has the absolutely longest arc and chord measurements, and the eastern the lowest for both dimensions. Relatively however (lambda-opisthion chord/arc), the occipital in the southern sample turns out to be considerably less rounded than the eastern sample; the northern and central samples are more rounded than even the eastern sample.

The large first canonical variate coefficients (Table 8) for lambda-inion (- 2.927) and inion-opisthion (- 2.799) also indicate occipital bone variations. From the univariate statistics in Table 6 it can be seen that these measurements show considerable absolute and relative differences and indicate marked variations in the degree of development of inion, or of its location relative to lambda and opisthion.

Several breadth measurements indicate cranial shape variations on the first canonical variate (Table 8). Three positive breadth measurements (bi-frontosphenoidale, + 2.949; bi-malar breadth, + 2.536; bi-frontotemporale, + 1.844) contrast with three negative breadth measurements (bi-zygion, - 1.991; bi-stephanion, - 1.239; bi-coronalia, - 1.224). From the univariate results (Tables 5 and 6) the northern and central crania have large bi-frontosphenoidale breadths, while those from the south and east have small bi-zygion breadths; the southern population has a relatively narrow bi-malar breadth, which contrasts to its broad bi-frontotemporale measurement.

One other readily apparent contrast from the weighted coefficients of canonical variate one (Table 8) is between nasion-prosthion (+ 1.459) and basion-prosthion (- 2.549). From the appropriate univariate data (Table 5) the southern population is the most divergent sample, having a short upper facial height (nasion-prosthion) and a long basion-prosthion measurement, probably implying a more prognathic face. The eastern sample, with small dimensions for both measurements, shows a similar metrical relationship to the southern sample; the northern and central samples have relatively long upper facial heights compared with their basion-prosthion dimensions.

On the second canonical variate mean scores (Table 7), the isolation of the eastern population is mainly due to differences (Table 8) between the positively weighted coefficients, porion-bregma arc (+ 2.235), basion-nasion (+ 2.143), bi-zygion (+ 2.005), mastoid height (+ 1.852), nasion-bregma chord (+ 1.849), and the negatively weighted coefficients, bi-auriculare (- 3.293), basi-bregmatic height (- 2.788), nasion-bregma arc (- 1.983) and nasion-opisthion (- 1.923). The main isolating features appear to be in breadth-height relationships, and in the shape of the frontal bone.

From the univariate results (Table 5) the eastern population has the shortest measurements (often considerably so) for all of the highly weighted second variate positive values. The eastern population is also separated because of frontal bone chord-arc differences; from the univariate results (Table 6), it is apparent that, relative to the nasion-bregma chord measurement, the eastern population has a long arc measurement. The increased arc is also supported by the greater nasion-bregma subtense measurement of the eastern population. The above differences show that the eastern population is distinct from the more nearly similar northern, central and southern populations in having a number of considerably smaller dimensions and also in its antero-posteriorly being more rounded, i.e. fuller frontal bone. Breadth dimensions also play a significant part in the discrimination on this second canonical variate. Thus, bi-frontotemporale (– 1.527) is by far the smallest in the eastern sample and bi-auriculare (– 3.293) appears to be important in the separation of northern and central from the other 2 samples and also from each other.

In the third canonical variate the highest positively weighted coefficients (Table 8) are supra-orbital breadth (+ 2.093), bi-stephanion (+ 1.626), bregma-lambda arc (+ 1.602), mastoid height (+ 1.427) and bi-fronto-sphenoidale (+ 1.345). The most highly weighted negative coefficients are for maximum cranial breadth (– 2.896), nasion-opisthion (– 2.012), bregma-lambda chord (– 1.659), bi-basioccipital (– 1.651), bi-porion arc (– 1.570) and maxillo-alveolar breadth (– 1.311). The separation achieved on the third canonical variate is principally of the southern samples from the central and eastern samples, with the northern samples intermediate. These coefficients re-emphasize the variation of the sample from the south in respect to parietal bone shape and also certain breadth measurement variations.

From the univariate results (Tables 5 and 6), in addition to the bregma-lambda chord/arc relationships already discussed, it can be seen that the southern sample has the largest measurements for bi-stephanion, bi-fronto-temporale and bi-porion arc, and the shortest measurement for supra-orbital breadth. Except for the parietal bone differences it would seem that this third canonical variate mainly stresses size differences.

Because of the limited findings for the male 4 sample cranial subsets, cranial indices and mandibles, the male 7 sample analysis, and the female 4 sample analysis no detailed tables of results have been included. However, the salient points emerging from those analyses will be briefly outlined in (b) to (f) below.

(b) Cranial subsets, 4 male Western Australian samples

Using the 17 facial variables only it can be seen from the small canonical roots that there is considerable reduction of the between relative to within group variance. Separation is poor on all 3 variates but the first does separate the southern from the other 3 samples. In the 17 variable cranial vault analysis separation is improved and is, in fact, complete on the 3 variates.

Although separation on this analysis is different to that on the whole cranium, this subset probably includes the most important variables involved in separating the samples. On the 8 cranial base dimensions separation is very poor, although on the first variate the central-southern are separated from the northern-eastern samples.

(c) Cranial indices, 19 variables, 4 male Western Australian samples

The cranial indices should reflect cranial shape differences well but do not result in good separation by canonical analysis. Samples tend to be paired in the variates, central-eastern in the first, central-southern in the second, and northern-central and also southern-eastern in the third variate.

(d) Mandibular measurements, 18 variables, 4 male Western Australian samples

The mandibular variables, on the first two canonical variates, give a similar picture of separation to that found on the whole cranium analysis. However, two of the numbers of mandibular specimens available were very small (northern — 12, central — 16, southern — 6, eastern — 2) and hence the results may not be reliable.

(e) Whole cranium, 50 variables, 7 male Western Australian samples

The canonical analysis using 7 samples for the northern-central combined area was based on rather small samples (4-8) and results are thus of doubtful validity. There is a clustering of 3 or 4 of the sample means on each variate but nevertheless a suggestion of a fair amount of between sample variation.

(f) Whole cranium, 15 variables, 4 female Western Australian samples

A single analysis was made of the 4 female samples but using only 15 of the cranial variables used in the coastal New South Wales study (Freedman, 1964). Separation was obtained on the 3 variates. The first puts the southern and eastern together between the northern and central samples; the second separates the southern from the other 3 samples; the third separates the eastern from the remaining 3 samples. Numbers in these 4 samples are very small (northern, 6; central, 5; southern, 11; eastern 3).

(g) Whole cranium, 15 variables, 4 male Western Australian and 3 coastal New South Wales samples

The variables utilised in this analysis are those used by Freedman (1964) except that, because of missing measurements, maxillo-alveolar length and bi-zygion breadth were omitted and interorbital breadth included. (For coastal New South Wales the basic univariate statistics for interorbital breadth in the 3 samples are: northern — N = 14, $\overline{X}$ = 19.79 mm, S.D. = 2.15 mm; central — N = 27, $\overline{X}$ = 18.93 mm, S.D. = 2.33; southern — N = 10, $\overline{X}$ = 19.00 mm; S.D. = 2.62 mm).

On the first canonical variate, which accounts for over 55% of the variance (Table 9, Fig. 3), the groups of samples from the 2 States are clearly separated. The second variate accounts for 19% of the variance; it spreads the 4 Western Australian samples, and separates the southern from the northern-central New South Wales samples. The third variate separates the southern from the other 3 Western Australian samples, and the central from the northern-southern samples from New South Wales; it accounts for only 9% of the variance. In each of the first 3 variates there are approximately similar numbers of positively and negatively weighted measurements.

On the first canonical variate the main positively weighted coefficients (Table 10) are basi-bregmatic height (+ 0.545), maxillo-alveolar breadth (+ 0.517) and maximum cranial breadth (+ 0.403), and the main negatively weighted coefficients are interorbital breadth (– 0.778), maximum cranial length (– 0.258) and nasion-nasospinale (– 0.255). The contrasting of maxillo-alveolar breadth (+ 0.517) and maximum cranial breadth (+ 0.403) with interorbital breadth (– 0.778) suggests that relative changes in breadth measurements are the most important in this variate.

From the univariate results (Freedman, 1964; and Tables 5 and 6), it can be seen that, for the 3 most heavily positively weighted measurements, the Western Australian samples almost all have smaller dimensions than those for the New South Wales samples; the only exceptions are the southern sample for basi-bregmatic height and maximum cranial breadth. For the only heavily negatively weighted measurement (interorbital breadth) the New South Wales mean sample measurements are all smaller than those from Western Australia. The contrasting of these breadth dimensions must mainly be responsible for the clear separation achieved. On these dimensions, and on the variate as a whole (Table 9, Fig. 3), the northern New South Wales sample most resembles the Western Australian samples; of the Western Australian samples, the eastern sample diverges most and in the opposite direction to the New South Wales samples.

The second canonical variate weighted coefficients (Table 10) highlight the positive coefficients of basi-bregmatic height (+ 0.681), interorbital breadth (+ 0.341), orbital breadth (+ 0.321) and nasion-prosthion (+ 0.319), and the negative coefficients of nasion-nasospinale (– 0.985) and basion-prosthion (– 0.588). In this variate height dimensions are mainly stressed, basi-bregmatic height getting a large positive coefficient.

The relationship between nasion-prosthion and nasion-nasospinale is especially interesting in this variate. The univariate statistics of the Western Australian samples in Table 5 show considerable variation for the nasion-nasospinale dimension and, when looked at relative to the nasion-prosthion measurement, it widely separates the eastern and central samples and locates the northern and southern in between, as does the variate as a whole. This is the main effect of this variate. The univariate mean values for basi-bregmatic height (Freedman, 1964) spread the New South Wales samples clinally, increasing from north to south, while the basion-prosthion values increase clinally in the opposite direction.

For the third canonical variate, the highest positively weighted coefficients from Table 10 are for orbital height (+ 0.639), nasal breadth (+ 0.581) and bi-zygomaxillare (+ 0.372). The main negative coefficients are bi-frontotemporale (– 0.433) and nasion-nasospinale (– 0.362). The positive coefficients for the orbital height and nasal breadth reflect the small mean univariate measurements for these variables in the southern Western Australian sample (Table 5). The major new contrast which emerges is between bi-zygomaxillare and bi-frontotemporale. From the univariate statistics (Table 5) the southern Western Australian sample has a broad bi-frontotemporale measurement relative to its bi-zygomaxillare breadth.

(B) Generalized distance analyses

(a) Western Australian samples

Generalized distance analyses were performed on all of the samples used for canonical analyses, except the two 50 variable analyses (male whole cranium, 4 sample and male whole cranium, 7 sample). As for the equivalent canonical analyses no tables of results are included for the generalized distance analyses.

From the male face and vault subset distance analyses the only consistent results are that, in each case, the distance separation between the northern and central samples is the smallest (2.16 and 1.96, respectively) and the D^2 value for the southern-eastern comparison the largest (12.14 and 13.07, respectively); the male cranial base subset analysis gives the smallest D^2 values (0.32 — 1.46) and poor discrimination. The male cranial indices analysis again results in the northern-central D^2 value being the lowest (3.67) and the southern-eastern the highest (13.01). The distances from north to central (3.67), north to south (5.60) and north to east (6.12) increase progressively. The male mandibular generalized distances are by far the largest. The northern-central figure is again the lowest (14.97) but, in this case, the central-eastern value (69.24) is slightly higher than that for the southern-eastern comparison (65.73). The female cranial distance analysis results in large distances between the samples but makes the northern-central value the largest (41.58) and the southern-eastern figure the smallest (13.91).

(b) Western Australian and New South Wales samples

A number of interesting results emerge from this last generalized distance analysis (Table 11). In each State there is a progressively increasing D^2 distance down the coast of the central and southern samples from the northern sample. Comparing the samples from the 2 States, the 2 northern samples are very similar and the D^2 distances between the equivalent parts of each State increase progressively in the central and southern comparisons. The Western Australian eastern sample is well separated from all of the other samples from the 2 States; the largest D^2 values found are between that sample (eastern Western Australia) and the 3 New South Wales samples, and the values are progressively greater from north to south.

Table 9: Canonical variate means for four Western Australian and three New South Wales male samples, using 15 cranial variables.

Sample	Canonical Variate Means		
	C.V. 1	C.V. 2	C.V. 3
WESTERN AUSTRALIA			
Northern	17.587	3.309	3.976
Central	17.413	2.173	3.875
Southern	17.791	3.798	2.397
Eastern	16.849	4.651	4.144
NEW SOUTH WALES			
Northern	18.686	2.946	4.435
Central	19.730	2.850	3.628
Southern	19.858	3.765	4.210
Canonical root:	1.282	0.440	0.215
% variation accounted for:	55.7	19.1	9.3

Table 10: Canonical variate analysis of four Western Australian, and three New South Wales* male cranial samples, using 15 cranial variables.

	Unweighted			Weighted		
	Variate I	Variate II	Variate III	Variate I	Variate II	Variate III
Maximum cranial length	-0.039	0.035	0.022	-0.258	0.230	0.145
Maximum cranial breadth	0.087	-0.058	-0.061	0.403	-0.268	-0.285
Basi-bregmatic height	0.116	0.145	-0.031	0.545	0.681	-0.148
Basion-prosthion	-0.004	-0.135	-0.016	-0.017	-0.588	-0.068
Basion-nasion	0.027	-0.019	-0.021	0.113	-0.081	-0.091
Bi-zygomaxillare	0.012	0.044	0.073	0.062	0.227	0.372
Supra-orbital breadth	0.019	0.028	-0.007	0.083	0.119	-0.031
Bi-frontotemporale	-0.045	-0.050	-0.082	-0.240	-0.268	-0.433
Nasion-prosthion	0.002	0.075	0.066	0.007	0.319	0.279
Nasion-nasospinale	-0.057	-0.222	-0.081	-0.255	-0.985	-0.362
Maxillo-alveolar breadth	0.155	-0.033	-0.007	0.517	-0.111	-0.023
Nasal breadth	-0.082	-0.119	0.238	-0.199	-0.289	0.581
Orbit breadth	-0.010	0.135	0.104	-0.024	0.321	0.248
Orbit height	0.005	0.027	0.257	0.013	0.069	0.639
Interorbital breadth	-0.360	0.158	-0.086	-0.778	0.341	-0.186

* Data from Freedman (1964)

Table 11: Generalized distance analysis of the four Western Australian and three New South Wales male samples, using 15 cranial measurements.

	GENERALIZED DISTANCE (D^2)						
	WESTERN AUSTRALIA				NEW SOUTH WALES		
	Northern	Central	Southern	Eastern	Northern	Central	Southern
WESTERN AUSTRALIA							
Northern	—	2.33	3.72	5.17	2.30	5.60	6.67
Central		—	5.26	7.79	2.88	6.32	8.99
Southern			—	7.11	5.98	7.12	7.79
Eastern				—	7.81	12.53	12.83
NEW SOUTH WALES							
Northern					—	2.10	3.01
Central						—	2.59
Southern							—

Table 12: Mean scores for each of the 7 sexing characters recorded for the male and female Western Australian crania. Larnach and Freedman's (1964) scores for New South Wales coastal crania are listed in brackets.

	Glabella	Super-ciliary ridges	Zygo-matic trigone	Malar tuber-osity	Mastoid size	Palatal size	Occipital markings	Total mean
Male:	2.30	2.27	2.17	1.82	2.96	2.27	1.73	15.50
	(2.26)	(2.41)	(2.57)	(2.35)	(2.28)	(2.69)	(2.55)	(17.11)
Female:	1.37	1.29	1.36	1.23	2.11	1.63	1.18	10.17
	(1.08)	(1.03)	(1.31)	(1.00)	(1.03)	(1.55)	(1.05)	(8.05)
Difference:	0.93	0.98	0.81	0.59	0.85	0.64	0.55	5.33
	(1.14)	(1.38)	(1.26)	(1.35)	(1.25)	(1.14)	(1.50)	(9.06)

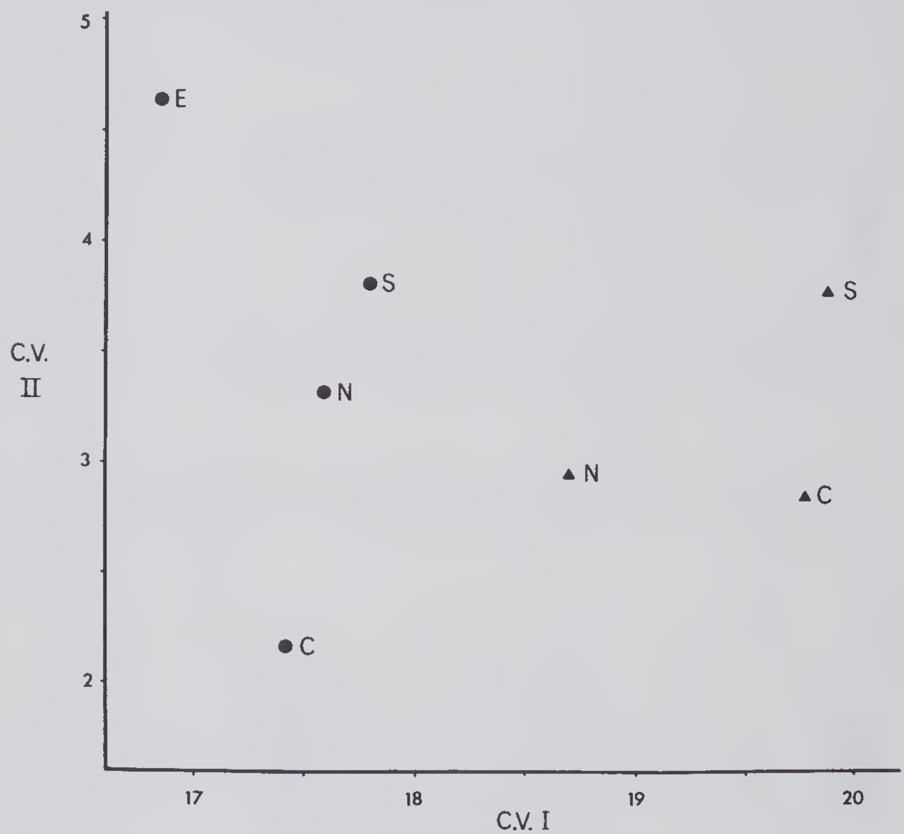

Fig. 3: Plot of canonical variate 1 means against canonical variate 2 means for the 4 Western Australian and 3 coastal New South Wales male cranial samples, using 15 variables.

DISCUSSION

From the checks performed, it would seem that the sexing procedure used (Larnach & Freedman, 1964) has differentiated male and female crania with a high degree of accuracy. (Each character is rated on a scale 1 to 3 with males tending to have the high values.) It is of interest that the mean scores obtained for the 7 sexing characters in the male Western Australian cranial samples were smaller than the equivalents from New South Wales in all but 2 instances (Table 12). The male mean score most significantly greater in the New South Wales sample was occipital markings where the difference was 0.82; 3 other differences (malar tuberosity, palatal size and zygomatic trigone) were larger in that sample in the range 0.40-0.53. Of the sexing features larger in the Western Australian sample, only the mastoid size difference was markedly bigger (0.68). On the other hand, in the female mean values the Western Australian scores were greater in each instance but none by a very large amount (less than 0.24).

The total mean difference between the 2 sexes was markedly less in the Western Australian sample (5.33) as compared with that for New South Wales (9.06). The greatest mean size differences between the sexes for the 2 samples were in the occipital markings (0.95) and in the size of the malar tuberosity (0.76). To some extent the variations between the samples may reflect observer differences, but 2 of the features were quantitative, and casts of the limits of the middle value (2) for each of the other features were used in making the assessments. It would therefore seem that there may well be real differences between the 2 samples in the amount of sexual dimorphism.

On univariate analysis the Western Australian crania of the 2 sexes were found to be substantially different (Tables 2-4) and hence were studied separately. Comparing the male and female mean values with those of the New South Wales series (Freedman, 1964) showed that, overall, the latter crania were larger. Thus, the male Western Australian crania were smaller, on average, for 11/16 features for which comparable data were available. The instances where the New South Wales mean differences were considerably larger were: basi-bregmatic height (3.22 mm), maxillo-alveolar breadth (2.57 mm) and maximum cranial breadth (2.04 mm). The mean measurements on which the Western Australian male mean values were considerably greater were: bi-frontotemporale (1.28 mm), orbital breadth (1.10 mm) and nasal breadth (0.55 mm). For the female mean dimensions, the New South Wales sample was larger for 12/16 features. They were considerably larger in maxillo-alveolar length (2.56 mm), basi-bregmatic height (2.24 mm), basion-prosthion (2.14 mm) and maximum cranial length (1.88 mm). The only measurements for which the Western Australian female sample mean was considerably larger was orbital breadth (1.84 mm).

It is interesting to note that for males, both on sexing characters and univariate mean values, the New South Wales sample figures were mostly greater than those for Western Australia. On the other hand, for females, the sexing character values for Western Australia were all greater than those for New South Wales but, for the univariate mean values, the New South Wales figures were mostly larger.

Comparisons were also made between the cranial univariate statistics obtained in the present study with those of 3 earlier studies (Morant, 1927; Hrdlicka, 1928; Wagner, 1937). Only mean values for small male samples were reported in each of these studies and hence neither 't' tests nor more complex analyses could be used for making comparisons. Only 6 measurements were common to all 4 studies, a further 5 to 3, and 8 to only the present and one other study.

Considering the 3 primary cranial measurements first, the mean maximum cranial lengths reported by Morant and Hrdlicka were close to that obtained in the present study (187.23 mm); however, Wagner recorded a considerably lower mean value (184.9 mm). For basi-bregmatic height and maximum cranial breadth Hrdlicka and Morant recorded larger mean values and Wagner smaller values. Perhaps more importantly, however, there are variations in relative size between these two measurements in the four studies. Thus, in the present study the 2 mean dimensions were very close, with height just slightly greater (0.08 mm), whereas Hrdlicka and Wagner recorded breadth greater than height (132.5 mm to 131.9 mm and 130.6 mm to 129.4 mm, respectively) and Morant records height (132.6 mm) greater than breadth (130.8 mm). These differences affect all three primary cranial indices (breadth/length, height/length and height/breadth).

Of the remaining dimensions for which mean values are available for all 4 studies, nasal breadth is relatively uniform for the 3 earlier studies (26.1-26.8 mm) but the figure recorded in this study for Western Australia is rather larger (27.98 mm). Of those for which 2 other samples have comparable dimensions, bi-zygion is 1.66 mm greater in the Western Australian sample than in the largest mean value of the other available dimensions and, for basion-prosthion, Hrdlicka's mean is almost 2 mm greater than that of Wagner and the present study. Where comparisons of the present study with single other studies are involved, variations of 1-2 mm occur. Some caution is clearly necessary in assessing the significance of such comparisons as these because of possible variations in technique. This is almost certainly the case for nasion-prosthion and orbital breadth where mean dimensions are available for 3 studies and variation in the former is 64.9-71.1 mm and in the latter from 39.9 to 44.3 mm. Further, in making comparisons between the Western Australian and other samples it has had to be assumed that prosthion and alveolar point, basion and endobasion, and nariale and naso-spinale are similar enough for comparisons to be made. The necessity for standardisation and a basic set of measurements and non-metrical observations on crania from particular areas is urgently required.

The canonical variate analysis of the Western Australian male cranial material has revealed considerable variation between samples from the northern, central, southern, and eastern subdivisions. Using the whole cranium, separation of the 4 samples is achieved on the 3 variates, and subset analysis confirms that the main discriminating features are in the calvarial vault, rather than the face or base. Canonical analysis of the cranial indices was disappointing, possibly because the association of features in the indices may not be the best ones for reflecting shape differences in this material. Small numbers made the male mandibular and female cranial canonical analyses unreliable, although the former gave similar results to the male, whole cranium analysis. The 7 sample northern-central analysis also suffered from the smallness of the samples but the results did appear to reinforce the general variability of the crania from Western Australia.

The main inter-relationships emerging from the 50 variable, 4 Western Australian sample canonical analysis (Table 7) were those of a north to south coastal cline, with the eastern sample being most similar to the central on the first variate but well separated from all 3 coastal samples on the second. The univariate statistics were used to analyse the sample differences in the highly weighted features of the canonical variates.

In this canonical analysis breadth measurements were found to account for a considerable amount of the variation — a result similar to that of Howells (1973) in his multivariate, world-wide, cranial studies. The breadth variations were particularly: those measured on the coronal suture (bi-stephanion, bi-coronalia and bi-frontosphenoidale); relative breadth changes affecting the degree of post-orbital constriction (supra-orbital and bi-fronto-temporale); various facial breadths (bi-malar breadth, bi-zygion, bi-zygo-maxillare and interorbital); plus variations in the calvarial breadths on the temporal bones (bi-auriculare, bi-mastoid, bi-porion and maximum cranial). The variations in breadth measurements recorded within Western Australia tended to highlight differences between the southern and eastern samples, with the northern-central samples generally closer to the eastern sample. The most obvious differences were the narrower frontal and broader temporal breadths of the eastern sample when compared to the southern sample.

There were important shape contrasts found in the occipital, parietal, temporal and frontal bones. From the differences recorded for the various chord/arc measurements, it was found that the southern sample parietal and temporal bones were fuller in the sagittal and coronal planes, contrasting to the less rounded northern and eastern parietal and temporal bones. The fullness in the southern sample crania did not extend beyond the lambdoid suture. In fact, relatively, the southern sample occipital bone was the most sagittally flattened, contrasting to the northern and central samples which had a longer arc (relative to the chord) measurement, due to the posterior extension of the inion. The eastern sample was contrasted to the other samples because of frontal bone shape differences. These differences included a marked post-orbital constriction and a relatively fuller antero-posterior frontal curvature. The eastern sample post-orbital constriction was particularly marked when compared to the southern population, which had both a larger bi-frontotemporale and a smaller supra-orbital breadth. Overall it could be seen that the northern and central samples were most similar, having a relatively rounder occipital bone shape; the southern was differentiated because of its parietal and temporal bone shapes, while the eastern sample was separated because of its frontal bone shape.

The first variate of the canonical analysis using 4 Western Australian and 3 coastal New South Wales samples clearly separated the samples from the 2 States (Table 9, Fig. 3). However, although the succeeding variates spread the samples within each State no definitive pattern of inter-relationships emerged. Better separation of Western Australia and New South Wales might be achieved if chord and arc measurements became available for New South Wales. From the small canonical roots in this analysis it would seem that, although good separation is achieved, the differences between the samples are not very great.

The generalized distance analysis of the 7 samples from the 2 States revealed not only a coastal clinal trend from north to south within each State, but also progressive morphometric distance separation between equivalent parts of the 2 States (Table 11). The eastern Western Australian sample was distinguished from all of the other samples. This final result is very suggestive of a north to south migration down the east and west coasts, with the central and the southern samples of the two coasts being longer separated than the northern and hence showing progressively more differences. The isolation of the eastern Western Australian sample, from both the remaining Western Australian and all 3 of the New South Wales samples, could be due to their long-term isolation under environmentally harsher conditions. The isolation of the central Australian desert populations (represented in this study by the eastern Western Australian sample) from northern Western Australian populations was earlier suggested by Banerjee (1963), studying head hair characteristics.

There is still far from unanimity in the views held about the origin of the Australian Aborigines. It is accepted by virtually all authors that there is considerable morphological diversity throughout the continent. However, the basis for this variation is still in considerable dispute. Since 1938 Birdsell has been elaborating a theory suggesting a trihybrid origin (e.g. Birdsell, 1967) and, more recently, Howells (1973) has postulated what might be termed a dihybrid theory. However, the most generally accepted view (e.g. Abbie, 1968; Macintosh, 1965) holds that a single stock colonised Australia and that the variation found is the result of the effects of selection and drift. From late Quaternary studies (e.g. Bowler, 1976) it would seem that the originating stock of the Australian Aborigines arrived in the north of the continent, at least 50,000 and possibly as much as 100,000 years ago, from Southeast Asia (Sahulland). Such a time span of occupation of Australia would seem to be more than adequate for the present level of diversification to have occurred. This view is supported by Kirk (1971) from a review of blood groups, serum proteins and red cell and serum enzyme gene frequency studies. He contends that even 10,000 years would be adequate to account for the present continental variation in these features. In addition, Simmons (1956) has pointed out the improbability of the trihybrid theory because of the absence in the present Australian Aboriginal population of: B, S of MN, rh (cde), rh″ (cdE), Kell (K), and Fy^b of the Duffy group. All of these factors would, improbably, have had to have been absent in each of the 3 hybridising stocks.

The starting point most commonly suggested for the southward migration of the originating stock is Cape York in the northeast of the continent. However, it has also been postulated that entry was in several small groups both at Cape York and also in northwestern Australia (see Abbie, 1969). To reach the southern extremes, which they are known to have reached 30,000-35,000 years ago (see Mulvaney, 1975), man must have been able to cope with the wide range of environmental situations which confronted him on his journey. Nevertheless, it would seem reasonable to postulate that the initial southward migration was made along the most congenial and easily traversed pathways, namely down the east and west coastlines. Such a migration pattern would accord well with the morphometric relationships described in this study. The differences found between the coastal samples could then be the result of distance decay (Wright, 1943), recurrent founder effects (Fix and Lie-Injo, 1975), drift, environmental adaptation, or any combination of these. The morphometric isolation of the Western Australian eastern sample, as suggested above, could be due to adaptation to harsh desert conditions, although, as Mulvaney (1975) notes, conditions were probably very different 50,000 years ago. The numerous complex, linguistic differences found throughout Aboriginal Australia suggest the probable gene flow barriers between the populations of the past (Capell, 1956; Wurm, 1972).

SUMMARY

1. From Western Australia 105 crania (70 male and 35 female) and 53 mandibles (36 male and 17 female) have been studied by both univariate and multivariate analysis. All crania were from known localities and were assumed to be of recent age. Sexing was by the Larnach and Freedman (1964) method.
2. Univariate statistical data for 50 cranial measurements, 22 derived indices and 18 mandibular dimensions were produced separately for males and females. Significant sexual dimorphism was found for most of the measurements. The male data were compared with those of Morant (1927), Hrdlicka (1928) and Wagner (1937). A variety of differences were found.
3. On broad linguistic grounds, a 4 sample subdivision (northern, central, southern and eastern) was made and studied by multivariate analysis using, separately, cranial measurements (whole and subsets), cranial indices and mandibular measurements. The male 50 variable canonical analysis produced the most important result. Coastal variation appeared to be clinal with the inland eastern sample having a more unique set of features. Using canonical variate weights and univariate mean values, it appeared that the parietal, temporal and occipital bone shapes were of considerable significance for differentiating the coastal samples, whilst the eastern sample diverged mainly because of its differently shaped frontal bone. Chord and arc measurements proved most useful when making these comparisons. Breadth measurements were also important in the discrimination.
4. The 4 Western Australian samples were compared with 3 from coastal New South Wales (Freedman, 1964) by multivariate analysis. Using canonical

analysis the first variate clearly separated the groups of samples from the 2 States. Mahalanobis generalized distance indicated that the Western Australian northern and New South Wales northern samples were morphometrically similar; the two central and two southern samples were progressively less similar, both from their own State northern sample and from the equivalent opposite State sample. These data would be in agreement with east and west coast southward migrations from an initial north of Australia originating population.

5. The variation found within and between the Western Australian and coastal New South Wales samples does not call for an hypothesis of more than one originating stock for the Australian Aboriginal population.

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A NEW SPECIES OF *ABUDEFDUF* (PISCES: POMACENTRIDAE) FROM THE INDO-AUSTRALIAN ARCHIPELAGO

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ABSTRACT

Abudefduf lorenzi n.sp. differs from all other species of *Abudefduf* by the presence of a dark spot on the posterior area of the caudal peduncle and base of the caudal fin. It is known from the northern and eastern coasts of New Guinea, Bismarck Archipelago, Solomon Islands, Ambon, northern Celebes, Palau Islands and Philippine Islands. It is largely or entirely allopatric with its closest relative, *A. bengalensis*.

INTRODUCTION

Major 20th century works on Indo-West Pacific fishes have assigned pomacentrids having teeth with compressed tips and a smooth preopercular margin to the genus *Abudefduf* Forsskål. During the last few years, Indo-West Pacific pomacentrids have been under study by John E. Randall, Alan R. Emery, and the authors. One result of this study has been the recognition of eight genera within the 'genus' *Abudefduf*. Most of these groups were recognised earlier by Bleeker (1877). Allen (1975) presents a key to these genera.

The genus *Abudefduf*, as currently recognised, is equivalent to Bleeker's subgenus *Glyphidodon*. It is a genus of deep-bodied species, usually with a barred colour pattern (except in *A. sparoides*), having uniserial teeth with

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compressed tips and bicuspid or entire margins (in adults), and usually with 13 dorsal spines (rarely 12 or 14). The genus includes *A. saxatilis* (Linnaeus) (tropical Atlantic), *A. taurus* (Müller and Troschel) (western Atlantic), *A. declivifrons* (Gill) (eastern tropical Pacific), *A. troschelii* (Gill) (eastern tropical Pacific), *A. abdominalis* (Quoy and Gaimard) (Hawaiian Islands), *A. whitleyi* (Allen and Robertson) (Great Barrier Reef and New Caledonia), *A. vaigienses* (Quoy and Gaimard) (Indo-West Pacific), *A. sexfasciatus* (Quoy and Gaimard) (Indo-West Pacific), *A. notatus* (Day) (Indo-Australian Archipelago and Indian Ocean), *A. sordidus* (Forsskål) (Indo-West Pacific), *A. septemfasciatus* (Cuvier) (Indo-West Pacific), *A. bengalensis* (Bloch) (Indo-Australian Archipelago and northern and eastern Indian Ocean), *A. margariteus* (Cuvier) (Reunion and Mauritius). This paper describes a new species of this genus which has hitherto been confused with *A. bengalensis.*

All measurements were made with dial calipers and recorded to the nearest 0.1 mm. Methods for counts and measurements generally follow those of Hubbs and Lagler (1949) with the following additions and qualifications: body depth—from midventral point between ventral fins to base of first dorsal spine; interorbital width—least bony width of interorbital; upper caudal lobe length—from bases of upper caudal rays to tip of longest upper caudal ray; lower caudal lobe length—from bases of lower caudal rays to tip of longest lower caudal ray; transverse scale rows—number of scale rows from upper end of gill opening to end of hypural plate; upper lateral line scales—number of tube-bearing scales, any pore-bearing scales following last tube-bearing scale not counted. Lengths of specimens are standard length (SL). The description is based mainly on specimens 80 mm or larger. Where characters differ significantly with size, they are discussed under 'developmental variation'. The term 'angulate', used in describing fin shapes, refers to a condition between 'rounded' and 'pointed'.

The following institutional abbreviations are used in the subsequent text: AM—Australian Museum, Sydney; AMNH—American Museum of Natural History, New York; BMNH—British Museum (Natural History), London; BPBM—Bernice P. Bishop Museum, Honolulu; CSIRO—Commonwealth Scientific and Industrial Research Organisation, Cronulla, Australia; FMNH—Field Museum of Natural History, Chicago; MNHN—Museum National d'Histoire Naturelle, Paris; MRHNB—Koninklijk Museum voor Midden-Afrika, Tervuren, Belgium; RMNH—Rijksmuseum van Natuurlijke Historie, Leiden; SIO—Scripps Institution of Oceanography, La Jolla, California; THUP—Tunghai University, Taichung, Taiwan; UMMZ—University of Michigan, Museum of Zoology, Ann Arbor, Michigan; USNM—National Museum of Natural History, Washington, D.C.; WAM—Western Australian

Museum, Perth; ZMA—Zoologisch Museum, Amsterdam; ZMK—Universitets Zoologiske Museum, Copenhagen.

Abudefduf lorenzi new species

(Figs. 1 and 2; Tables 1 and 2)

Glyphidodon bengalensis (*non* Bloch, 1787: 110), Günther (1862: 41; Ambon).

Abudefduf bengalensis (*non* Bloch, 1787: 110), Montalban (1928: 80-81; in part; Philippine Islands); Fowler and Bean (1928: 128-129; in part; Philippine Islands); Herre (1936: 291; Solomon Islands).

Abudefduf species Allen (1975: 114; Philippine Islands, Palau Islands, Molucca Islands, New Guinea, New Britain, Solomon Islands).

Holotype

FMNH 23564, 100.0 mm, Tunnibuli, Ysabel Island [Tunnibuli Bay, Santa Isabel Island; approximately 8° 25′ S, 159° 50′ E], Solomon Islands, collected by the Crane Pacific Expedition, 18 April 1929.

Paratypes

AM I.12069, 91.7 mm, Gizo, Solomon Islands, collected by E. Pybus, August 1911; AM I.15360-101, 2 specimens, 68.1 and 69.4 mm, Malaita, Solomon Islands, collected by W. Dawbin, July 1968; AM I.16694-003, 27.0 mm, Madang, New Guinea, collected by G. Allen using quinaldine, depth 1-2 m, 15 May 1972; AM I.16710-001, 2 specimens, 25.6 and 37.5 mm, Urakthapel Island, Palau Islands, collected by G. Allen using rotenone, depth 1 m, 9 January 1972; BMNH 1858.4.21.307, 2 specimens, 61.2 and 115.0 mm, Ambon, collected prior to 1858; BPBM 9501, 4 specimens, 71.0-103.3 mm, Arakabesan Island, Palau Islands, collected by J. Randall using spear, depth 0-1 m, 9 April 1970; BPBM 15998, 88.2 mm, Honiara Harbour, Guadalcanal, Solomon Islands, collected by J. Randall using spear, depth 3 m, 7 July 1973; CSIRO C282, 122.5 mm, Kieta, Bouganville Island, Solomon Islands, collected by I. Munro using beach seine, 21 October 1949; CSIRO C452, 97.8 mm, mouth of Kulineua River, New Hanover, Bismarck Archipelago, collected by I. Munro, 9 November 1949; CSIRO C1778, 94.0 mm, same data as preceding specimen; FMNH 23563, 88.7 mm, collected with holotype; FMNH 40675, 32.7 mm, Nasugbu, Batangus Province, Luzon, Philippine Islands, collected by A. Herre, 12 June 1940; RMNH 886, 108.1 mm, Celebes, collected by E. Forsten, 1840-42; RMNH 11818, 2 specimens,

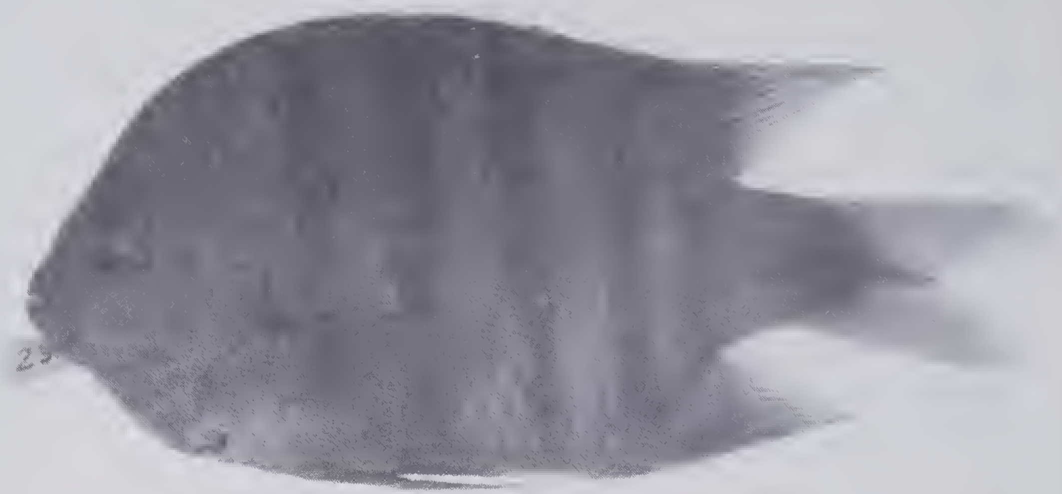

Fig. 1. *Abudefduf lorenzi*, holotype, FMNH 23564, 100.0 mm, from Solomon Islands.

Fig. 2. *Abudefduf lorenzi*, approximately 125 mm TL, photographed underwater at Florida Island, Solomon Islands in depth of one metre.

65.5 and 78.8 mm, Gorontalo, northern Celebes, collected by Rosenberg, 1865; RMNH 14932, 118.8 mm, Geelvink Bay, New Guinea, collected by Rosenberg, 1864; RMNH 14933, 80.7 mm, Ambon, collected by E. Ludeking, 1861-67; RMNH 27463, 96.5 mm, Ambon, no date; USNM 216250, 32.3 mm, Kuia Island, Trobriand Islands, New Guinea, collected by B. Collette using rotenone, depth 0-0.6 m, 10 June 1970; WAM P24924, 86.7 mm, off Cape Tawui, Rabaul, New Britain, collected by G. Allen using rotenone, depth 2 m, 9 August 1973.

Diagnosis

A species of *Abudefduf* with the following combination of characters: dorsal soft rays 11-13 (usually 12); anal soft rays 11 or 12 (usually 12); preorbital naked; suborbital with row of scales on posterior 1/3-1/2 of series in specimens larger than about 35 mm; interorbital scales reaching to level of nostrils; most of inferior preopercular limb broadly naked; pattern of six dark, narrow, vertical bars on sides and a dark spot on posterior area of caudal peduncle and basal portion of caudal fin; upper caudal lobe angulate to pointed with straight to slightly curved posterior margin.

Description

(Based on the holotype and 26 paratypes.) Data from the holotype are presented, followed in parentheses by the range and, for morphometrics, the mean from the holotype and paratypes. Morphometrics expressed as % SL are presented in Table 1.

Dorsal XIII,12 (XIII,11-13 except one specimen with XIV spines, usually XIII,12); anal II,12 (II,11-12, usually 12); total pectoral rays 18 (17-19); transverse scale rows 27 (26-30, usually 27-29); upper lateral line scales 20 (20-22, usually 20); gill rakers 8 + 18 (6-8 + 15-18, usually 6 or 7 + 16 or 17), totalling 26 (22-26, usually 22-24).

Depth of body 1.8 (1.6-2.0, 1.7), length of head 3.2 (2.7-3.2, 3.1), both in standard length. Snout 3.2 (3.0-4.2, 3.3), orbit 3.1 (3.0-3.6, 3.3) in specimens larger than 80 mm (see below for developmental variation in orbit length), length of upper jaw 3.3 (3.2-3.6, 3.3), interorbital width 2.8 (2.7-3.5, 3.1), caudal peduncle depth 1.7 (1.6-2.1, 1.7), length of first dorsal spine 4.0 (3.7-5.4, 4.3), of sixth dorsal spine 2.0 (1.6-2.2, 2.0), of thirteenth dorsal spine 1.7 (1.7-2.4, 1.9), of longest dorsal ray (third, fourth, or fifth, usually fourth) 1.1 (0.9-1.4, 1.1), of first anal spine 4.4 (3.5-5.4, 4.4), of second anal spine 2.1 (1.7-2.4, 2.0), of longest anal ray (fifth or sixth) 1.2 (1.1-1.6, 1.2), of upper caudal lobe 0.8 (0.8-0.9, 0.9), of lower caudal lobe

0.9 (0.9-1.1, 1,0), of pectoral fin 0.9 (0.9-1.2, 1.0), of pelvic fin 0.8 (0.8-1.0, 0.9), all in length of head. Depth of caudal peduncle in its length 0.9 (0.8-1.0, 0.9).

Jaw teeth with compressed tips, bicuspid or entire margins (see below for developmental variation in tooth margins); interorbital scales extending anteriorly to a point even with or, rarely, slightly anterior to nostrils; preorbital naked, posterior 1/3-1/2 of suborbital series with a row of scales (see below for developmental variation in suborbital squamation); preopercle with three regular rows of large scales and dorsally one row of small scales ventral to suborbital series, upper limb naked, lower limb mostly naked but frequently with 1-3 small scales anteriorly.

Dorsal spines increasing in length posteriorly from first through 4th-6th, fourth, fifth, or sixth through twelfth subequal, thirteenth usually slightly longer than twelfth; soft dorsal fin pointed; anal fin angulate to pointed; upper caudal lobe angulate to pointed, posterior margin straight to slightly curved; lower caudal lobe rounded to pointed, posterior margin straight to curved (see below for developmental variation in shape of lower caudal lobe); adpressed pectoral fin reaching to transverse level of ninth, tenth, or eleventh dorsal spine; ventral fin with filamentous outer ray, reaching to bases of anal spines or first three anal rays.

Colour in alcohol: ground colour of head and body tan to dark brown, snout, interorbital, nuchal region, and frequently lips and lower jaw, darker; a pattern of six dark bars present on body, width of each bar approximating distance from anterior surface of one dorsal spine to posterior surface of following spine; bars located as follows: 1) across nape to dorsal angle of opercular opening (frequently indistinct or absent), 2) from bases of 1st-3rd dorsal spines to behind pectoral axil, 3) from bases of 4th-6th dorsal spines to lower abdomen, 4) from bases of 8th-10th dorsal spines to area just dorsal to anal-urogenital region, 5) from bases of twelfth and thirteenth dorsal spines to bases of anterior anal rays, 6) from bases of middle soft dorsal rays to bases of last anal rays and anteroventral area of caudal peduncle; caudal peduncle with large dark spot posteriorly which extends onto base of caudal fin, remainder of caudal fin tan to brown; dorsal and anal fins similar to ground colour of adjacent body surfaces; pectoral fins tan to hyaline with small dark spot superiorly on base; ventral fins with brown rays, membranes partially whitish, causing extended ventral fins to be similar to or slightly darker than ground colour of lower abdomen, and retracted ventrals to be whitish.

Colour when alive: Allen (1975) presented an underwater colour photograph of this species, which is reproduced here in black and white as Fig. 2.

Table 1: Morphometric proportions (% SL) of holotype and paratypes of *Abudefduf lorenzi.*

Standard length (mm)		25.6-37.5			61.2-78.8			80.7-97.8			103.3-122.5		(holotype)
	$\overline{X}$	Range	N	$\overline{X}$	Range	N	$\overline{X}$	Range	N	$\overline{X}$	Range	N	100.0
Body depth	56.9	55.7-58.9	5	56.8	48.8-61.4	3	58.3	54.6-62.0	9	57.5	55.6-59.3	5	56 1
Head length	37.2	35.7-39.1	5	32.4	31.8-32.7	3	32.5	31.1-33.7	10	32.4	31.7-33.2	5	31.1
Snout length	9.6	8.5-11.9	5	9.3	8.8-9.8	3	9.8	9.1-10.4	10	10.2	9.9-10.6	5	9.8
Orbit length	15.2	14.1.17.4	5	11.3	10.4-11.9	3	10.0	8.9.10.7	10	9.5	9.1-9.7	5	10.0
Upper jaw length	11.8	10.5-12.9	5	9.9	9.8-10.1	3	9.7	9.4-10.0	10	9.6	9.2-10.1	5	9.5
Interorbital width	9.9	8.6-11.3	5	10.6	9.8-11.9	3	10.3	9.8-11.2	10	10.6	9.8-11.2	5	10.9
Caudal peduncle depth	17.7	16.8-19.0	5	18.6	18.4-18.8	3	18.7	17.8-19.6	10	18.0	16.8-19.2	5	18.1
Caudal peduncle length	14.4	12.5-17.0	5	17.4	16.5-18.3	3	16.1	13.7-18.2	10	16.0	14.5-17.6	5	16.5
Upper caudal lobe length	40.1	39.3-41.9	5		37.7	1	36.4	34.9-39.8	8	35.7	34.1-37.6	4	37.1
Lower caudal lobe length	38.2	36.8-39.8	5		34.6	1	34.1	31.0-36.8	9	33.1	31.3-34.8	4	33.3
Pectoral fin length	33.2	31.0-34.1	5	33.5	32.7-34.1	3	33.5	30.3-37.1	10	32.0	29.1-34.8	5	32.8
Pelvic fin length	36.8	34.8-39.8	5	36.8	35.7-37.4	3	37.7	34.4-40.1	9	36.2	33.6-38.7	5	37.9
First dorsal spine length	9.3	7.8-10.7	5	7.8	7.6-8.1	2	7.8	6.9-8.7	10	6.8	5.9-8.1	3	7.7
Sixth dorsal spine length	17.8	16.4-19.9	5	17.6	16.6-18.6	2	17.1	15.3-18.6	10	15.4	14.1-17.4	4	15.5
Thirteenth dorsal spine length	15.7	14.1-16.8	5	17.6	17.4-17.9	2	18.3	16.6-19.8	10	17.1	16.2-19.4	4	17.8
First anal spine length	8.4	6.8-10.1	5	7.5	6.7- 8.4	2	7.7	5.8-9.3	10	6.6	6.2-7.2	3	7.0
Second anal spine length	18.5	18.0-20.0	5	16.5	15.4-17.6	2	17.0	15.0-19.0	10	14.9	13.3-17.4	4	15.1
Longest dorsal ray length	26.0	24.6-26.1	4	28.6	28.5-28.8	2	30.4	26.2-34.0	10	31.0	27.8-36.7	5	28.7
Longest anal ray length	25.1	24.2-27.0	4	26.7	25.9-27.8	3	27.4	23.3-30.1	10	25.0	23.1-27.8	4	26.0

There are two major differences in coloration between living and preserved specimens; the ground colour of live specimens is pale silvery-grey to whitish (*vs.* tan to dark brown), and the anteriormost dark bar (across nape) is much more distinct than in preserved specimens.

Developmental variation: The ratio head length/orbit length has a mean of 2.8 and a range of 2.6-3.1 for specimens less than 80 mm. Three juvenile specimens (25.6-32.3 mm) have not developed suborbital scales. Adult specimens of *Abudefduf* usually have bicuspid or entire tooth margins. However, apparently all or most of the teeth (except for the posteriormost in each jaw, which remain peglike) originate in a tricuspid condition. The bicuspid shape results from the reduction of the central cusp and/or enlargement of lateral cusps. The entire or flattened condition probably results from wear on bicuspid teeth. If one considers tricuspid, bicuspid, and entire tooth margins as early, middle, and late developmental stages, respectively, in any one individual the most advanced tooth type is usually found near the symphyses, earlier types being found more laterally and posteriorly. In *A. lorenzi* tricuspid and bicuspid teeth are found in the five smallest specimens (26.5-37.5 mm); larger specimens (61.2-122.5 mm) have the typical adult condition with a combination of bicuspid and entire teeth. It is possible that the shape of the lower caudal lobe changes with an increase in standard length (Fig. 3a, b). The two largest specimens examined (118.8 and 122.5 mm) have rounded lower caudal lobes; smaller specimens (25.6-115.0 mm) have angulate to pointed lobes.

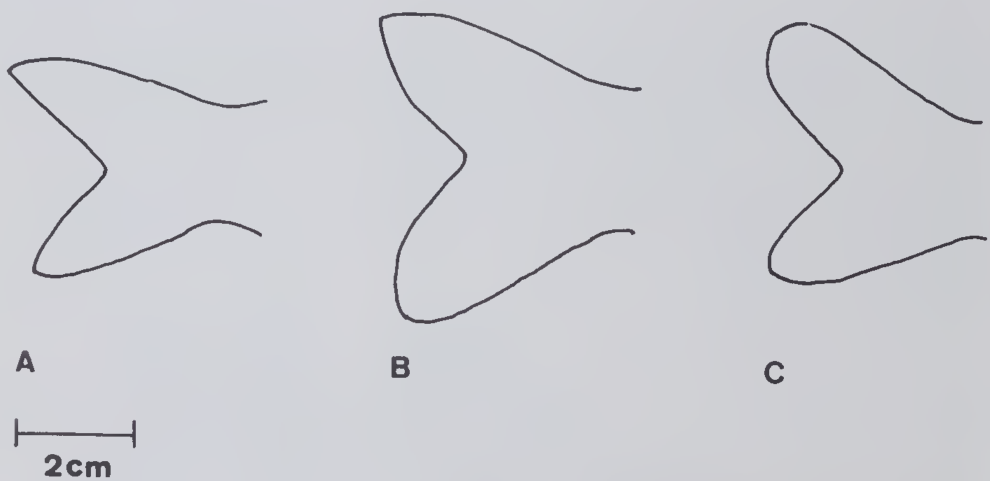

Fig. 3. Outlines of caudal fins: a) *Abudefduf lorenzi*, 100.0 mm; b) *A. lorenzi*, 118.8 mm; c) *A. bengalensis*, 104.3 mm.

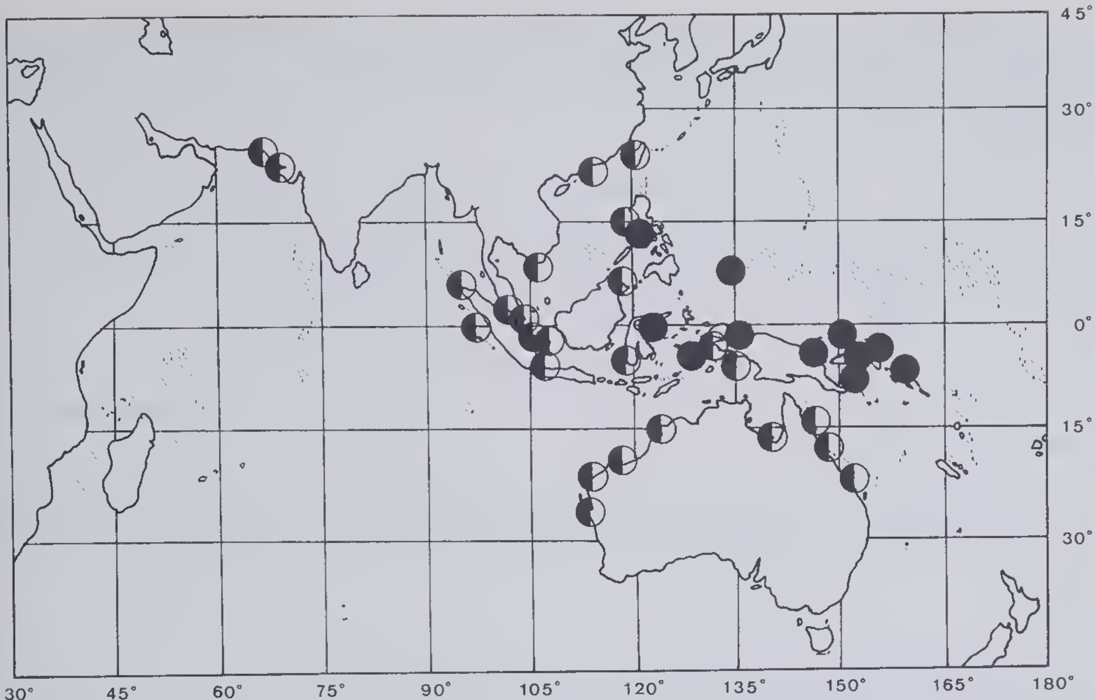

Fig 4. Localities for specimens of *Abudefduf lorenzi* and *A. bengalensis* examined in the present study: Shaded circles = *A. lorenzi*; half-shaded circles = *A. bengalensis*.

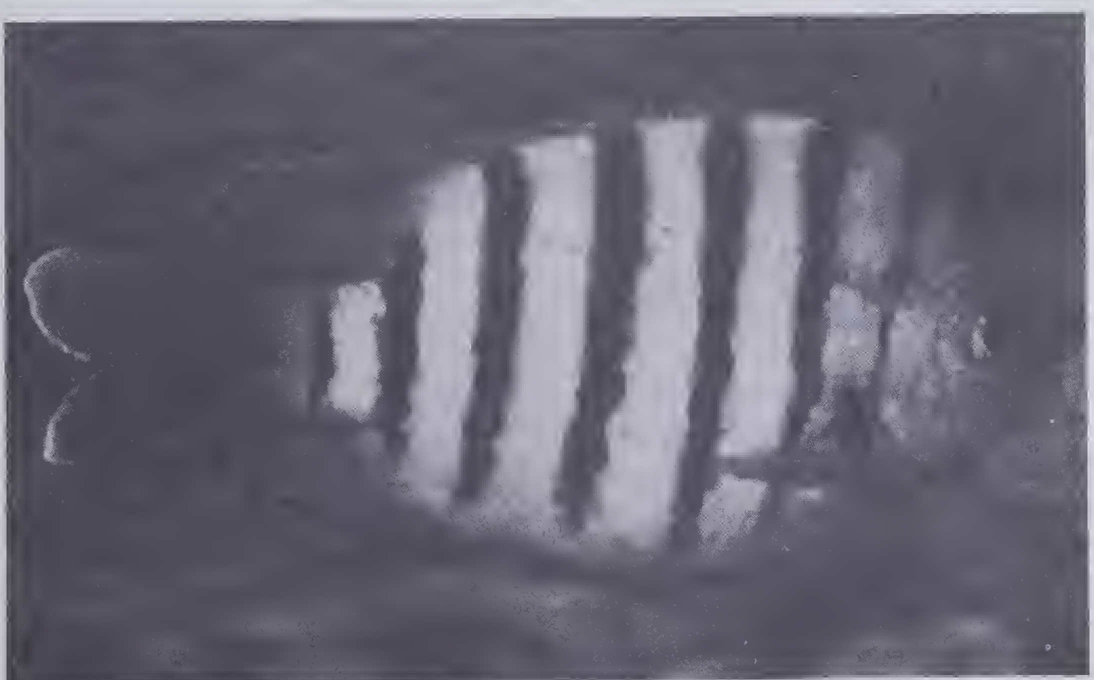

Fig 5. *Abudefduf bengalensis*, approximately 150 mm TL, photographed underwater at One Tree Island, Great Barrier Reef in depth of two metres (note characteristic rounded upper lobe of caudal fin).

Distribution (see also Fig. 4): Known from the northern and eastern coasts of New Guinea, Bismarck Archipelago, Solomon Islands, Maluku Islands (Ambon), northern Celebes (Gorontalo), Palau Islands, and Philippine Islands.

Habitat: *A. lorenzi* inhabits protected lagoon areas and sheltered coastal reefs, usually near shore in 0.5 to six metres depth. It is also common around docks and breakwaters, occurring individually or in aggregations containing about 20-30 fish. The diet consists chiefly of benthic algae.

Comparisons: *A. lorenzi* is readily separable from all other *Abudefduf* on the basis of the dark spot on the posterior region of the caudal peduncle and base of the caudal fin. *A. sparoides* has a dark ovoid spot on the caudal peduncle, but in this species the spot is located more anteriorly, below the soft dorsal fin and on the anterior part of the caudal peduncle. In addition, *A. sparoides* is the only species in the genus which lacks a pattern of dark bars.

A. lorenzi is most closely related to *A. bengalensis* (Fig. 5), the species with which it has been confused by most previous authors. *A. lorenzi* differs, however, in several characters, in addition to having the large dark spot on the caudal peduncle and fin. The two species possess a similar pattern of narrow, dark bars, but *A. bengalensis* has an additional bar (often indistinct or absent in preserved specimens) at the base of the caudal fin in place of the large blotch found in *A. lorenzi.* Locations of the six anteriormost bars in *A. bengalensis* are very close to those of *A. lorenzi*, with the frequent exception of the sixth bar, which is often located on the anterior or middle region of the caudal peduncle (*vs.* below the soft dorsal fin in *A. lorenzi* and some *A. bengalensis).* In adult specimens of *A. bengalensis*, both lobes of the caudal fin are rounded with strongly curved posterior margins (Figs. 3c and 5); in *A. lorenzi* the upper caudal lobe is angulate to pointed with its posterior margin straight to only slightly curved (Fig. 3a, b). Differences also exist between these species in numbers of dorsal and anal soft rays (Table 2); 11-13 (usually 12) dorsal soft rays in *A. lorenzi vs.* 13-15 (usually 13 or 14) in *A. bengalensis*, and 11 or 12 (usually 12) anal soft rays in *A. lorenzi vs.* 13 or 14 in *A. bengalensis.* In addition, most specimens of *A. bengalensis* possess 19 pectoral rays compared with a usual count of 18 for *A. lorenzi.*

We have examined 233 specimens of *A. bengalensis*, 21.3-138.1 mm SL from the following localities: northern Australia (Queensland to Western Australia), West Irian, Aru Islands, Celebes, Sabah, Java, Belitung and Bangka (off southeastern Sumatra), Batu Island (off west coast of Sumatra), We (off northwestern end of Sumatra), Singapore, Strait of Malacca, Vietnam

Philippine Islands, Hong Kong, Taiwan, India, and West Pakistan (Karachi); this total includes 116 specimens from northern Western Australia examined at WAM. We have also examined the type specimens of *Glyphidodon affinis* Günther and *Glyphisodon palmeri* Ogilby at BMNH and AM respectively. Both species are junior synonyms of *A. bengalensis.*

Seven specimens from the Indonesian region (MRHNB 18470-71, 18473; RMNH 10117, 27462) cannot be identified as either *A. bengalensis* or *A. lorenzi*, but probably belong to the latter species on the basis of fin ray counts. The specimens are faded making it impossible to detect the dark spot at the base of the caudal fin. In addition, the caudal fin lobes are damaged and precise locality data is missing for most of the specimens.

It is not known if the distributions of *A. lorenzi* and *A. bengalensis* overlap. They appear to be largely allopatric (Fig. 4), but may possibly co-occur in the vicinity of West Irian.

The holotype and one paratype of *A. lorenzi* (FMNH 23563 and 23564) are two of four specimens described by Herre (1936) from the Solomon Islands as *A. bengalensis.* The two specimens (BMNH 1858.4.21.307) from Ambon described by Günther (1862) as *G. bengalensis* are also among the paratypes of *A. lorenzi.*

Etymology: Named in honour of Konrad Lorenz for his contributions to the science of ethology.

Table 2. Soft dorsal, soft anal, and pectoral fin ray counts for *Abudefduf lorenzi* and *A. bengalensis.*

Species	Dorsal Soft Rays					Anal Soft Rays				Pectoral Rays				
	11	12	13	14	15	11	12	13	14	16	17	18	19	20
Abudefduf lorenzi	2	23	2			1	26				2	23	2	
Abudefduf bengalensis			23	85	2			56	53	1	1	33	66	5

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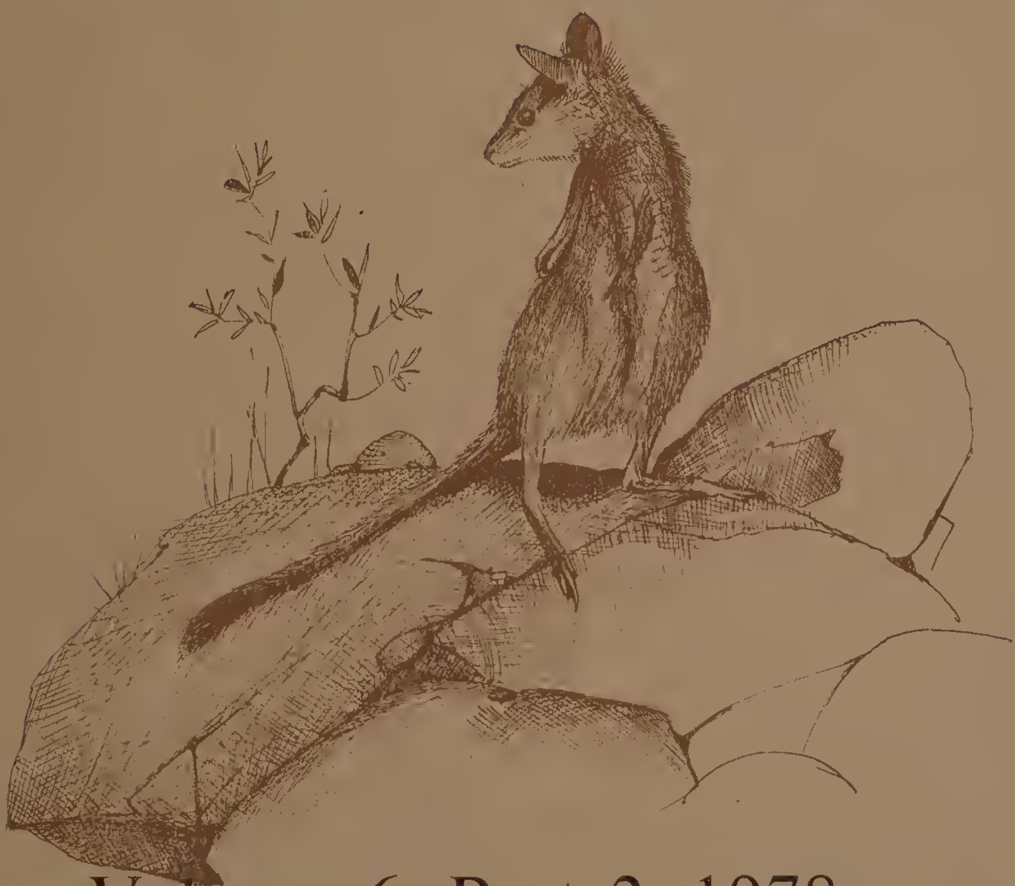

Volume 6, Part 2, 1978

Cover: *Petrogale burbidgei* is the smallest of the rock wallabies. It is described for the first time in this issue of the Records. Known only from low woodlands on sandstones in the Prince Regent River Reserve, Bonaparte Archipelago and the Mitchell Plateau areas, Kimberley, Western Australia.

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A COMPARATIVE STUDY OF THE STRUCTURE, FUNCTION AND ADAPTATION TO DIFFERENT HABITATS OF BURROWS IN THE SCORPION GENUS *URODACUS* (SCORPIONIDA, SCORPIONIDAE)

L.E. KOCH*

[Received 24 August 1976. Accepted 8 December 1976. Published 30 June 1978.]

ABSTRACT

Data are presented on the sites and nature of spiralling of *Urodacus* burrows. The dispositions of the burrows of *U. hoplurus* in three areas in Western Australia are statistically analysed in relation to various features of the environment. Burrow parameters of *U. hoplurus* and *U. yaschenkoi* are compared. Members of the genus *Urodacus* have been able to colonize desert areas owing to the evolution of the deep spiral burrowing habit which is an adaptation for the maintenance of suitable levels of moisture and temperature.

INTRODUCTION

Scorpions of the genus *Urodacus* (endemic Australian subfamily Urodacinae, Scorpionidae) construct burrows which range from shallow to about 100 cm deep and which may or may not be under cover. The burrows of a few *Urodacus* species have been mentioned (Kraepelin, 1916; Anon, 1917; Butler, 1930; Glauert, 1946, 1957; Southcott, 1954) and studies have been made of the burrow sites of *U. manicatus* in Canberra, A.C.T. (Smith, 1966) and of the burrows of *U. yaschenkoi* in N.S.W. (Shorthouse, 1971). The taxonomy of the genus *Urodacus* has recently been revised (Koch, 1977).

The present paper on *Urodacus* species includes the results of observations on large numbers of burrows of *U. hoplurus* and *U. yaschenkoi*. Because the burrow sites of one of the *Urodacus* species that has shallow burrows (*U. manicatus*) had been studied in detail (Smith, 1966) it was decided to make observations on a species that makes deep burrows (*U. hoplurus*). Results of studies of its burrows in relation to various environmental features

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are given below. These studies were at three specially selected localities in Western Australia. The burrow-form in this species is compared and contrasted with that in *U. yaschenkoi* which also has deep burrows. The available information on these and other *Urodacus* species gained by observations made at scattered localities is presented and discussed.

For assistance in the field I thank Mr D.D. Giuliani, Big Pine, California, U.S.A. I am grateful to Mr T. Wachtel, Hawthorn, Victoria, for the statistical analyses. Plant names were provided by the State Herbarium, Western Australia. The present paper is abridged from part of a chapter in a Ph.D. thesis (University of Reading, England).

SPECIMENS AND RECORDING

The tables of raw data pertaining to this study are deposited in the library of the Western Australian Museum.

Specimens. The scorpions collected from the burrows have been coded, registered and lodged in the Western Australian Museum. The burrows are given these code numbers, e.g. A1, in the plan drawings.

Collecting and Burrow Recording. The following digging procedure was adopted for recording burrow characteristics. A cylindrical column of soil (usually of 15 cm radius) was left undisturbed around the entrance of the burrow, and a circular excavation (usually 60 cm wide and 30 cm deep) was made around this column. The path of the burrow was then followed by careful digging of the column and recorded as a plan drawing on squared paper, with the corresponding depths at successive selected points being noted. The scorpion was eventually collected from the terminal chamber.

After rain (e.g. at Marloo, W.A., where a large series of scorpions was collected) the scorpions were in the upper part of the first spiral near the entrance. Each burrow was approached from behind the entrance so as not to disturb the scorpion and cause it to descend. The scorpion was then collected by lifting it out in a spadeful of soil.

Measurements of the study areas and burrow dimensions have been converted to metric: burrow entrance dimensions had been measured to the nearest 1/16 inch, tree-distance to the nearest foot, and other burrow dimensions to the nearest 1/4 inch.

Plan Drawings and Graphs of the Burrows. The caption of each plan drawing of a burrow's path includes the data on burrow depth at the successive points measured from ground level (x) to full depth.

In order to construct the plan drawings, the following parameters were included: the length (sl) and depth (dl) from burrow entrance to completion of the first quarter turn; the length and depth from last quarter turn (i.e. at the penultimate point on the plan drawing) to the middle of the terminal chamber. Also included, in some sections of the work, are the total length (l) and total depth (d) of the burrow, the total number of turns, and the angle in degrees of descent (ϕ) during the first quarter turn ($\tan \phi = dl/sl$).

In an attempt to determine any common characteristics of the burrows, the data in the plan drawings were graphed. In these graphs, the successive points corresponded with those on the plan drawings. The ordinate was the vertical depth of the burrow, the abscissa the horizontal projection of the burrow from its entrance (as measured from the plan drawing). The ordinate and abscissa were drawn to the same scale. The curve of the graph showed the burrow unwound from its spiral-form while keeping the slope unchanged at all points: the actual length of the burrow was the length of the curve (the arc length) as measured with a piece of string. The overall slopes of these graphs, i.e. the lines joining the first and last points (entrance and terminal chamber) are discussed.

BURROW FORMS IN *URODACUS*

General Characteristics

The burrow entrance of *Urodacus* species is elongate, elliptical and slit-like. On the ground nearby there is usually a tumulus of freshly dug soil, produced as a result of the digging and burrow-cleaning activities of the occupant. The scorpion burrow entrances are easily distinguishable from those made by other creatures, e.g. ants, by their shape and by the tumulus being present only on one, the vestibular, side of the entrance.

In species that have burrows under rocks, e.g. *U. manicatus*, *U. planimanus* and in some areas *U. novaehollandiae* (and probably also *U. elongatus* which taxonomically is close to these three species), the burrow entrance leads immediately into an expanded cleared area under the rock. This area is thought to be constructed to give the scorpion room to manoeuvre while eating or mating, and has been termed the "living area" by Smith (1966) for *U. manicatus* (as *U. abruptus*). The burrow proceeds from the living area and is usually shallow (i.e. less than 10 cm deep).

Burrows that occur in "open ground" (i.e. those with their entrances not under cover of rocks or other large objects on the ground) do not have the above type of living area. Instead, the burrows are deep, spiral, and have a horizontal terminal chamber which, unlike the otherwise uniform cross-section, is somewhat larger and of adequate size for the scorpion to turn around. In these burrows, the angle of descent during the first quarter turn ranges from 14° to 49°. These burrows have up to ten turns; they are referred to as tortuously spiral when they have more than two turns. The shape of the burrow entrance of all deep spiralling species is similar; that of *U. hoplurus* has been illustrated (Koch, 1970).

In later sections, the burrows of *U. hoplurus* and *U. yaschenkoi* are analysed. Of the other species, the burrows of *U. novaehollandiae* are the least spiral and usually occur in sheltered sites under rocks or logs, whereas those of *U. giulianii* are the most spiral and occur in open ground. The plan drawings (Figs 1, 2) and the ranges and means of the burrow parameters (Table 1) indicate that the two species in the taxonomically based *hoplurus* species-group, *U. giulianii* and *U. lowei* (Koch, 1977), have noticeably longer and deeper burrows and greater angles of descent during the first quarter turn than those in the *armatus* species-group, *U. novaehollandiae* and *U. armatus.*

Nature of Burrow Graphs

The overall slopes of the burrow graphs were drawn for all the data and ranged from 18° to 53°. The species have the following ranges (mean, and n).

U. novaehollandiae	22° to 25° (23.5, n = 2)
U. armatus	22° to 29° (25.5, n = 4)
U. hoplurus	18° to 53° (33.5, n = 25)
U. giulianii	19° to 23° (21.0, n = 2)
U. lowei	27° to 39° (34.5, n = 4)
U. yaschenkoi	24° to 46° (32.2, n = 23)

There is obviously no significant difference between the mean values of the slopes of *U. hoplurus* and *U. yaschenkoi.*

For the above six species, the surface distance between entrance and terminal chamber ranged from 2 to 50 cm.

Data for Species

Information on the distribution and habitats of the species has been given (Koch, 1977). Data, including that available from the literature,

TABLE 1

RANGES AND MEANS OF BURROW PARAMETERS IN VARIOUS *URODACUS* SPECIES

(Measurements in cm)

Statistic	Burrow entrance to first quarter turn: Length (sl)	Burrow entrance to first quarter turn: Depth (dl)	Last quarter turn to middle of chamber: Length	Last quarter turn to middle of chamber: Depth	Total length (l)	Total depth (d)	Total no. of turns	Angle of descent (o) during first quarter turn (ϕ) ($\tan \phi$ = dl/sl)	Grade (o) (= sin d/l)
					U. novaehollandiae				
Range	19-23	6-10	13-19	5.6	43-50	18-20	0.5-0.8	19-26	24-25
Mean (N = 2)	21.0	8.0	16.0	5.5	46.5	19.0	0.7	22.5	24.5
					U. armatus				
Range	9-14	3-6	2-18	1-10	29-60	11-29	0.8-1.5	17-35	22-29
Mean (N = 4)	9.5	3.5	14.5	7.0	44.5	20	1.2	19.5	25.5
					U. giulianii				
Range	8-13	5-6	10-18	1-3	63-99	21-48	4.0-10.0	39-42	19-23
Mean (& N)	10.0 (4)	5.5 (2)	13.3 (4)	2.0 (2)	81.0 (2)	35.5 (4)	6.7 (3)	40.5 (2)	21.0 (2)
					U. lowei				
Range	10-26	7-19	11-35	5-13	65-100	26-58	0.3-2.0	39-49	31-36
Mean (& N)	18.0 (4)	12.5 (4)	27.8 (4)	8.8 (4)	84.0 (4)	42.8 (5)	1.3 (5)	44.5 (4)	34.0 (4)

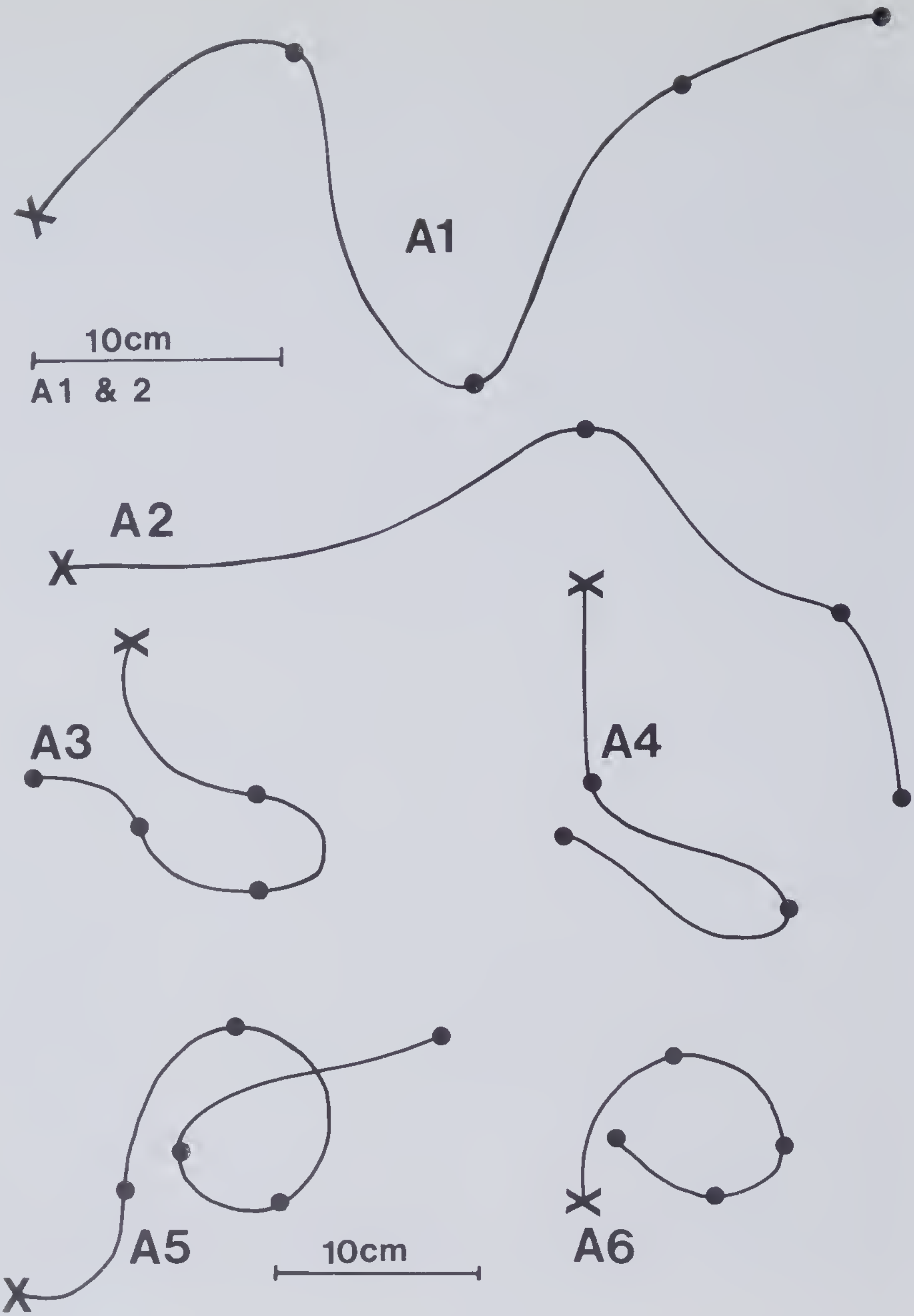

Fig. 1: Plan drawings of the burrows of various *Urodacus* species. A1, A2, *U. novaehollandiae*. A3 to A6, *U. armatus*. Burrow depths (cm) at the successive points from ground level (x = 0) are as follows: A1—0, 4, 11, 18, 20; A2—0, 10, 14, 18; A3—0, 6, 9, 13, 14; A4—0, 6, 15, 20; A5—0, 3, 9, 17, 19, 29; A6—0, 4, 6, 9, 11.

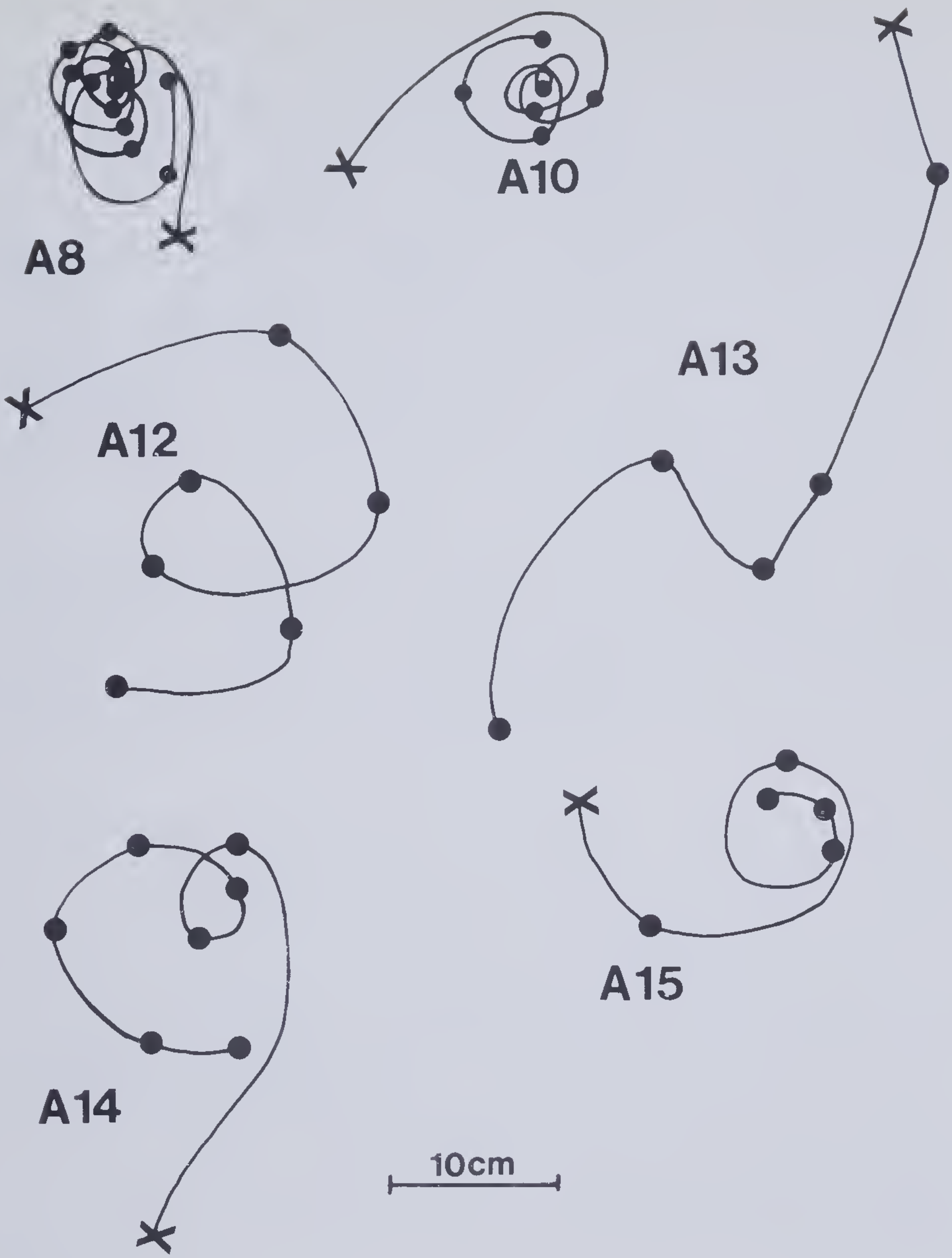

Fig. 2: Plan drawings of the burrows of various *Urodacus* species. A8, A10, *U. giulianii*. A12 to A15, *U. lowei*. Burrow depths (cm) at the successive points from ground level (x = 0) are as follows: A8—0, 6, 9, 10, 13, 17, 20, 22, 25, 32, 33, 38, 38; A10—0, 5, 7, 11, 15, 19, 22; A12—0, 11, 27, 30, 38, 52, 53; A13—0, 19, 28, 30, 36, 39; A14—0, 5, 12, 25, 30, 47, 52, 58; A15—0, 5, 8, 27, 36, 38.

Museum labels, and collectors, regarding the sites and nature of the burrows of *Urodacus* species are as follows.

U. manicatus. Burrows occur almost exclusively under rocks (viz. in an area at Canberra, A.C.T.; Smith, 1966). The rock selected by each scorpion usually covers a ground area of 36-71 sq. cm. Home sites have little or no leaf litter. The burrow is shallow, and horizontal or inclined.

U. novaehollandiae. Burrows may or may not be under rocks. In the hills, near Perth, W.A., e.g. at Boya and Darlington, the species occurs under rocks; each rock usually covers a ground area of about 91-897 sq. cm. Burrow depth is usually 25-30 cm, sometimes as much as 60 cm. There seems to be no fixed pattern of spiralling, the only common features being (1) the living area, (2) the terminal chamber of about 5 cm by 5 cm, and (3) that the burrow spirals slightly and irregularly to a depth of 10-20 cm before descending sharply to 25-60 cm.

Where the species occurs in rock-free ground, e.g. in the sandy coastal country at Bullsbrook, W.A., and Gnangara, W.A., the burrow entrances are found amongst the roots of shrubs and under fallen twigs and branches and also in open ground. The entrance width is 19 mm. These burrows spiral to a depth of about 30 cm ending more or less directly under the entrance. Burrows can be very abundant in these sandy areas, and were found as close together as 64 cm.

U. planimanus. Burrows are under rocks mainly on the foothills and slopes of lateritic hills. Each of these rocks usually covers a ground area of about 30 sq. cm. The burrow is shallow and sometimes scarcely evident.

U. armatus. Burrows are either under rocks (e.g. at Red Hill, W.A., the rock covered a ground area of 124-206 sq. cm) or, more often, in open ground. Burrows proceed downwards at about 45° and spiral loosely, sometimes tortuously. At Mt Remarkable, W.A., (in June 1969) the burrows were 15 cm deep, but at other localities they reached 36 cm. Some burrow plaster-casts made by a University of W.A. biology field-study group in a disturbed area at Dryandra, W.A., have a horizontal side tunnel about 6 cm long at 7 cm from the entrance.

U. megamastigus. Burrows are about 28 cm deep and occur in open ground.

U. hoplurus. Burrows are up to 68 cm deep. They are tortuously spiral, and occur under fallen branches or in open ground. Maximum entrance dimensions are length 41.3 mm, width 22.2 mm.

TABLE 2

CHARACTERISTICS OF THE BURROWS OF *URODACUS* SPECIES

Species	If burrows unknown: Expectation* (= x, y or z)	Cover: (+) Under rocks, logs, fallen twigs (—) In open ground	Depth: (A) Shallow (B) Moderately deep (C) Deep	Spiralling: (+) Yes (—) No	If spiralling, then tortuous: (+) Yes (—) No
1. *manicatus*		+	A	—	
2. *elongatus*	x				
3. *novaehollandiae*		+ and —	A to B	+	—
4. *planimanus*		—	A	—	
5. *centralis*	x				
6. *armatus*		+	B to C	+	—
7. *koolanensis*	y				
8. *megamastigus*		—	B	+	—
9. *varians*	y				
10. *hoplurus*		+ and —	B to C	+	+
11. *giulianii*		—	B to C	+	+
12. *carinatus*	z				
13. *macrurus*	z				
14. *excellens*	z				
15. *spinatus*		—	C	+	+
16. *lowei*		—	C	+	—
17. *similis*	z				
18. *hartmeyeri*		—	B (to C?)	+	—?
19. *yaschenkoi*		—	C	+	+

* x = expected to be similar to *novaehollandiae*
y = expected to be similar to *armatus*
z = expected to be similar to *lowei*

U. giulianii. Burrows are up to 48 cm deep, tortuously spiral, and occur in open ground.

U. spinatus. Burrows are tortuously spiral and mostly about 46 cm deep, but up to 92 cm deep at Cape York, Qld. They have been found in hard sandy soil (Kraepelin 1916), and in a sand and gravel ridge at Blue Mountains (Cape York Peninsula) Qld.

U. lowei. Burrows are loosely spiral, up to 58 cm deep, and occur in open ground.

U. hartmeyeri. Burrows occur in open ground in sandhills, and apparently are of moderate depth (about 15 cm). Entrance size is 25.4 mm by 19.0 mm.

U. yaschenkoi. Burrows are found in sandy soil. They are tortuously spiral, up to 100 cm deep, and occur in open ground. Entrance size reaches 55.0 mm by 25.0 mm.

The available information on entrance location, depth, and form of the burrows of all *Urodacus* species is summarized (Table 2). For those *Urodacus* species on which there are no direct observations, the burrow form that is to be expected is indicated. This expectation is based on the taxonomic resemblance of the species to other species in the genus and on the assumption that there is direct correlation between morphological similarity of the species and their burrow characteristics.

THE BURROWS OF *U. HOPLURUS* AND THEIR RELATIONS TO ENVIRONMENTAL FEATURES

The Study Areas

The following three areas were chosen because they had high abundance of *U. hoplurus* burrows and relatively homogeneous substrate.

(1) Marloo, W.A. — The observations were made from 31 January to 3 February, 1968, near the Marloo (28° 20′ S, 116° 08′ E) bungalow, 21 km from Gabyon Homestead. The area was of flat-land and the soil was shallow earthy loam with red-brown hardpan, rating Um 5.3 (Northcote, 1965). The vegetation was open mulga. Burrows were studied in a linear transect 3.7 m wide, orientated east to west from the bungalow.

In a nearby area of size 54 m by 91 m, on the afternoon of 2 February, 1968, after a short but heavy shower of rain, 55 *U. hoplurus* (consisting of 18 males 37 females) were dug from their burrows. That night in an adjacent area, three adult *U. hoplurus* were observed roaming on the ground.

(2) Mt Remarkable, W.A. — The observations were made from 14 to 17 June, 1969. The study area was near the junction of the road to Kalgoorlie (through Yerilla) and the road to the Mt Remarkable homestead (29° 20′

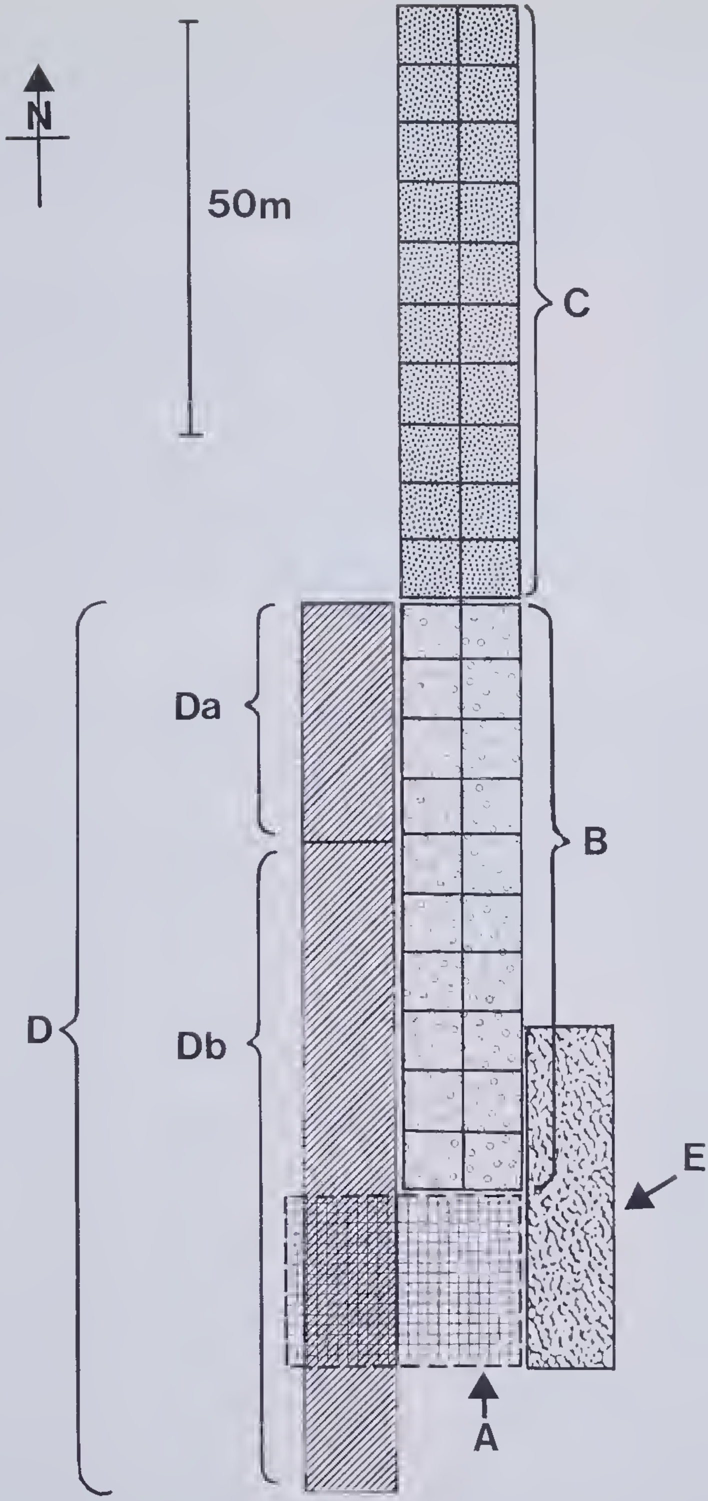

Fig. 3: Sub-areas A to E at Mt Remarkable, Western Australia.

S, 121° 59′ E). The land was flat with soil similar to that at Marloo. Vegetation consisted of four main shrubs and trees: *Acacia aneura* F. Muell., *A. craspedocarpa* F. Muell., *A. tetragonophylla* F. Muell., and *Eremophila compacta* S. Moore. The first two were the most common. There were many dry branches on the ground. There were no recently dead trees or fresh fallen branches. Night searches were conducted during the period, but no roaming scorpions were found.

The area was divided into five sub-areas (Fig. 3) by scraping straight lines to form grids on the ground. These sub-areas had the following dimensions.

Sub-area A	21.6 m by 28.8 m
Sub-areas B and C	Each sub-area was 14.4 m by 72.0 m, and was further sub-divided into 20 squares, each of side length 7.2 m
Sub-area D	10.8 m by 108.0 m Da was 10.8 m by 28.8 m; Db was 10.8 m by 79.2 m
Sub-area E	11.8 m by 42.0 m

In sub-area A, plan drawings were made of the burrows and the scorpions were collected; in sub-areas B to E, the disposition of the burrows was recorded in relation to various habitat features.

(3) 8 km ESE of Kookynie, W.A. — This is 48 km W of the Mt Remarkable sampling area. On 19 June 1969, burrows were investigated in an area 100 m by 100 m.

Nature of the Data Recorded

1. Burrow entrance dimensions.
2. Various burrow parameters (Table 3; and Tables 4-7 for *U. hoplurus* and *U. yaschenkoi*).
3. Direction (to nearest 22° 30′) that burrow entrance faced.
4. Clockwise or anticlockwise spiralling of burrow.
5. Presence or absence of a nearby shrub (30 cm to 3 m in height) or tree (3 m or more in height) within 3.0 m (also within 3.7 m) of burrow entrance.
6. Distance (to nearest 30 cm) from mid-point of burrow opening to middle of base of closest tree. Whether the tree was living or dead was noted.
7. The angle of the burrow (along burrow width) to closest tree. Four categories: facing, backing, right angle, intermediate angle.

8. The turning angle, i.e. the smaller of the two angles required to be turned by a scorpion leaving the burrow in order to face the tree. Four categories: facing, backing, parallel, intermediate angle.
9. The number of burrows that had a fallen branch along the top edge of entrance.
10. Presence or absence of a fallen branch within 3.8 m (also within 60 cm) of burrow entrance.
11. The angle that a branch formed with the burrow entrance. Four categories: parallel, right angle, 45° angle, intermediate angle.
12. The number of isolated fallen branches with no burrow entrance within 75 cm. To be counted a branch had to be of length 107 cm or more, width 60 cm or more, and obviously not part of another fallen branch.
13. Presence or absence of a fresh tumulus of soil.
14. Presence or absence of litter, i.e. leaves and twigs within 15.2 cm of the entrance; twigs were defined as having a diameter of less than 2.0 mm.

Results and Analysis

At Marloo, *U. hoplurus* burrows had entrance widths of 3.2 cm to 3.8 cm (n = 12). Burrows were 20 cm to 25 cm deep and the terminal chamber was 5.0 cm wide, 2.5 cm high and 5.0 cm long (n = 4). The surface distance from entrance to chamber was 10 cm. Compass direction and number of burrows were: N 2, NW 1, S 2, SE 1, ESE 2, NE 2. There was 50% (i.e. n = 6) clockwise spiralling. There were two burrows 50 cm from a 1.2 m to 1.5 m high shrub, and there was one burrow 3.7 m from a large tree with its entrance turned 90° from the tree. Two of the burrows (16.7%) had a fallen branch across the top edge of the entrance. In the area 54 m by 91 m, near Marloo, the closest two burrows were 1 m apart. Since there were 55 burrows, the abundance of burrows was 1 every 8.8 sq. m.

At Mt Remarkable, sub-area B, of size 14.4 m by 72.0 m, had 63 burrows. The frequency of occurrence of the burrows in the 20 squares was 0 burrows (3 squares), 1 (4), 2 (3), 3 (0), 4 (3), 5 (3), 6 (2), 7 (2). Sub-areas B to E with a total area of 3725.6 sq. m had 176 burrows; hence the abundance of burrows was 1 every 21.2 sq. m. (In sub-area A, which partly overlaps part of area D, the abundance of burrows was 1 every 41.5 sq. m). The highest abundance of burrows was 1 every 7.4 sq m; this was in sub-area E, 11.8 m by 42.0 m.

For a total of 166 *U. hoplurus* burrows, 71 were clockwise giving a figure of 42.8% clockwise spiralling. [For a total of 93 *U. yaschenkoi* burrows, 47 were clockwise giving a figure of 50.6% clockwise spiralling. Spiralling direction in terms of burrow dimensions is analysed later (Table 6).]

The direction of facing of the burrow entrance appears to bear no relation to any particular compass direction, the values for 154 *U. hoplurus* burrows being: N 12, NNE 3, NE 19, ENE 6, E 9, ESE 8, SE 18, SSE 4, S 14, SSW 4, SW 18, WSW 7, W 1, WNW 6, NW 12, NNW 8. In sub-area E, the turning angle of 56% (total n = 29) of the burrow entrances was parallel in relation to orientation to trees within 3 m.

U. hoplurus is among those species of *Urodacus* that have large burrow entrances. The following ranges and mean values of entrance dimensions (mm) of *U. hoplurus* were obtained for the combined data from one locality, Mt Remarkable: length 15.9-41.3 (29.2) n = 78; width 6.4-22.2 (12.8) n = 78.

The numbers of burrow entrances in relation to orientation to trees at Mt Remarkable were as follows. Entrance facing a tree, 7; entrance backing a tree, 6; entrance at 90° to a tree, 14. Thus about half of burrow entrances were orientated at 90° and the other half were edge on to the trees. About half the trees, having burrow entrances within 3 m, in the total area were living trees. Shrubs having burrow entrances within 3 m, in sub-area E, represented 6% of the total number of trees and shrubs.

The number of burrow entrances in relation to the angles they made with fallen branches were as follows. Entrance parallel to a branch, 18; entrance at 90° to a branch, 4. Thus 81.8% of those burrow entrances that were near fallen branches were oriented parallel to the branches.

TABLE 3

PRESENCE AND ABSENCE OF *URODACUS HOPLURUS* BURROW SITES IN RELATION TO VARIOUS ENVIRONMENTAL FEATURES

Feature	Present	Absent	% Present
Litter	82	50	62.1
Fallen branch	124	52	70.4
Tree	109	67	61.9
Fresh tumulus	94	36	72.3

Totals (Table 3) of the presence or absence of litter, a fallen branch, a tree within 3 m, and a fresh tumulus at each burrow site reveal that high percentages (61.9 to 72.3%) of burrows were associated with the presence of each of these environmental features. A Chi-square analysis of these various features against one another shows that the number of burrows associated with any one of these features is not more significantly higher (at 5% probability level) than that with any other of the features: litter *vs* fallen branch χ^2 =

2.006, d.f. = 1, P = 0.16; litter *vs* tree χ^2 = 0.001, d.f. = 1, P = –; fallen branch *vs* tree χ^2 = 2.860, d.f. = 1, P = 0.01.

THE BURROWS OF *U. HOPLURUS* AND *U. YASCHENKOI*

U. hoplurus and *U. yaschenkoi* are both large species which have deep, tortuously spiral burrows. But whereas the burrows of *U. yaschenkoi* occur in open ground, those of *U. hoplurus* occur not only in open ground but also under cover.

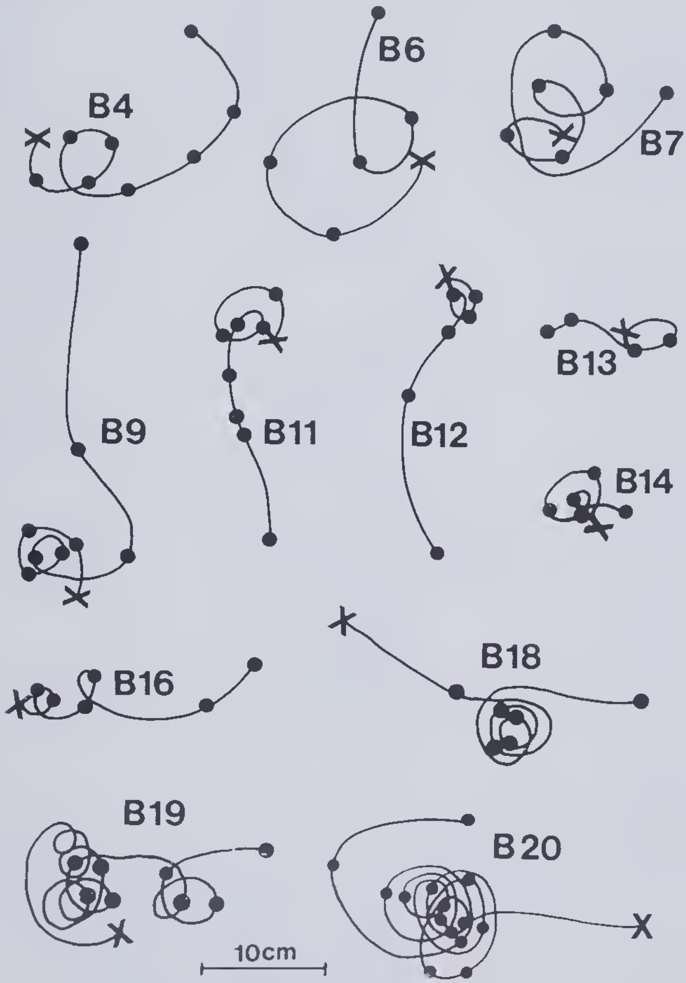

Fig. 4: Plan drawings of the burrows of *Urodacus hoplurus*. Burrow depths (cm) at the successive points from ground level (x = 0) are as follows: B4—0, 4, 6, 8, 9, 15, 22, 24, 25; B6—0, 10, 13, 25, 34, 39; B7—0, 4, 6, 10, 17, 23, 30; B9—0, 4, 6, 7, 8, 10, 22, 25, 30; B11—0, 4, 6, 8, 10, 15, 20, 20, 23; B12—0, 5, 5, 8, 10, 20, 25; B13—0, 5, 11, 18, 20; B14—0, 3, 6, 8, 14, 20; B16—0, 8, 10, 13, 15, 27, 28; B18—0, 9, 11, 18, 22, 26, 27; B19—0, 8, 11, 15, 22, 25, 33, 39, 46; B20—0, 9, 10, 14, 16, 19, 22, 27, 30, 32, 37, 38, 43, 47, 52.

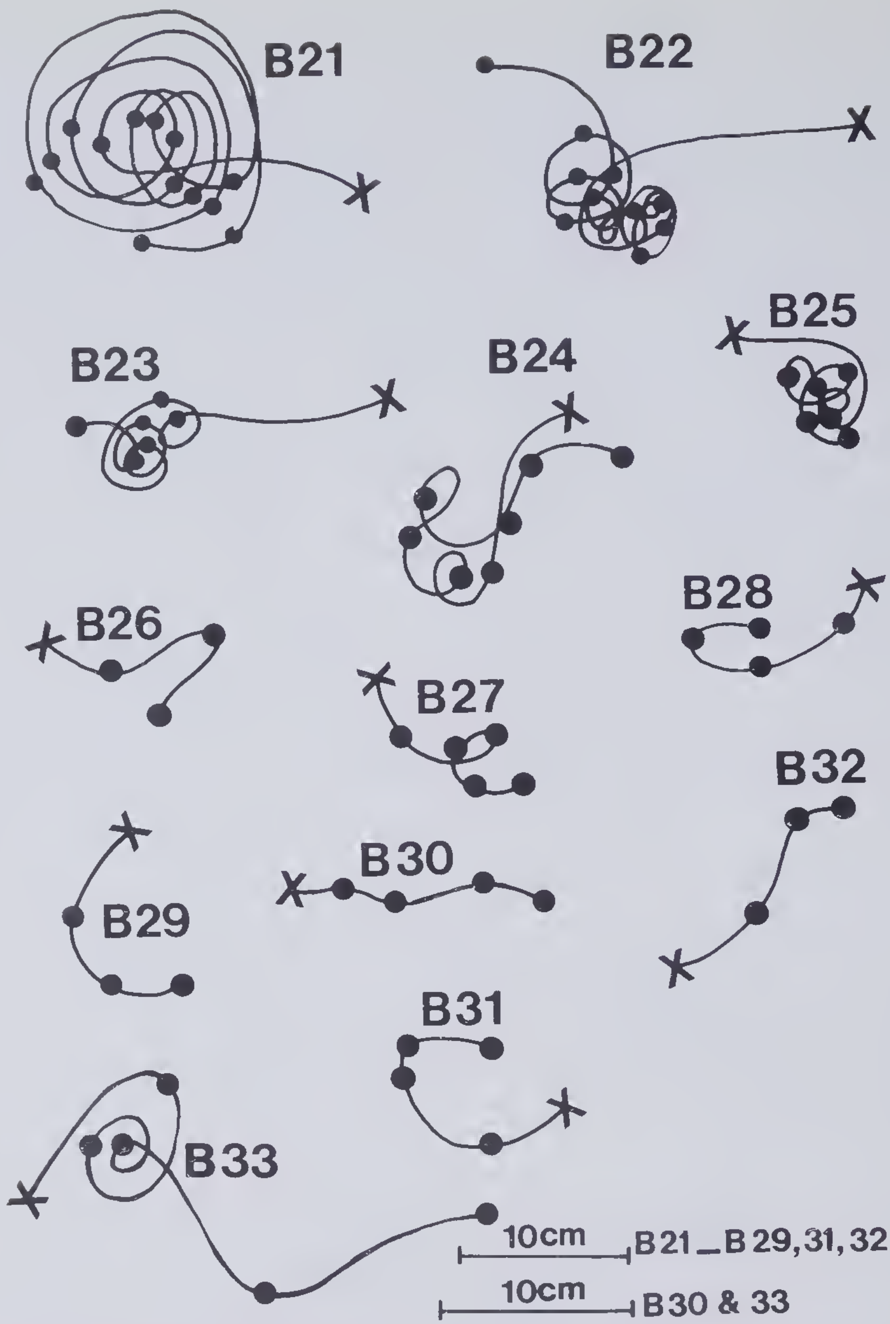

Fig. 5: Plan drawings of the burrows of *Urodacus hoplurus*. Burrow depths (cm) at the successive points from ground level (x = 0) are as follows: B21—0, 4, 9, 13, 18, 22, 29, 34, 45, 50, 57, 60, 64, 68; B22—0, 6, 13, 17, 18, 25, 36, 46, 52, 59, 64; B23—0, 4, 6, 8, 11, 13, 15; B24—0, 5, 6, 8, 13, 15, 18, 19; B25—0, 3, 5, 7, 10, 13, 14; B26—0, 5, 15, 18; B27—0, 1, 1, 2, 10, 12; B28—0, 3, 10, 15, 17; B29—0, 5, 13, 16; B30—0, 3, 11, 14, 15; B31—0, 4, 3, 15, 15; B32—0, 1, 13, 17; B33—0, 8, 14, 18, 21, 25.

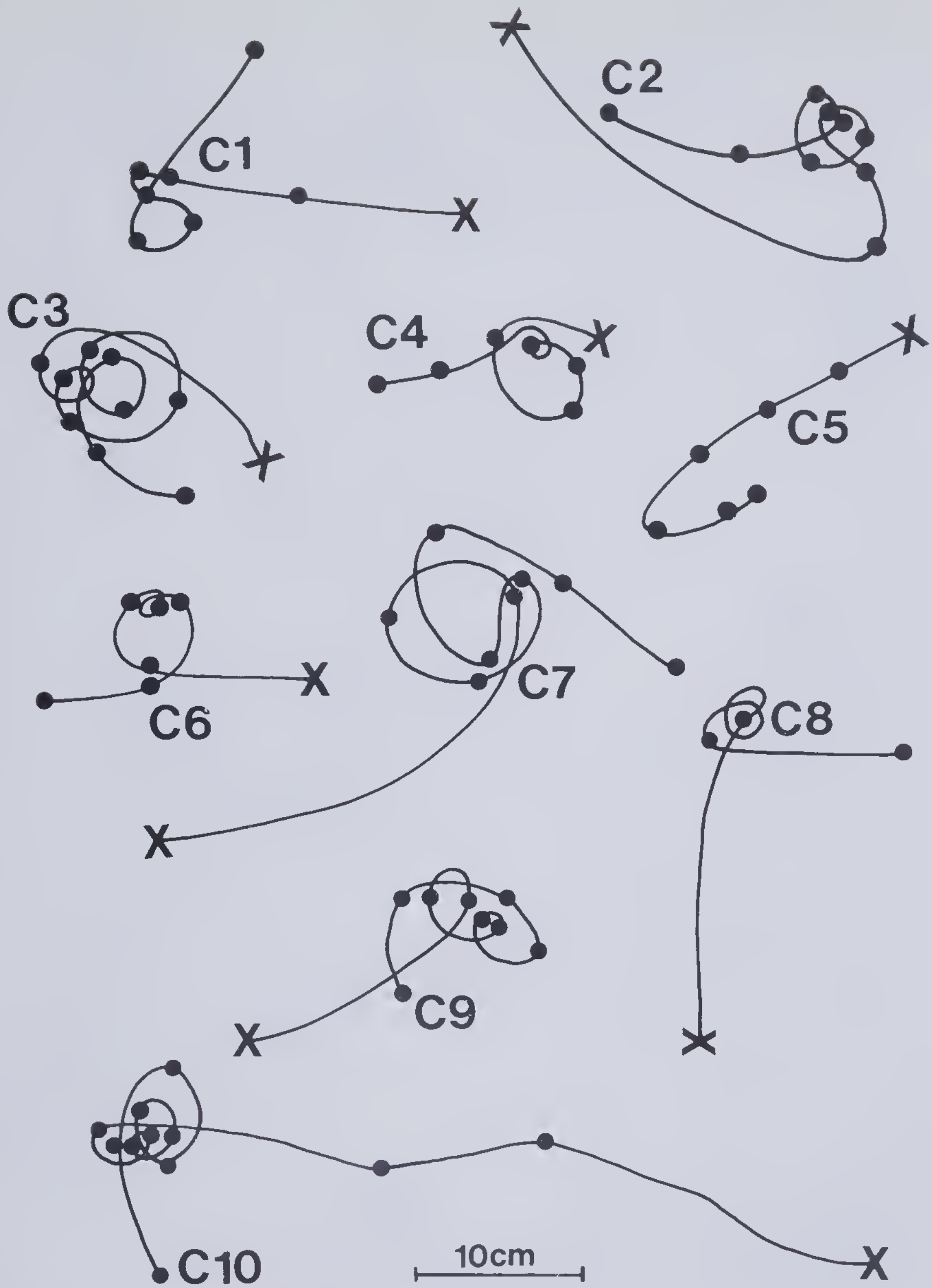

Fig. 6: Plan drawings of the burrows of *Urodacus yaschenkoi.* Burrow depths (cm) at the successive points from ground level (x = 0) are as follows: C1—0, 8, 14, 18, 21, 26, 29, 31; C2—0, 6, 11, 15, 19, 24, 25, 30, 37, 39; C3—0, 6, 9, 11, 15, 17, 19, 24, 28, 30; C4—0, 5, 14, 15, 21, 26, 27; C5—0, 5, 7, 10, 14, 19, 20; C6—0, 6, 9, 11, 17, 23, 25; C7—0, 7, 14, 17, 21, 27, 37, 45, 46; C8—0, 6, 28, 30; C9—0, 4, 10, 15, 18, 24, 30, 35, 38; C10—0, 6, 9, 13, 15, 22, 27, 34, 38, 40, 40, 46.

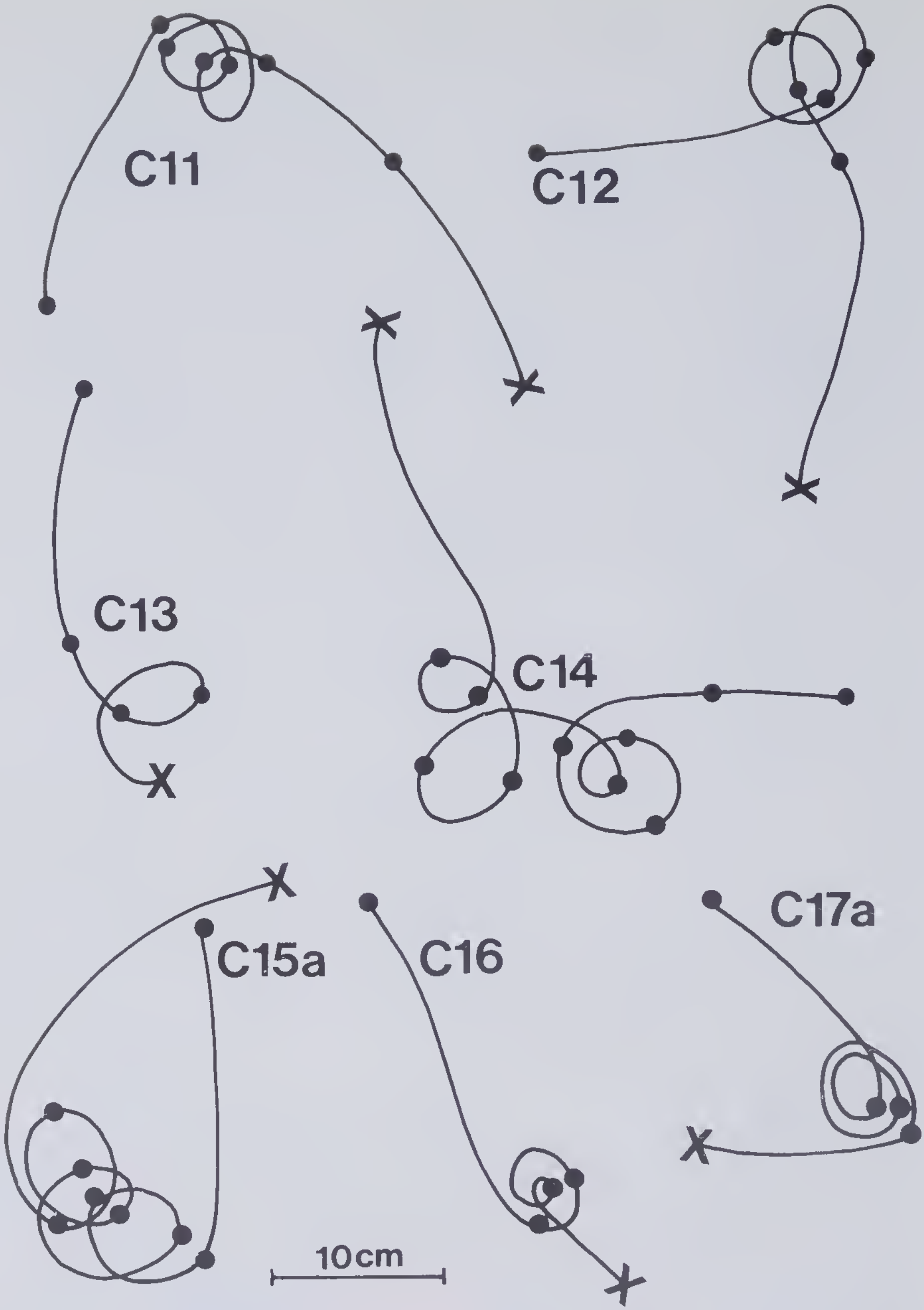

Fig. 7: Plan drawings of the burrows of *Urodacus yaschenkoi*. Burrow depths (cm) at the successive points from ground level (x = 0) are as follows: C11—0, 6, 14, 30, 35, 38, 39, 40; C12—0, 10, 15, 23, 27, 32, 36; C13—0, 8, 10, 17, 23; C14—0, 5, 11, 17, 20, 32, 47, 54, 66, 69, 72; C15a—0, 10, 13, 18, 25, 33, 41, 50, 55; C16—0, 15, 18, 25, 29; C17a—0, 10, 19, 37, 42.

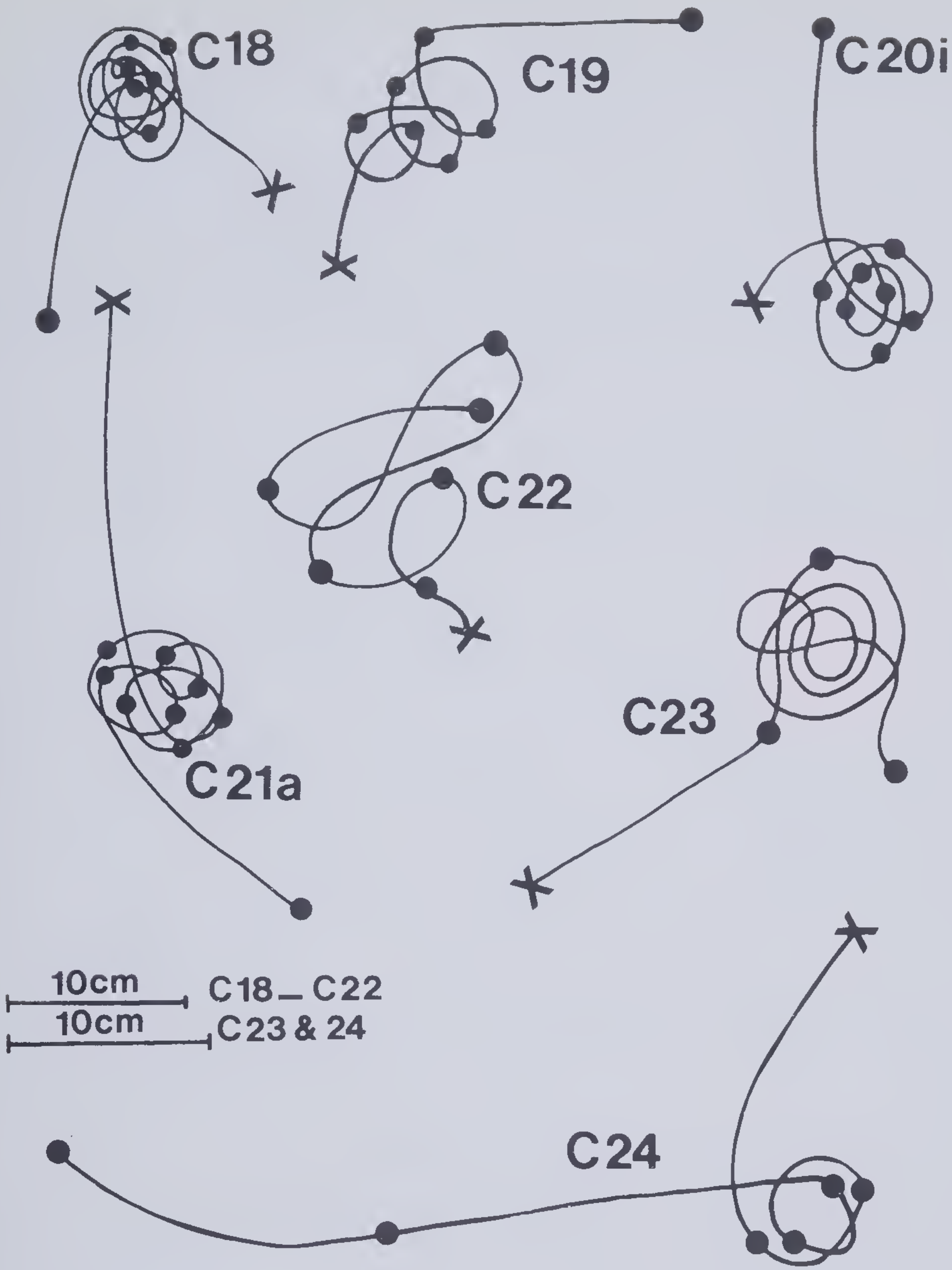

Fig. 8: Plan drawings of the burrows of *Urodacus yaschenkoi.* Burrow depths (cm) at the successive points from ground level (x = 0) are as follows: C18—0, 8, 13, 19, 24, 34, 53, 54, 60; C19—0, 9, 14, 22, 30, 43, 48, 53; C20i—0, 10, 18, 24, 30, 37, 44, 53, 60; C21a—0, 11, 17, 20, 27, 30, 40, 44, 54, 58; C22—0, 8, 14, 29, 41, 47, 50; C23—0, -, -, 71; C24—0, 11, 23, 28, 33, 38, 39.

TABLE 4

VALUES OF BURROW PARAMETERS IN *URODACUS HOPLURUS* AND *URODACUS YASCHENKOI*
(measurements in cm)

Burrow Nos: *U. hoplurus* B4, B6, B7, B9, B11-14, B16, B18-35
U. yaschenkoi C1-4, C6-14, C15a, C17a, C18-20, C21a, C22-24

Statistic	Burrow entrance to first quarter turn		Last quarter turn to middle of chamber		Total length (l)	Total depth (d)	Total no. of turns	Angle of descent (o) during first quarter turn (ϕ) ($\tan \phi = dl/sl$)
	Length (sl)	Depth (dl)	Length	Depth				
				U. hoplurus				
Range	5.08-17.78	1.27-10.16	6.35-35.56	1.27-13.97	20.32-182.88	12.70-67.31	0.3-8.0	14-59
Mean	8.89	5.56	15.66	4.68	61.13	27.78	2.68	37.46
S.D.	3.76	2.39	8.27	3.36	43.31	15.31	2.20	9.12
N	26	24	24	22	23	24	25	24
				U. yaschenkoi				
Range	10.16-27.94	5.08-16.51	7.62-53.34	1.27-10.16	45.72-125.73	25.40-72.39	1.3-5.5	18-42
Mean	19.63	10.04	22.51	5.26	84.18	44.74	2.95	30.76
S.D.	4.60	3.26	10.84	2.06	24.54	13.90	1.00	5.90
N	22	21	22	21	21	22	22	21

Plan drawings are presented of the burrows of *U. hoplurus* (Figs 4, 5) and *U. yaschenkoi* (Figs 6, 7, 8). The ranges, means and standard deviations of the burrow parameters are presented for *U. hoplurus* (Table 4) and *U. yaschenkoi* (Tables 4, 8 and 9). The results of statistical comparisons ('t' tests) of the burrow parameters of these two species are presented in Table 6. The analysis reveals some significant differences between the two species. *U. yaschenkoi* has significantly greater length and depth of burrow from entrance to first quarter turn (P<0.001), length from last quarter turn to middle of terminal chamber (P<0.05), and total length (P<0.05) and total depth (P<0.001) of burrow. *U. hoplurus* has a significantly greater angle of descent from burrow entrance to first quarter turn (P<0.01 and P<0.001).

TABLE 5

STATISTICAL COMPARISONS ('t' TESTS) OF BURROW PARAMETERS OF *URODACUS HOPLURUS* AND *U. YASCHENKOI*

(measurements in cm)

[Data from Raw Data Tables A.4.6 and A.4.7; including all clockwise and anticlockwise spiralling]

Parameter:
- A Burrow entrance to first quarter turn, length
- B Burrow entrance to first quarter turn, depth
- C Last quarter turn to middle of chamber, length
- D Last quarter turn to middle of chamber, depth
- E Total length
- F Total depth
- G Total number of turns
- H Angle of descent to first quarter turn

Parameter	Mean		t	d.f.	P
	U. hoplurus	*U. yaschenkoi*			
A	8.89	19.63	30.73	46	***
A (including data from Raw Data Tables A.4.8 and A.4.9)	8.89	18.58	10.83	119	***
B	5.56	10.04	5.30	43	***
B (including data from Raw Data Tables A.4.8 and A.4.9)	5.56	9.23	6.05	81	***
C	15.66	22.51	2.42	44	*
D	4.68	5.26	0.68	41	n.s.
E	61.13	84.18	2.14	42	*
F	27.78	44.74	3.92	44	***
G	2.68	2.95	0.53	45	n.s.
H	37.46	30.76	2.88	43	**
H (including data from Raw Data Table A.4.8)	37.46	30.92	4.02	81	***

* P<0.05 ** P<0.01 *** P<0.001

TABLE 6

STATISTICAL COMPARISONS ('t' TESTS) OF DIRECTION OF SPIRALLING IN RELATION TO BURROW PARAMETERS IN *URODACUS HOPLURUS* AND *U. YASCHENKOI*

(measurements in cm)

Parameter:
- A Burrow entrance to first quarter turn, length
- B Burrow entrance to first quarter turn, depth
- C Last quarter turn to middle of chamber, length
- D Last quarter turn to middle of chamber, depth
- E Total length of burrow
- F Total depth of burrow
- G Total number of turns
- H Angle of descent to first quarter turn

Parameter	Mean Clockwise	Mean Anticlockwise	t	d.f.	P
		U. hoplurus			
A	9.11	9.49	0.21	20	n.s.
B	5.72	5.93	0.18	18	n.s.
C	17.42	16.31	0.27	18	n.s.
D	5.81	4.50	0.74	16	n.s.
E	56.24	76.43	0.91	16	n.s.
F	28.30	32.07	0.48	17	n.s.
G	2.76	4.43	2.14	18	*
H	37.57	37.50	0.01	17	n.s.
		U. yaschenkoi			
A	18.42	21.34	1.41	18	n.s.
A (Raw Data Table A.4.8)	16.87	17.93	0.90	36	n.s.
A (Raw Data Table A.4.9)	20.96	17.85	2.37	33	*
B	8.38	11.94	2.82	18	**
B (Raw Data Table A.4.8)	8.22	9.49	2.05	36	*
C	25.65	21.59	0.84	18	n.s.
D	5.59	4.57	1.19	18	n.s.
E	88.14	82.04	0.54	18	n.s.
F	42.80	43.43	0.11	18	n.s.
G	3.25	2.46	1.97	18	n.s.
H	28.10	33.70	2.31	18	*
H (Raw Data Table A.4.8)	29.57	17.93	9.20	36	***

* $P<0.05$ ** $P<0.01$ *** $P<0.001$

TABLE 7

CORRELATION ANALYSIS OF BURROW PARAMETERS IN *URODACUS HOPLURUS* AND *U YASCHENKOI*

Parameter:

- A Burrow entrance to first quarter turn, length *vs* depth
- B Last quarter turn to middle of chamber, length *vs* depth
- C Total length *vs* total depth
- D Total length *vs* total number of turns
- E Total depth *vs* total number of turns
- F Total length *vs* angle of descent
- G Total depth *vs* angle of descent
- H Total number of turns *vs* angle of descent
- I Burrow entrance to first quarter turn (Raw Data Table A.4.8), length *vs* depth
- J Burrow entrance to first quarter turn (Raw Data Table A.4.8), length *vs* angle of descent
- K Burrow entrance to first quarter turn (Raw Data Table A.4.8), depth *vs* angle of descent

Parameter	r	d.f.	P
	U. hoplurus		
A	0.88	22	**
B	0.59	20	**
C	0.94	21	**
D	0.86	21	**
E	0.79	22	**
F	—0.24	20	n.s.
G	—0.12	20	n.s.
H	—0.23	20	n.s.
	U. yaschenkoi		
A	0.81	19	**
B	0.14	19	n.s.
C	0.82	19	**
D	0.64	19	**
E	0.76	20	**
F	—0.25	19	n.s.
G	—0.33	19	n.s.
H	—0.39	19	n.s.
I	0.76	36	**
J	—0.30	36	n.s.
K	0.38	36	*

* $P<0.05$ ** $P<0.01$

TABLE 8

VALUES OF BURROW PARAMETERS IN *URODACUS YASCHENKOI*

Burrow Nos: C5, C13, C15b-h, C17b-u, C21b-j

Statistic	Burrow entrance to first quarter turn		Angle (o) of descent during first quarter turn
	Length (cm)	Depth (cm)	
Range	11.43-26.67	6.35-13.97	22-46
Mean	17.35	8.79	31.00
S.D.	3.57	1.97	5.30
N	38	38	38

The significance of clockwise against anticlockwise spiralling has been statistically analysed ('t' tests) in relation to each of the burrow parameters (Table 6). The analysis shows that for most burrow parameters of *U. hoplurus* there is no significant difference between the two directions of spiralling, but that the total number of turns is greater ($P<0.05$) in burrows exhibiting anticlockwise spiralling. This last result, however, is on the borderline of significance.

In the data pertaining to *U. yaschenkoi*, there is no significant difference between the two directions of spiralling. But with respect to the length from burrow entrance to first quarter turn there is a significantly higher number ($P<0.05$) of burrows having clockwise spiralling in one analysis (that of the data referred to in Table 9). With respect to the depth from burrow entrance to first quarter turn there are significantly higher numbers ($P<0.01$ and $P<0.05$) of burrows having anticlockwise spiralling in two analyses (that of the data referred to in Tables 4 and 8). (The angle of descent to the first quarter turn is more highly significant ($P<0.05$) anticlockwise in one analysis and more highly significant ($P<0.001$) clockwise in an analysis using another set of data.)

The results are presented of correlation analyses of the various parameters (Table 7). As would be expected, both length and depth are very strongly correlated. Similarly, there are very strong correlations between total length and total number of turns, as well as total depth and total number of turns. Although the correlation between the angle of descent to the first quarter turn and either length or depth of burrow is not statistically significant, the analysis shows that the relationship is inverse as would be expected on a logical basis.

TABLE 9

VALUES OF A BURROW PARAMETER IN *URODACUS YASCHENKOI*

Burrow Nos: C20ii-xxxvi

Statistic	Burrow entrance to first quarter turn Length (cm)
Range	12.70-27.94
Mean	19.27
S.D.	4.12
N	35

Discussion

Neither *U. hoplurus* nor *U. yaschenkoi* was observed digging during the daytime, but observations made at night showed much evidence of fresh soil having been added to tumuli. In hard soil, *U. hoplurus* ceased digging at about 3 cm; there were five such "false-start burrows" in sub-area B, 14.4 m by 72.0 m, at Mt Remarkable.

The sampling area at Marloo, as well as the Mt Remarkable areas, are low-lying and were damp; they would be under water at frequent intervals during the wet season. In general, it seems that the areas of red-brown soil, in which *U. hoplurus* is abundant, are subject to flooding. Examination of such areas during wet years indicates that places around trees are the least likely to become flooded. There are naturally more fallen branches in places with dead trees and more litter in places with living trees. As shown in the present study, the abundance of *U. hoplurus* burrows is positively correlated with such places. This finding could indicate an adaptation by *U. hoplurus* to maintain a permanent burrow by reducing the chances of excess flooding of its burrows. General observations on *U. yaschenkoi* indicate that it occurs mainly in open country. Its burrows occur in sandy soil which would make them less prone to flooding than *U. hoplurus* burrows.

Burrow entrances of *U. hoplurus* are orientated in the same direction as fallen branches where these contact the ground. The choice by individuals of the actual direction of facing of these burrows would be expected to be influenced by prevailing wind direction, with orientation of the entrances being such as to avoid sand and litter being blown into the burrows. Studies of general wind direction in an area, however, would be difficult because wind direction would alter depending upon many factors and their combinations in the micro-environment around burrows situated amongst rocks, logs, tree bases and branches on the ground. Topography in general has to affect the direction of entrance facing in any burrowing species, but does not apply here because *U. hoplurus* was studied on level ground. The choice of direction of burrow facing would not be influenced by factors such as intense light or shade from trees because burrows are constructed mainly at night.

All the *U. hoplurus* burrows in the study areas were occupied except for a few (less than 1%) that were old. This indicates low mortality because higher percentages of abandoned burrows, estimated as being several weeks old, had been noted at other localities.

Except in a few burrows (less than 4%), the direction of spiralling did not reverse. The choice of burrow spiralling direction seems to be fortuitous. The possibility that abnormalities in features of the hands are responsible for choice of spiralling direction is precluded because these scorpions do not lose their hands in combat and they are bilaterally symmetrical. Advantages of the extensive spiralling would include reducing the effects of wind-blown debris and sheet-flooding, and the avoidance of neighbouring burrows under crowded conditions; also the continual change in direction would make it difficult for predators (e.g. the large lizard, *Varanus gouldi*, as recorded by Koch, 1970) to locate the scorpion. The main function of spiralling, however, is the maintenance of suitable levels of moisture and temperature (as discussed in the next section).

ADAPTATIONAL AND EVOLUTIONARY TRENDS REVEALED BY *URODACUS* BURROWS

The species of *Urodacus* can be classified according to the type of burrow they build.

Type 1: shallow burrows under objects, especially small rocks, on the ground.

Type 2: deep tortuously spiral burrows present in open ground.

Most *Urodacus* species belong to one or other of these types, e.g. *U. manicatus* and *U. planimanus* to Type 1 and *U. spinatus* and *U. yaschenkoi* to Type 2. Two examples of intermediate species are *U. novaehollandiae* and *U. hoplurus*. *U. novaehollandiae* has burrows of Type 1, but in a few areas has moderately deep, loosely spiral burrows in open ground; thus it is an intermediate species which is closer to Type 1 than to Type 2. *U. hoplurus* has moderately deep to deep tortuously spiral burrows which occur either under cover, usually consisting of branches on the ground, or in open ground. Thus *U. hoplurus* also is an intermediate species. The presented study on the distribution and abundance of *U. hoplurus* burrows in relation to various environmental features has been in areas having cover in the form of fallen branches, twigs and litter. The results reveal in particular that *U. hoplurus* shows a preference for making its burrows under cover. Hence in this regard *U. hoplurus* is closer to Type 1 than to Type 2, although in regard to the depth and tortuousness of its burrows it is closer to Type 2.

The burrows of *Urodacus* scorpions, like those of other creatures, reach a depth where conditions are favourable. It is well known (Andrewartha, 1964; Gray, 1968; Ettershank, 1971; Shorthouse, 1971) that, in contrast to the wide range of temperature and the excessive heat and dryness at ground level, the air in soil-burrows remains at moderate temperature and high humidity. For example, at least the air in the bottom chamber of burrows of ctenizid trapdoor spiders remains saturated while hot dry summer conditions prevail at the surface. Saturated air occurs below 8-10 cm in clay soils and 20 cm in sandy soils (Gray, 1968). Spider burrows which have plastered silken linings and often have lids can afford to be considerably shallower than the unlined burrows of carabid beetles and scorpions. Certain other small animals rely upon underground refuges at least during the hottest times of day, e.g. some species of the lizard genus *Amphibolurus* which have penetrated extensively into arid regions (Bradshaw & Main, 1968).

The burrows of *Urodacus* in open ground, in contrast to those under surface objects, are deeper, have more spirals, and occur in the more arid parts of Australia. These observations indicate the important role of the numerous spirals of a scorpion's open burrow in maintaining a suitable micro-environment of moisture and temperature.

These traits in burrowing habits are paralleled by evolutionary trends in the morphology of the scorpions (Koch, 1977). These changes in *Urodacus* species in relation to increasing aridity include larger size, lighter colour, higher trichobothrial numbers, more complex capsule of male paraxial organ, and more exaggerated development of unequal terminal claws on the legs. *U. yaschenkoi*, which is widespread where the annual rainfall is less than 550 mm, displays all these morphological trends and is the extreme example of the Type 2 burrow recognized above.

In conclusion, it is clear that deep spiral burrow construction has evolved as an adaptation for the avoidance of harsh surface conditions, and has enabled species of the genus *Urodacus* to spread to otherwise inhospitable arid environments.

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

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ABSTRACT

The 17 species and subspecies of *Egernia* occurring in Western Australia are described and keyed, viz. *E. depressa* (Günther), *E. stokesii stokesii* (Gray), *E. stokesii aethiops* nov., *E. stokesii badia* nov., *E. kingii* (Gray) [syn. *E. nitida* (Gray)], *E. napoleonis* (Gray) [*E. nitida* of authors, not Gray], *E. carinata* H.M. Smith, *E. formosa* Fry, *E. douglasi* Glauert, *E. luctuosa* (Peters) [syn. *E. lauta* DeVis], *E. pilbarensis* nov., *E. pulchra pulchra* Werner, *E. pulchra longicauda* Ford, *E. multiscutata bos* Storr, *E. inornata* Rosén, *E. striata* Sternfeld, *E. kintorei* Stirling & Zietz. A lectotype is designated for *Tropidolopisma dumerilii* Duméril & Bibron [= *E. kingii*]. The Victorian representative of *E. luctuosa* is described as a new species, *E. coventryi*.

INTRODUCTION

This paper brings up to date an earlier revision of the *Egernia whitii* group (Storr, 1968) and deals for the first time since Mitchell (1950) with the other western members of the genus. It is based on specimens in the Western Australian Museum (registered numbers cited without prefix). I have also used some specimens in the National Museum of Victoria (numbers prefixed with NMV), Australian Museum (AM), Queensland Museum (QM), collection of the British Joint Services Expedition to Central Australia (JSE), and British Museum (Natural History), for the loan of which I am indebted to Mr A.J. Coventry, Dr H.G. Cogger, Miss J. Covacevich, Lt-Cdr A.Y. Norris and Mr A.F. Stimson.

I am grateful to Mrs Ariadna Neumann for translating Peters' original descriptions of *Cyclodus (Omolepida) luctuosus* and *Tropidolepisma richardi*.

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Egernia Gray, 1839, Ann. nat. Hist. 2: 288. Type-species (by monotypy): *Tiliqua cunninghami* Gray.

Tropidolopisma Duméril & Bibron, 1839, 'Erpétologie générale' 5: 744. Type-species (by monotypy): *Tropidolopisma dumerilii* Duméril & Bibron [= *E. kingii*].

Liopholis Fitzinger, 1843, 'Systema reptilium', p. 22. Type-species (by monotypy): *Lygosoma moniligera* Duméril & Bibron [= *E. whitii*].

Silubosaurus Gray, 1845, 'Catalogue . . . lizards . . . British Museum', p. 104. Type (by monotypy): *Silubosaurus stokesii* Gray.

Tropidolepisma Gray, 1845, 'Catalogue . . . lizards . . . British Museum', p. 105. Emendation of *Tropidolopisma* Duméril & Bibron.

Lissolepis Peters, 1872, Mber. k. preuss. Akad. Wiss. 1872: 776. Type (by monotypy): *Lissolepis luctuosa* (Peters).

Diagnosis

Medium to very large skinks with strong pentadactyl limbs, lower eyelid moveable and without transparent disc, interparietal completely separating parietals, no supranasal, four supraoculars (first two in contact with frontal), normally two loreals, usually two presuboculars, normally three temporals (lower secondary usually largest, primary smallest), and prominent ear aperture bearing one or more large lobules. Distinguishable from *Tiliqua* by fragile tail (except in *E. depressa* and *stokesii*), unpigmented tongue, and absence of occipitals and large suboculars (when suboculars present in *Egernia* they are much smaller than presuboculars).

Distribution

Australia, Tasmania and New Guinea.

Species-groups

The Western Australian species of *Egernia* can be allotted to one or another of five groups*, viz.

* The sixth species-group of *Egernia*, viz. the *major* group (Horton, 1972), does not extend to Western Australia. The supposed occurrence of one of its members, *E. richardi*, in the Kimberley Division (Cogger, 1975), is based on the erroneous belief that *richardi* is an older name for *E. douglasi*.

(1) *cunninghami* group

These are moderately large to very large spiny skinks. The two western species, *E. depressa* and *stokesii*, have the tail very short, non-fragile, and heavily armed with recurved spines. They are consequently hard to extract from their hiding places — hollow logs or rock crevices in arid and semi-arid country. They are partly vegetarian.

(2) *kingii* group

This group is closest to the *striolata* group, from which its single member differs in its greater size and style of coloration. *E. kingii* is endemic to the wetter parts of southwestern Australia. A robber of seabird eggs, it flourishes on small islands.

(3) *striolata* group

These are medium-sized species with strong to weak postnarial groove and mostly with keeled dorsals. The upper lips (as in the *whitii* group) are usually paler than the rest of the face; there is a tendency to form a dark loreotemporal and pale dorsolateral stripe; the dark dorsal spots are often oblong in shape and laterally edged with white; and the venter may be pink or orange. Between them the four western species (*napoleonis*, *carinata*, *formosa* and *douglasi*) occupy much of the State but not sandy deserts. They do not burrow but shelter in hollow logs, behind the bark of fallen trees, among rocks or under the 'skirts' of blackboys (*Xanthorrhoea* spp).

(4) *luctuosa* group

This group comprises two medium to moderately large species. One of them (*luctuosa*) is found along swampy watercourses in the wetter parts of southwestern Australia, the other (*coventryi*) in similar habitats in Victoria. They are close to the *striolata* group, differing mainly in their highly glossy scales and complete series of suboculars. They are possibly nocturnal, for they are commonly collected in mammal traps.

(5) *whitii* group

This is a highly successful group and the only one represented in sandy deserts. It comprises small to large, slender to stout species with smooth scales (except in *E. pulchra*). As in other groups, wet-country species tend to be black and grey in coloration, and dry-country species red or yellow. The creamy-white edge to eyelids and lack of postnarial groove separate most of its members from the *striolata* group. In Western Australia it comprises *E. pulchra*, *multiscutata*, *inornata*, *striata* and *kintorei*. Perhaps the newly described *E. pilbarensis* belongs here; it shares some traits with *E. margaretae* of Central Australia, likewise an inhabitant of rocks in arid mountain ranges.

KEY

1. Tail cylindrical, from almost as long to much longer than head plus body, fragile, not spiny 5

   Tail depressed, less than half as long as head plus body, spiny, not fragile 2

2. Dorsal spots darker than ground colour; scales of back with one large and two small spines (except in juveniles); no enlarged nuchals; nasals usually in contact; labials usually 6 ... ... *E. depressa*

   Dorsal spots (if any) paler than ground colour; scales of back with one or two small spines; enlarged nuchals present; nasals separated; labials 7 or 8 3

3. Dorsal ground colour blackish or very dark brown 4

   Dorsal ground colour reddish brown ... ... *E. stokesii badia*

4. Back and sides usually with clusters of whitish spots; upper lips whitish; nasals usually widely separated; postnarial groove strong and usually extending to top of nasal ... ... *E. stokesii stokesii*

   Back and sides usually unspotted; upper lips dark; nasals narrowly separated; postnarial groove weak and usually not extending to top of nasal ... ... *E. stokesii aethiops*

5. Dorsal scales keeled 6

   Dorsal scales smooth or striate 10

6. Edge of eyelids dark or white; postnarial groove present 7

   Edge of eyelids white; no postnarial groove 9

7. Dorsal pattern (if any) consisting of whitish dots; upper lips dark; abdomen greyish ... ... *E. kingii*

Dorsal pattern consisting mainly of black spots; upper lips pale; abdomen pink 8

8. Black dorsal spots rounded and not encroaching on laterodorsal strip of ground colour; dorsal keels strong ... ... *E. napoleonis*

Black dorsal spots oblong and spread evenly across back; dorsal keels weak ... ... *E. carinata*

9. Nasals separated; tail 1.9 or less times as long as head plus body ... ... *E. pulchra pulchra*

Nasals usually in contact; tail 1.8 or more times as long as head plus body ... ... *E. pulchra longicauda*

10. Black pigment present 11

No black pigment 14

11. A complete series of suboculars; ear aperture nearly as wide as high ... ... *E. luctuosa*

Subocular series incomplete; ear aperture narrow 12

12. Dorsals striate; postnarial groove present; SVL up to 170 ... ... *E. douglasi*

Dorsals smooth; no postnarial groove; SVL up to 96 13

13. Dorsal ground colour grey or brown; abdomen bluish grey; upper labials usually 8; pale-spotted, black laterodorsal stripe usually present ... ... *E. multiscutata bos*

Dorsal ground colour reddish brown or yellowish brown; abdomen pinkish white or yellowish white; upper labials usually 7; no black laterodorsal stripe ... ... *E. inornata*

14. Broad dark brown upper lateral stripe extending forward to temples or beyond 15

No dark brown upper lateral stripe 16

15. Back spotted with dark brown; SVL up to 107; upper labials 7 ... ... *E. formosa*

No dorsal spots; SVL up to 170; upper labials 6 or 7 ... ... *E. douglasi*

16. Head depressed (as in *E. pulchra*); back uniformly reddish brown; plantar scales tubercular; midbody scale rows 32-34; lamellae under fourth toe 13-16; living among rocks ... ... *E. pilbarensis*

Head deep (as in *E. m. bos*); back reddish brown with faint to moderately strong reddish brown longitudinal stripes; plantars flat; midbody scale rows 36-52; lamellae under fourth toe 17-25; burrowing in sandy or clayey country 17

17. Pupil much narrower than high; greyish brown of sides gradually merging with reddish brown of back; upper labials usually 7; ear lobules usually triangular ... ... *E. striata*

Pupil slightly narrower than high; grey of sides sharply demarcated from pale reddish brown of back; upper labials usually 8; ear lobules usually rectangular ... ... *E. kintorei*

EGERNIA DEPRESSA

Silubosaurus depressus Günther, 1875, 'Zoology . . . Erebus & Terror', p. 15. 'Swan River' [= southern interior of Western Australia].

Diagnosis

A small, extremely spiny member of the *Egernia cunninghami* group with very short, depressed, non-fragile tail. Further distinguishable from *E. stokesii* by trispinose dorsals and supracaudals, nasals usually in contact, fewer upper labials (usually 6, *vs* usually 7 or 8), and no enlarged nuchals.

Distribution

Interior of Western Australia from the Pilbara and Great Sandy Desert south to the northeastern Wheat Belt and Eastern Goldfields, and west nearly to Shark Bay. Extralimital in far southwest of Northern Territory (Petermann Ranges).

Description

Snout-vent length (mm): 54-117 (N 155, mean 89.4). Length of appendages (% SVL): foreleg 25-33 (N 139, mean 28.8), hindleg 25-36 (N 141, mean 31.2), tail 32-44 (N 141, mean 38.2).

Nasals in contact, usually forming a moderate to long median suture; rarely (4%) separated, and then vary narrowly; postnarial groove strong and usually completely dividing nasal. Prefrontals in contact, almost invariably (98%) forming a long median suture. Frontal wider than interparietal, except in juveniles (where usually slightly narrower). No enlarged nuchals. Supraciliaries 4-6 (N 104, mean 5.2). Second loreal usually higher than wide. Presuboculars normally 2, occasionally 1 (when first fused to second loreal). Upper labials 5-7 (N 107, mean 6.0). Temporals 3, primary smallest. Ear aperture moderately narrow and nearly vertical; lobules 1-6 (N 95, mean 3.3), acute or subacute in adults, obtuse or subacute in juveniles, first or second usually largest. Midbody scales in 28-38 rows (N 111, mean 33.4), mid-dorsals bearing 3 (occasionally 4 or 5) keels terminating in a spine, central spine much the largest (in juveniles central spine weak and usually not flanked by smaller spines). Central spines of median supracaudal scales larger than dorsal spines but much shorter than lateral and dorsolateral caudal spines, flanked (except in juveniles) by 1 or 2 small spines. Subdigital lamellae smooth or weakly unicarinate, 9-18 (N 113, mean 13.6) under fourth toe.

Dorsally pink, reddish brown, pale brown, brownish grey or olive grey, marked anteriorly (foreback, nape and sometimes head) with reddish-brown blotches, often arranged in irregular transverse bars; and marked posteriorly (tail, hindback, and often midback and flanks) with triangular blackish-brown spots (usually white-edged) clustering into short, irregular, transverse bars. Loreo-temporal streak dark reddish brown, occasionally extending forward to nostril and backward to beyond arm. Upper lips whitish. Chin shields often with dark sutures. Throat and breast occasionally spotted or streaked with greyish brown. Under tail spotted or flecked with blackish brown, dark grey or reddish brown, markings often extending to abdomen.

Geographic variation

The most distinctive population is that of the Pilbara. It is characterized by:

(1) ground colour pink, rather than brownish or greyish

(2) blackish dorsal spots small and tending to be isolated rather than to cluster, and they are not white-edged
(3) postnarial groove in 70% (*vs* 2%) of specimens incompletely dividing nasal, i.e. terminating at top of nostril
(4) fewer supraciliaries (4 or 5, N 13, mean 4.2; *vs* 4-6, N 91, mean 5.3)
(5) second loreal commonly wider than high (rarely so elsewhere)
(6) more numerous upper labials (6 or 7; *vs* almost invariably 6 elsewhere)
(7) fewer midbody scale rows (28-34, N 13, mean 31.3, *vs* 30-38, N 98, mean 33.7 elsewhere)
(8) fewer lamellae under fourth toe (9-15, N 14, mean 11.4; *vs* 11-18, N 99, mean 14.0 elsewhere)
(9) shorter limbs, especially hindleg (25-32% of SVL, N 14, mean 29.3; *vs* 26-36, N 126, mean 31.4 elsewhere).

Remarks

The Pilbara population has almost diverged to the extent of being a separate subspecies. However, it is connected to the main body of *E. depressa* by intermediate populations in the upper Ashburton-Jiggalong region. Moreover the isolated Central Australian population approaches it in some respects, especially coloration.

In the Pilbara this skink is apparently confined to exfoliating granite and other rocks. In the better-wooded country further south it is mostly found in hollow trees, especially mulgas.

Material

North-west Division: Silver Grass Peak, near source of Robe River (19222); Mt Herbert (29091); Abydos (10793-6); Comet Mine, Marble Bar (18588); Mt Edgar (16659-63); near Nullagine (12309); Jiggalong (26065-6); 32 km W of Mundiwindi (25155-6); Giles Point, 48 km W of Mt Newman (54214); Turee Creek (17690); Booloogooroo (27764); 34 km N of Carnarvon (47604); Carnarvon (34142, 40536); Callagiddy (40662-3); Yinnietharra (41059, 47248); Kumarina (22746); Landor (1690-1, 2700); 105 km N of Meekatharra (29090); 88 km N of Overlander Roadhouse (51746); 17 km SE of Gladstone (16664-5); Woodleigh (49929); Yaringa South (13033); Overlander Roadhouse (13123); Meekatharra (6009); Gabanintha, 35 km E of Nannine (4892); Quinns, near Nannine (325-7); Cue (731-2, 13229); Dalgaranga (24782); Mt Magnet (2112); Yalgoo (1744, 22867); 16 km S of Yalgoo (20540-1); 32 km SW of Yalgoo (29594); Muralgarra (7511-2); Gnows Nest and vicinity (4761-3, 22868, 22945, 23815-6, 25665-6, 53496-

7); 32 km S of Mt Magnet (29102); 29 km N of Paynes Find (48149-50); Fields Find (13644); Rothsay State Forest (27763).

South-west Division: Marloo, Wurarga (3819-22); 32 km E of Mullewa (29993-4); Tallering (54199); Pindar (3839-40); Gullewa (4594); Caron (7280-1); Marchagee (354-6); Wubin (32021); Pithara (4252); Bimbijy Station, via Beacon (43923-4).

Eastern Division: Well 46, Canning Stock Route (4059); Carnarvon Range (51878); Barrow Range (20725); 32 km E of Warburton Range (15697-701, 15728-34); Warburton Range and vicinity (14635-8, 17784-5, 22033-5, 22071, 22166-70, 31363); 70 km SW of Wiluna (21140-2); 80 km NNW of Sandstone (46229); Albion Downs (19788); Laverton (1200, 1358-9, 23906); Mt Margaret Mission (17677-8); Cundeelee Mission (12994-6); Kalin Rock (12992); Grants Patch, 50 km E of Kalgoorlie (7066, 8226); Kalgoorlie (5975, 9989, 46129); Kambalda (31550-1); 'Goldfields' (5-6).

Northern Territory: Shaw Creek (25° 03′ S, 129° 42′ E) (JSE 139); 6 km N of Mt Bowley (34201-2).

EGERNIA STOKESII STOKESII

Silubosaurus Stokesii Gray, 1845, 'Catalogue . . . lizards . . . British Museum'. Houtman Abrolhos, W.A. (J. Gilbert).

Diagnosis

A moderately large member of the *E. cunninghami* group with tail very short, depressed, strongly spinose and non-fragile. Further distinguishable from *E. depressa* by dorsals with one or two weak spines and supracaudals with one strong spine, presence of enlarged nuchals, nasals separated, and more numerous upper labials (usually 7 or 8, *vs* usually 6).

Distribution

Wallabi and Pelsart Groups of the Houtman Abrolhos, off west coast of Western Australia.

Description

Snout-vent length (mm): 56-158 (N 112, mean 111.1). Length of appendages (% SVL): foreleg 23-34 (N 110, mean 26.4), hindleg 26-38 (N 110, mean 31.0), tail 28-43 (N 109, mean 36.9).

Nasals separated, usually widely; postnarial groove strong, usually (80%) completely dividing nasal. Prefrontals usually forming a long median suture; rarely (8%) narrowly separated. Frontal wider than interparietal (except in one juvenile). Enlarged nuchals 1-4 (N 68, mean 2.9) on each side. Supraciliaries 4-7 (mostly 5, N 55, mean 5.3), second usually largest and occasionally (14%) fused to first supraocular. Second loreal usually higher than wide. Presuboculars usually 2, occasionally 1 (when first fused to second loreal), rarely 3. Upper labials 7-9 (N 68, mean 7.7). Temporals 3, lower secondary largest, primary smallest. Ear aperture moderately narrow and nearly vertical; lobules 1-4 (N 66, mean 2.5), usually serrate, first usually (second occasionally) largest. Midbody scales in 32-36 rows (N 68, mean 33.8), paravertebrals with 2 keels terminating in short blunt spine; remaining dorsals with one spinose keel. Caudal spines, especially laterals and laterodorsals much longer. Subdigital lamellae weakly unicarinate, 12-18 (N 68, mean 14.7) under fourth toe.

Back and tail blackish brown, usually with clusters of 3-11 quadrilateral or triangular brownish white spots, each occupying whole or half of scale; clusters transversely elongate and tending to align transversely. Some head shields, especially on occiput and loreotemporal streak, wholly dark brown; remaining head shields pale with dark edges. Flanks and legs dark brown with clusters of 1-5 whitish scales. Upper lips whitish. Under surface greyish brown, darkest on chin and throat; spotted with greyish white, spots largest on chin and throat and tending to leave a coarse reticulum or bars of dark brown ground colour.

Geographic variation

The population on tiny Tattler Island (only a few metres off West Wallabi Island and connected by dry land at low water) is peculiar in the tendency for the frontonasal to divide longitudinally and in the high frequency of separated prefrontal (40%) and incomplete postnarial groove (80%).

Material

South-west Division: East Wallabi I. (16555-90, 19917-8, 28909-10, 29058-60, 47828); West Wallabi I. (16591-618, 16621-51, 21847, 29498); Tattler I. (16652-8); Middle I. (27186); Murray I. (30452).

EGERNIA STOKESII AETHIOPS subsp. nov.

Holotype

R25731 in Western Australian Museum, collected by G.M. Storr on 29

August 1965 on Baudin Island, Freycinet Estuary, Western Australia, in 26° 31′ S, 113° 39′ E.

Diagnosis

A dark, relatively small subspecies of *E. stokesii*, differing from *E. s. stokesii* in almost total lack of colour pattern, short snout, weak postnarial groove, narrowly separated nasals, and very small first supraocular (when not fused to very large second supraciliary).

Distribution

Only known from one small island (Baudin) in Shark Bay, west coast of Western Australia.

Description

Snout-vent length (mm): 63-161 (N 12, mean 120.0). Length of appendages (% SVL): foreleg 23-29 (N 12, mean 25.2), hindleg 28-35 (N 12, mean 31.0), tail 31-36 (N 11, mean 33.7).

Nasals narrowly separated; postnarial groove shallow and seldom (20%) completely dividing nasal. Prefrontals forming a moderate to long median suture, except in one specimen (where separated). Frontal short for an *Egernia*, usually much wider than interparietal. Enlarged nuchals 2-4 (N 12, mean 2.8) on each side. Supraciliaries 5, second very large and often (60%) fused to small first supraocular. Second loreal usually higher than wide. Presuboculars 2. Upper labials 7 or 8 (N 12, mean 7.4). Temporals 3, lower secondary usually largest, primary smallest. Ear aperture moderately narrow and nearly vertical; lobules 2-4 (N 11, mean 2.9), serrate, first usually largest. Midbody scales in 34 rows (N 12), paravertebrals with 2 keels terminating in weak spine, other dorsals with one keel and weak spine. Median supracaudals with a weak spine, laterals and laterodorsals with a strong spine. Subdigital lamellae smooth or weakly unicarinate, 14-16 (N 12, mean 15.0) under fourth toe.

Blackish brown above, usually without spots; occasionally small clusters of brownish white or greyish white, especially on flanks. Under surface moderately dark brownish grey, occasionally spotted paler.

Paratypes

North-west Division: Baudin I. (25723-30, 25732-4).

EGERNIA STOKESII BADIA subsp. nov.

Holotype

R29590 in Western Australian Museum, collected by Mr W.H. Butler in September 1967 at Rothsay, Western Australia, in 29° 18′ S, 116° 54′ E.

Diagnosis

A large reddish brown subspecies of *E. stokesii* with whitish ventral surfaces.

Distribution

Arid and semi-arid zones of southwestern Western Australia from the lower Gascoyne south to the northern and northeastern Wheat Belt. Also Dirk Hartog Island, Shark Bay.

Description

Snout-vent length (mm): 81-194 (N 32, mean 161.3). Relative length of appendages (% SVL): foreleg 23-30 (N 20, mean 26.2); hindleg 28-34 (N 20, mean 31.1); tail 34-45 (N 20, mean 39.6).

Nasals widely separated; postnarial groove strong and usually (84%) completely dividing nasal. Prefrontals in long median contact. Frontal usually wider than interparietal, occasionally (especially in juveniles) no wider. Enlarged nuchals 1-4 (N 19, mean 2.5) on each side. Supraciliaries 4-6 (N 19, mean 5.4), second often (60%), first or fourth occasionally, largest. Second loreal usually (70%) higher than wide. Presuboculars 1-3 (N 19, mean 2.1). Upper labials 7-9 (N 19, mean 8.1). Temporals 3, lower secondary largest (usually much larger than upper secondary), primary smallest. Ear aperture very narrow and nearly vertical; lobules 2-4 (N 19, mean 3.2), long and serrate, first (occasionally second) largest. Midbody scale rows 32-38 (N 21, mean 36.2), paravertebrals and occasionally adjacent dorsal series bicarinate (rarely tricarinate), remaining dorsals unicarinate; all keels terminating in short spine. Supracaudals strongly unispinose, lateral and laterodorsal spines longest. Subdigital lamellae smooth or unicarinate, 12-16 (N 19, mean 14.7) under fourth toe.

Dorsally brown or reddish brown, usually more reddish on head and tail, sometimes with little or no pattern, but usually back, sides, base of tail and legs with angular greyish-white spots which mostly occupy whole of scale and cluster into groups of 4-20 to form irregular transverse bars, a few blackish-brown spots margining some clusters in a few specimens. Upper lips, ear lobules and lower surfaces pale.

Fig. 1: Map of Western Australia, showing location of specimens of *Egernia depressa*, *E. s. stokesii*, *E. s. aethiops* and *E. s. badia*.

Paratypes

North-west Division: Callagiddy, 34 km SE of Carnarvon (34562); Dirk Hartog I. (42374); Rothsay State Forest (29591).

South-west Division: Mullewa (2776); Three Springs (8842); 7 km N of Carnamah (23833); 43 km SE of Perenjori (28911); Caron (4147-8, 23817, 27761-2); Bunjil (1117-8); Latham (3355-6); Coorow (1277); Buntine Reserve (43651); Pithara (2829); Kalannie (15816); 14 km E of Kalannie (21966); North Mollerin (2271); Miling (7932); Damboring (877); Ballidu (5230); Koorda (4556, 5278); 23 km N of Mukinbudin (22897); Kununoppin (44538); Benjabbering (37722); Kellerberrin (21210) [found in schoolyard, but possibly transported in firewood from well north of town].

EGERNIA KINGII

Tiliqua Kingii Gray, 1839, Ann. nat. Hist. 2: 290. Australia (Capt. P.P. King).

Tropidolopisma Dumerilii Duméril & Bibron, 1839, 'Erpétologie générale' 5: 745. Australia.

Tropidolepisma nitida Gray, 1845, 'Catalogue . . . lizards . . . British Museum', p. 106. Australia (Turner).

Diagnosis

A very large *Egernia* with keeled dorsal scales, fragile tail, strong postnarial groove, and dorsal and lateral coloration dark grey or black with or without small whitish spots or short streaks. Further distinguishable from members of *Egernia striolata* group by dark upper lip and absence of broad longitudinal stripes, especially dark upper lateral-temporal-loreal band and pale laterodorsal band.

Distribution

Southwestern Australia, north to the Hutt River, east to Duke of Orleans Bay, and inland to Gingin, Tutanning Reserve, Mooterdine, Katanning and Jerramungup; also numerous islands from the Houtman Abrolhos to the Archipelago of the Recherche.

Description

Snout-vent length (mm): 64-244 (N 109, mean 166). Length of appendages (% SVL): foreleg 22-34 (N 98, mean 26.7); hindleg 31-42 (N 98, mean 35.7); tail 94-157 (N 44, mean 127.7).

Nasals narrowly to moderately separated; occasionally (7%) just touching; postnarial groove usually strong, occasionally weak, seldom (3%) completely dividing nasal by continuing upwards from top of nostril. Prefrontals in contact or separated. Frontal slightly wider (juveniles) or much wider (adults) than interparietal. Enlarged nuchals 1-5 (N 85, mean 2.7) on each side. Supraciliaries 5-9 (N 89, mean 6.9), largest usually first, occasionally third, rarely second (when second and third fused). Presuboculars 2, rarely 3. Upper labials 7-10 (N 95, mean 8.8). Temporals 3, lower secondary much the largest, primary smallest (except in one specimen). Ear aperture moderately narrow and nearly vertical; lobules 4-6 (N 84, mean 5.0), obtuse or subacute, first usually very small, second or third usually largest. Midbody scales in 32-46 rows (N 89, mean 38.3); dorsals with 2 or 3 (occasionally 4) keels, moderately sharp in adults, weak in juveniles. Subdigital lamellae smooth, 22-29 under fourth toe (N 88, mean 25.0).

Upper surface black, dark grey, dark brown or dark olive, usually palest and brownest on head. Back and sides usually dotted white, cream, pale brown or pale grey; dots usually arranged in short longitudinal series of 2-4, often coalescing to form dashes. Under surface (especially throat and tail) usually spotted, streaked, variegated or clouded with greyish brown or black; rarely immaculate.

Geographic variation

Egernia kingii undergoes much individual variation, especially in coloration. However, there is considerable geographic variation.

Number of midbody scale rows increases from northwest to southeast; in the Abrolhos it ranges from 32-36 (N 22, mean 34.4); on the west coast and hinterland north of lat. 32° S, 34-40 (N 21, mean 36.4); west coast and hinterland south of 32° S, 36-42 (N 17, mean 39.6); south coast, 40-45 (N 23, mean 41.2); and Archipelago of the Recherche, 42-46 (N 6, mean 43.8). Number of lamellae under fourth toe increases slightly over the same area, averaging 24.1 in the Abrolhos and 25.7 in the Recherche. Upper labials average 8.4 in the Abrolhos, 8.7 on west coast and hinterland north of 32° S, and 9.0 elsewhere. Prefrontals are separated in 8% of specimens from the Abrolhos and west coast, 27% of specimens from the south coast and 72% of specimens from the Recherche. In the Abrolhos the second loreal is usually higher than wide; southwards and eastwards its relative height decreases, so that it is usually no higher than wide in the Recherche. Ear lobules average 4.3 in the Abrolhos, 4.8 in the northern sector of the west coast, and 5.5 further south.

Fig. 2: Map of Western Australia, showing location of specimens of *Egernia kingii* and *E. luctuosa*.

Variation in other meristic characters is non-clinal, with the lowest counts in the Abrolhos and little or no variation elsewhere. For example, number of supraciliaries averages 6.4 in the Abrolhos and 7.1 elsewhere. Nuchals average 2.3 in the Abrolhos and 2.8 elsewhere.

Remarks

The original description of *T. dumerilii* is a composite of *E. kingii* and *E. napoleonis*. In order to stabilize their name, I hereby designate the specimen measured by Duméril & Bibron as lectotype of *T. dumerilii*; its great size (SVL 217) identifies it with *E. kingii*.

The presumed holotype of *T. nitida* Gray (43.5.11.2, stuffed specimen in British Museum) agrees well with specimens of *E. kingii* from the vicinity of Perth. It has SVL 240, nasals separated moderately widely, prefrontals forming a median suture, frontal wider than interparietal, 3 enlarged nuchals on each side, *ca* 7 supraciliaries (first largest), 2 loreals (second much higher than wide), 2 presuboculars, 8 and 9 upper labials, lower secondary temporal much the largest, 4 ear lobules, 37 midbody scale rows (mid-dorsals moderately cuspidate and bearing 3, occasionally 4 or 2, keels) and 25 lamellae under fourth toe. It is olive brown above without pale spots; it is pale below.

Material

South-west Division: North I., Houtman Abrolhos (16666, 47819-20); East Wallabi I., H.A. (28907-8, 46553); West Wallabi I., H.A. (16698); Seagull I., H.A. (25850); Long I., H.A. (37504); No. 3, south of Gun I., H.A. (30450); Pelsart I., H.A. (22949-56, 27171, 43596); 11 km E of mouth of Hutt River (27775, 53726); 65 km S of Dongara (19760-1); Boullanger I. (16678); Cervantes Is (16680, 19921); Gingin (3787); Yanchep National Park (47660); Marmion Beach (24086); Morley (51782); West Leederville (4348); Rottnest I. (16684-5, 51754); Carnac I. (4977, 25363-6); Garden I. (29786, 34651); North Lake (21850); Carmel (36176); Churchmans Brook (16701); Armadale (835); North Jarrahdale (30945); Jarrahdale (9347-8); Tutanning Reserve (39955); Mooterdine (27770-1); Contine (53617); Yunderup (21555, 36447); mouth of Capel River (26556-7); Ludlow (45755); Nannup (45756); Kojonup (2727); Katanning (12080-3); Jerramungup (12961); Tambellup (2102-3); Margaret River (49815-6); Mammoth Cave (88); Scott River (36041); St Alouarn I. (39686); Chatham I. (49817-20); Walpole (51444); Eclipse I. (4789, 49278); 3 km W of Bald Head (25076); Michaelmas I. (52166); Breaksea I. (51046); Coffin I. (22751); Two Peoples Bay (36374, 36376-8, 36381, 53158); King Creek (27769, 53618); Waychinicup River (53619); Bald Island (19966-7, 22596, 29693, 53138); Cape Riche (29823); Pallinup River (7879); Phillips River (22533).

Eucla Division: Oldfield River (22571); Gull I. (39083); Sandy Hook I. (41918); Wilson I. (53152-3); Mondrain I. (53111, 53115).

EGERNIA NAPOLEONIS

Tiliqua Napoleonis Gray, 1839, Ann. nat. Hist. 2: 290. Australia.

Egernia nitida, auctt., especially Loveridge (1934: 339) and Mitchell (1950: 287), *nec* Gray.

Diagnosis

A member of the *E. striolata* group with dorsal scales strongly keeled and proximal upper caudals not enlarged. Further distinguishable from *E. carinata* by presence of broad pale dorsolateral stripe and rounded (not rectangular) black dorsal spots, and from *E. kingii* by whitish (not dark) upper lips and pink (not greyish) abdomen.

Distribution

Western populations: Southwest of Western Australia from Jurien Bay south and east to Cheyne Beach and inland to Mt Peron, Bullsbrook, Mundaring, Wandering, Tambellup and the Stirling Range; also Rottnest, Hamelin, Eclipse and Bald Islands.

Eastern populations: South and southeast coasts and coastal hills of Western Australia from Bremer Bay east to Twilight Cove; also many islands in the Archipelago of the Recherche.

Description of western populations

Snout-vent length (mm): 42-111 (N 276, mean 77.8). Length of appendages (% SVL): foreleg 24-34 (N 232, mean 28.0), hindleg 30-47 (N 233, mean 38.5), tail 108-163 (N 140, mean 135.8).

Nasals separated, usually narrowly; occasionally (6%) in short contact; postnarial groove strong. Prefrontals in contact, usually forming a long median suture; occasionally (7%) narrowly separated. Frontal wider than interparietal in adults; slightly wider or slightly narrower in juveniles. Enlarged nuchals 0-6 (N 186, mean 2.5) on each side. Supraciliaries 4-8 (N 198, mean 5.5); second usually, first or third occasionally, largest. Second loreal usually wider than high. Presuboculars 2, rarely 3. Upper labials 7-10 (8 in 80% of specimens, N 185, mean 8.1). Temporals 3, lower secondary largest, primary smallest. Ear aperture moderately narrow and nearly vertical; lobules 2-6 (usually 4, N 173, mean 4.2), usually subacute in adults and obtuse in juveniles; first usually very small, second usually largest. Midbody scales in 32-42 rows (N 170, mean 36.2), dorsals tending to be tricuspidate in adults and bearing 3, 2 or 4 strong, acute keels; dorsals not cuspidate in juveniles and bearing 2 or 3 (occasionally 4) weak, obtuse keels. Subdigital lamellae broadly callose; 19-28 (N 167, mean 23.4) under fourth toe.

Dorsally dark olive or brown, back with black spots of variable size and shape and tending to align in 3 longitudinal series and leaving unspotted a broad paler laterodorsal stripe. Upper lateral zone usually black anteriorly and extending forward as an irregular stripe through temples and orbit to lores. Upper labials white or pale brown or olive, or pale-centred, more or less sharply differentiated from scales above them. Back occasionally and sides often dotted with white. Under tail and occasionally throat grey. Abdomen salmon-pink in life. Subdigital lamellae and sometimes plantar tubercles dark brown.

Description of eastern populations

Snout-vent length (mm): 48-133 (N 50, mean 100.7). Length of appendages (% SVL): foreleg 23-35 (N 49, mean 28.5), hindleg 32-46 (N 50, mean 38.9), tail 117-172 (N 30, mean 144.0).

Nasals separated, usually narrowly (in very short contact in one specimen). Prefrontals in contact, usually forming a long median suture. Frontal much wider than interparietal in adults, slightly wider in juveniles. Enlarged nuchals 1-4 (N 42, mean 2.4) on each side. Supraciliaries 5-7 (N 48, mean 6.0), second usually, first or third occasionally, largest. Second loreal wider or narrower than high. Presuboculars 2 (80%) or 3. Upper labials 8 or 9 (N 48, mean 8.4). Temporals 3, lower secondary largest, primary smallest. Ear aperture moderately narrow and nearly vertical; lobules 3-7 (N 46, mean 4.6), subacute or acute in adults, obtuse in juveniles, first very small, second or third largest. Midbody scales in 36-46 rows (N 46, mean 40.1), dorsals bearing 3 or 2 (occasionally 4) moderately sharp and strong keels in adults and 2 or 3 weak obtuse keels in juveniles. Subdigital lamellae broadly callose, 21-28 (N 46, mean 24.4) under fourth toe.

Dorsally dark olive or brown; head shields black-edged; back with black spots of variable shape and size; median spots tending to align and form a vertebral stripe; lateral spots tending to arrange in transverse or oblique series and sometimes coalescing into an irregular zigzagging stripe; broad laterodorsal stripe of ground colour. Upper lateral zone usually black anteriorly and extending forward as an ill-defined stripe through temples and orbit to lores. Upper lips paler than rest of face. Sides often, and back occasionally, white-dotted. Sutures between gular scales black. Throat greyish, usually spotted black. Abdomen salmon-pink in life. Under tail grey. Subdigital lamellae dark brown.

Geographic variation

The populations west of long. 119° E are fairly uniform. Those from islands off the south coast are the most distinctive in coloration; on Eclipse Island, and to a lesser extent on Bald Island, the black dorsal spots tend to coalesce into three stripes. In other respects the populations north of Yanchep are the most distinctive. Here the limbs are somewhat shorter than further south (mean length of foreleg 26.4 *vs* 28.2, and hindleg 35.9 *vs* 38.8). Subdigital lamellae are fewer (mean 22.0 *vs* 23.6); ear lobules are fewer (2-5, mean 3.5; *vs* 3-6, mean 4.2); and the frequency of individuals with contiguous nasals is higher (25 *vs* 4%). Other variation in the west is clinal, e.g. relative length of tail increases and number of supraciliaries decreases from north to south.

The eastern populations differ from the western in their colour pattern, greater size and more numerous midbody scale rows, supraciliaries and upper labials. Coming from several islands and from widely separated sectors of the mainland coast, they are understandably less uniform than the western populations. In the Cape Le Grand National Park, for example, the number of midbody scale rows (40-46, N 13, mean 42.1), number of ear lobules (4-6, N 13, mean 4.7) and frequency of 9 upper labials (40%) are considerably higher than on nearby North Twin Peak Island (where the corresponding counts are 36-40, N 9, mean 38.1; 3-4, N 9, mean 3.8; and 9%).

Material

South-west Division, west of 119° E: 2 km W of Mt Peron (49127); 5 km W of Padbury HS (48466); Mt Lesueur (49119-20); 12 km S of Padbury HS (22227-9); 10 km NE of Jurien Bay (29208, 46561); 12 km SE of Jurien Bay (46555-60); 17 km N of Lancelin (16699); 13 km N of Yanchep (12842); Bullsbrook (29166); Wanneroo (31552); Mussel Pool (51546, 51548); Gidgiegannup (37715, 46611); Mundaring (26449, 30393-4); 10 km E of Kalamunda (17311, 19159); Guildford (26035); Rottnest I. (2009-10, 2359, 2557, 2856, 3733, 22335); Bibra Lake (16700); Bickley (6467); E of Pickering Brook (51158); Kelmscott (51396, 51404); Mt Randall (40210); Wungong Gorge (47658); Wandering (4366); Dwellingup (39965-9); 5 km E of Dwellingup (40122, 40124); Boddington (6058);

Dryandra (31941, 40836, 47790); Contine (27781-2); Mooterdine (29816); Waroona (41241); Mt William (16702); Collie and district (22832, 24826, 46391); Meelup (near Cape Naturaliste) (16703); Dunsborough (12324-7); Busselton (26220, 47379-81, 47383); 12 km SW of Boyup Brook (31122-4); Bridgetown (1163-6, 8374); 17 km E of Nannup (21893); Nannup (47378, 47382, 47384); Margaret River (4604); Witchcliffe (6816); Karridale (13464); Hamelin I. (16705-6); Hamelin Bay (16704); Deepdene (12773-5); 8 km NW of Augusta (16707, 37805-6, 39013); Cape Leeuwin (16708); Scott River (14179, 36046); Carey Brook (22783-4); 10 km WNW of Manjimup (39730); Meerup (47879-83); between upper reaches of Perup and Tone Rivers (42569-73, 42578); Tambellup (1533-6); Mt Toolbrunup (818, 21818, 51788); Bluff Knoll (51787); Tolls Pass, Stirling Range (1998); 17 km S of Rocky Gully (46305); Yeagerup (47924-5); Mt Chudalup (49708); East Broke Inlet (47960-7); Walpole (51436, 51443, 51459, 51463, 51477-8); Valley of the Giants, Nornalup (26036-41); Kent River (265, 44673-5, 46539-40); Denmark and district (24952-3, 24970, 40975); Mitchell River (43829-35); Chorkerup (4486); West Cape Howe (21816-7); Torbay Head (51792); Torbay Inlet (16709-10); Eclipse I. (6802, 11279, 45771, 49678-84); Albany (6788); Two Peoples Bay (36352-3, 36380, 37833, 53157); Gidley Creek (27778-9); King Creek (27780; Cheyne Beach (16711-4, 31166, 36020-8); Bald Island (16715-60, 19968-71, 40818-21, 53175, 53205-16).

South-west Division, east of 119° E: Hunter River, 8 km E of Bremer Bay (36201); Boondardup River (34° 13′ S, 119° 31′ E) (37197, 37207); West Mt Barren (36886-7); East Mt Barren (16761, 39001).

Eucla Division: Cape Le Grand National Park, including Mt Le Grand, Frenchmans Peak, Lucky Bay, Rossiter Bay and Duke of Orleans Bay (22525, 41987-98); Boxer I. (10116); Sandy Hook I. (41917); Corbett I. (53147-9); Wilson I. (53154-5); Mondrain I. (10114); North Twin Peak I. (16762-3, 53086-7, 53097-102, 53104-5); Middle I. (47657); "Archipelago of the Recherche" (11382); Toolinna Rockhole (32° 46′ S, 124° 57′ E) (45350), Point Dover (53759); Twilight Cove (44976).

EGERNIA CARINATA

Egernia carinata H.M. Smith, 1939, Fieldiana Zool. 24: 11. Toolbrunup [18 km E of Tambellup], W.A. (J. Baldwin).

Diagnosis

A member of the *E. striolata* group with dorsal scales very weakly keeled, proximal supracaudals not enlarged, and no pale laterodorsal stripe. Further distinguishable from *E. napoleonis* by oblong (rather than round) black dorsal spots, and from *E. formosa* by black (rather than dark brown) dorsal spots and anterior upper lateral stripe.

Distribution

Southern interior of Western Australia, north to the Southern Cross district, west to the eastern and southern Wheat Belt, south nearly to the Stirling Ranges, and east nearly to the Great Australian Bight.

Description

Snout-vent length (mm): 47-105 (N 48, mean 87.5). Length of appendages (% SVL): foreleg 24-30 (N 47, mean 26.6), hindleg 30-40 (N 47, mean 35.5), tail 89-129 (N 33, mean 112.4).

Nasals separated (usually narrowly) or just touching (6%); postnarial groove moderately strong. Prefrontals in contact, usually forming a long median suture (very narrowly separated in one specimen). Frontal wider than interparietal. Enlarged nuchals 2-4 (N 44, mean 2.8) on each side. Supraciliaries 5-7 (N 45, mean 6.1); first (46%), third (42%), fourth (10%) or fifth (2%) largest, *never* second. Second loreal wider than high. Presuboculars 2 (3 in one specimen). Upper labials 7-9 (N 47, mean 7.8). Temporals 3, lower secondary largest, primary smallest. Ear aperture moderately narrow and nearly vertical; lobules 2-4 (N 46, mean 3.2), obtuse in juveniles, usually subacute in adults, first or second largest. Midbody scales in 29-34 rows (N 48, mean 31.4) with 2-5 (mostly 4 or 3) low wide keels (actually the troughs between the keels are more conspicuous than the keels themselves, so that the scales would be better described as striate). Subdigital lamellae broadly callose, 19-24 (N 43, mean 21.2) under fourth toe.

Dorsally olive grey or olive brown, with or without a broad rufous band across neck. Back evenly covered with about 8 longitudinal series of black spots (leaving no broad pale unspotted laterodorsal stripe), spots usually oblong in shape and often laterally edged with white. Upper lateral zone black with white dots, extending forward as a stripe to orbit, not always extending back on to rear of body. Upper labials pale, more or less sharply differentiated from darker scales above them. Chin and throat with or without a pale grey wash, scales with or without dark sutures.

Geographic variation

This species has a small compact distribution, and there is consequently little geographic variation. Number of upper labials increases from west to east (7 or 8 in the Wheat Belt, i.e. east to the longitude of Yellowdine; 8 from Karalee to Norseman; and 8 or 9 in far east). Rufous-necked individuals seem to be confined to the northernmost part of range, i.e. from Southern Cross east to Boorabbin and south to Split Rock.

Remarks

Egernia carinata is geographically intermediate between *E. napoleonis* and *E. formosa*, and in many respects it is morphologically intermediate, e.g. number of midbody scale rows, subdigital lamellae, supraciliaries and upper labials, and in the strength of dorsal keels.

E. carinata agrees with *napoleonis*, and not with *formosa*, in the possession of black pigment. It agrees with *formosa* rather than *napoleonis* in usually having the dorsal spots oblong in shape and pale-edged. It differs from both species in the shortness of its tail and in having no pale laterodorsal stripe.

One of the southern populations of *E. napoleonis*, viz. that from the Stirling Ranges, approaches within 40 km of the range of *E. carinata*, whereas the northern populations (north of Yanchep) are separated by more than 250 km. Yet it is these northern populations of *napoleonis* that most resemble *carinata*. Relative length of limbs, for example, is almost identical in northern *napoleonis* and *carinata* (and *formosa*).

Material

South-west Division: 65 km E of Narembeen (25829); Lake Varley (18477, 27259); Dragon Rocks Reserve (43733-4); North Tarin Rock Reserve (40080, 44440); Kukerin (6103-4, 6109); Chinocup Reserve (41076); Lake Magenta Reserve (39887-9, 39933, 45927, 47334); Ongerup (2535, 2537).

Eastern Division: 21 km W of Boorabbin (25954); 37 km S of Karalee (33982); 45 km S of Karalee (33980-1); 47 km S of Karalee (33959-61, 33964-6); 24 km S of Yellowdine (37936); 29 km S of Yellowdine (37921-8); "fork leading to Yellowdine-Marvel Loch road" (33983); 48 km S of Southern Cross (25217); Cheritons Find (23326).

Eucla Division: Split Rock, 30 km N of Mt Holland (37829); Norseman (8014); Pine Hill (36227-8); Junana Rock, 11 km NW of Mt Ragged (17606-7, 36246).

Egernia formosa Fry, 1914, Rec. West. Aust. Mus. 1: 184. "Perth" (W.D. Campbell) [in error, probably for Boulder, W.A.].

Diagnosis

A member of the *E. striolata* group with smooth dorsals and unenlarged supracaudals. Further distinguishable from *E. carinata* by absence of black pigment and presence of broad pale laterodorsal stripe. Distinguishable from *E. douglasi* by spotted back, lesser size and more numerous upper labials, midbody scale rows and subdigital lamellae.

Distribution

Arid interior of Western Australia from the southern highlands of the Pilbara (Roebourne Tableland, Hamersley Ranges and Ophthalmia Range) south nearly to Norseman, and east to the western edge of the Great Victoria Desert and the Nullarbor Plain.

Description (excluding Pilbara specimens)

Snout-vent length (mm): 57-96 (N 37, mean 79.0). Length of appendages (% SVL): foreleg 22-30 (N 37, mean 26.7), hindleg 30-40 (N 37, mean 35.7), tail 108-150 (N 15, mean 136.1).

Nasals separated, usually narrowly; occasionally (9%) in short contact; postnarial groove weak. Prefrontals forming a median suture (77%) or just touching or very narrowly separated. Frontal slightly wider (juveniles) or much wider (adults) than interparietal. Enlarged nuchals 1-5 (N 35, mean 3.1) on each side. Supraciliaries 6 or 7 (N 37, mean 6.8), first (57%) or third largest. Second loreal usually wider than high. Presuboculars 2. Temporals 3, lower secondary largest, primary smallest. Upper labials 7 (N 35). Ear aperture moderately narrow and nearly vertical; lobules 3 or 4 (N 32, mean 3.7), usually obtuse, occasionally truncate or subacute; first usually very small, second usually largest. Midbody scales in 28-30 rows (N 37, mean 28.9), dorsals usually smooth, rarely faintly striate. Subdigital lamellae usually smooth or callose, occasionally distal lamellae obtusely keeled; 17-22 (N 34, mean 19.1) under fourth toe.

Dorsally pale brown or olive. Back with dark brown oblong spots (lateral edges occasionally pale), not extending to laterodorsal region and occasionally arranged anteriorly into two paravertebral stripes. Broad pale laterodorsal stripe. Broad dark brown upper lateral stripe extending forward to temples or lores. Back and sides (except on laterodorsal and upper lateral stripes) occasionally dotted or flecked with brownish white. Lips, chin and throat barred with brown.

Geographic variation

The five specimens from the Pilbara are excluded from the above description, for they could prove to be subspecifically distinct. They differ in their greater size (SVL 84-107, mean 100.6), more numerous scale rows (30), more numerous lamellae under fourth toe (21-23, mean 22.0), more numerous supraciliaries (7 or 8, mean 7.2) with first invariably largest, more numerous ear lobules (3-6, mean 4.6), and in three of the specimens the dorsal spots are paler and less numerous than in central and southern specimens.

Specimens from the central zone (Carnarvon Range to Laverton) are to a small extent intermediate between Pilbara and southern specimens. They are slightly larger than southern specimens and have slightly more numerous midbody scale rows, subdigital lamellae, supraciliaries and ear lobules.

Material

North-west Division: Python Pool, Mt Herbert (33423); Tambrey (20016); Wittenoom Gorge (12126); Marandoo Mine, Mt Bruce (52702); 7 km SW of Mt Newman (23994).

Eastern Division: Carnarvon Range (40233); Mt Fisher, 175 km E of Wiluna (13712*a-b*); White Cliffs (20659, 51069, 51666-9, 53262-3); 40 km NE of Laverton (16765); Linden (46626); Yarri (46615-6); 12 km W of Callion (22540-6); 16 km N of Bardoc (20609); Dedari (19140); "Goldfields" (16-7); Bulong (4299); 13 km W of Karonie (41573-4); 7 km E of Chifley (21655-6); 10 km N of Coonana (16766); Queen Victoria Spring (13029); Zanthus (26426); "Loongana" (29172).

Eucla Division: 24 km N of Norseman (45669).

EGERNIA DOUGLASI

Egernia striolata douglasi Glauert, 1956, West. Aust. Nat. 5: 117. Wotjulum, W.A. (A.M. Douglas).

Diagnosis

A large member of the *E. striolata* group with striate dorsals and unenlarged supracaudals. Distinguishable from *E. formosa* by its unspotted colour pattern, greater size, and fewer upper labials, midbody scale rows and subdigital lamellae.

Distribution

Only known from two localities in subhumid northwest Kimberley.

Description

Snout-vent length (mm): 140-170 (N 4, mean 153.5). Length of appendages (% SVL): foreleg 23-25 (N 4, mean 23.7), hindleg 30-34 (N 4, mean 32.0), tail 81-101 (N 2).

Nasals separated; postnarial groove extending to top of scale. Prefrontals in median contact. Frontal about as wide as interparietal. Enlarged nuchals 2-5 (N 4, mean 3.9). Supraciliaries 6 or 7 (N 3, mean 6.7), first or last largest. Second loreal wider or narrower than high. Presuboculars 2. Temporals 3, lower secondary largest. Upper labials 6 or 7 (N 3, mean 6.5). Ear aperture moderately narrow and nearly vertical; lobules 3 or 4 (N 3, mean 3.7), subacute or obtuse, second largest. Midbody scales in 26 or 28 rows (N 3, mean 26.5), dorsals with 3-7 striations. Subdigital lamellae smooth, 16-19 (N 4, mean 17.1) under fourth toe.

Dorsal and lateral surfaces reddish brown (Wotjulum) or dark olive brown (Mt Hart), marked on each side with dark brown (Wotjulum) or black (Mt Hart) as follows: (1) broad anterior dorsal stripe beginning a little behind foreleg and continuing forward on to head (where it becomes narrower) and converging on snout, posterior section of stripe angularly wavy and in one specimen continuing back to tail as two series of obscure spots; (2) upper lateral stripe angularly wavy, beginning a little behind foreleg and continuing narrowly forward through temples and orbit to lores; (3) transverse bars on lips and at Mt Hart also on throat and side of neck.

Remarks

Glauert compared this skink with *E. striolata* of eastern Australia. However, it is still nearer to *E. formosa*, which it resembles in habit and coloration. Moreover it is clearly the northern representative of a western group of closely related allopatric or parapatric species, in which there is unidirectional change in several characters, e.g. a steady decrease in number of midbody scale rows, subdigital lamellae and upper labials from *E. napoleonis* through *carinata* and *formosa* to *douglasi*.

Material

Kimberley Division: Wotjulum (11793-4); Mt Hart (57074-5).

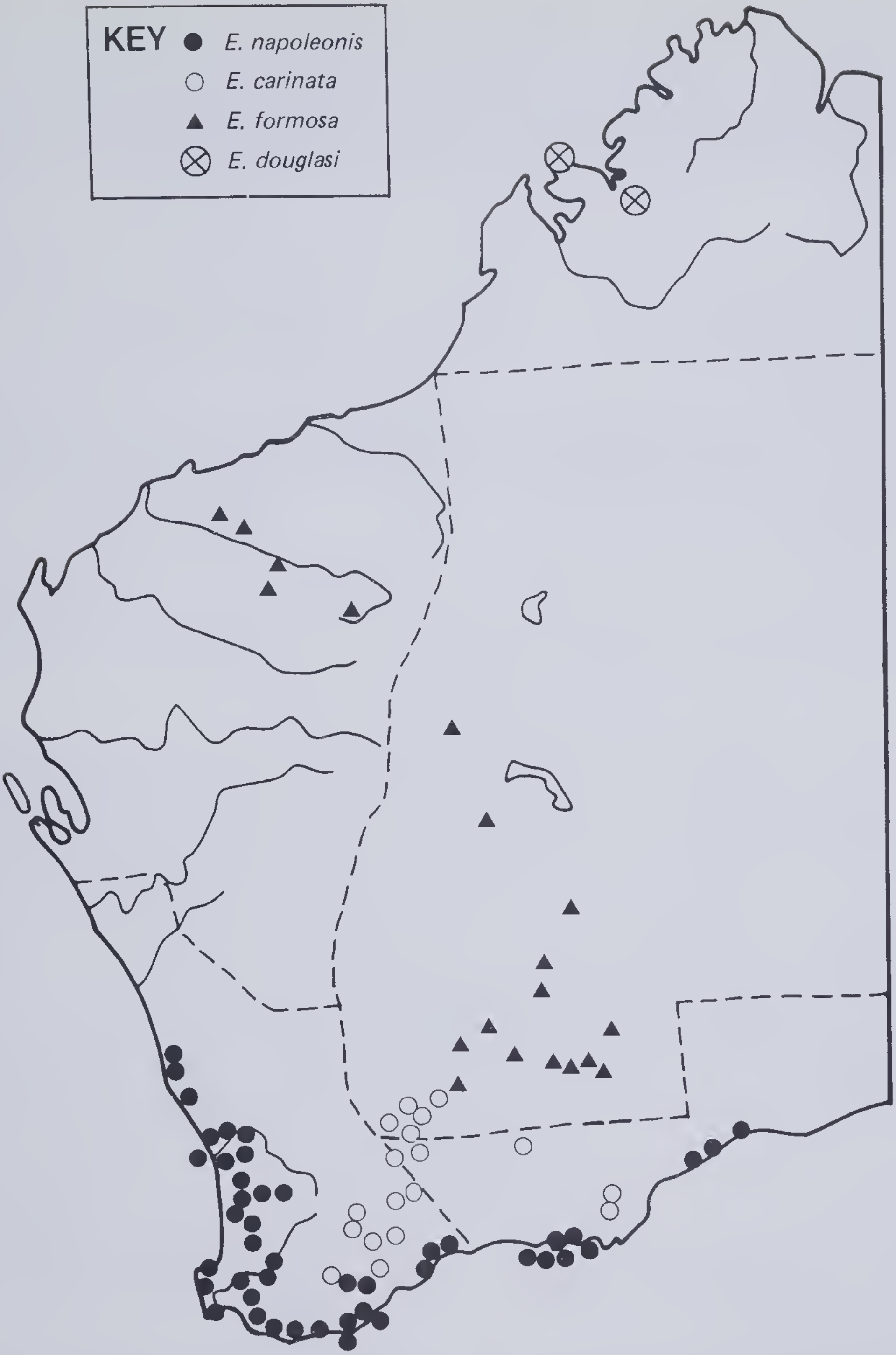

Fig. 3: Map of Western Australia, showing location of specimens of *Egernia napoleonis*, *E. carinata*, *E. formosa* and *E. douglasi*.

EGERNIA LUCTUOSA

Cyclodus (Omolepida) luctuosus Peters, 1866, Mber. k. preuss. Akad. Wiss. 1866: 90. King George Sound, W.A.

Egernia lauta DeVis, 1888, Proc. Linn. Soc. N.S.W. (2) 2: 813. "Queensland" [in error for Western Australia].

Diagnosis

A large member of the *E. luctuosa* species-group with spotted back and subnarial groove.

Distribution

Humid zone of southwestern Western Australia from Perth south and east to Cheyne Beach, and inland to Dwellingup, Jarrahwood, Pemberton and Chorkerup.

Description

Snout-vent length (mm): 59-129 (N 47, mean 110.3). Length of appendages (% SVL): foreleg 21-28 (N 44, mean 23.9), hindleg 28-40 (N 46, mean 33.7), tail 156-214 (N 19, mean 173.4).

Nasals in contact, usually forming a long median suture; occasionally (4%) very narrowly separated; postnarial groove very short, usually extending from bottom of nasal up to central-bottom of nostril, then occasionally curving up around posterior edge of nostril (but for never more than half way to top of nostril). Prefrontals in contact, usually forming a long median suture; occasionally (6%) very narrowly separated. Frontal wider than interparietal. Enlarged nuchals 0-4 (N 42, mean 2.9) on each side. Supraciliaries 6-9 (usually 8, N 37, mean 8.0), first largest (rarely second, when narrow second fused to third), last often higher than low fourth to penultimate. Second loreal usually (95%) wider than high. Presuboculars usually 3, occasionally (10%) 2, rarely (2%) 4. Upper labials 7 or 8 (N 47, mean 7.4). Temporals 3, lower secondary largest, primary smallest. Ear aperture nearly as wide as high; lobules 2, usually subacute in adults and obtuse in juveniles; first usually larger. Midbody scales in 22-28 rows (N 47, mean 24.9), dorsals striate, central 2-5 striae orientated longitudinally, lateral striae much shorter and obliquely orientated (at right angles to anterolateral facet of scale). Subdigital lamellae broadly callose, 21-28 (N 38, mean 24.1) under fourth toe.

Dorsal ground colour varying from greenish yellow through yellowish brown to very dark brown. Six longitudinal series of oblong or square black dorsal spots, occasionally pale-edged; innermost spots covering inner half of most paravertebral scales, outer spots confined to median strip of dorsal scales. Head shields irregularly edged with black. Black spots on side of body densely clustered in upper lateral zone, much less dense in lower lateral zone. Centres of upper labials pale, resulting in a narrow labial streak. Under surface washed with grey and often spotted with black.

Material

South-west Division: Herdsman Lake (31955); Mongers Lake (12910, 30044-5); Leederville (758); Dwellingup (39970); Jarrahwood (45752); Carey Brook (27793); Pemberton (12300); Yeagerup (47859-61, 47927); Walpole (51439, 51454, 51457); 44 km S of Rocky Gully (46258); Kent River (46543); 8 km W of Denmark (27794-5); Denmark (8476); Chorkerup (4419); Albany (53738-41); Two Peoples Bay (16767-8, 36351, 36368-9, 36373, 36379); Gidley Brook (27791); King Creek (27788-90); Mt Many Peaks (27792); Waychinicup River (27785-7, 53758); Cheyne Beach (23327, 36018-9); "Queensland" (QM J249, holotype of *E. lauta*).

EGERNIA COVENTRYI sp. nov.

Holotype

D18284 in the National Museum of Victoria, collected by P.A. Rawlinson and K.C. Norris on 5 March 1971 at Shipwreck Creek, *ca* 20 km SW of Mallacoota, Victoria, in 37° 37′ S, 149° 39′ E.

Diagnosis

A small member of the *E. luctuosa* group, distinguishable from *E. luctuosa* by its striped rather than spotted back and long postnarial groove; it is also smaller, with relatively shorter appendages, smaller ear aperture, nasals and prefrontals, and fewer midbody scale rows, subdigital lamellae, supraciliaries and upper labials.

Distribution

Southern Victoria.

Description

Snout-vent length (mm): 32-102 (N 27, mean 80.4). Length of appendages (% SVL): foreleg 19-26 (N 26, mean 22.0), hindleg 29-37 (N 26, mean 32.3), tail 129-171 (N 13, mean 149.1).

Plate 1: Photograph of specimen of *Egernia coventryi.*

Nasals narrowly separated (63%) or in short contact; postnarial groove extending to top of nostril. Prefrontals separated (64%), usually narrowly, or forming a short to long median suture. Frontal wider than interparietal. Enlarged nuchals 2-4 (N 27, mean 3.1) on each side. Supraciliaries 5-7 (N 27, mean 6.5), first largest when 7, second largest when 5 or 6 (owing to fusion of wide third with narrow second). Second loreal usually (78%) wider than high. Presuboculars usually 2, occasionally (22%) 3, rarely (7%) 1. Upper labials 6 or 7 (N 27, mean 6.9). Temporals 3, lower secondary usually largest, primary smallest. Ear aperture small, nearly as wide as high; lobules 2, subacute in adults, obtuse in juveniles, first larger. Midbody scale rows 21-24 (N 25, mean 23.2), mid-dorsals faintly striate, central striae longitudinally orientated, anterolateral striae (when present) short and obliquely orientated (i.e. at right angles to anterolateral facets of scales). Subdigital lamellae broadly callose, 17-21 (N 23, mean 18.6) under fourth toe.

Dorsally yellowish brown, grey or olive. Usually a wide ragged-edged blackish-brown laterodorsal stripe from nape to base of tail, leaving a pale to moderately dark dorsolateral stripe and vertebral band of ground colour. Sides with many blackish-brown scales, especially in upper lateral zone; in most specimens many dark scales bearing a central whitish dot or dash. Head and face of dorsal ground colour, with or without irregular blackish-brown spots. Usually a whitish streak through centre of upper labials. Under surface greyish white, darkest under tail.

Remarks

Named after Mr A.J. Coventry of the National Museum of Victoria in appreciation of his services to Australian herpetology.

Paratypes

Victoria: Grampians (NMV D17299); Johnstones Creek, W of Portland (NMV D14740); Dennington, 10 km NW of Warrnambool (28715; NMV D18282); Healesville (AM R8871, 9496-7); Bayswater (NMV D17169); French I. (NMV D38510); Cape Liptrap (NMV D42220, 47895); Rosedale (NMV D989, 2501-2); near Bemm River P.O. (NMV D34217-23, 34237); 1 mile N of Sandpatch Point (NMV D34240-1); Shipwreck Creek (NMV D18283, 18285); "Victoria" (NMV D1307).

EGERNIA PILBARENSIS sp. nov.

Holotype

R31117 in Western Australian Museum, caught by Mr A.M. Douglas at 1730 hr on 10 September 1967 in a break-back trap on a rocky ridge 6 km NW of Pyramid, Western Australia, in 21° 01′ S, 117° 24′ E.

Diagnosis

A moderately large, reddish brown, almost patternless *Egernia* with smooth scales, very short toes and tuberculate palms and soles.

Distribution

Rocky hills of the Pilbara region of northwestern Western Australia, including the Dampier Archipelago.

Description

Snout-vent length (mm): 100-121 (N 5, mean 111.6). Length of appendages (% SVL): foreleg 22-27 (N 5, mean 24.3), hindleg 29-36 (N 5, mean 32.0), tail 117-167 (N 5, mean 132).

Plate 2: Photograph of specimen of *Egernia pilbarensis.*

Nasals separated (4 specimens) or in very short contact (one specimen). Prefrontals in medium to long contact (4 specimens); very narrowly separated (1 specimen). Frontal as wide as (one specimen) or wider than interparietal (4 specimens). Enlarged nuchals 3 or 4 (N 5, mean 3.4) on each side. Supraciliaries 7 (4 specimens) or 8 (1 specimen); first largest. Second loreal wider than high. Upper labials 8 or 9 (N 5, mean 8.6). Temporals 3, lower secondary largest, primary smallest. Ear aperture narrow rectangular, almost vertical; lobules 4-6 (N 5, mean 5.0), subacute, second to fourth largest. Midbody scales in 32 or 34 rows (N 5, mean 33.6), mid-dorsals smooth or very faintly striate. Lamellae under fourth toe 13-16 (N 5, mean 14.5); proximal lamellae broadly callose, distal lamellae smooth (i.e. thin-scaled). Plantar tubercles brown, becoming large towards heel (as in *Ctenotus pantherinus calx*).

Back and sides reddish brown, darkest on lores and temples and anteriorly in upper lateral zone. Sides unmarked or dotted with white or indistinctly marked with pale obliquely vertical lines. Upper labials pale brown or brownish white, slightly to sharply differentiated from scales above them. Lower labials and chin shields with or without dark sutures. Gulars with or without brown spots or edges.

Paratypes

North-west Division: Cape Lambert (AM R37481); Python Pool, Mt Herbert (33424); Rosemary I. (37379-80).

EGERNIA PULCHRA PULCHRA

Egernia pulchra Werner, 1910, *in* Michaelsen & Hartmeyer's 'Fauna Südwest-Australiens' **2**: 470. Torbay, W.A.

Diagnosis

A slender, moderately large, flat-headed member of the *E. whitii* group with keeled dorsals and much black and grey in coloration. Further distinguishable from *E. multiscutata* by smooth subdigital lamellae.

Distribution

Humid southwest corner of Western Australia, north along the Darling Range to Dwellingup, and east along the south coast to Cheyne Beach; also in the Stirling Ranges and on Eclipse Island.

Partial redescription

Snout-vent length (mm): 41-110 (N 57, mean 88.0). Length of appendages (% SVL): foreleg 24-36 (N 48, mean 28.4), hindleg 33-48 (N 47, mean 39.4), tail 152-193 (N 24, mean 167.5).

Nasals separated. Prefrontals forming a long median suture (separated in one specimen). Frontal much wider than interparietal in adults, slightly wider in juveniles. Enlarged nuchals 1 (rarely 2) on each side. Supraciliaries 6-10 (N 42, mean 7.7), first usually (88%) largest. Second loreal usually wider than high, occasionally (26%) no wider. Presuboculars 2 (N 38). Upper labials 7 or 8 (N 47, mean 7.2). Temporals 3, lower secondary much the largest, primary smallest. Ear aperture narrow to moderately wide; lobules 2-6 (N 38, mean 3.4), obtuse or acute, third from bottom usually largest. Midbody scales in 34-40 rows (N 46, mean 36.6), dorsals with 2-4 (mostly 3) keels (weak in adults, very weak in juveniles). Subdigital lamellae divided, 22-30 (N 39, mean 25.4) under fourth toe.

Coloration and geographic variation

See Ford (1963, 1965) and Storr (1968).

Additional material

South-west Division: Dwellingup (39962-4); Nannup (47385-8); Cowaramup (34001); Canebrake Road, 23 km N of the Scott River (36049-51); Pemberton (33437); Yeagerup (47926); Meerup, east Warren River (47888); 43 km S of Rocky Gully (46260-1); small islet S of Signal Point, Broke Inlet (45751); Walpole (51433-5, 51441, 51458, 51460-1, 51470); Kent River area (46541); Cheyne Beach (31167, 36031-2, 36316-7).

EGERNIA PULCHRA LONGICAUDA

Egernia pulchra longicauda Ford, 1963, West. Aust. Nat. 9: 26: Favourite Island, Jurien Bay, W.A. (J. Ford).

Diagnosis

Distinguishable from *E. pulchra pulchra* by orange abdomen, nasals usually in contact, and very long tail.

Distribution

Jurien Bay islands (Favourite, Boullanger, Whitlock and Escape) off lower west coast of Western Australia.

Description and geographic variation

See Storr (1968).

Additional material

None.

EGERNIA MULTISCUTATA BOS

Egernia bos Storr, 1960, West. Aust. Nat. 7: 99. Cheyne Beach, W.A.

Diagnosis

A small deep-headed member of the *E. whitii* group with smooth dorsals and usually much black and grey in coloration. Further distinguishable from *E. pulchra* by bicarinate subdigital lamellae.

Distribution

Semi-arid and subhumid sandplains and coastal dunes of southern Western Australia: Shark Bay (Bernier Island); lower west coast from Stockyard Gully south to Lancelin Island, including islands in Jurien Bay (Sandland, Favourite, Boullanger, Essex); and from the south coast (west to Cheyne Beach) north to York, Corrigin, Bendering, Kambalda, Coonana and Madura. Extralimital in southern South Australia.

Description

Snout-vent length (mm): 34-96 (N 139, mean 70.4). Length of appendages (% SVL): foreleg 25-36 (N 124, mean 31.0), hindleg 34-51 (N 124, mean 41.2), tail 126-179 (N 62, mean 151.0).

Nasals separated, usually widely or moderately widely, seldom narrowly. Prefrontals usually forming a long median suture, very rarely separated. Frontal usually a little wider than interparietal, except in juveniles (where occasionally narrower). One enlarged nuchal on each side. Supraciliaries 6-10 (N 102, mean 7.6), first almost invariably (97%) largest. Second loreal usually wider than high. Presuboculars usually 2, rarely (7%) 3. Upper labials 7-8 (N 123, mean 7.7). Temporals normally 3, lower secondary much the largest, primary smallest. Ear aperture very narrow to moderately narrow, nearly vertical; lobules 3-6 (N 115, mean 4.0), usually obtuse, occasionally subacute or truncate, first usually largest. Midbody scale rows 37-46 (N 105, mean 41.6). Subdigital lamellae bicarinate, 21-30 (N 109, mean 24.1) under fourth toe.

Coloration and geographic variation

The only thing to add to the analysis in Storr (1968) is that three of seven specimens from near Cocklebiddy in the southeast of Western Australia are almost patternless. Such variants were previously known only from Eyre Peninsula, South Australia.

Additional W.A. material

South-west Division: Mt Peron (48435, 49131-5, 49215); Cockleshell Gully (48465, 48516, 49296); Mt Lesueur (52037); 16 km NE of Jurien Bay (31282, 31558, 46566-71, 46585); Jurien Bay (31533-6); Boullanger I. (31286-7); lower Hill River (40487); York (39103); Boyagin Reserve (41012-3); Tutanning Reserve (40562); Bendering Reserve (43406-7, 43444, 43675); Lake Varley (28949-50); Dragon Rocks Reserve (43721, 43776); Greenshield Soak, 27 km E of Pingrup (39804); Lake Chinocup Reserve

(43476, 43484); lower Fitzgerald River (36783, 36929); Cheyne Beach (36029-30).

Eastern Division: Kambalda (47249).

Eucla Division: 32 km WNW of Norseman (31283-5); 14 km N of Norseman (47250); 6 km N of Norseman (51070-1); Rossiter Bay (42589); 19 km W of Israelite Bay (31091); 8 km W of Israelite Bay (31092-100); 17-26 km SE of Cocklebiddy (34481-4, 53405-7); 32 km N of Madura (29423).

EGERNIA INORNATA

Egernia inornata Rosén, 1905, Ann. Mag. nat. Hist. (7) 16: 139. Western Australia (N. Holst) [probably the Eastern Goldfields].

Diagnosis

A small, deep-headed, smooth-scaled member of the *E. whitii* group with dorsal coloration varying from pale brownish yellow to dark coppery red. Further distinguishable from *E. multiscutata* by subdigital lamellae narrowly callose or obtusely unicarinate (seldom bicarinate) and upper labials seldom more than 7, and from *E. striata* by presence of black or blackish brown pigment.

Distribution

Arid and semi-arid interior of Western Australia, north nearly to lat. 24° S, and south to the northern and eastern Wheat Belt, Eastern Goldfields and southern edge of Great Victoria Desert. Extralimital in Northern Territory, South Australia and New South Wales.

Description

Snout-vent length (mm): 32-84 (N 106, mean 65.3). Relative length of appendages (% SVL): foreleg 24-36 (N 104, mean 28.4), hindleg 32-44 (N 104, mean 38.5), tail 113-148 (N 43, mean 128.2).

Nasals separated. Prefrontals usually forming a median suture, occasionally just touching or narrowly separated. Frontal usually wider than interparietal in adults, narrower in juveniles. One enlarged nuchal on each side. Supraciliaries 5-8 (N 60, mean 7.5), first largest. Second loreal wider or narrower than high. Presuboculars 2 (rarely 1 or 3). Upper labials usually (95%) 7, rarely 8, very rarely 6 (N 93, mean 7.0). Ear aperture usually narrow; lobules 3-6 (N 86, mean 3.8), subacute or obtuse, first usually largest. Temporals 3, lower secondary much the largest, primary smallest. Midbody scales in 34-42 rows (N 84, mean 37.8), dorsals smooth, occasionally with very faint striae. Subdigital lamellae slightly compressed with an apical series of grey to dark brown obtuse keels or narrow calli (occasionally an additional keel on slope of lamella), 21-27 (N 85, mean 24.0) under fourth toe.

Coloration and geographic variation

See Storr (1968).

Additional W.A. material

North-west Division: Marloo (30854).

South-west Division: East Yuna Reserve (48189); Lochada, E of Morawa (45704); Buntine Reserve (43655).

Eastern Division: 50 km S of Warburton Range (41581); Lake Throssell (39700); Wanjarri (37784-5, 48037); 30 km N of Neale Junction (48758); 29 km W of Laverton (53286-7); Plumridge Lakes (48706, 48726); 75 km N of Kalgoorlie (52086-7); 3 km W of Dedari (51732); Yellowdine (36180); 29 km S of Yellowdine (37929).

EGERNIA STRIATA

Egernia striata Sternfeld, 1919, Senckenbergiana 1: 79. Hermannsburg, N.T. (M. von Leonhardi).

Diagnosis

A moderately large, deep-headed member of the *E. whitii* group with pupil vertically narrow and back reddish brown longitudinally striped with dark brown. Further distinguishable from *E. inornata* by lack of black pigment, and from *E. kintorei* by fewer labials and presuboculars and more pointed ear lobules.

Distribution

Arid zone of Western Australia from the Pilbara and Great Sandy Desert south to Carnarvon and the Great Victoria Desert. Extralimital in southern Northern Territory and northwestern South Australia.

Description

Snout-vent length (mm): 41-112 (N 115, mean 83.3). Length of appendages (% SVL): foreleg 23-36 (N 111, mean 28.2), hindleg 31-47 (N 111, mean 36.5), tail 109-151 (N 61, mean 127.8).

Nasals separated moderately to very widely, rarely (2%) narrowly. Prefrontals usually forming a median suture; rarely (8%) separated. Frontal usually a little wider than interparietal in adults and a little narrower in juveniles. Enlarged nuchals 1 (rarely 2) per side. Supraciliaries 7-10 (N 92, mean 8.5), first largest. Second loreal higher or narrower than wide. Presuboculars 2 (very rarely 3). A complete series of small suboculars present. Upper labials usually 7, rarely (5%) 8 (N 97, mean 7.1). Temporals 3, lower secondary much the largest, primary smallest (not counting a postocular that could be construed as a small upper primary temporal, especially as it usually precludes contact between upper secondary and lower [if not only] primary). Ear aperture narrow to moderately narrow, nearly vertical; lobules 4-6 (N 96, mean 4.7), obtuse or subacute, usually slightly decreasing in size downwards. Midbody scales in 39-46 rows (N 93, mean 42.1). Subdigital lamellae with an apical series of narrow calli, proximal lamellae often divided or notched, 18-24 (N 94, mean 21.4) under fourth toe.

Coloration and geographic variation

See Storr (1968).

Additional W.A. material

Eastern Division: 8 km S of Charlies Knob (53614); Ngaral Soak, 58 km NW of Carnegie (33394); Carnarvon Range (40212-5, 51383); Dunes S of Carnarvon Range (39783); Winduldarra RH (26° 31′ S, 126° 01′ E) (48741); 29 km E of Terhan RH (34303); 5 km E of Point Sunday, Laverton-Emu track (53555, 53583); Ivor Rocks, White Cliffs (53259); 20 km S of Neale Junction (48791).

EGERNIA KINTOREI

Egernia kintorei Stirling & Zietz, 1893, Trans. Roy. Soc. S. Aust. 16: 171. Lectotype locality: 95 km S of Barrow Range, W.A. (Elder Expedition).

Egernia dahlii Boulenger, 1896, Ann. Mag. nat. Hist. (6) 18: 233. Roebuck Bay, W.A. (K. Dahl).

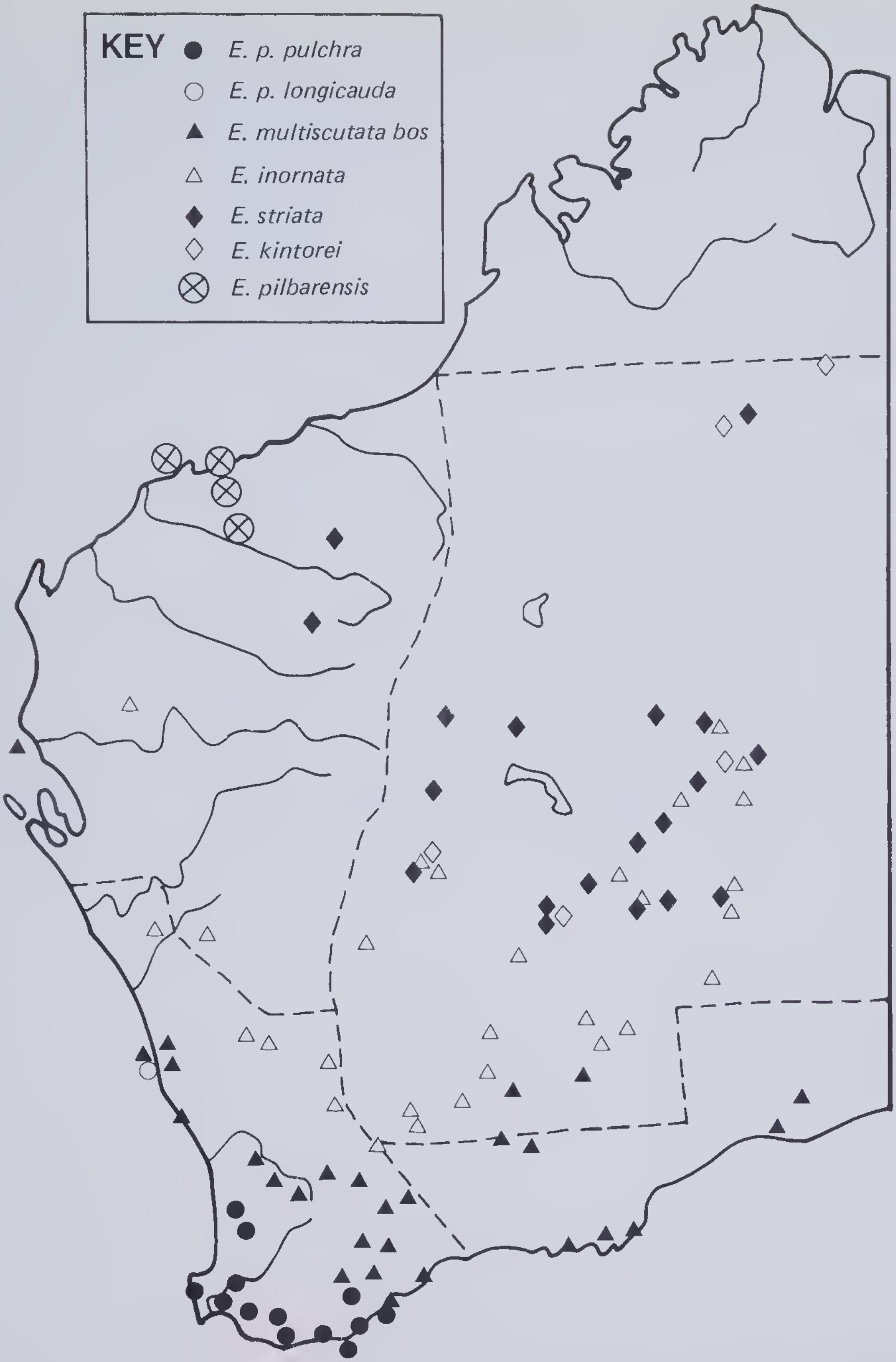

Fig. 4: Map of Western Australia, showing location of specimens of *Egernia p. pulchra*, *E. p. longicauda*, *E. multiscutata bos*, *E. inornata*, *E. striata*, *E. kintorei* and *E. pilbarensis*.

Diagnosis

A very large, robust, deep-headed member of the *E. whitii* group with short thick appendages and pale reddish brown back sharply demarcated from grey sides. Further distinguishable from *E. striata* by much wider pupil, more numerous upper labials and presuboculars, and more obtuse ear lobules.

Distribution

Great Sandy, Gibson and Great Victoria Deserts of Western Australia. Extralimital in the Tanami Desert of Northern Territory.

Description

Snout-vent length (mm): 111-187 (N 10, mean 141.2). Length of appendages (% SVL): foreleg 25-31 (N 10, mean 27.0), hindleg 29-37 (N 10, mean 33.5), tail 106-130 (N 7, mean 118.3).

Nasals widely separated. Prefrontals forming a median suture. Frontal usually wider than interparietal. One enlarged nuchal on each side. Supraciliaries 7 or 8 (N 9, mean 7.8). Second loreal much higher than wide. Presuboculars usually 3. A complete series of small suboculars. Upper labials 8 or 9 (N 10, mean 8.1). Ear aperture narrow; lobules 4 or 5 (N 10, mean 4.6), obtuse or rectangular. Midbody scale rows 43-52 (N 10, mean 47.0), smooth or striate. Subdigital lamellae smooth or weakly callose, proximal lamellae usually divided or notched, 19-23 (N 9, mean 20.3) under fourth toe.

Coloration

See Storr (1968).

Additional material

None.

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MAMMALS OF THE ORD RIVER AREA, KIMBERLEY, WESTERN AUSTRALIA

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ABSTRACT

This survey of the Ord River area recorded 26 species of native mammal, mostly from localities that are now submerged beneath Lake Argyle. These species are representative of Kimberley mammals and (unlike the bird and reptile fauna of the area) include no arid element.

Material from archaeological and palaeontological sites in the area indicate that at least three species of native mammal not collected on these surveys were in the area at about the time of its European settlement. Further, there were fewer species of native rodents in the survey area than might be expected and a general absence of arboreal species. With the exception of chiropterans, this mammal fauna was considered low in species and numbers. This is attributed to the combined effects of European settlement, particularly the introduction of cats and the degradation of riverine woodlands by livestock, feral donkeys and fire.

Observations are presented on the period of births for some species.

INTRODUCTION

Lake Argyle is in the east Kimberley about 50 km south of Kununurra. It was formed by a dam, completed in 1971, across the Ord River, and is the major reservoir for an irrigation project designed to establish agriculture in the region. It began to fill during the 1971/72 wet season. The Lake now has an area of 480 square kilometres at normal spillway level (its extent is indicated on Fig. 1) and 1300 square kilometres at the maximum flood storage level. It encompasses parts of the previous grazing leases of Argyle Downs and Lissadell Stations. Low lying grassy plains formed the greater

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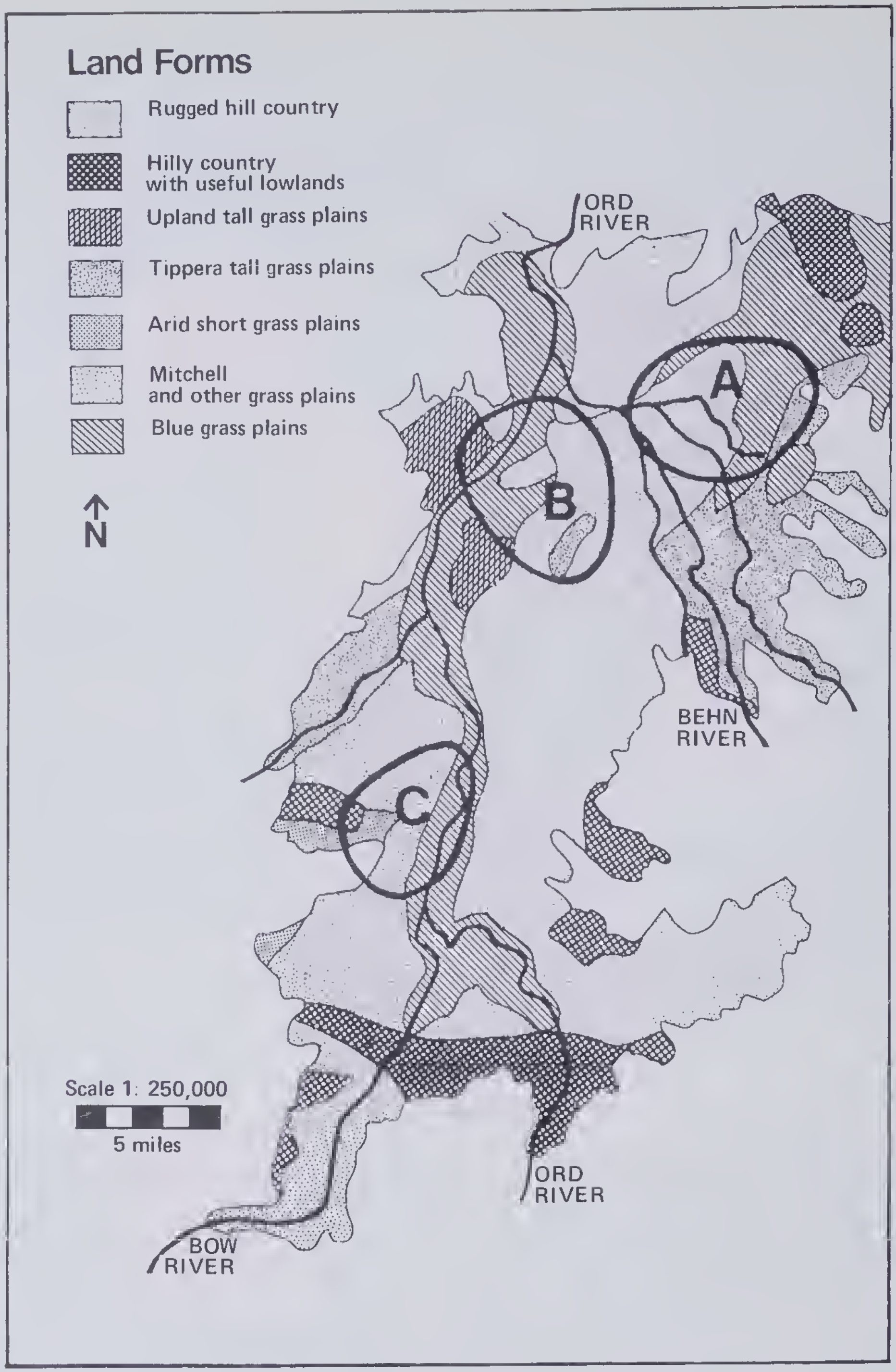

Fig. 1: Showing the land forms (from C.S.I.R.O. Land Research Series No. 28) within that part of the Ord River Basin to be flooded. The three general areas selected for the October 1971 survey (A, B and C) are outlined.

part of the Reservoir area. Hilly country and upland plain to the east and south west, and ridges and foothills of the Carr Boyd Ranges to the north, are included.

In 1885 the Durack family established the first major settlements in the Ord River basin at Argyle, Lissadell, and Rosewood Stations. Stewart (1970) reports that until the 1890s most of the beef produced at these stations was sent to the gold mining area at Halls Creek. With the decline in gold production from that area, their cattle were marketed by exporting them live from Wyndham to the Philippines or by droving them overland to Queensland. By 1920 the cattle population in the region had reached approximately its present numbers.

Although the Ord River Basin had been settled for 85 years prior to the filling of the Dam in 1971, with the exception of birds, there was no record of the fauna of the Reservoir area. For this reason the Western Australian Wildlife Authority commissioned the Western Australian Museum (WAM) to survey the area in October 1971, prior to its being flooded. The objectives of this survey were threefold: to record the mammals, birds, reptiles, frogs, freshwater fish and molluscs present; to indicate which animals may require rescuing when flooding began and how their rescue should proceed; and to predict ecological changes that may occur in the general area and propose recommendations for the management of fauna in the area. Recommendations arising from the October 1971 survey were compiled by me and submitted to the Western Australian Wildlife Authority in November 1971.

In January and February 1972, a party from the Western Australian Museum again visited the area to take vertebrate fauna for their collections, and for those of the National Museum of Victoria, the Australian Museum (Sydney) and the Northern Territory Museum. All these museums contributed towards the cost of collecting. This second visit to the area was at a time when animals were being confined and stranded on the numerous islands formed by the rising waters of Lake Argyle, particularly near the dissected hilly country in the northern region of the Reservoir. A third collection of mammals from the Ord area was made by L.E. Keller, Field Museum of Natural History, Chicago, between 19-24 November 1976 in the vicinity of Lissadell Homestead. Ms Keller has kindly allowed me to examine and report on these specimens.

In conjunction with the October 1971 faunal survey, an archaeological excavation of two Aboriginal sites in the Ord Reservoir Area was carried out by C.A. Dortch in association with D. Merrilees and M. Archer, all of the Western Australian Museum. These two sites, Miriwun and Monsmont, have been described by Dortch (1972) in an interim report on the excavations. Both sites (Fig. 2) have palaeontological material but Miriwun is particularly rich in mammals. The mammal bones are, however, very fragmented, as is to be expected in a site of this nature. The mammals of the upper surface strata are believed to have been formed in the deposit after Aboriginal contact with Europeans (C.A. Dortch, pers. comm.); they are mixed with occasional pieces of fencing wire, cattle *(Bos taurus)* bones and Aboriginal artifacts made of European bottle glass. The mammals in the surface strata of these sites are listed to enable comparison between mammals occurring in the reservoir area about the time of the first European settlement, and those recorded there in 1971-72 and 1976.

Apart from the collecting by W.H. Butler at Kalumburu (4 December 1965 to 1 February 1966), few mammals have been collected in the Kimberley during the wet season. Mammals collected at the Ord River in October, January and February should, then, complement the sparse information available on mammal breeding in the Kimberley.

Information obtained from the Ord River specimens is presented in conjunction with breeding information obtained from other female Kimberley specimens in WAM collections, and from pertinent published accounts. Most of these WAM specimens have numbers that are prefixed with an 'M'. However, some of those collected by W.H. Butler for the joint 1963/65 American Museum of Natural History and WAM expedition have numbers that are prefixed with a 'B'.

METHODS

1-24 October WAM Survey

For the vertebrate survey three areas within the Ord Reservoir were selected from the Ord-Victoria area map in the C.S.I.R.O. Land Research Series No. 28 (1970). These survey areas include representatives of the major land forms within the Reservoir area. These, and the three general areas (A, B & C) surveyed, are indicated in Fig. 1. The major habitats for mammals within these areas were selected following an aerial reconnaissance on 1-2 October 1971. They are located in Fig. 2 (1-20) and are described in the Environment section (p. 197). Each of these areas was trapped. This involved a total of 1040 Elliott, 776 breakback and 208 cage trap-nights.

The survey was divided into two phases. The first phase, concerned with the general faunal survey, took place between 1-20 October. For this phase 3 teams were formed.

Team 1	R.J. McKay & J. Dell
Team 2	Mr & Mrs W.H. Butler
Team 3	D.J. Kitchener & R. Graves

B.R. Wilson was with the survey between 6-13 October. He joined the teams that allowed him the best coverage of the mollusc fauna. Although each of these teams set mammal traps, individuals had particular specialist interests which covered the faunal groups referred to in the Introduction. Each team spent time in each of the predetermined survey areas A, B and C, according to the following schedule.

	Team 1	Team 2	Team 3
Area A	16-20 October	11-15 October	3-10 October
Area B	3-10 October	16-20 October	11-15 October
Area C	11-15 October	3-10 October	16-20 October

The second phase of the survey took place between 20-24 October. During this period attention was concentrated on the areas that may become important during the actual rescue operation and on any habitat that was not examined in the first phase of the survey. The additional areas surveyed for mammals included Banana Springs, mouth of Hicks Creek, termitaria near Old Lissadell Homestead, Mount Misery and Monsmont.

The mammal traps used were (i) *breakbacks* — a metal rat trap, (ii) *Elliott traps* — collapsible trap with solid aluminium walls with dimensions 0.1 x 0.3 x 0.1 m, (iii) *cage traps* — a collapsible trap made from wire mesh with dimensions 0.6 x 0.5 x 0.6 m. Traps were set at approximately 1600 hrs and baited with 'Universal bait', a mixture of peanut butter, bacon, raisins and oats. They were checked each day between 0500-0700 hrs. In addition to trapping and shooting, mammals were collected by mist-netting over creeks, and spotlighting at night from Landrovers. Each of the 3 teams conducted spotlighting traverses in each of areas A, B and C. Each team's traverses were conducted on the same night (4th, 7th, 11th, 14th and 18th), at the same time (1830-2130 hrs), and by travelling over the same section of road. Where possible, a driving speed of 24 kph was maintained. The routes travelled during these traverses are shown in Fig. 2.

4 January-16 February WAM Survey

The members of this survey team were D.J. Kitchener, L.A. Smith, R.E. Johnstone and W.K. Youngson. Collecting was focused on small islands created by the rising water of Lake Argyle. The main areas examined were at the mouth of Hicks and Matilda Creeks, Mt Misery, Monsmont, Argyle Downs, Argyle Lagoon, Banana Spring, and the Spillway. Small islands which were to be covered as the lake continued to rise were systematically burnt; mammals and reptiles were caught as they ran from burning *Triodia* sp. In addition planigales were collected from rafters of the almost submerged Argyle Downs Homestead.

A limited amount of trapping was carried out. Between 7-28 January, 10 Elliott, 10 breakback and 4 cage traps were set at each of three sites: in spinifex on rocky slopes, just above the lake water level near the Landing; on slopes behind the Main Dam settlement in open low eucalypt woodland over spinifex; and on sparsely grassed flats 11 km south of Main Dam on the west side of the dam (opposite Monsmont).

Bats were collected from 8 caves. These caves were referred to as Spillway Cave (8 km N Main Dam), Aboriginal Cave (6.5 km NE of Main Dam), Landing Cave (200 m E of the Landing), Harrys, Tit, Wallaby, Lauries and Fairy Martin Caves (on slopes of Monsmont). Cave floor plans are sketched in Fig. 3.

19-24 November, Field Museum — Chicago, Survey

The members of this survey team were L.E. Keller, K. Morris and R. Munster. Collecting was concentrated around Lissadell Homestead. Mist nets were set over dams at the Station and 6 traplines, each consisting of 8 stations placed 20 m apart, were established over the survey period. These traplines were placed in areas similar to areas 11, 12 and 17 described in the Environment section (p. 197). Two lines were placed on a limestone outcrop vegetated by a deciduous sparse low woodland with arid short grass. Four types of traps were placed at each trapping station: a cage, Sherman (similar to Elliott traps but about two-thirds their size), breakback, and 'special' (intermediate in size between breakback rat and mouse traps). Universal bait was used and traps were inspected between 0500-0700 hrs.

Basic body measurements and weight were recorded from mammals collected during these surveys. Stomachs of larger macropods were preserved. Most specimens were fixed in 10% formalin and then preserved in 75% ethyl alcohol. All specimens were dissected in the laboratory and an examination made of their reproductive organs *in situ*.

Specimens from both WAM surveys were registered into the WAM collections. Those collected in October have the catalogue numbers M11613-652 and in January-February M11457-612. Field Museum specimens have the field numbers 3243-80; these specimens are now lodged in the Field Museum of Natural History, Chicago.

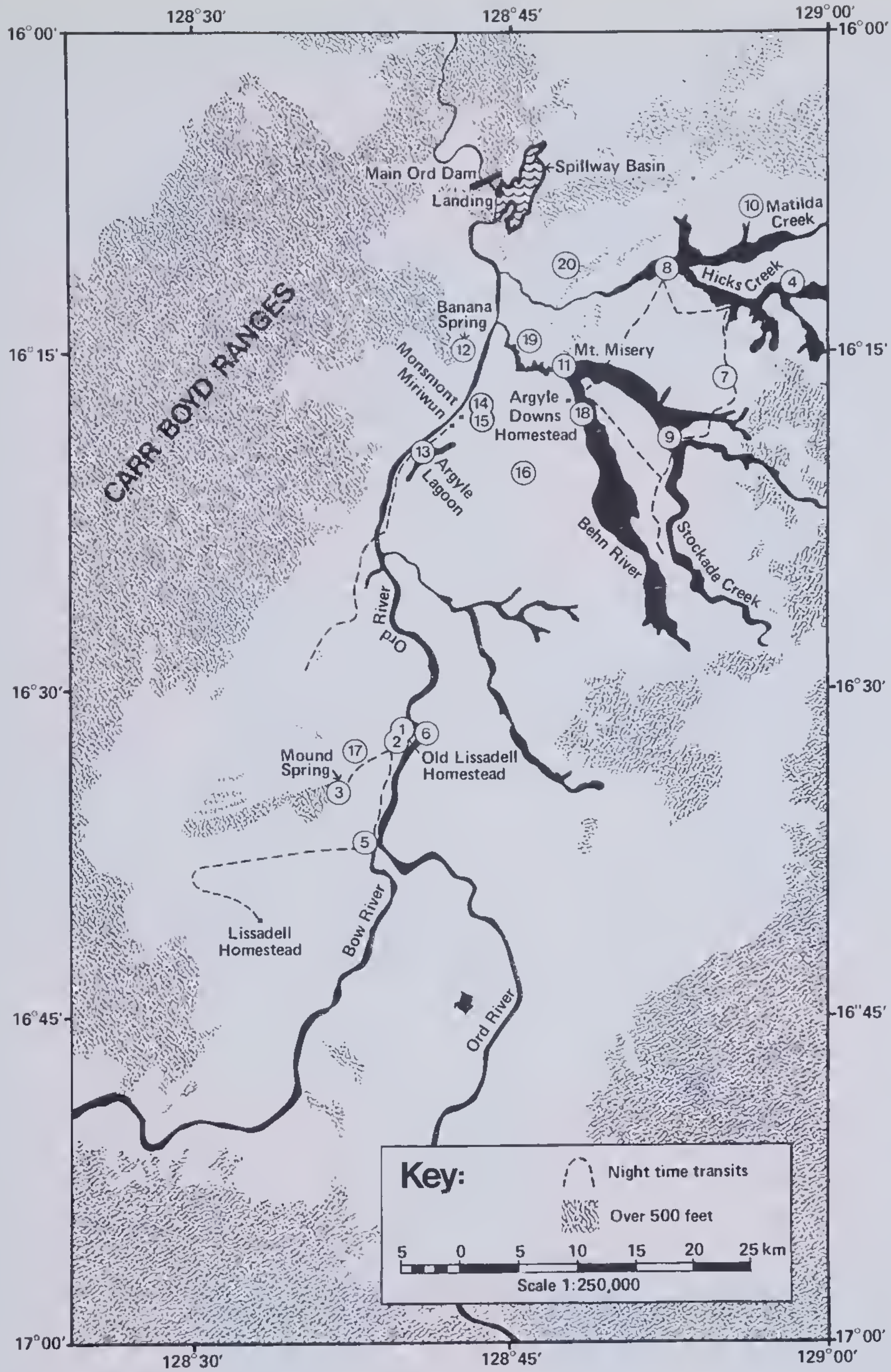

Fig. 2: Map of the Ord River Basin showing the major drainage systems, the location of the October trapping areas (1-20), and other sites referred to in text. The broken lines indicate the routes of the spotlighting transects.

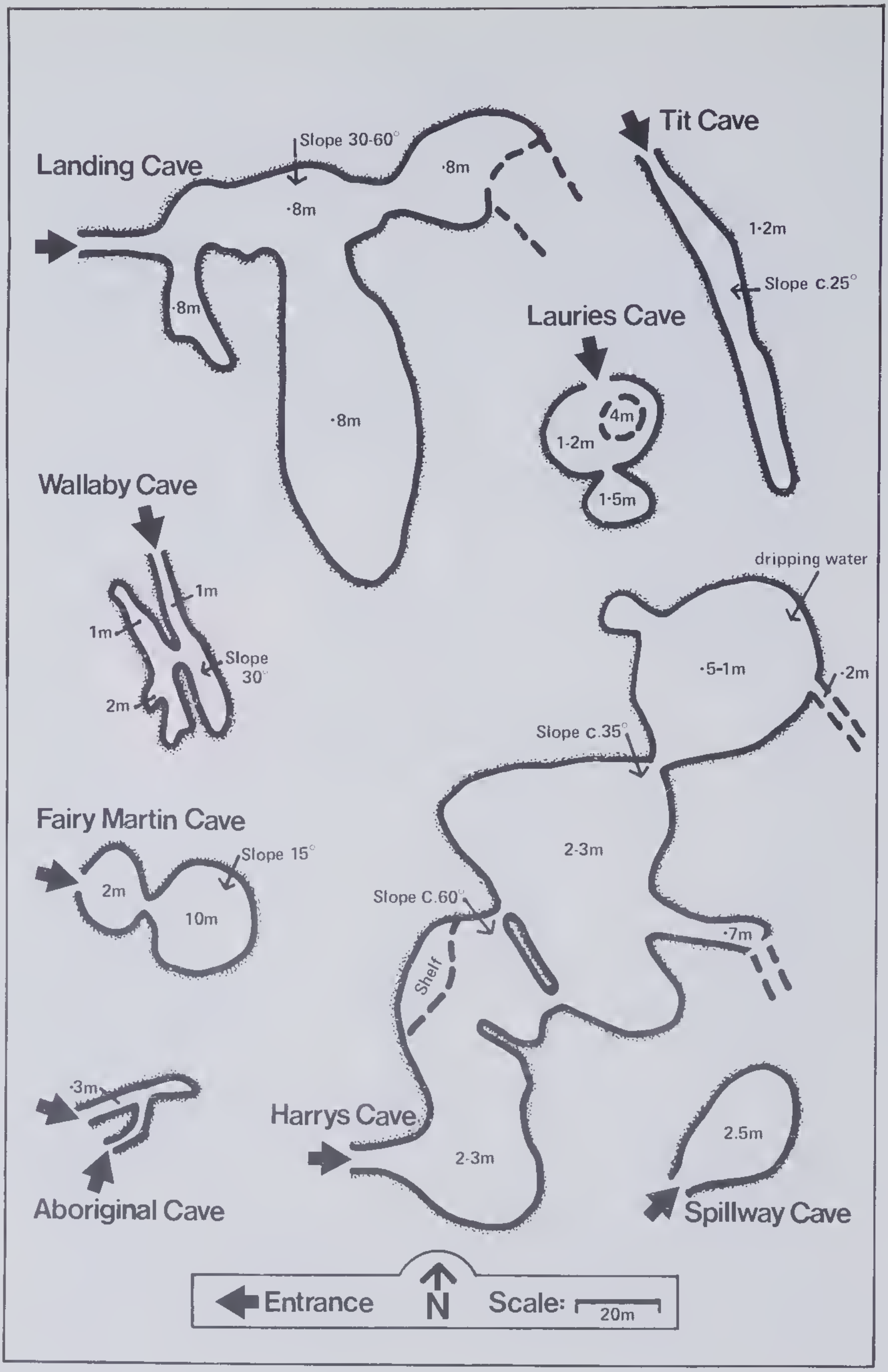

Fig. 3: Sketches of the floor plan of seven bat caves from the Ord River area. The entrance to the caves is arrowed. The height of each cavern and the incline, if present, is indicated on the drawings. See text for localities.

Outlines of the geomorphology, physiography, and climate of the Ord River area are covered in the C.S.I.R.O. publication 'Lands of the Ord-Victoria area, Western Australia and Northern Territory', *Land Research Series* no. 28 (1970). Briefly, the Ord River flows through a sequence of lower Cambrian volcanics, middle Cambrian limestones and shales, and Devonian sandstones. The volcanics have mostly been dissected to form mesas and buttes but in the northern areas there are appreciable areas of plains. The vegetation of the Ord area is both structurally and floristically similar to the belt of woodland with grassy understory which stretches from east to west across the continent in similar latitudes. The maximum daily temperature seldom falls below 29°C; it varies by only about 15 degrees throughout the year. The highest temperatures in the lower Ord Valley generally occur in November. Seasons are determined by the presence or absence of rainfall and its associated humidity. There is a marked seasonal distribution of rainfall with the maximum precipitation occurring in the period of December to March. A long dry season covers the remainder of the year. The first rain may fall at any time from October to December. The close of the wet season is generally mid-April to mid-May. Most rainfall is cyclonic and erratic within the wet season and, although the annual average is fairly reliable at 762 mm, there are marked variations in the monthly recordings from year to year.

During October 1971 a number of major habitats were recognised for the mammal survey. These are listed below. The descriptions apply to areas 1-20 which are located in Fig. 2. The descriptions of vegetation structure throughout this report basically follow Specht *et al.* (1974).

Area 1

Sparse woodland fringing the Ord River. Upper slopes comprised a mixed assemblage of low trees including *Calotropis procera* (Willd) R.Br. ex Ait., *Eucalyptus alba* and *Lysiana subfalcata* (Hook.). There was no shrub layer and grasses were sparse in this zone. Lower down on the embankment the trees were larger with *Eucalyptus camaldulensis* Dehn., reaching a height of over 30 m. There is a second stratum of smaller trees and shrubs including *Melia composita* Willd., *Melaleuca leucodendron, Dolichandrone heterophylla* (R.Br.) F. Muell., *Eucalyptus microtheca* F. Muell., *Ficus coronulata* F. Muell., *F. glomerata* Willd., *Hakea arborescens* R.Br. and the climber *Passiflora foetida* L. A third stratum comprises *Ehretia* cf. *urceolata* W.V. Fitzg., *Santalum lanceolatum* R.Br., *Phyllanthus reticulatus* Poir. and *Acacia* *farnesiana* Willd. A fourth stratum of moderately dense grasses with *Achyranthes aspera* L. was present (Plate 1). *Pandanus* sp. was common along the water edge together with *Barringtonia acutangula* Gaertn.

Areas 2 & 4

Woodland on grassy plains sloping away from low hills. *Eucalyptus grandifolia* R.Br. and *E. tectifica* F. Muell., *Terminalia arostrata* Ewart et Davies and *Dolichandrone heterophylla* (R.Br.) F. Muell., were the dominant trees. The grass *Chrysopogon* sp. was 0.5 m tall, and sparse throughout. Occasional low shrubs were present and included *Hibiscus meraukensis* Hochr., *Sesbania simpliciuscule* Benth., *Grevillea mimosoides* R.Br., *Carissa lanceolata* R.Br. (Plate 2).

Area 3

Mound Spring — a series of brackish soaks overgrown with the fern *Acrostichum speciosum* Willd. which had formed a peaty mound. This mound was fenced against cattle and as a result the enclosure contained a specialised vegetation that formed a moderately dense cover dominated by a *Melaleuca* sp. to 7 m and containing *Sesbania formosa* (L.F. Muell.) N.T. Burbidge. There was also *Fimbristylus ferruginea* (L.) Vahl., a dense low grass cover of *Cynodon* sp., and the low shrubs *Ptilotus exaltatus* Nees. and *Enchylaena tomentosa* R.Br. (Plate 3).

Areas 5, 6, 8 & 9

The dry watercourse of Hicks and Stockade Creeks, their banks, and the adjacent areas. Trees and shrubs growing on the banks included *Lysiphyllum cunninghamii* (Benth.) De Wit., *Nauclea* sp. and *Eugenia eucalyptoides* F. Muell. (Plate 4). As was typical of other large watercourses in the reservoir area, there was a sparse woodland surrounding the creeks to a distance of about 300 m from the dry creek bed. The woodland at this site was dominated by *Eucalyptus* sp. and *Atalaya hemiglauca* (F. Muell.) Benth. *Eugenia eucalyptoides* and *Bauhinia* sp. were also common. Grasses, which included *Panicum* sp., and *Eulalia* cf. *fulva* Kuntze, formed a low dense ground cover. There was no shrub layer.

Areas 7 & 16

Woodland with *Eucalyptus* cf. *dichromophloia* F. Muell., *Santalum lanceolatum*, and *Terminalia arostrata* over grasses to 1 m. There were at least 4 species of grasses including *Aristida* sp. and *Chrysopogon* sp. There was no shrub layer (Plate 5).

Plates 1-11: See Environment section for description.

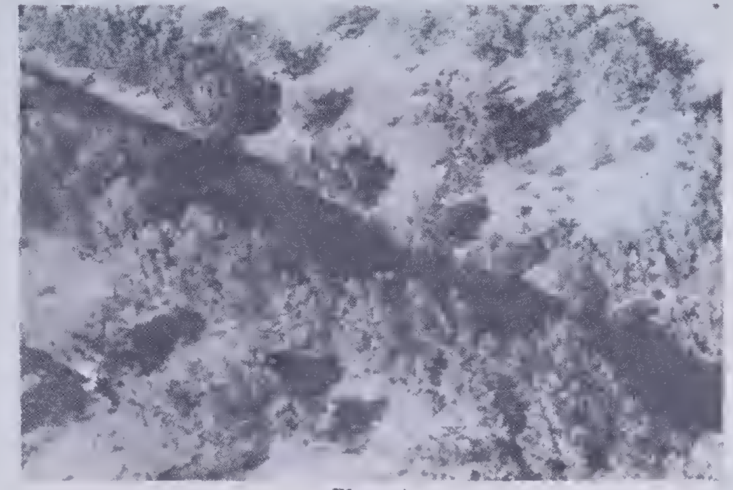

Plate 1

Plate 2

Plate 3

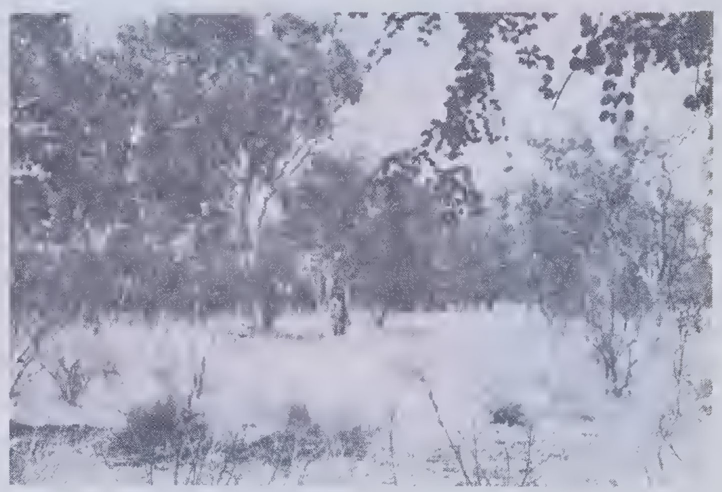

Plate 4

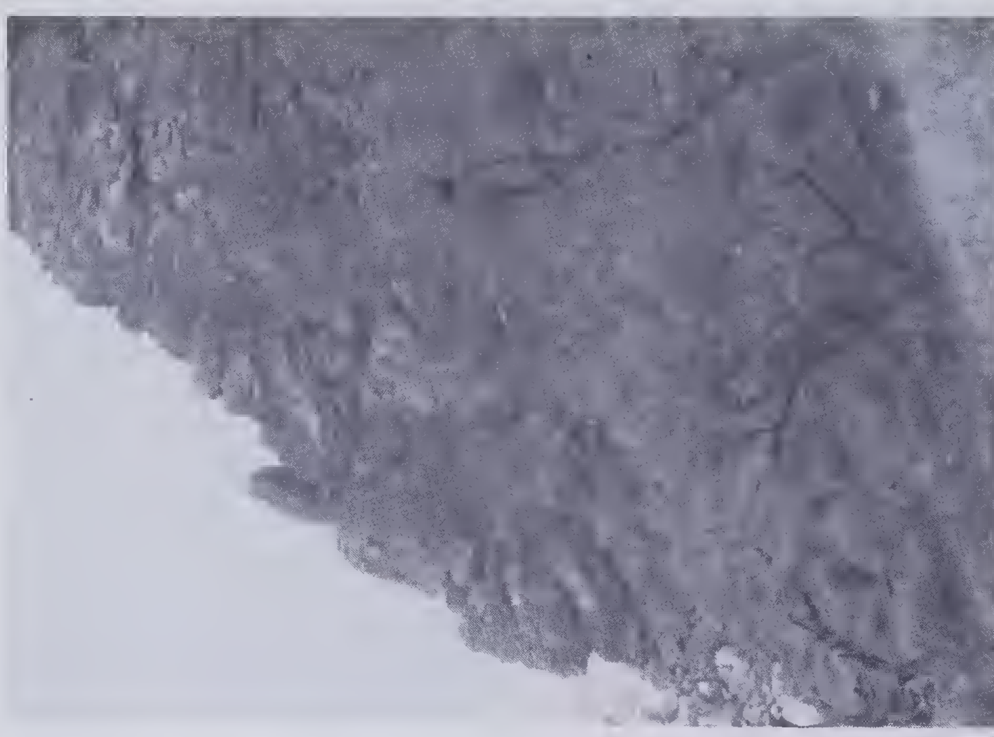

Plate 7

Plate 5

Plate 6


Plate 8

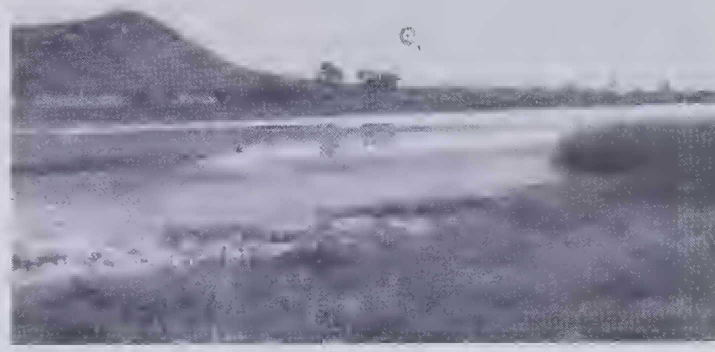
Plate 9


Plate 10


Plate 11

Areas 10 & 19

Low undulating hills with sparse woodland dominated by *Eucalyptus brevifolia.* On top of the hills, a broad-leafed *Eucalyptus* was dominant. On higher slopes *Eucalyptus* cf. *dichromophloia* F. Muell. was common. Lower slopes had scattered clumps of *Acacia holosericea* Don., and occasional low *Eucalyptus tectifica.* Ground cover was small dense clumps of spinifex, *Triodia* sp. (Plate 6).

Areas 11 & 14

Rugged hills along the east bank of Ord River and slopes of Mt Misery. *Triodia* sp. and several species of grasses including *Cenchrus* sp. and *Eulalia fulva* occupied crevices amongst boulders on scree slopes, together with occasional low shrubs of *Rhynchosia rhomboidea* F. Muell., *Aerva tomentosa* Forsk, and *Celtis philippensis* Blanco. The lower slopes had *Lysiphyllum cunninghamii* trees beneath which was a dense low grass layer (Plate 7).

Area 12

Banana Spring — a stream 1 m wide arises from Banana Spring and flows slowly through a dense woodland of *Melaleuca viridiflora* Gaertn. This stream was covered in many places by an unidentified mat plant. There were frequent pandans to 5 m, and a sparse, 2 m tall shrub layer of *Lysiphyllum cunninghamii.* The grasses *Arundinella nepalensis* Trin., 2.5 m, and *Heteropogon contortus* (L.) Beaur., to 1 m, occurred throughout (Plate 8).

Area 13

Argyle Lagoon — this lagoon was an oval sheet of water about 500 m long and 100 m wide. The edge of the water was surrounded by a 10 m wide belt of sedge *Eleocharis sphacelata* R.Br. that was trampled flat by cattle at its outer edges. A 30 m wide belt of grass *Brachiaria* sp. that had been closely cropped by cattle encircled this sedge. Thickets of *Acacia farnesiana* Willd. were scattered along the grass belt. The *Brachiaria* sp. ended at a line of trees that formed the edge of a sparse woodland encircling the lagoon (Plate 9).

Area 15

Low hills with large fine-grained granitic boulders. The lower slopes and base were covered with open woodland dominated by *Eucalyptus brevifolia* Shau. and *Eucalyptus* sp. Beneath these eucalypts was a scattered shrub layer of *Acacia wickhamii* Benth. that was denser at the edge of the scree slope. Large clumps of spinifex and grasses formed an almost continuous ground cover. Occasional clumps of spinifex were the only vegetation further up the slopes (Plate 10).

Areas 17 & 20

Grasslands on scree slopes and runoff areas from the rocky outcrops. Characterised by spinifex, *Triodia* sp., with scattered trees and occasional shrubs including *Melaleuca nervosa* (Lindl.) Cheel., *Cassytha* sp., *Dichrostachys spicata* (F. Muell.) Domin., *Gyrocenpus americanus* Jacq., *Ventilago viminalis* Hook., *Lysiphyllum cunninghamii* (Benth.) De Wit, *Carissa lanceolata*, *Eucalyptus pruinosa* Schau., *Hakea arborescens*, *Terminalia arostrata* and *Melaleuca minutifolia* F. Muell. (Plate 11).

SYSTEMATIC LIST

MONOTREMATA

Family TACHYGLOSSIDAE

Tachyglossus aculeatus (Shaw, 1792) — Echidna

In October, tracks and diggings were recorded by W.H. Butler near the mouth of the Behn River and on the northern slopes of Mt Misery.

MARSUPIALIA

Family MACROPODIDAE

Macropus robustus Gould, 1841 — Euro

In October 1971 these were frequently seen on Mt Misery, the Carr Boyd Ranges, the west side of the Ord River (area A), several at Banana Spring, and a group of 11 near Mound Spring. In November 1976 they were frequently seen on limestone outcroppings near Lissadell Homestead. One adult male and 1 adult female with pouch young were shot near the Spillway area in open eucalypt woodland over spinifex on 23 and 28 January 1972. Compared with other Kimberley material, this pouch young (pes length 76.3 mm) was approximately the same size as one collected at Drysdale River National Park in mid-August 1975 (M14328 — pes length 59.5 mm) and was only slightly smaller than one collected at Inglis Gap in mid-September 1965 (B1341 — pes length 113.1 mm) and Parry Creek in

August 1965 (B1439 — pes length 112.3 mm). The size and date of collection of these pouch young are consistent with the Frith and Calaby (1969) statement that this species has a continuous breeding season.

Macropus agilis (Gould, 1842) — Sandy Wallaby

On 24 October, 2 females, both with large pouch young (pes lengths 81.0 and 87.6 mm), were shot in tall grass on the sandy river bank near the mouth of the Behn River. On 6-8 February 2 adult females, neither with pouch young or enlarged teats, were collected in low eucalypt woodland near the Ord Dam Spillway. It appears from pouch young spirit specimens in the WAM collections, that young are born during the wet season (B1958, 4 January, pes length 25.5 mm) and that in some parts of the Kimberley birth of young extends over a considerable period. For example, W.H. Butler collected 4 female *M. agilis* at Injudinah Swamp (west Kimberley) between 12 and 27 August 1963, with pouch young. These pouch young (B227, B237, B244, B248, B267) ranged from very small with ears still fused, to very large and fully furred (pes lengths 107.4, 41.4, 49.0, 4.8 and 17.2 mm respectively). Further pouch young were collected in north Kimberley at Kalumburu in January 1966 (B1958 — pes length 25.5 mm) and in south Kimberley at Mt Anderson in May 1966 (B1958 — pes length 46.0 mm), and Erskine Well (M4224 — pes length 68.5 mm).

Johnson (1964) noted that in the Northern Territory between April and October nearly every adult female *M. agilis*, and some that were subadult, had a pouch young (one instance of twins was recorded). Further, he suggested from the condition of the nipples and occasional instances in which females carrying small pouch young were accompanied by half grown young, that a 'series of offspring may be produced by each female during the dry season'.

Combined, these observations suggest that this species may give birth to young continuously throughout the year.

Johnson (1964) indicates that this wallaby is continuously distributed across the northern part of Australia in low-lying coastal areas. He suggests that it is widely distributed elsewhere in northern Australia but is probably rare or absent in drier and more rugged terrain in the interior. Calaby and Keith (1974) record it as common in the Port Essington District, Northern Territory, in eucalypt forest, especially in moister areas containing abundant perennial grass. Johnson (1964) records mobs of hundreds on plains near large rivers in the Northern Territory. Frith and Calaby (1969) state that in some areas they are regarded as pests and are thought to seriously interfere with establishment of improved pastures in Northern Territory and Westery Australia, and crops in northern Queensland.

Onychogalea unguifera (Gould, 1841) — Northern Nail-tailed Wallaby

O. unguifera was the only macropod seen on the regular October spotlight transects. An indication of numbers can be obtained from the fact that in a total distance travelled of 775 km on the regular spotlight runs, an average of one per 28 km was sighted. They were seen in most habitats, especially stony parts of grassland bordering the Ord River and on low undulating hills that lead down to the river. On 4 October an adult male was shot while spotlighting in open grassland near the junction of the Bow and Ord Rivers. On 8 February a female with a pouch young (M11611 — pes length 8.4 mm) was shot in grassland 16 km N of Ivanhoe Homestead. A very small pouch young, similar in size to the one collected at Ord River in February 1972, was collected at Cape Bossut (west Kimberley) in August 1973 (B271 — pes length 10.5 mm); much larger but still unfurred young were collected at Kalumburu in December 1965 (B1871, B1893, B1913, B1916 — pes lengths 32.5, 43.3, 31.5, 95.1 mm respectively. Another unfurred young was collected at Turkey Creek in November 1976 (3249 — pes length 36.3 mm). W.H. Butler also sighted a female with a large pouch at the Ord River in early October.

Petrogale brachyotis Gould, 1841 — Short-eared Rock Wallaby

During the October 1971 and January/February 1972 surveys these were frequently sighted alone or in pairs in hills and rocky areas. They were not seen on the plains.

On 10 October a female with pouch young was collected 10 km W of Argyle Downs Homestead. Between 13-15 October 2 adult males, subadult female (weight 1.4 kg, pes length 11.1 cm), and a female with a pouch young (pes length 49 mm), were trapped at the same place. Between 14 January and 12 February a further 6 adult males and 6 adult females (5 with pouch young) were collected from several localities: 1 km S of the dam; near Argyle Lagoon; and 10 km W of Argyle Downs Homestead.

The pouch young from the Ord River in October (M11641 — pes length 27.4 mm) was about the same size as those collected there in January and February (M11601, M11603-6, pes length 10.6, 20.5, 26.5, 48.1 and 36.7 mm, respectively). In northwest Kimberley a pouch young was collected at Prince Regent River Reserve (M12399, pes length 33.4 mm) in August 1974 and two fully-furred pouch young at Drysdale River National Park (M14320-1, pes lengths 73.9 and 64.3 mm, respectively).

These observations indicate that similar size young are found in October, February and August, suggesting that in the Kimberley *P. brachyotis* gives birth to young throughout the year.

Family DASYURIDAE

Antechinus bilarni Johnson, 1954 — Harney's Antechinus

One adult male trapped 9 January on a grassed embankment at the bottom of cliffs 2.5 km SE of Main Dam. These traps were placed about 10-50 m above the rising reservoir water-line.

Planigale ingrami subtilissima (Lonnberg, 1913) — Kimberley Planigale

Between 8 and 17 January 1972, 3 males and 4 females were collected: 1 from the gut of a Children's Python *(Liasis childreni* Gray) on a small island 6.5 km south of Main Dam, 3 from rafters in the almost submerged Argyle Downs Homestead, and 2 from beneath spinifex on a small island, 6.5 km S of Main Dam.

The 2 females stranded on islands by rising water were thought to be subadult: neither had a formed pouch and both had 10 tiny teats arranged in a semi-circle. The other 2 females were adults: 1 had a small pouch young with crown to rump length 7 mm; the other had an enlarged pouch and elongated teats and is also thought to have been recently carrying young (Woolley [1974] has described the pouch of these 2 females). Rudeforth (1950) briefly reported on several specimens collected near the Kimberley Research Station, Kununurra. These observations led Woolley (1974) to suggest that this species, unlike the majority of dasyurid marsupials, breeds in the summer months. A further female (M9662) was collected by R. Beeton between 11-17 August 1972 from an irrigation paddock 8.3 km N of Kununurra. This female had four small pouch young with crown to rump ranging from 7.9 to 8.5 mm. Its pouch was about 12 mm deep; the small anterior pockets described by Woolley (1974) were still obvious but the teats were now arranged in two lines (only four were elongated) and none of these elongate teats were contained within the anterior pockets of the pouch. This additional observation of a female in August 1972, with pouch young which were about the same size as the pouch young of a female collected in January, suggests that this species has either an extended period of births or several widely-spaced breeding seasons.

Sminthopsis froggatti (Ramsay, 1887) — Larapinta

In October a female was collected by hand in Mitchell Grass at the base of a rocky outcrop near Argyle Lagoon (area 13). This animal was still lactating and had eight swollen teats and an enlarged pouch. A left and right dentary attributed to this species was collected among owl pellets on the surface of Harrys Cave on 3 February.

RODENTIA

Family MURIDAE

Rattus villosissimus (Waite, 1897) — Long-haired Rat

Five damaged skulls were removed from owl pellets collected *ca* 5 m inside the mouth of Harrys Cave on 3 February. They appeared to have been deposited recently.

Zyzomys argurus (Thomas, 1889) — Common Rock-rat

Three adult males, 2 adult females and a subadult male and female (weights 16.0 and 17.8 gm) were collected in November 1976 near Lissadell Homestead. These were trapped in open woodland over spinifex on sandstone (similar to areas 11 and 14) and in low open woodland on limestone. One female had 3 large foetuses with crown to rump lengths of about 25 mm. The other was not pregnant but had implantation scars on the uterine horns.

Pseudomys forresti (Thomas, 1906) — Forrest's Mouse

A minimum number of 8 individuals (represented by right dentaries) were located during February 1972 among owl pellets on the surface of Harrys Cave, *ca* 5 m from the mouth of the cave. A male (M14857) was collected at Kununurra by J. Start in August/September 1976.

Pseudomys delicatulus (Gould, 1842) — Little Native Mouse

A male (M2863) was collected at Kimberley Research Station, Ord River, in 1951 by Mr A.J. Drysdale.

Pseudomys nanus (Gould, 1858) — Western Chestnut Native Mouse

Two males were collected by burning spinifex clumps on 14 January 1972 on a small island formed by the rising reservoir, 5 km SW of Ord Dam. One female with small 'thread' uteri was collected in November 1976 near Lissadell Homestead in spinifex (similar to areas 17 and 20).

Mus musculus Linnaeus, 1758 — House Mouse

On 12 October a female was trapped in tall grass beside the Argyle Downs airstrip.

CHIROPTERA

Family MEGADERMATIDAE

Macroderma gigas (Dobson, 1880) — Ghost Bat

On 3 February R.E. Johnstone shot one in the deepest cavern of Harrys Cave. Unfortunately his torch failed and he was unable to locate the fallen animal. He saw at least three others at that time. No further specimens were sought from Harrys Cave because of the extremely hazardous climb required to reach the mouth of the cave.

Family VESPERTILIONIDAE

Nyctophilus arnhemensis Johnson, 1959 — Arnhem Land Long-eared Bat

Two females were mist-netted over a dam at Lissadell Homestead in November 1976. Both were lactating and had faint implantation scars on uterine horns indicating they had recently given birth to young.

Eptesicus pumilus caurinus Thomas, 1914 — Little Bat

On 19 October 1971 2 juveniles were collected from the bottom of an archaeological excavation pit 2 m deep at Monsmont. These had forearm lengths of 23.7 and 25.5 mm. Between 15 January and 12 February 1972 this species was collected from Spillway Cave (18 ♀♀, 14 ♂♂), Aboriginal Cave (1 ♂), Landing Cave (17 ♀♀, 11 ♂♂), Harrys Cave (1 ♀), and Fairy Martin Cave (1 ♀). In November 1976, 1 adult male and 1 adult female were collected from a cave near Lissadell Homestead and 1 adult female was mist-netted over a dam at the Homestead.

Breeding colonies occupied Spillway and Landing Caves; specimens examined from these caves comprised 13 adult females, 14 subadult females, 10 subadult males, and 4 adult males. Three of these adult females were each carrying 2 large foetuses which had crown to rump lengths of 9.1 to 10.9 mm, 6 had given birth and had distended teats and swollen mammary glands, and 4 had both small teats and uteri and little tooth wear — suggesting that they were recent adults and had not yet bred.

At the Ord River this species gives birth to young at least from October to February. This is indicated by the collection of 2 juveniles in October, lactating females and females which appear to have recently weaned young in mid-January and females carrying large young in mid-February. These observations coupled with those of Maddock and McLeod (1976) who recorded births of *E. pumilus caurinus* at Tennant Creek, Northern Territory, in August, September, October, March, and June (they had no data from

November to February) confirms the belief that this species is polyoestrous and gives birth to young throughout the year.

Maddock & McLeod (1976) found no evidence of maternity colonies in their study of *E. pumilus caurinus.* The occurrence in Spillway Cave of pregnant females together with adult females, recently weaned young, and adult males, further suggests that such colonies are not formed in this species. These authors found that in mine shafts females nursing young were usually found well along the shafts where temperature was more constant; other individuals roosted near the main entrance of adits. If such a grouping of individuals occurred in the caves at the Ord River then it would be expected that adult males would be amongst the first to escape from the caves we visited there. This may explain the low proportion of adult males to adult females in our collection from the Ord River area.

Chalinolobus gouldii (Gray, 1841) — Gould's Wattled Bat

Four females and 1 male were mist-netted over a small pool near Old Lissadell Homestead at 1830 and 1930 hrs on 17 October 1971. Four females and 2 males were mist-netted over a dam at Lissadell Homestead in November 1976.

Three of the October females had recently given birth to young. They had enlarged teats *ca* 4 mm long, swollen mammary glands, and uteri with implantation scars. The uteri appeared to have not yet fully involuted (maximum width 3 to 4.5 mm). The other female was carrying 2 foetuses which had crown to rump lengths of 15.2 and 16.7 mm. Three of the November females had recently given birth to young, using the same criteria as above, although their uteri had involuted further. The other November female was carrying 2 foetuses with crown to rump length of 2.9 mm.

The October female specimens were included by Kitchener (1975) in his study of reproduction of this species. In that study it was suggested that births in the Kimberleys begin in late September or early October, which is earlier than in the southern areas.

Chalinolobus nigrogriseus rogersi Thomas, 1909 — Frosted Bat

Eight males and 2 females were collected between 7-19 October 1971. These were shot or mist-netted between 1830 and 1900 hrs. Apart from 2 males shot in low eucalypt woodland near trapping area 1, all were collected in watercourses. The 2 females were collected at a height of 2 m over a small pool near Old Lissadell Homestead on 16 and 17 October (*C. gouldii* were also collected there at about the same time). Five of the males were shot flying at a height of 3 to 4 m along a creek bed, with pools, near Argyle Downs Homestead. The other male was shot over water near the mouth of Hicks Creek. In November 1976, 2 adult females were mist-netted over a dam at Lissadell Homestead.

One of the October females had 2 large foetuses with crown to rump length of 12.1 and 15.7 mm. It had small teats. The other female appeared to have recently weaned young; it had elongated teats *ca* 3.5 mm long, slightly swollen mammary glands, and slightly enlarged uterine horns with implantation scars. Both the November specimens had small uteri, although one had elongate teats and swollen mammary glands. The WAM collections have a further 9 adult female spirit specimens collected between 1965 and 1975 as follows: 8-25 August from Ninbing, east Kimberley (B155 and M7604); Pine Creek, Northern Territory (M10185); Parry Creek, south of Wyndham (M7603); and Drysdale River National Park (M14034-6, M14052 and M14053). Only one of these (M14034) showed any enlargement of uteri, mammary glands or teats — and that was slight.

These observations suggest that *C. nigrogriseus* gives birth to young in the dry season and perhaps completes its period of births prior to the wet season.

Nycticeius greyi (Gould, 1858) — Little Broad-nosed Bat

Three adult males were shot at dusk on 8 October 1971 in cadjeput woodland near Old Lissadell Homestead. In November 1976 4 adult males and 4 adult females were mist-netted over a dam at Lissadell Homestead. Each of these females had 2 foetuses of which the crown to rump lengths ranged from 6.3 to 13.2 mm. None of these females had enlarged teats.

The WAM has a further 18 female spirit specimens from the Kimberley and nearby Northern Territory collected since 1965. These specimens were collected between 19-22 June (M10211, M10563, M10584), 12-27 August (M12242-3, M12245-8, M14082-4, M15061-2, B1611, B1657), 21 September (B302-3) and 2 November (M8473). None had enlarged teats, mammary glands, or uterine horns. It appears from these observations that *N. greyi* gives birth to young immediately prior to and during the wet season.

Family HIPPOSIDERIDAE

Hipposideros ater gilberti Johnson, 1959 — Dusky Horseshoe Bat

On 22 January 1972, 2 adult females and 2 subadult males were collected from Wallaby Cave. On 15 January and 3 February a total of 3 adult males, 8 adult females, and 9 juveniles were collected from Harrys Cave. Dorsal pelage colour of adults and subadults differed considerably: subadults had fur with Ridgway (1912) colours of 'pallid mouse grey' tipped with 'hair brown', adults were a 'warm buff' tipped with 'cinnamon brown' (recorded from dried spirit specimens).

The 8 adult females examined from the above collections had slightly enlarged teats, *ca* 2.3 mm long, and slightly swollen mammary glands; all had only one uterine horn slightly swollen (in 7 it was the left, and in 1 the right horn) and 3 had a suggested implantation scar on the swollen horn.

The WAM collections have a further 7 adult female *H. ater* spirit specimens, all with small teats. Specimen M6161, collected on 14 April 1964 at Carlton Crossing, Ord River, had thin uteri; M10026, collected in June 1966, 50 km E of Kununurra, had its right horn slightly swollen to a diameter of 2 mm; M6295-9, collected on 19 September 1964 from a mine shaft at Pine Creek, Northern Territory, all had a single foetus; these ranged in crown to rump length from 3.5 to 8.0 mm. Johnson (1964) records that on 30 October 1920 at Douglas River, Northern Territory, Hoy collected a hairless young *H. ater gilberti* attached to the teat. On 30 October 1948 at Oenpelli, Northern Territory, Johnson collected a female *H. ater gilberti* which had a single foetus with crown to rump length of 16.5 mm. These observations suggest that females may be in early pregnancy in June. A single young is usually carried in the left uterine horn through to October when the birth season begins. The presence at the Ord River of juveniles and young adults with forearm length ranging from 26.7 to 36.6 mm suggests that the period of births is extended over several months. By February births appear to have ended and many young of the year are already weaned and flying.

Observations at the Ord River and those of A.M. Douglas at several other northern localities suggest that in summer this bat roosts only in deep caverns or tunnels where humidity is high, possibly because it is more prone to dehydration than some of the other cave bats such as *Eptesicus pumilus* and *Taphozous georgianus*.

Rhinonicteris aurantius (Gray, 1845) — Orange Horseshoe Bat

On 16 April 1964 a male (M6076) was collected by K. Richards after it flew into a car radiator near the Kununurra Research Station. In June 1966 a female (M10023) was collected by A.M. Douglas at Cave Spring, 50 km E of Kununurra.

Family MOLOSSIDAE

Tadarida loriae (Thomas, 1897) — Little Northern Scurrying Bat

Two males were mist-netted over a dam at Lissadell Homestead in November 1976.

Family EMBALLONURIDAE

Taphozous georgianus Thomas, 1915 — Common Sheath-tailed Bat

On 23 October 1971, 3 pregnant females and 1 adult male (and 1, sex not determinable) were shot flying near cliffs at Monsmont. Between 15 January and 3 February 1972 they were collected from Aboriginal Cave (10 ♀♀, 7 ♂♂), Landing Cave (5 ♀♀, 6 ♂♂), Harrys Cave (2 ♀♀, 3 ♂♂), Tit Cave (3 ♀♀, 2 ♂♂), Wallaby Cave (1 ♂), Lauries Cave (4 ♀♀) and Fairy Martin Cave (1 ♂). The larger colonies consisted of adult females, adult males, juveniles and subadults. In November 1976, 3 adult males and 1 pregnant female were collected from a cave near Lissadell Homestead.

The 1971-72 specimens were included in a study of the reproductive cycle of this species by Kitchener (1973). It was concluded in that study and later (Kitchener 1976), that over its range in Western Australia, *T. georgianus* is monoestrous, giving birth to a single young between October and April. There appears to be a brief anoestrus from mid-autumn to mid-winter before females begin reduced activity in reproductive organs prior to onset of oestrus. Males apparently produce sperm throughout the year.

Taphozous flaviventris Peters, 1867 — White-bellied Sheath-tailed Bat

No specimens were collected but this distinctively marked bat was seen by W.H. Butler on 7 October 1971 over the Ord River near trapping area 1.

Family PTEROPODIDAE

Pteropus scapulatus Peters, 1862 — Red Flying Fox

At the Ord River in October a large camp of 50,000-100,000 individuals occupied pandans at Banana Springs. Occasional smaller groups were seen in these *Pandanus* along billabongs. This colony had left Banana Springs when it was visited on 15 January. Ratcliffe (1931) recorded that *P. scapulatus* follows the blooming of eucalypts and other trees to feed on nectar and blossom. It is consequently the most nomadic of the Australian *Pteropus*.

Nelson (1965) studied *P. scapulatus* in southeast Queensland and recorded that movement into camps occurred from November-December, when copulation and conception occur. After conception sexes segregate but individuals may remain in the camp for a short period before moving in small numbers to new camps, or into camps of other *Pteropus.* Parturition occurs in late April-early May when the population is dispersed.

At Banana Springs in October territorial fighting and vocalisation were frequent. It is possible, however, that copulation had largely ceased at that time because there appeared to be a partial segregation of sexes (in one small area 48 of 54 individuals counted were males).

Between 22-24 October 8 males and 3 females were shot at Banana Spring. None of these females had noticeably swollen uteri although all had large teats; in 2 females the teats were triangularly-shaped and *ca* 14 mm long. There are 2 other *P. scapulatus* female spirit specimens from the Kimberley in the WAM collections: M4272, collected at Derby on 8 June 1960; and M13951, collected at Stewart River on 11 September 1975. Neither of these adults had swollen teats or enlarged mammary glands or uteri.

On 21 October 1971, J. Dell saw a White-breasted Sea-Eagle (*Haliaeetus leucogaster* Gmelin) take a *Pteropus* from the Banana Spring camp.

CARNIVORA

Family CANIDAE

Canis familiaris Linnaeus, 1758 — Dingo

In October tracks and sightings were most frequent in areas B and C (Fig. 1). On 21 October a male and female pair was sighted on slopes of Mt Misery. On 17 October a female with 2 three-quarter grown pups was seen in the dry river bed near the mouth of Behn River. In January a female and litter of at least 2 pups, probably not more than 6 weeks old, were seen in a small cave on the east side of Monsmont.

Family FELIDAE

Felis catus Linnaeus, 1758 — Feral Cat

In October numerous tracks and several individuals seen in areas A, B and C. One was shot near trapping area 7.

PERISSODACTYLA

Family EQUIDAE

Equus caballus Linnaeus, 1758 — Horse

In October, station horses were mostly confined to paddocks. There was a small group of wild horses at Banana Spring.

Equus asinus Linnaeus, 1758 — Donkey

In October a herd of 6 were seen at the base of Mt Misery and several were seen at Banana Spring.

ARTIODACTYLA

Family BOVIDAE

Bos taurus Linnaeus, 1758 — European Cattle

There were large station herds throughout the Ord Basin in October, including the foothills of Carr Boyd Ranges.

POST-EUROPEAN MAMMAL REMAINS AT MIRIWUN AND MONSMONT

Dortch (1972) records that the first archaeological salvage work in the Ord Reservoir area was carried out in April and May 1971. He notes that the stratigraphical sequences of artifact material collected from several rock shelters during that survey included a surprisingly thick post-European horizon of approximately 30-40 cm. There was, however, only a small amount of faunal remains. In late September Dortch examined several other archaeological sites in the reservoir area. Two of these sites, Miriwun and Monsmont, contained abundant faunal remains. He describes the Miriwun site as a well-sheltered deposit 20 m long by 5-8 m wide. The deposit is only 1.2 m thick. The monsmont trenches covered about 7 m^2 and were about 3 m deep. They were located in the same line of cliffs about 1500 m downstream from Miriwun.

The entire mammal remains from Miriwun and Monsmont excavations were excavated according to the stratigraphy of the deposit. D. Merrilees and C. Dortch have kindly allowed me to examine the mammals from the surface layer which are believed to have accumulated in the deposit after contact with Europeans.

The mammals identified from the surface material (from tooth-bearing bone only) are as follows:

Macropodidae
- *Macropus (?robustus)*
- *Macropus agilis*
- *Petrogale brachyotis*

Peramelidae
- *Isoodon auratus* (Ramsay, 1887)
- *Macrotis* sp.

Dasyuridae
- *Dasyurus hallucatus* Gould, 1842

Muridae
- *Rattus* cf. *villosissimus*
- *Zyzomys argurus*
- *Pseudomys* sp.

Vespertilionidae
- *Eptesicus pumilus*

DISCUSSION

The Ord River basin is a semi-arid low country salient into the Kimberley Plateau and contains some birds and reptiles from the arid interior (G.M. Storr pers. comm.). Consequently it was thought that the mammal fauna of this basin might contain some drier-country mammals such as the murids, *Pseudomys hermannsburgensis* (Waite, 1896), *P. desertor* Troughton, 1932, *Notomys alexis* Thomas, 1922, and the dasyurids *Ningaui ridei* Archer, 1975, *Antechinomys spenceri* Thomas, 1906, *Sminthopsis hirtipes* Thomas, 1898 and *Sminthopsis murina ooldea* Troughton, 1965. This was not the case, however, because the 26 native mammals recorded in this report are typical of those found elsewhere in the Kimberley and include no arid element.

Comparison between collections from the Ord River area and those from other large-scale surveys in the Kimberley, viz., Prince Regent River Reserve (McKenzie *et al.*, 1975), Drysdale River National Park (McKenzie *et al.*, 1977), Bonaparte Archipelago (McKenzie *et al.*, 1977) and Mitchell Plateau (Kitchener *et al.*, in prep.) indicates that the Ord River area is relatively rich in bats, but has relatively fewer rodents than the other areas (see Appendix I). Notable absentees from the list of Ord River mammals are such arboreal species as the Golden-backed Tree-rat (*Mesembriomys macrurus* [Peters, 1876]); Sugar Glider (*Petaurus breviceps* Waterhouse, 1839); Scaly-tailed Possum (*Wyulda squamicaudata* Alexander, 1919) — recorded at Turkey Creek, *ca* 60 km SE of Lissadell Homestead — and the Northern Brush Possum (*Trichosurus arnhemensis* Collett, 1897). The absence of this group of mammals probably relates to the degradation of the riverine woodlands in the Ord River basin. These woodlands appear to have suffered considerably from regular burning and from direct and indirect grazing pressures of stock.

The Ord River basin also appears to have habitat suitable for the Little Rock-wallaby (*Peradorcas concinna* [Gould, 1842]), Golden Bandicoot (*Isoodon auratus* [Ramsay, 1887]), and Little Northern Native Cat (*Dasyurus hallucatus*). Their absence from the collections is more difficult to explain. The mammal material from Miriwun and Monsmont archaeological and palaeontological sites shows that the bandicoots *Isoodon auratus* and *Macrotis* sp. and the native cat, *Dasyurus hallucatus*, were in the area at about the time of the first European settlement. (*Peradorcas concinna* is recorded from sub-surface layers at these sites.) Probably the combination of intense overgrazing by stock and donkeys in recent years and the introduction of feral cats has contributed to the loss of mammal species in the area. Interestingly, the bandicoots *Macrotis lagotis* (Reid, 1837), *Perameles bougainville* Quoy & Gaimard, 1824 and *Chaeropus ecaudatus* (Ogilby, 1838) were among the first mammals to disappear from southwest Western Australia with the advent of extensive farming. A fourth bandicoot, *Isoodon obesulus* (Shaw, 1797), is now almost gone from wheat-growing areas of the South West.

Combined, these observations suggest that in Western Australia bandicoots are amongst the first mammals to disappear in the face of European settlement and farming.

Specimens from the Ord Basin throw a little light on breeding by macropodid, chiropteran and dasyurid mammals in the Kimberley. Despite the markedly seasonal climate of the region there is an indication that the macropods *Macropus robustus*, *M. agilis*, *Onychogalea unguifera* and *Petrogale brachyotis* give birth to young during both wet and dry seasons.

On the other hand it appears that most of the bats are seasonal breeders. *Chalinolobus gouldii*, *C. nigrogriseus*, *Nycticeius greyi*, *Hipposideros ater* and *Taphozous georgianus* begin giving birth to young at the end of the dry season. While *T. georgianus* continues to give birth to young to the end of the wet season, in these others births probably cease by the middle of the wet season. *Nyctophilus arnhemensis* (this collection) and *Macroderma gigas* (see Douglas, 1967) give birth at the end of the dry season but lack of specimens precludes any definition of their season of births. *Eptesicus pumilus* appears to give birth to young throughout the year. Only the nomadic Red Flying Fox, *Pteropus scapulatus*, is known to avoid the wet season for births, giving birth at the start of the dry season.

Young of the dasyurids *Sminthopsis froggatti* and *Planigale ingrami subtilissima* are known to leave the pouch towards the end of the dry season. Those of *P. ingrami subtilissima* also leave the pouch during the wet season.

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Appendix I: Listing, by family, the number of species of native mammals recorded during the large-scale surveys of the Kimberley.

Family	Ord River Area	Pr. Regent River Res.	Drysdale R. Nat. Park	Mitchell Plateau	Bonaparte Archipelago
Macropodidae	4	6	3	5	2
Phalangeridae	0	1	0	1	1
Petauridae	0	1	1	1	1
Peramelidae	0	2	0	1	2
Dasyuridae	3	2	1	4	2
Muridae	5	10	7	10	7
Megadermatidae	1	0	0	0	0
Vespertilionidae	5	7	9	6	1
Hipposideridae	2	0	0	2	2
Molossidae	1	0	2	1	0
Emballonuridae	2	1	2	2	1
Pteropodidae	1	3	2	2	1
Canidae	1	1	1	1	1
Tachyglossidae	1	1	1	1	1
Total	26	35	29	37	22

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ABORIGINAL SITES ON MILLSTREAM STATION, PILBARA, WESTERN AUSTRALIA

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ABSTRACT

Part of the Fortescue valley on Millstream station, Pilbara, Western Australia is under consideration for reservoir construction. The proposed reservoir would inundate a number of Aboriginal sites; to meet this contingency Western Australian Museum staff carried out a site survey. Significant features of valley geomorphology, site topography and stone artifact assemblages are described, and various painting and engraving sites are noted. Aboriginal narratives describing mythological and ritual aspects of various localities in the valley are recorded.

INTRODUCTION

(J.C., W.C.D. and C.E.D.)

In Western Australia all Aboriginal sites are protected by the Aboriginal Heritage Act (1972); and the Registrar of Aboriginal Sites, Western Australian Museum, has had since 1970 the responsibility of recording sites in threatened areas.

On several recent occasions staff of the Aboriginal Sites Department and other Museum staff have co-operated in the assessment and salvage of Aboriginal sites which were threatened or due to be destroyed. A notable example of these activities is the Ord valley salvage project where a number of significant archaeological sites were recorded and excavated before they became permanently inundated by the waters of Lake Argyle (Dortch 1977).

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A potentially similar situation exists in part of the Fortescue valley, Millstream pastoral station, Pilbara (Fig. 1), where a water storage reservoir under consideration would, if constructed, result in the inundation of a number of Aboriginal sites. Because of this the former Registrar of Aboriginal Sites organised a site survey[1] aimed at assessing and recording sites in the proposed reservoir area, that is, that part of the Fortescue valley extending from Gregory Gorge upstream as far as Millstream station homestead (Fig. 2).

The site survey was conducted at two levels: a brief general search for archaeological sites; and a more time-consuming programme of enquiries among Aborigines with knowledge of local sites. Neither aspect of the survey is complete. The pattern of site distribution emerging from the archaeological study is certain to be modified by further, more intensive field research; and the ethnographic enquiries so far have obtained data of particular significance to local Aborigines, and not necessarily of ecological or archaeological importance.

Physical Environment

Millstream pastoral station contains the largest series of permanent pools in the Fortescue valley. The pools are widely known for their scenic attractions, and they form a virtual oasis in the generally arid region flanked to the south by the Hamersley Range and to the north by low hills known as the Tableland (Fig. 1; Kriewaldtord and Ryan 1967).

The Fortescue River flows only after heavy rain, which is seldom and irregular. It has a straight narrow drainage basin, and has cut a long deep canyon through volcanic rocks from Gregory Gorge downstream to its flood plain near the mouth. Upstream from the gorge the river does not increase appreciably in elevation, but below the gorge the valley is an active torrent bed. The river was well established in the Tertiary, when it had a wide flat valley with thick alluvial deposits, and probably flowed west to join the existing Robe River system. During Quaternary times uplift of the Pilbara block rejuvenated streams flowing off the Tableland. The active headward erosion cutting back into the relatively soft Proterozoic rocks tended to

1. The Millstream survey party included the following Western Australian Museum staff.

   W.C. Dix, formerly Registrar of Aboriginal Sites
   J. Clarke, Research Officer, Aboriginal Sites
   C.E. Dortch, Curator of Archaeology
   K. Palmer, formerly Research Officer, Aboriginal Sites
   R. Bevacqua, formerly Salvage Archaeologist, Aboriginal Sites

result in capture of westward flowing streams (Kriewaldtord and Ryan 1967); the present Fortescue River downstream from the permanent pools is probably the result of such capture. Here the river enters a narrow gorge and is actively eroding its bed; its gradient is higher and tributary streams have been rejuvenated. This active erosional environment in which successive floods remove older sediments results in archaeological deposits which are generally superficial and of relatively very recent origin (Plate 1; Fig. 3a).

Upstream from Gregory Gorge the river flows through its original, flat alluviated valley. In this superficially dry reach there is an extensive aquifer currently exploited for fresh water by pumping from a series of bores directly to the consumer townships serving the iron ore industry. Here the old valley deposits, ranging in age back to the Tertiary, are still preserved, and are being slowly cut back by the river. (These deposits are referred to here as the 'Fortescue valley surface': Plates 1 and 2; Fig. 3b.)

Pools (Plates 3 and 4) occur where the river has cut down through permeable alluvium and these permanent features are maintained by waters of the aquifer. The alluvium of the main channel undergoes repeated erosion, resulting in the re-sorting of contained archaeological material. Archaeological assemblages on the Fortescue valley surface and on the surfaces of mature alluvial terraces on tributary streams (notably Millstream) away from the heavily eroded main channel are apparently not eroded, though some of these have been severely disturbed by European development.

The Aboriginal Sites

Sites fall into two categories: those of immediate concern to Aborigines, and those which are identifiable by archaeological evidence. The latter category consists of surface scatters of stone artifacts, considered here in some detail, as well as several art sites described below.

Aboriginal interest in the area focuses on the total valley (some 110 km in length) and particularly on the gorges and pools. From an Aboriginal viewpoint it is unsatisfactory to discuss individual sites in isolation since the river constitutes a unity over and through which the Dreamtime ancestors travelled, and their function as creators, instigators and founders of traditional belief is inextricable from the natural features that are seen to proclaim their validity. Nevertheless it is necessary to describe specific sites for the purpose of the survey.

The area was homeland for *Indjibundi* speaking people (cf. Tindale 1974). Von Brandenstein (1967) reported that less than 1,000 people spoke the

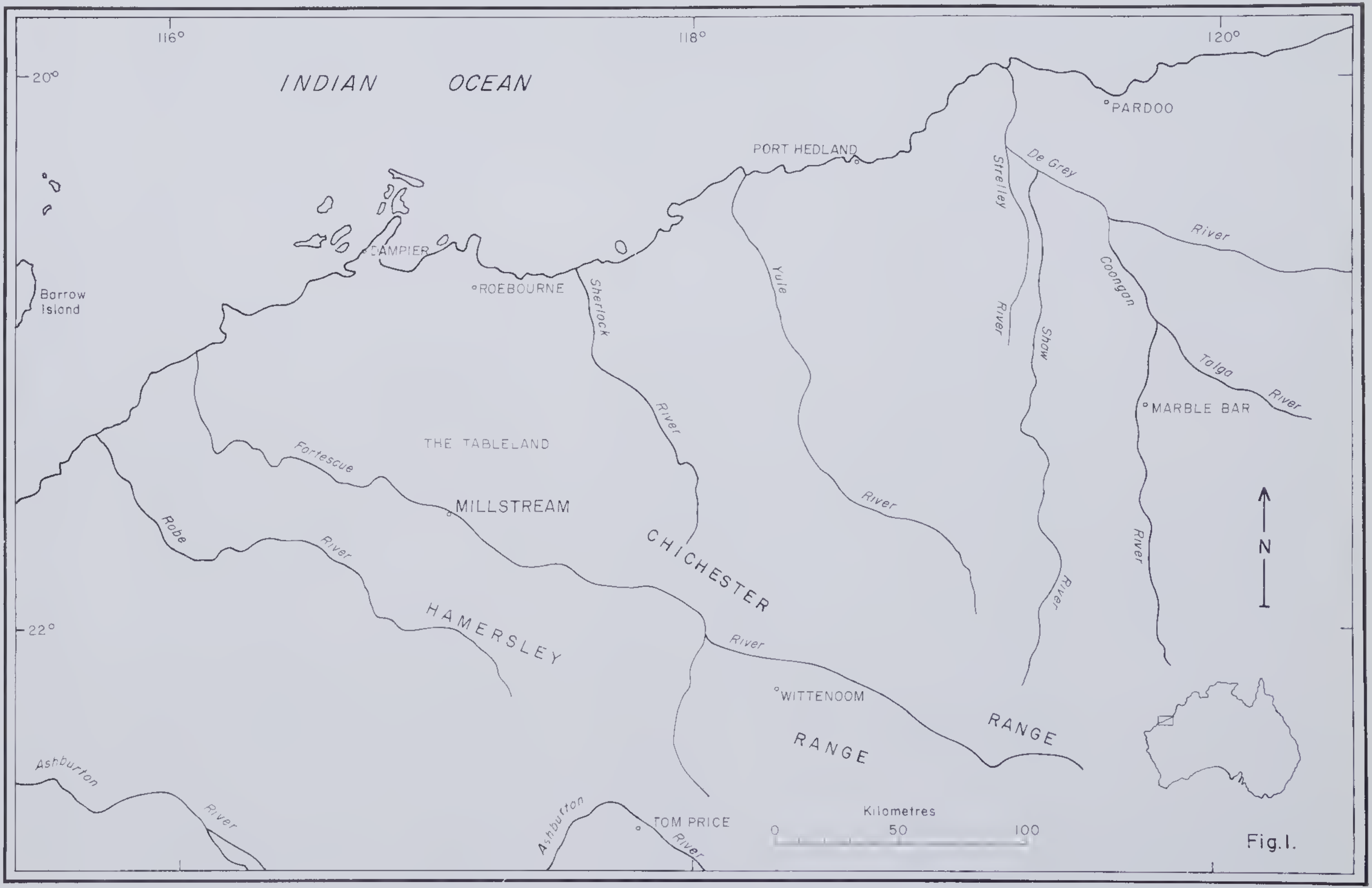

Fig. 1: Area map showing localities mentioned in the text.

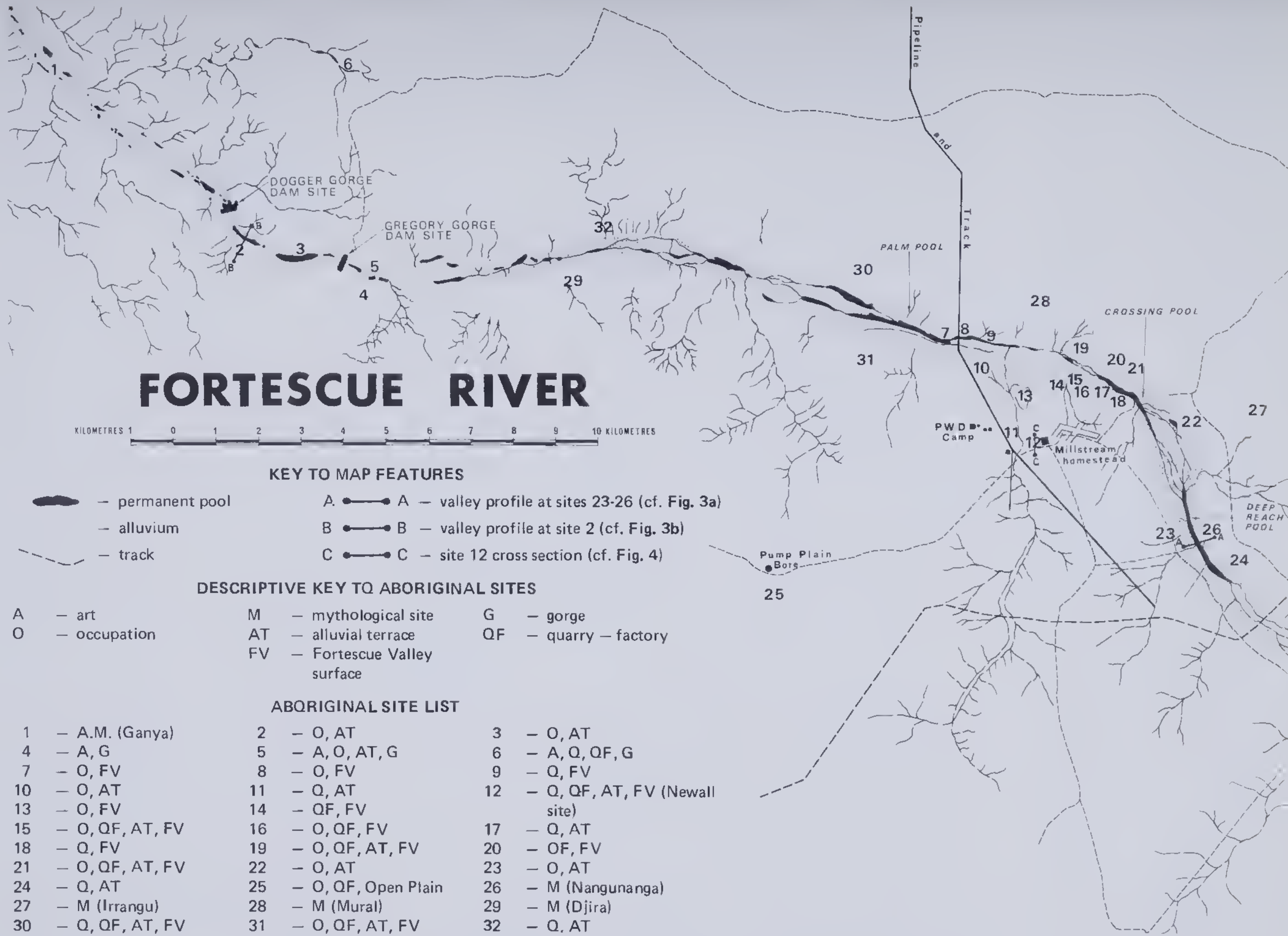

Fig. 2: Map showing numbered Aboriginal sites on Millstream station.

language in the mid-1960s; even so the language is one of the two best-known in the Pilbara (the other being the *Nyangamade* language, east of De Grey river. These people today are dispersed throughout the Pilbara, particularly at Roebourne, Onslow and Wittenoom (Fig. 1). In addition to *Indjibundi* people, *Bandjima* and *Kurima* speakers contributed information on the mythology and associated ritual of the area, described below.

Numbered Aboriginal site locations recorded in the Millstream survey are shown in Fig. 2. Where mentioned in the text these site numbers are given in brackets, for example (14).

The Newall Collection

Millstream station is of particular interest to Australian archaeologists because of the Newall site (12; Fig. 2) at Millstream homestead. The site is well-known because it was the only archaeological site in Western Australia about which information was published during the first half of this century. In 1912 Mr R.S. Newall collected perhaps 200 retouched stone tools from a confined area (12; Fig. 2) near the pools from which the station homestead drew fresh water, and within the same year he lectured on his finds to the Prehistoric Society of East Anglia at Norwich, England (Newall 1914). Almost half his collection consists of varieties of microlithic backed pieces (i.e. geometric microliths, backed points and backed bladelets, cf. McCarthy 1967) and his account is among the earliest attempts to describe this stone tool category in the Indo-Pacific area. A few years before, the Sarasin brothers (1905) had illustrated geometric microliths from Sulawesi, but did not seem to have comprehended their typological distinction; and Etheridge and Whitelegge (1907) had described 'surgical knives' (microlithic backed points) from New South Wales which they compared with Indian backed blades.

Newall illustrated both geometric and asymmetric microliths, noting (1914, pp. 304-5) that many could be classified either as triangular or semi-circular. In the same year, Kenyon and Mahoney (1914, pp. 6, 12) referred to 'pygmy' tools in Victoria, but claimed that their size was simply a function of the scarcity of stone. As Newall envisaged cultural determinants, he may be linked with Etheridge and Whitelegge as the first to attempt a description of Australian backed blade assemblages.

No further Western Australian microlithic tools were described until another English visitor referred to them in 1943 (Noone 1943). Even in his initial survey of Australian prehistory Mulvaney (1961; p. 80) noted that the Millstream specimens were the only substantial evidence for microlithic backed tools within the entire State; and when Glover (1967) published his definitive typological study of Newall's material, comparative material still remained meagre. More recently the collection has been important in other discussions of microlithic stone tool origins and distribution (e.g. Pearce 1973) though more recent finds and some dated material have altered the picture somewhat (Dortch 1977; Dortch and Gardner 1976; Mulvaney 1975).

OCCUPATION SITES AND STONE QUARRY-FACTORIES

(J.C., W.C.D. and C.E.D.)

The term 'occupation site' here refers to any concentration of stone tools and other artifacts in primary position, or nearly so, in a locality which by reason of its physical features would probably have made a suitable camping place for groups of hunter-gatherers. Millstream occupation sites are typically located on the alluvial terraces along the river and its tributaries, and on the weathered bedrock and colluvium of the Fortescue valley surface (Fig. 3b). These sites are all within a few hundred metres of abundant fresh water and shade. Some (e.g. the Newall site, 12) cover hundreds of square metres, others only a few square metres. The artifact evidence for occupation consists of scatters of flaked stone artifacts (tools, flakes, chips, cores and fragments) with occasional grindstones, anvil stones and baler shells (*Melo* sp.), the last probably the remains of containers. A few sites (e.g. the Newall site, 12) also contain chipped glass and other Aboriginal artifacts made of European material.

We did not use systematic sampling techniques in our collecting from the Millstream sites because most of the sites we examined are actively eroding and some have been extensively disturbed by European occupation.

For convenience the occupation and quarry-factory sites on Millstream station are divided between those along the river and its tributaries (sites 2, 3, 5, 7-24, 31 and 32) and sites 6 and 25 which are well away from the river. At the former sites silicified shale and to a lesser extent secondary silica rocks were the chief raw materials for stone working. Some quarrying of river gravels took place as there are flaked river pebbles at a number of sites.

It is difficult to make a fine distinction between occupation sites and quarry-factories. In some cases (e.g. site 16) the presence of retouched tools, including much-used pieces (e.g. adze slugs), with quarry debris, shows that people were living on the outcrops (silicified shale in this case) of stone they quarried. Other sites are predominantly quarry-factories. One of these is site 14 where there are thousands of cores, flakes, chips and fragments (but very few retouched tools) lying on a prominent outcrop of silicified shale exposed above the Fortescue flood plain (Plate 2). However, even at this site occupation of the adjacent alluvial terrace cannot be discounted as much of the archaeological material probably has been stripped away by erosion, or buried by alluviation.

All the occupation sites are within 200 m of reliable water sources and lie on land which is topographically suitable for use by people as a campsite: usually a flat area with some degree of shade and shelter from prevailing winds. Sites shown in Fig. 2 are distinguished as to whether they lie on alluvium (AT) or on bedrock (FV — Fortescue valley surface). No dominant trend of occupation on either topographical situation seems evident. However the alluvial terraces certainly offer better camping places than the rocky slopes and it is possible that the latter sites were used largely during floods. The wide range of flaked stone artifacts, including many adze slugs, cores, fine chippings and different kinds of flaked tools, as well as anvils, grindstones, and fragments of baler shells show that the occupation sites were used by groups engaged in normal daily craft and domestic activities.

Several of the more important sites or site complexes are briefly described in the following:

The Newall Site (12)

The Newall site is a dense scatter of stone artifacts and other material located on Millstream Creek, a spring-fed tributary of the Fortescue River; the site is 200 m west of Millstream homestead and on the south side of Chinderwariner Pool (Plate 3; Fig. 4). The site has been extensively disturbed in recent years: much of the original surface has been levelled by a grader, and part of the site has been built over by homestead outbuildings. It is very difficult now to judge the extent of the site, but it is likely that before European disturbance it covered the length of the series of pools which characterise this part of Millstream.

The site is on a low alluvial fan flanked by calcrete outcrops to the south-east and extending 200 m westward to the permanent pools in the calcrete along Millstream Creek (Fig. 4). The fan grades from calcrete colluvium at the top to a red brown calcareous sandy alluvial soil with high organic content. The vegetation consists of paperbarks and palm trees on the alluvium flanking the pools and acacia scrub on the slope merging to spinifex towards the crest. The bulk of the artifact scatter lies halfway between the calcrete outcrops and the pools. Secondary silica rocks were quarried from the calcrete, and artifacts of this stone are numerous at the site.

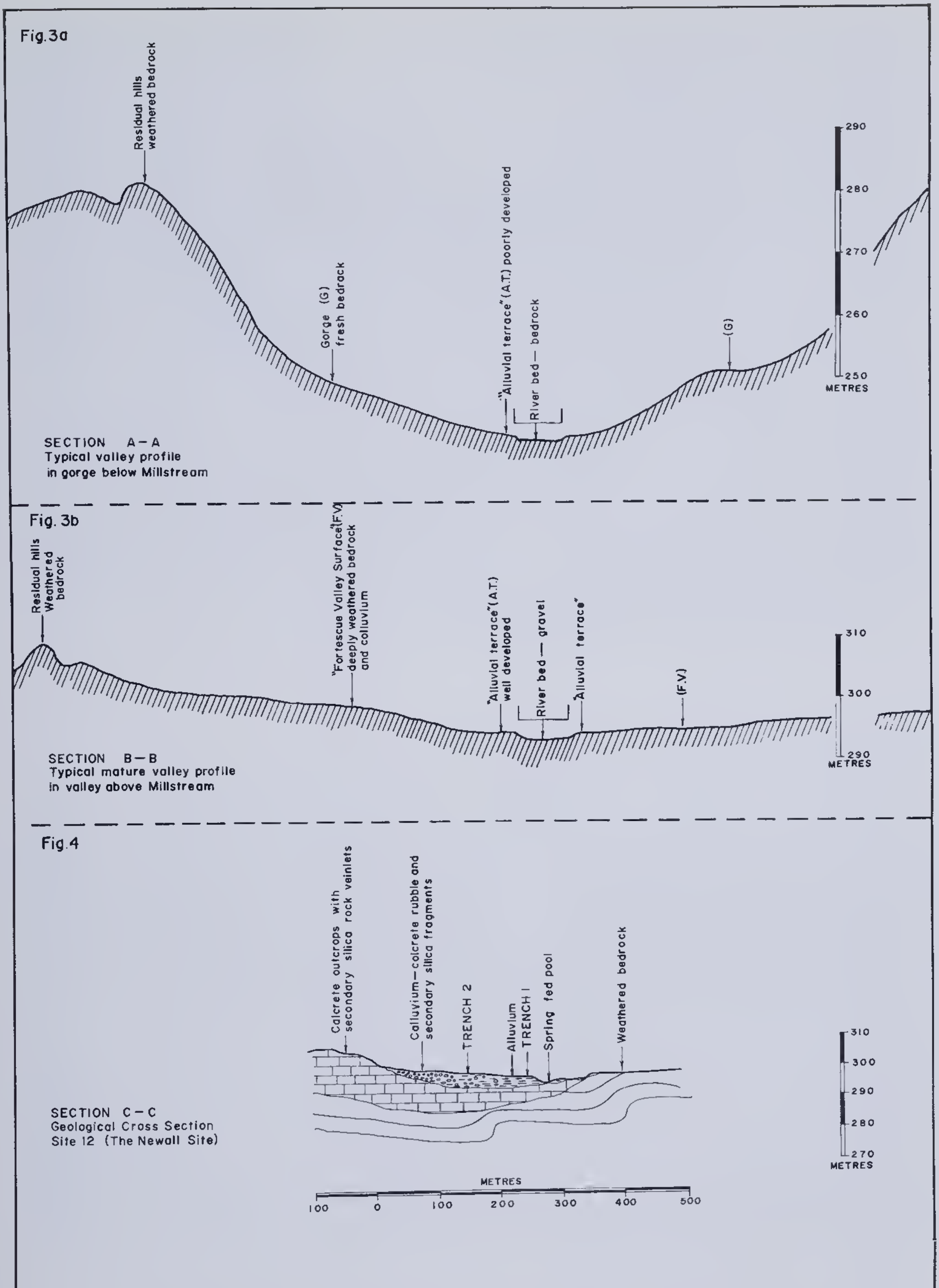

Fig. 3: Typical Fortescue valley profiles, Millstream station.

Fig. 4: Geological cross-section of the Newall site (12).

Plate 1: Gregory Gorge, looking downstream from sites 4, 5 (cf. Fig. 3a).

Plate 2: Fortescue valley at site 14, 15 km upstream from Gregory Gorge, showing mature valley profile. Foreground and middle distance show Fortescue valley surface (cf. Fig. 3b), and the wooded area beyond is flood plain alluvium. Horizon shows southern edge of the Tableland.

Plate 3: Chinderwariner Pool, near the Newall site, showing lush vegetation including paperbarks, palms and water lilies.

Plate 4: Crossing Pool at site 18, showing wooded surface of flood plain on north bank and exposed bedrock of Fortescue valley surface in cliff faces on each side of the flood plain.

We carried out two test pit excavations at the Newall site (Fig. 4). Each pit measured 50 x 50 cm, and was dug to a depth of about 50 cm. The first (Trench 1) was located on the alluvium 70 m southeast of Chinderwariner Pool, and contained stone artifacts only in its upper 10 cm. We dug the second test pit (Trench 2) in the lower part of the alluvial fan in a zone grading between colluvium and alluvium (Fig. 4). The tabulation below lists all the archaeological material which we recovered from Trench 2.

Trench 2, Newall site, 12

Depth below surface	Silicified shale	Secondary silica	Quartz
Surface to 3 cm	2 flakes	1 blade 1 bladelet 17 flakes 3 cores	—
3-10 cm	1 notched flake 3 flakes	9 flakes	1 fragment
		1 land snail shell (*Rhagada* sp.*)	
10-20 cm	4 flakes 2 fragments	1 notched flake 13 flakes	1 flake
20-30 cm	—	—	—
		2 land snail shells as above	
30-40 cm	3 flakes	1 flake	
		Several fragments of land snail shell as above	
40-50 cm	1 flake		

* Pers. comm. H. Merrifield

Despite the extensive modern disturbance noted above we were able to collect several hundred stone artifacts from the surface of the Newall site. The apparent scarcity of artifacts within the alluvium and the absence of rolled artifacts at the site suggests that the artifact concentration at or very near the present surface did not accumulate through the erosion of separate assemblages of successive occupation surfaces. Instead this distribution seems to show that extensive occupation took place only when the pool was established in its present position and aggradation of the alluvium had become negligible (Fig. 4). We conclude then that the surface assemblage is simply occupation debris accumulated on the stable surface of a mature alluvial deposit.

We have not attempted to make an inventory of our surface collection, though it should be compared quantitatively with Glover's published Newall collection (Glover 1967), and with another unpublished part of Newall's collection which has recently come to light but is not yet available for study.

The Crossing Pool Series (15-18)

Crossing Pool is one of the series of large, deep pools (Plate 4; Fig. 2) formed in the bed of the Fortescue River. The alluvium around the pool supports gallery forest consisting of paperbarks, eucalypts and palms. The surrounding weathered bedrock of the Fortescue valley surface is covered in sparse scrub. We identified a number of archaeological sites around the pool and made extensive collections at sites **15** and **16**. The geomorphological setting at sites **15** and **16** is similar to that of the Newall site. Site **16** is a scatter of stone artifacts on a formation of weathered silicified shale which forms a small hill above the Fortescue flood plain. The river has cut a cliff face on the north side of the hill; to the northwest there is a scree-covered slope which is cut by a small tributary valley entering the flood plain. Artifacts are scattered over the scree-covered slope and on the sandy alluvium of the tributary valley. The artifact scatter on the slope is part of site **15**.

We dug a 50 x 50 cm test pit (Trench 1) into the alluvium at site 15, the deposit being much the same as the alluvium at the Newall site. Finds from this excavation are tabulated as follows:

Trench 1, Crossing Pool, 15

Depth below surface	Silicified shale	Secondary silica	Quartz
Surface to 10 cm	2 bladelets 5 flakes 1 core	—	2 flakes 1 fragment
		1 freshwater snail shell (*Stenomelania* cf. *denisoniensis**)	
10-20 cm	7 flakes 1 fragment	—	1 bladelet 2 flakes 2 fragments
20-30 cm	2 flakes 3 fragments	—	—
30-40 cm	3 flakes 4 fragments	—	—
		1 land snail shell fragment (*Rhagada* sp.*)	
40-50 cm	1 flake 1 split pebble 5 fragments	1 flake	—

* Pers. comm. H. Merrifield

Plate 5: 'Driller's Hole', site 6. The photograph is taken from the main quarry-factory area: in the lower right corner there is a semi-permanent pool below the head of the gorge; the two figures in the middle distance are standing by engraved boulders; in the background is spinifex grassland with sparse eucalypts typical of the Tableland.

Site 14

We have previously described this site (Plate 2) as a quarry-factory. It lies 500 m west of sites 15 and 16 and 1,500 m north of the Newall site. Site 14 is a shale prominence, the slopes of which are covered with quarrying debris. The site is the probable source of the yellow silicified shale which was commonly made into tools at the Crossing Pool sites and the Newall site.

Pump Plain Bore, 25

This is a site located on the edge of a large, non-permanent swamp developed on a calcrete surface deposit in the open plain 6.5 km south of the Fortescue River. The site is basically a quarry-factory where outcropping chalcedony was quarried. Pump Plain Bore is the only such chalcedony quarry-factory yet recorded in the area.

Site complexes 30 and 31

These consist of a series of surface scatters of stone artifacts on the scree slopes and alluvial fans which flank the low hills on both sides of the Fortescue valley. Most of the artifacts consist of silicified shale and secondary silica rock quarried from outcrops exposed in the hillslopes of the valley. There are very few artifacts on the surface of the alluvium, though it is probable that prehistoric camps were often located here and the resulting scatters of stone artifacts have been buried or swept away by erosion.

'Driller's Hole', 6

'Driller's Hole' is at the nickpoint of an incised tributary of the Fortescue River 4.5 km north of the proposed Gregory Gorge dam site (Plate 5; Fig. 2). Headward erosion has cut a gorge terminating in a waterfall. The gorge contains a series of pools which are probably sources of good water for several months after rain. The rocks along the edge of the gorge were quarried by Aboriginal stone workers and in several places there are heaps of pointed blades, flakes and cores all made of lithic sandstone or sub-greywacke. Thin-section examination of this stone shows that it is firmly indurated and fine-bedded, consisting generally of fine-grained (0.05 to 0.1 mm), highly angular particles of quartz and feldspar (mainly plagioclase and commonly turbid with alteration) together with ill-defined, altered cherty lithic fragments, minor muscovite, chlorite and accessory zircon. The sample examined was marked by small (0.05 mm) porphyroblasts of pyrite (1-2%) and by scattered rhombs of poikiloblastic dolomite. The rock is not significantly metamorphosed; its 'flinty' character is due to the marked bonding between the cherty material (some of which might be cement) and the more clearly defined clastic fragments.

Aspects of the stone quarrying and tool manufacture carried out at 'Driller's Hole' are discussed below. There are also several engraved rock surfaces at the site.

STONE ARTIFACT ASSEMBLAGES
(C.E.D.)

The flake and blade tool component of the assemblages collected at the Newall site (12) and Crossing Pool (15, 16) is consistent with, though typologically more diverse than the Newall collection of stone tools, and it is clear that Newall was very selective in his sampling. Therefore the following description, while remaining supplementary to Glover's study of the Newall collection (Glover 1967), provides a broader picture of the Millstream stone artifact assemblages than can be determined from the earlier material.

Technology

Silicified shale was the principal stone used for tool manufacture at the occupation sites and quarry-factories on the Fortescue River and Millstream. Most of the dominant flaked tool forms, that is, backed microliths, adze flakes or small scrapers and notched or denticulated flakes, are made of this stone. The other stones used include a secondary silica rock which outcrops in the eroded calcretes exposed in the Fortescue valley surface; chalcedony, one source of which is at Pump Plain Bore (25); and lithic sandstone (sub-greywacke) from 'Driller's Hole' (6) or perhaps other, as yet unidentified, quarries.

Thin-section examination of the silicified shale shows that it consists of sparse, minute clastic quartz grains in an extremely fine, foliated, very murky matrix composed of opaline silica, clay, limonite dust and possibly other components. The rock is laminated; some of the laminae are slightly coarse-grained (0.02 mm) consisting of abundant silicified fragments and less abundant angular quartz grains in a matrix similar to the bulk of the rock. Occasional unsilicified areas were noted in hand specimens. For several reasons the silicified shale is not suitable for the manufacture of large tools, particularly large blades or points with lengths in excess of about six cm. The primary sedimentary structures, that is, the sandy beds and compositional differences noted in thin-section, make it difficult to obtain large blocks of the stone which can be used for blade or point production. The stone also lacks mechanical strength because it is internally fractured due to thermal alternation and dehydration of the opaline silica. Aborigines informed one of us (K.P.) that the surface stone was unsuitable; 'cool' stone useful for flaking could only be obtained by digging down into the eroded bedrock. On the whole blade and flake production at the sites where silicified shale is predominant seems to have been limited rather than enhanced by the physical qualities of this stone.

These assemblages are based primarily on a flake technology though there is an important blade and bladelet element. (We divide blades and bladelets on the basis of size and proportions; cf. Tixier 1963: Fig. 7.) Flakes are mostly irregular with very variable size and proportions. Faceted butts occur and are much less common than plain.

There are several different kinds of flake cores in the Millstream assemblages. Most are simply amorphous or irregular fragments, or sometimes tabular slabs from which flakes have been removed randomly from convenient striking platforms. There are also single platform flake cores made on chunky fragments or thick flakes. Most of these are small with maximum dimensions of three to six cm. We found no typical horsehoof cores (e.g. Mulvaney 1975: Fig. 26) at Millstream. Typical Levallois flake cores and discoidal cores seem to be absent, though both these forms are known in north-western Australia (Dortch 1972; 1977). However, some of the flake cores made on pieces of tabular silicified shale are technologically the same as discoidal cores (Bordes 1961, pp. 72-3), with the difference that their flaking faces are not circular in plan but irregular or rectangular. A chalcedony specimen of one of these is shown in Fig. 5:6. There are also many bipolar or scalar cores (White 1968) in the Millstream assemblages; a thermally-fractured example is shown in Fig. 5:8.

Blade and bladelet production in the riverside occupation sites and quarry-factories is based on two distinct methods.

> The first is direct percussion of which there are two variants: in one the cores are unprepared tabular fragments from which a few blades or bladelets have been struck from convenient corners; the other is a formal method by which a crested flaking face is produced deliberately by retouch in order to prepare the core for successive blade removal. Bordes and Crabtree (1968, pp. 3-4) provide the most detailed description of the latter technique. These authors point out that bilateral cresting is not always necessary when working with angular material, as with the informal Millstream blade cores above. Most of the Millstream crested blades have only unilaterally retouched crests; the very few bilaterally

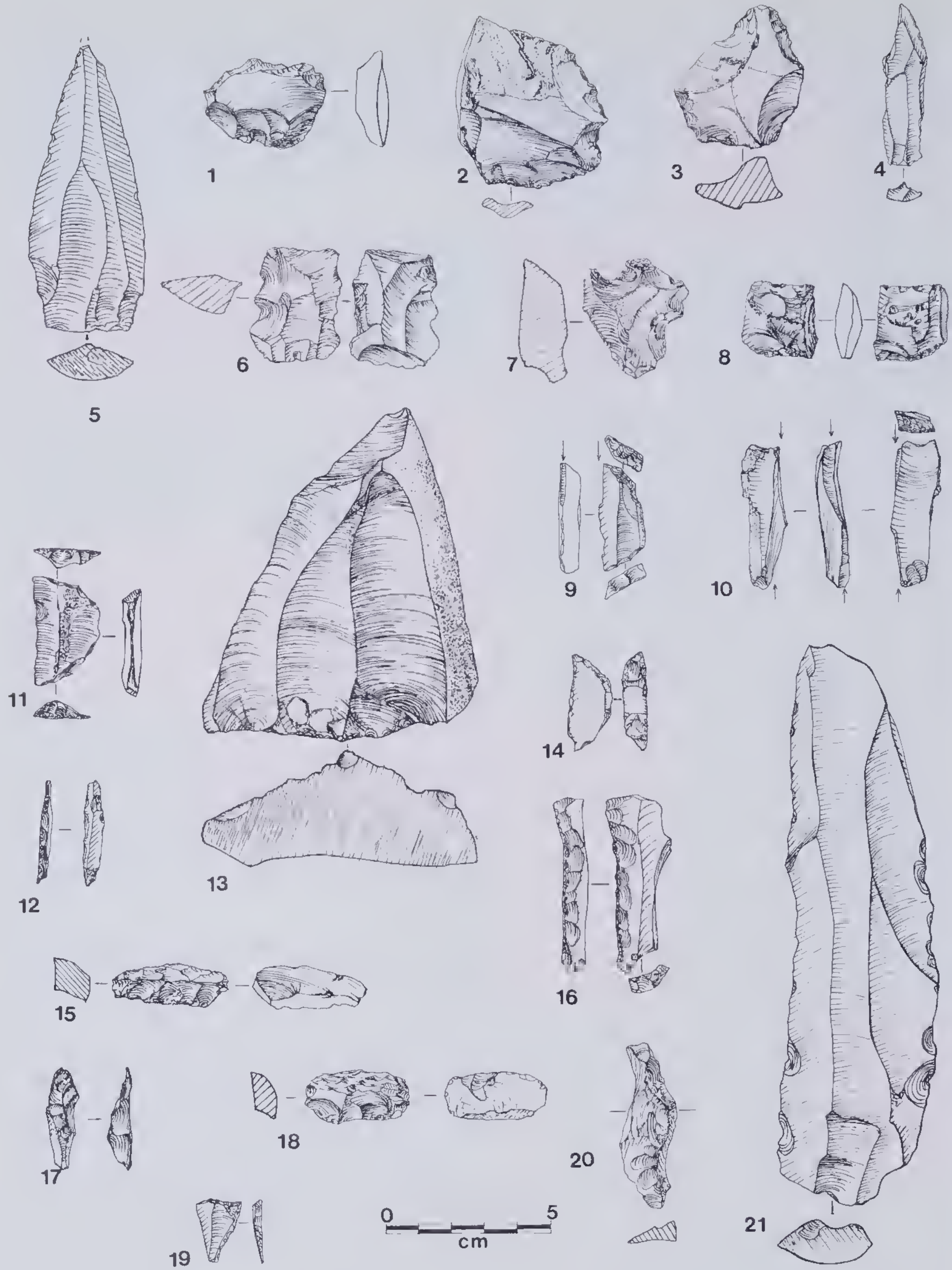

Fig. 5: Flaked stone artifacts from surface sites, Millstream station.

crested blades which have been identified are irregular. A bilaterally crested bladelet and blade are illustrated in Figs 5:17 and 20.

One of the Millstream bladelet cores is shown in Fig. 6:8. The piece is made on a tabular fragment and has a faceted striking platform. Cores such as this were used in the production of bladelets with faceted butts (Fig. 5:4).

The second method of bladelet production is a form of bipolar technique. The cores used are small elongate fragments (Fig. 6:2) which were flaked in the same way as in bipolar flake production (Bordes 1961; White 1968). The core is held on an anvil and several sharp blows are sufficient to produce a number of small bladelets or elongate flakes. The advantage of the technique is that it enables usable blanks to be produced with ease on very small cores. These cores can also be flaked by direct percussion while being held in the hand, in which case the bladelets or flakes are struck from either side of one extremity in much the same way that burins are spalled. Bladelets produced experimentally by this technique are usually irregular and often are relatively thick with quadrilateral sections.

It is likely that variants of blade and flake production other than those outlined here were used in the silicified shale quarry-factories on Millstream station. For instance, there are a number of specimens which are technologically and typologically the same as burins on straight or concave truncation (Fig. 5:10). In some cases several burin spalls have been struck from the truncated ends of these pieces. Were these tools used as gravers or chisels (i.e. *burins*) as is probably the case with their Eurasian and African analogues? Or are the Millstream specimens specialised bladelet cores?

The lithic sandstone quarry at 'Driller's Hole' is the only leilira point and blade factory known in the Millstream area, though others have been recorded in the Chichester Range 120 km east (Dortch 1972). Here we collected a number of large blade cores of pyramidal form as well as others (Fig. 5:13) which are intermediate in form between prismatic blade cores and Levallois point cores. Typical Levallois point cores appear to be absent. Very large numbers of prismatic blades (Fig. 5:21) are strewn over the surface of the 'Driller's Hole' quarry-factory. There are also pieces closely resembling Levallois points (Fig. 5:5; cf. Bordes 1961, Plates 6:3, 4, 8:5; Dortch 1972, Figs 4:b, c, d, f). It appears that pointed blades resembling elongated Levallois points were manufactured in the Fortescue valley by a para-Levallois technique, that is, successive blank production on pyramidal cores. It is also possible that typical Levallois point cores were further flaked following the removal of one or two Levallois points, a technique identified in the Ord valley, Kimberley (Dortch 1977).

Fig. 6: Flaked stone artifacts from surface sites, Millstream station.

Flaked Stone Tools

For convenience we have followed the order of Glover's tool analysis in the description below.

Backed microliths: Very few backed microliths (50 specimens) were found in our sampling of the Millstream sites; almost all came from the Newall site (12) and Crossing Pool (15, 16). Glover (1967, p. 419) divides the microliths of the Newall collection into two groups according to their length:width ratios. The first group (A) are geometric microliths in the strictest sense, that is, those having distinctive 'geometric' forms. The dominant forms of these in the assemblages we collected are segments (Figs. 5:11, 6:5), trapezes (Fig. 6:10), or triangles (Fig. 5:19) according to the profiles formed by their abruptly retouched backs and unretouched or lightly-trimmed thin edges. Some of the segments are very thick (Figs. 5:14, 6:11) and clearly resemble smaller examples of the elouera (cf. Mulvaney 1975, Fig. 36d) of eastern Australia. Glover's group B consists of backed microliths having length:width ratios greater than 2:1. These consist mainly of asymmetric backed points ('bondi points': McCarthy 1967, p. 40) and rectilinear backed bladelets which may be pointed or not (Fig. 5:12, 6:3); some of the latter have bilateral abrupt retouch, the thinner edge being only partially trimmed. Fig. 6:6 is an irregular asymmetric backed point with a faceted butt.

The dominant forms within each of Glover's groups A and B grade into one another; for example, Fig. 6:7 is intermediate in form between the asymmetric backed points and the rectilinear backed bladelets. There also seems to be a gradation in form between groups A and B. Possibly some of these intermediate forms represent discrete tool types. These include elongate segments (Fig. 6:1) and trapezes (Fig. 5:9) which are each intermediate in form between the typical geometric category (group A) and some forms of rectilinear backed bladelets whose backs are slightly curved or oblique at the extremities (Fig. 6:9).

A notable feature of these assemblages is the number of backed microliths of all kinds which are in part naturally backed. There are also numbers of naturally backed bladelets or small flakes which, though lacking retouch, resemble microliths in size and proportions. The elongate trapeze in Fig. 5:9 has natural backing on the lateral edge parallel to the chord. (Note that the distal oblique extremity of this piece is terminated by a single burin facet.) These assemblages also contain obliquely or transversely truncated pieces (Figs 6:4, 6:12), most of which are somewhat larger than the backed microliths.

Adze flakes and scrapers: In his description of the Newall collection Glover (1967, p. 421) noted that "... no hard and fast distinction can be made between scrapers and adzes". This is certainly as true for the Millstream material as it is for many other Australian assemblages. The statement is not only applicable to the finely retouched, small flake tools thought to have been hafted; but also to large core tools such as pebble choppers, which could have been used as hand-held adzes; and to nuclei-form or core scrapers, including horsehoofs, which may have been used as choppers or hand-held adzes rather than as 'scrapers'. The only tools from Millstream which are indisputably adzes of hafted type are the tula adze slugs (Figs 5:15, 18). These are a numerous and very well characterised group (cf. McCarthy 1967, pp. 27-28; Mulvaney 1975, pp. 233-235). They seem to be confined to the larger occupation and factory sites such as the Newall site and Crossing Pool, a distribution which agrees with adze flakes being maintenance tools in the sense of Binford and Binford (1969).

The flaked tool assemblages from Crossing Pool and the Newall site also contain what we designate as non-tula forms of probable adze flakes (Fig. 5:1), characterised by the undercutting and crushing or blunting of the periphery of the working edge associated with adze use. These may have single or double working edges; most are made on flakes and a few are on small blades. One of the latter is seen in Fig. 5:16. The piece has an invasively flaked working edge whose outer part is heavily crushed and blunted. The proximal end of the piece has been obliquely truncated. Other blades and flakes have invasive or scalar retouch but not all of these appear to have been used as adzes. We have not identified any invasively flaked projectile points in the Millstream area, though a presumably prehistoric specimen is known from Pardoo Station 300 km to the northwest (Fig. 1, Dortch 1977).

The retouched tools identifiable as flake-scrapers include many of generalised form on small flakes (Fig. 5:3); many of these could have been hafted and used as adzes. There are also a few end-scrapers on blades, bladelets and flakes, and very many irregular scrapers on thick flakes.

Other pieces: The scrapers on thick flakes above merge imperceptibly with a numerous group of Millstream artifacts which are perhaps best described as thick notched flakes (Fig. 5:7). The function of these artifacts is unknown; they may be small flake cores or they may have been cutting tools or scrapers.

There are also very many flat, notched or denticulated flakes (Fig. 5:2). Other pieces from the Millstream sites (such as blades, bladelets and flakes) have edge damage probably resulting from their having been trampled by livestock or disturbed by erosion rather than from retouch (including deliberate notching) or use. In the case of the leilira blades in **Figs 5:5, 21** most of the small flake scars on the edges are fresh showing that they were produced long after the blade was manufactured and are probably natural or accidental in origin. In many cases, particularly with very thin pieces such as the bladelet in **Fig. 5:4,** it is uncertain whether the chipping along the edge is fine retouch, use-wear, natural damage, or a combination of these.

As noted earlier some of the Millstream sites, particularly the Newall site, contain numbers of grindstones and anvil stones. We have not attempted to classify these tools here as most are fragmentary. It should be emphasised, however, that it is the presence of grindstones and anvils, along with flaked stone tools and *dèbitage* resulting from tool manufacture, which enabled us to identify some assemblages as occupation sites.

ART SITES

(J.C. and W.C.D.)

Two concentrations of rock art (sites 4, 5) occur in Gregory Gorge, one on each side of the gorge on vertical rock surfaces close to river base level. This art has two features which set it apart. Firstly, at each site there are both paintings and engravings, an unusual occurrence in the Pilbara. Secondly, the engravings are stylistically different from the major Pilbara engraving sites, although they have much in common with other river valley sites in the area. Wright states that the art of Gregory Gorge has the highest ratio (86%) of human figures to other motifs of any Pilbara site examined; and that in the areas where the human figures are most prominent ". . . the engravings are mostly of the closely drawn elongated type typical of the Fortescue River sites." (Wright 1968, p. 49.)

Site 4 is the larger of the two Gregory Gorge concentrations and consists mainly of engravings. Some 150 individual figures were counted although many are linked. Most representations are of human or human-like 'stick' figures (Plates 7, 8), the few exceptions being emus. The very faded paintings show greatly enlarged emu footprints and configurations of lines.

At 'Driller's Hole' (6), there are a relatively small number of engravings so patinated as to be almost indiscernible. There are others at *ganya* (1), a site recorded by Wright as *pirina* (Wright 1968, p. 25).

Plate 6: Part of site 4, Gregory Gorge, showing engravings restricted to prominent bed of fine-grained lithic sandstone (scale on left edge of engraved surface is 20 cm long).

Plate 7: Close-up view of engraved stick figure at site 4, Gregory Gorge, showing how percussion has removed darker surface zone of weathered rock (scale length: 20 cm).

Plate 8: Engraved stick figures at site 4, Gregory Gorge (scale length: 5 cm).

Engravings at sites 1, 4, 5 and 6 have style factors in common and utilise similar rock strata. The same style characteristics are repeated many kilometres downstream at *Bilanu*, again on similar rock, suggesting a common origin. The stick figure engravings are generally 20-25 cm in length, the maximum size being controlled by the available space between natural joint and bedding plane fractures (Plates 7, 8). They have been produced by selective removal of the darker surface zone of weathered rock and range from 0-3 mm deep. The technique used appears to have been percussion with a hand-held rock, which must have been sharp to produce the fine detail in many examples.

The surfaces on which engravings have been made in Gregory Gorge are restricted to one particular bed of fine-grained lithic sandstone in a sequence of sandstones, cherts and volcanic rocks (Plate 6). The sequence has been gently folded and the rock band containing the engravings dips 10° eastward but becomes more horizontal to the east. Most of the engravings are on near-vertical surfaces formed by well-developed joint planes normal to the bedding. Joint spacing is about 40 cm and the bed on which the engravings were

Plate 9: Remains of painting at site 5, Gregory Gorge. The painting is visible only because the pigment, which is almost completely lost, has altered the weathering products on the surface and left an image of lighter coloured rock (scale length: 20 cm).

made 50-70 cm thick. The rock is firmly indurated with a very finely crystalline to cherty matrix. It is more resistant to weathering than the overlying and underlying shales, which in weathering permit large joint blocks to become loose and fall out. The cherty nature of the rock makes it very brittle; there is evidence of impact flaking on exposed edges which may be of human origin or due to impact by flood borne material. The rock is being weathered very slowly by chemical processes. It contains small pyrite cubes which oxidise in weathering to produce the dark surface colour. It also contains dolomite, which is leached by water to give the surface texture, and feldspars which break down to form clays, giving the softer surface zone which was used for engraving. The impermeable nature and high silica content prevent weathering extending more than about two mm from the surface.

It is probable that other Fortescue sites which have not been examined so closely utilise a similar band of rock. To some extent the nature of the rock, imposing as it does a size restriction on the engravings (yet providing a flat surface which can be pecked relatively clearly) is a key factor in the similar appearance of engravings throughout the valley.

The paintings at sites 4 and 5 are very faded and show red and white pigments only. They are on similar surfaces to the engravings but are consistently about two m higher up, suggesting that lower paintings have been washed away by floodwater. Some paintings are only visible because the pigment (now almost completely lost) has altered the weathering products on the surface and left an image of lighter coloured rock (Plate 9). Apart from the probable emu footprints the paintings' motifs are not obvious, even to local Aborigines; and most are so faded that it is not possible to say whether they are complete. A few other paintings have been recorded in the Wittenoom area (Fig. 1) and on Hooley station in the Chichester Range, but to date none have been found in abundance anywhere in the Pilbara region.

Art sites on Millstream station appear to have links with occupation sites 5 and 6; and the engravings at Ganya (site 1) have ritual significance, as noted in the next section. Nevertheless, even though Aboriginal informants have said that the art was made by the *marga* (in this case the 'Two Men') as they travelled down the river, relatively little mythological importance seems to be attached to it, with the significant exception of some engraved ceremonial decorations at a few unspecified art sites. Our own findings are largely in keeping with Wright's statement that ". . . the guides casually indicated where the engravings were, then . . . spent the whole time searching for certain eroded marks which they had been told had a ritual significance . . . I wondered whether their apparent lack of interest in the engravings indicated that these pictures had no significance in the ceremonies associated with this place." (Wright 1968, p. 25.)

MYTHOLOGICAL AND RITUAL SITES
(K.P.*)

There are two important mythological sequences. The first and more substantial is of the general nature of the 'Two Man' myth (Berndt, R.M. & C.H., 1964, p. 205). It follows the Two Men in their travels down the river in the Dreamtime while establishing the belief system that was and still is followed by the Aborigines in the region. The second is an aetiological myth about one pool in the river and apparently not connected with the first story line.

The Two Man Myth

The Two Men were brothers called *Duwaramada* and *Balindjamada* and they had a short-tailed dog called *Dyudurli.* They are described as *marga* men, ancestors from the Dreamtime who were very tall and thin but human in other respects (Palmer, 1975, p. 155). They appear to have come out of the ground.[2]

> *That's when they first started. And they came up to a proper, like a proper human being, sort of coming up.*[3]

The myth is preoccupied with the establishment of the circumcision procedure and associated ritual.

Site 27: *Irangu dalu*

Duwaramada's and Balindjamada's first activity was to establish the material resource for the circumcision cutting stone. This was known as the

* Part of the material in the following section is being published in a separate paper (Palmer, in press).

2. The *Bugadjimbiri* in the *Nyamil* line came out of the ground at De Grey. Informant, Yandeearra, September 1974.
3. Informant: a *Gurima* man with some *Bandjima* association, though he also speaks *Mardudyunira.* He was born near Pannawonica, and has spent his life working on station properties in the area.

irangu, a term for a stone knife, or esoterically as the *gandi*. The reef of fine-grained rock that the Two Men left behind is referred to as *dalu*[4], a term used generally of sites associated with the myth. Stone from the site is still prized for its qualities as a *djimari*[5] though *irangu dalu* (27) could not be visited by women because of its sacred associations. The choice of the correct stone depended on its colour:

> *You go by the colours, it mustn't be red or things, you know red, no good red colour . . . red's like a danger, like you know for blood . . . Make the boy, you know when you do the boy in it'll bleed, you know too much.*[6]

The correct stone was brown or white and had to be extracted from below the surface:

> *But this one mustn't be from the surface, from outside, you've got to dig 'em up a bit, you know from the sunshine . . . a little bit underneath from the ground, a few inches deep.*[7]

The site was so prized traditionally that men from other areas would visit the region in order to trade artifacts for the *irangu.*[8]

Site 28: *Muṛal*

Muṛal dalu (28), another material resource site, is a red ochre mine in the banks of the river a few km downstream from site 27. *Muṛal* according to the informant meant 'blood' and the ochre was used to decorate the Two Men prior to their initiation. The ochre is first ground and then mixed with fat:

4. *Dalu* generally means a pet, but is also used for a place associated with the perpetuation of a particular plant, animal, fish or disease, or more generally a resource centre known for its Dreamtime affinities. Further east the term *nyuga* is used often with specific reference to the conception totem, while *djabija* is used for a perpetuation centre (cf. Tonkinson 1974, p. 75).
5. The prepared circumcision knife.
6. Informant, footnote 3, May 1975.
7. Informant, footnote 3. Informants from Onslow at a similar site on Nyang station (April 1974) and a *Nyamil* informant at a site at Yarrie station (April 1975) independently made the same statement.
8. Informant, May 1975: a man of *Indjibundi* and *Bandjima* descent born at Deepdale station. He has worked on stations in the area and became a dogger (dingo hunter) in 1953, and has always taken a keen interest in traditional matters, learning much from older people who are now dead. *Bandjima* informants preferred to use the term *guran* to *irrangu.*

Dripping nowadays, years ago it was the kangaroo fat, that's what they used . . . and you put it in this one and rub it up like that, he's very soft and nice . . . no colour only just that red, he look pretty, dress him up like that, smell good too, somehow.[9]

Site 1: *Ganya*

Some km further down the river there is, in the flat stratum of the river bed, a circular dome-shaped rock formation several metres across. At its periphery is a smooth shallow groove, "like a wheel rut", said to have been caused by the dancing feet during the first initiation ceremonies for Duwaramada and Balindjamada. This is *ganya* (**1**), the major site of the complex and of fundamental importance to the established circumcision rituals of the region.

The ceremony centres on the dancing circle. For some weeks prior to the initiation dancing takes place clockwise round the circle and a variety of songs are sung. The dance, circle and songs are known collectively as the *bundud* and roles depend upon relationships to the initiates, there being two major groups which form the basis of local Aboriginal social organisation in general. The contemporary blood relationships, including brother and sister and the grandparent generation, are known as the *djindjanu* — the workers. The girls from this group perform the dancing and as a whole they are subservient to the parental kinship sections, which include aunts and uncles, known as the *gangu* mob — the 'bosses'. Age also confirms status amongst the *gangu* themselves, while the closer blood relationships take a more prominent role in the proceedings. During the *bundud* the *gangu* may sit inside the circle and beat time with a stick on a *yandi*[10]. Meanwhile the initiates, known as the *bagali* or more exactly the *marlu-lu*, have spent time away in the bush cared for by the *mumiya*, a male clown with special privileges which include his being allowed to dance — an otherwise female prerogative. The *marlu-lu* is strictly a prisoner, since he will have been 'grabbed' by the *gangu* men and forcibly marched away: the manner in which he is then treated will probably depend on his record for good behaviour previously, since misdemeanours are dealt with harshly at this time. The *bundud* is 'open' until the last night or nights when a warning song tells the women and children to leave. The remaining men then sing the 'big' (i.e.

9. Informant, footnote 8.

10. A *yandi* is an open wooden dish or vessel, known elsewhere as a *coolaman* and as a *pitchi* dish. The name also applies to the action of winnowing seed from husks in the dish, and in contact times separating tin concentrates from river sand by hand.

sacred) songs for the rest of the night until a little before sunrise when they go to the boys and sing secret/sacred circumcision songs known as *muwra* prior to the operation.

They then return to the *bundud* place with the initiates, encircling them 'like a cyclone' and singing. The rest of the group form two converging lines down which the men proceed, the whole movement being known as the *bidara.* A bough shed is prepared nearby for the initiates who must rest in its shade, and the *gangu* sit nearest to them. It is traditional for the relations to cry for the boys as they return in the *bidara.* The ritual food, known as the *djiḍa*[11], is also displayed at the *bidara*, and the *gangu* have proprietory rights over its distribution.

Ganya, in the Fortescue, was where the *bidara* ritual was first established and its validity is verified by the rocks that bear the marks of the *bundud.* Informants point to marks made in the centre of the circle by naked buttocks where the *gangu* sat, and to footprints in the rock. It is felt that during the creative period the rock was soft and the peripheral groove shows where the *djindjanu* danced. Two hollows adjacent to the site are marked as being the bough shed for the two boys. One set of footprints leads away from the *bundud*, and are said to be the marks left by a man who took a girl into the bush for illicit sexual activity; but the connection with the *bundud* was not explained.[12] Nearby is a *dalu* for the moon *(wilara).* This is associated with the kangaroo *(marlu)* and consists of a small circular patch of white quartz in the horizontal rock. While the *dalu* is not specifically a part of the *bundud* mythology, informants claim that it was placed there by the Two Men as they "laid down the law" in the river.[13] The moon was made to shine brightly in the Dreamtime by the *marlu*, who urinated on it to clean off the grease and dirt. The *marlu* was thus assured of safety at night when he could see his enemies more clearly. The practice was repeated traditionally to ensure a bright moon, ironically for kangaroo hunting, though water from a *yandi* was used in preference to urine.[14] There was also an associated sun *dalu*, but little or no information was available about its function.

11. *Tjiri*, type of spinifex (Pitj). *Tjiru*, long strong spinifex, also *tjirangku*, boy of 12 years old (Ten Raa & Woenne 1973).

12. Informant, footnote 3.

13. There is a possible connection between the term for the prisoner *marlu-lu* and the word for kangaroo, *marlu* (Berndt & Berndt 1964, p. 206 ff).

14. Informants, April 1974 — *Ngarluma* man, approximately 80 years old, and was born on Croyden station and has worked in the area all his life. Until his recent blindness he was regarded as a leader of the local people, and is still highly respected. See also footnotes 3, 8.

Other Sites

The final sites of the complex are located some distance downstream at a place known as *bilanu.* Here two hollows in the hillside are said to have been the resting place of the Two Men after they left *ganya* and travelled down the river. They fed on catfish, the fat of which is metamorphosed in the form of greyish rocks adjacent to the hollows.[15]

Numbers of engraving sites (**Fig. 2**) are found along the banks of the Fortescue River. Many have representations of thin stick-like human figures, said to be *marga,*[16] drawn during this creative period by the *marga* themselves — or sometimes specifically by the Two Men (who were *marga*) who "laid all the law for us".[17] Their significance to Aborigines rests often not in what they represent figuratively but in that they are a part of the great creative process and must not be interfered with since they are representative of that spirit time. In some instances ceremonial decorations have been recognised by informants[18] who emphasise these as another aspect of the mythology and rituals ordained in the Dreamtime. To an extent the myths and rituals depended on the engraved decorations for their authenticity and inviolability. In this sense the rock circle of *ganya* can be seen to occupy a similar place in the mythology to the engravings.

Several km upstream from *ganya* is the place where the Two Men disseminated the circumcision ritual and belief amongst the tribes of a wide area. One informant[19] mentions 13 initiates who first came to the place to be "put through the law". Each was circumcised in turn. Some were strong enough to go through the operation without crying or shedding too much blood; others shouted with pain or were in danger of bleeding to death. Those who fell short were deemed unworthy to "carry the law" and were given just the songs "for the fun of it" and could only cut their arms, not their foreskins.

Site 29: *Djiḍa*

The place known as Kumana Hill (**29**) now stands at the side of the river as the metamorphosed *djiḍa,* or ritual food collected at the time. Today,

15. Informant, footnote 3, April 1974.
16. The *marga* is a general term for an ancestral figure, used widely throughout this area of Western Australia.
17. Informants, March 1974 — *Bandjima* man, now living at Onslow as leader and spokesman for the Aboriginal community. He is a respected law man, with considerable interest in its conservation. *Indjibundi* woman, born at Millstream.
18. Informants, April 1974 — see footnotes 3 and 16, *Bandjima* man.
19. Informant, footnote 3, April 1974.

this is collected for the initiation ceremony and laid out adjacent to the dancing area. Only those in charge of the proceedings (the 'bosses') are allowed to touch it, though a general distribution at the end of the ritual ensures that all get a share. Today the *djiḍa* consists of many bags of flour and tins of jam and meat. Traditionally it was made up of plant seed, from which the damper was prepared, and fresh meat. The size of the amassed food indicated the prestige of the occasion and the Dreamtime contribution is accordingly massive, being now metamorphosed and appearing as a huge block of rock some 22 m in height at the side of the river. Some of the boulders at the foot of the hill are formed of conglomorate; the small, smooth pebbles are said to be plant seed. Several different sorts of seed are represented there:

> *It was a mix up of food too, it used to be . . .* yambula *[that] is a run of weeds growing in the flat . . . another one,* gadbi, *that's another tucker name, weed, a little seed.* Bunina *grows out of one of them trees, and he's very oily, he's a black seed, and the* guwnura *is a grass grow like the buffalo grass . . . very rich stuff* guwnura. *And* bila, *he's a very rich food, grows on the gravel country.*[20]

The meat was made up from kangaroos, goannas, emus, and turkeys when they could be obtained. The transformation to stone was not explained by a particular event, though one informant felt that "something went wrong". His second version was more typical:

> *I told 'em [the old people] "Why turn into stone?" They say "Well, that's the law of the country, years ago". And that's why they put the evidence there, and you've just got to believe it like that.*[21]

Site 26: *Nangunangga*

There remains one myth, not directly connected with the *ganya* complex of sites, that explains the formation of Deep Reach Pool (26), a large permanent pool a few km above Millstream homestead. The story in outline runs as follows:

> *Two boys were out in the bush, waiting their time to be initiated. A* mamiya *was looking after them. He was, however, a little negligent and on one occasion took rather longer than he should fetching the boys their food. The boys grew impatient and seeing a bird, stoned it, then plucked, cleaned, cooked and ate it. Nearby was a water snake,* barimidi.

20. Informant, footnote 8, May 1975.
21. Above informant, footnote 8, May 1975.

He smelt the food cooking and got very excited. He caused a cock-eyed bob to start and it whistled all sorts of ducks and birds towards the boys, who were naturally very pleased, and eagerly went about trying to collect the birds in the confusion. Meanwhile the barimidi *drew closer to the boys. The* mamiya *saw what was happening and tried to warn everybody, but alas it was too late. The* barimidi *turned around and made a great suction through his anus and drew them all inside of him. And it was because of this that there is now a huge pool at* nangunangga *(Deep Reach).*[22]

Informants from Strelley station told Aborigines at Yandeearra[23] that Millstream was the centre for a song line dominated by a water snake and associated with a rain-making ritual. It was believed that if the snake was upset there would be a huge flood. The information was confirmed by *Indjibundi* people from Roebourne who talked of a snake and a huge flood which would result from any disturbance to the river. There is no indication at present that the rain-making ritual and associated snake are connected with the *barimidi* story, but the similarities are too obvious to ignore.

CONCLUSION

In this paper we have recorded data relating to several of the diverse Aboriginal activities which have taken place in the area now occupied by Millstream pastoral station. The study, detailed as it is in some respects, does not purport to be an integrated analysis, neither in the terms of cultural ecology nor as a developmental impact statement. Further assessment of traditional Aboriginal subsistence and land-use in this area is needed; ethnobotanical enquiries (cf. Scott 1972) in particular would yield important information. A more detailed study of the archaeological sites and artifact assemblages collected from them would undoubtedly be profitable, though we maintain our view that erosion and other disturbances severely limit the value of many sites.

Despite the present scarcity of ecologically relevant ethnographic and archaeological data it seems reasonable to assume that the Millstream area,

22. Above informant, footnote 8, May 1974.
23. Informants, Yandeearra, August 1975, after a conversation with a *Nyungamada* man from Strelley station.

with its abundant water and food resources, would have supported relatively large numbers of people for longer periods than elsewhere along the Fortescue. Several verbal reports indicate that up to 200 Aborigines camped at or near Millstream in the early pastoral years. Wright (1968, p. 25) noted: "My Aboriginal informants told me that in the early days people came from surrounding groups to this place in *Indjibundi* territory for inter-tribal meetings 'to make the law'." This corresponds with a report from a pastoral property near the mouth of the Fortescue that in the 'early days' Aborigines used to walk up the Fortescue river to Millstream station for their 'holidays'. Among its chief commodities was stone sought for ritual or tool-making purposes, and wattle for spears; it was also generally known to be a good place to catch fish and gather edible roots. Tindale (1974, pp. 22, 57, 58, 59, 241-42) has a number of significant comments on *Indjibundi* cultural ecology.

Ethnographic data relating to mythological and ritual sites in this part of the Fortescue valley certainly support the archaeological evidence showing that it was an important area. Mythological sites identified appear to bear no particular relationship to occupation sites although quarry sites were known as sources of ritual stone and ochre. Other mythological sites relate to topographical features: pools, outcrops and unusual configurations of rocks. It is not surprising that a prominent feature like Deep Reach Pool (*Nangun-angga:* site 26) has associated aetiological myths; and it is because of such sites that the area is still very important to the Aborigines. The *Ganya* site (1) is also well-known to the Aboriginal people in the region. Both sites represent a source of important Pilbara belief and ritual and certain associated ceremonies have spread widely, as described by von Brandenstein and Thomas in the following.

> *The pundut ritual originated on the Fortescue River near Gregory Gorge. Since then it has expanded and contracted to and fro, each time altering and 'modernizing' its rules . . . 'pundut' refers to the hitting of covered-up bark pieces (now car tyres) and the thuds effected by this method. A vital part of the pundut ritual is the animal fables in song form . . .* (Brandenstein & Thomas, 1974, p. 90).

The Aboriginal people who still retain detailed knowledge of the myths surrounding the Millstream area desire that the valley be preserved. We hope that this is a possibility, not only for them, but for the many other Australians, Aboriginal or not, for whom Millstream has a special significance.

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A DISTINCTIVE NEW *ANTHIAS* (TELEOSTEI: SERRANIDAE) FROM THE WESTERN PACIFIC

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ABSTRACT

A description is given of *Anthias randalli*, a distinctive new serranid fish from the Philippine, Molucca, Palau and Marshall Islands. Males are characterised by bright red and violet horizontal bands, while females are relatively uniform reddish-orange. *A. randalli* is known from caves and underwater cliffs at depths of 30 to 68 m.

INTRODUCTION

The genus *Anthias* Bloch consists of small, brightly coloured, planktivorous fishes, associated mainly with coral reefs. Sexual dimorphism is common in this group, and certain species have been shown to be sequentially hermaphroditic, sex change being governed by behavioural cues (Shapiro 1977).

Many species are known from the western Pacific (Katayama 1960; Heemstra 1973; Masuda, Araga & Yoshino 1975; Allen & Burhanuddin 1976; Randall & Lubbock, in press); live coloration, which is an important diagnostic feature, is recorded for a number of these species. In the present study we describe a strikingly coloured and sexually dimorphic species that differs significantly from previously known *Anthias* both in coloration and in morphology. It was collected from the Philippine, Molucca, Palau, and

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Marshall Islands at depths of 30 to 68 m, and was usually associated with caves and underwater cliffs.

Type specimens are deposited at the Australian Museum, Sydney (AMS); Bernice P. Bishop Museum, Honolulu (BPBM); British Museum (Natural History), London (BMNH); Musée d'Histoire Naturelle de Genève (MHNG); United States National Museum of Natural History, Washington, D.C. (USNM); and the Western Australian Museum, Perth (WAM).

ANTHIAS RANDALLI n. sp.

(Figs 1 and 2)

Holotype

BMNH 1977.1.21.1, 69.7 mm SL, male, at 40 m, large cave on vertical drop-off, Baring, Olango Island, Cebu Strait, Philippine Islands, collected by R. Lubbock on 18 August 1976.

Paratypes

AMS I.19756-001, 66.3 mm SL, collected with holotype; BMNH 1976. 1.21.2, 65.6 mm SL, at 45 m, vertical drop-off, Baring, Olango Island, Cebu Strait, Philippine Islands, collected by R. Lubbock on 3 August 1976; BMNH 1976.1.21.3, 41.1 mm SL, at 30 m, vertical drop-off, ½ km north of Caubyan Daku Island, Camotes Sea, Philippine Islands, collected by R. Lubbock on 15 August 1976; BPBM 9532, 44.0 mm SL, at 33-52 m, base of drop-off, SW side of Angulpelu reef, Palau Islands, collected by J. Randall, A. Emery and E. Helfman on 22 April 1970; BPBM 19983, 2 specimens, 27.8 and 38.7 mm SL, at 46 m, 70° drop-off with caves, outside reef off S end of atoll, 50 m SE of small boat passage, Kwajalein, Marshall Islands, collected by J. Randall, N. Bartlett, R. Hergenrother and K. Burnett on 8 April 1976; MHNG 1551.39, 52.4 mm SL, collected with holotype; USNM 217534, 56.7 mm SL, collected with holotype; WAM P25233-007, 6 specimens, 22.3-41.3 mm SL, at 40 m, S coast off Latulahat, Ambon, Molucca Islands, Indonesia, collected by G. Allen and J. Randall on 29 January 1975; WAM P25239-002, 8 specimens, 34.8-46.9 mm SL, at 40 m, S coast off Latulahat, Ambon, Molucca Islands, Indonesia, collected by G. Allen and J. Randall on 29 January 1975; WAM P25628-001, 3 specimens, 53.5-55.8 mm SL, at 45 m, steep drop-off, Bairakaseru Island, Palau Islands, collected by G. Allen and W. Starck on 5 March 1972.

Diagnosis

A species of *Anthias* with the following combination of characters: dorsal rays X,15-17, usually 16; anal rays III,7-8, 8 rare; pectoral rays 16-18, usually 17; tubed lateral line scales 38-46, mostly 41-43; gill rakers 8-10 + 1 + 21-23; body depth 2.63-2.96 in SL (standard length); head length 2.79-3.30 in SL; spinous dorsal fin not scaled, third dorsal spine prolonged; anal fin tip acute, caudal fin lunate; flattened dorsal profile of head (see Fig. 1); colour pattern in life and in alcohol as described below.

Description

Dorsal rays X,16 (X,16 except one paratype with X,15, three paratypes with X,17); anal rays III,7 (one paratype with III,8); pectoral rays 16 (16-18, usually 17) (upper one or two and sometimes lowermost unbranched); pelvic rays I,5; principal caudal rays 15 (uppermost and lowermost unbranched); lateral line scales 43 (38-46); scales above lateral line to origin of dorsal fin 5; scales below lateral line to origin of anal fin 19 (18-21); circumpeduncular scales 22 (21-23, usually 22); gill rakers 8 + 1 + 22 (8-10 + 1 + 21-23); branchiostegal rays 7. Distributions of selected meristic data (according to locality) are given in Table 1.

Table 1: Distributions according to locality of selected meristic data from type specimens of *Anthias randalli*.

Locality	Lateral-line scales									Soft dorsal rays			Soft anal rays		Pectoral rays		
	38	39	40	41	42	43	44	45	46	15	16	17	7	8	16	17	18
Philippine Is			1	1	1	3					4	2	6		2	2	1
Molucca Is	1	1		2	6	2		2		1	13		14		2	11	1
Palau Is				1		1	1		1		2	1	4			3	1
Marshall Is				1							2		1	1		2	

Body depth 2.83 (2.63-2.96) in SL; body moderately compressed, the width 6.22 (5.79-6.88) in SL; head length 3.15 (2.79-3.30) in SL; snout 3.88 (3.49-5.71) in head; front of upper lip of males slightly thickened and occasionally with very small papilla; diameter of orbit 3.81 (2.76-3.77) in head; posterior edge of orbit without fleshy papillae; interorbital space smoothly convex, the bony width 4.33 (4.10-5.00) in head; least depth of caudal peduncle 2.46 (2.43-2.86) in head. Further morphometric data are given in Table 2.

Fig. 1: Holotype of *Anthias randalli*, 69.7 mm SL (photographed after two months in formalin).

Fig. 2: Underwater photograph of male *Anthias randalli*, approximately 65 mm SL, taken by R. Lubbock at 40 m off Baring, Olango Island (type locality).

Table 2: Measurements of selected type specimens of *A. randalli*, expressed in thousands of SL.

	Holotype	Paratype			
	BMNH 1977.1. 21.1	BMNH 1976.1. 21.2	USNM 217534	BPBM 9532	WAM P25233-007
Standard length (mm)	69.7	65.6	56.7	44.0	33.6
Depth of body	353	380	346	355	363
Width of body	161	172	162	161	155
Head length	317	322	303	332	333
Snout length	82	85	74	75	83
Diameter of orbit	83	85	95	107	110
Bony interorbital width	73	75	74	75	77
Length of maxillary	156	157	148	155	152
Least depth of caudal peduncle	129	122	118	125	128
Length of caudal peduncle	129	120	115	123	143
Predorsal length	320	309	302	316	324
Preanal length	628	645	631	657	664
Prepelvic length	357	367	354	377	381
Length of first dorsal spine	56	56	44	59	48
Length of second dorsal spine	80	88	90	102	95
Length of third dorsal spine	265	233	203	166	155
Length of filament on third dorsal spine	50	79	48	41	18
Length of tenth dorsal spine	118	122	118	121	119
Length of longest dorsal ray	182	220	169	166	137
Length of dorsal fin base	636	640	637	630	622
Length of first anal spine	66	66	62	70	68
Length of second anal spine	155	163	162	170	167
Length of third anal spine	151	143	153	152	140
Length of longest anal ray	306	309	240	209	202
Length of anal fin base	175	163	169	177	152
Length of pectoral fin	275	277	261	289	271
Length of pelvic fin	277	280	246	284	271
Length of caudal fin	359	337	386	343	345

Mouth oblique and moderately large, the maxilla reaching to a vertical at posterior edge of pupil; lower jaw projecting slightly when mouth closed; upper posterior corner of maxillary slightly less broadly rounded than lower;

Plate 1: Colouration in life of *Anthias randalli*, male holotype, 69.7 mm SL (upper) and female paratype, 56.7 mm SL. Painting by Dr W.B. Amos.

greatest depth of maxillary 1.56 in orbit of holotype; no supplemental maxillary bone; an inner row of villiform teeth of moderate size along side of upper jaw broadening to a maximum of about 5 rows anteriorly, the innermost and most medial of these teeth notably enlarged, lying nearly flat, and sometimes angling inward (occasionally a second similarly enlarged tooth immediately beside medial tooth); one or two canines laterally at front of upper jaw followed by a row of about 14 teeth along side of jaw which are about as long but more slender, those posteriorly angling forward; one or two enlarged canines anteriorly on each side of lower jaw which project outwards and slightly forward, and about one third back in jaw a single enlarged canine curving posteriorly; posterior to the latter, a row of moderate canines (about 13 in holotype) on side of jaw; lower jaw with a patch of villiform teeth anteriorly; vomer with a chevron-shaped patch of villiform teeth; palatines with elongate patch of villiform teeth; pharyngeals with numerous villiform teeth; tongue pointed, the upper surface with scattered very small papillae; gill membranes free from isthmus; gill rakers slender and long (largest 1.26 in orbit of holotype), notably longer than gill filaments (longest gill filament of first gill arch of holotype contained 1.88 in longest raker).

Opercle with three flattened spines, the central one the largest and most posterior, the upper somewhat anterior to lower; two lower spines acute, the upper slightly obtuse and indistinct; distance between tips of two lower spines about four-fifths the distance between central and upper spines; lower margin of preopercle smooth, corner and upper margin finely serrate (26 serrae on holotype; number of serrae variable but tending to increase with size; paratype 65.6 mm SL with 35 serrae, paratype 56.7 mm SL with 27 serrae, paratype 33.6 mm SL with 19 serrae, and paratype 22.3 mm SL with 12 serrae); lower margin of subopercle with 7-8 (2-9) serrae; interopercle with 7 (0-7) serrae near upper end of margin.

Anterior nostril in a membranous tube (higher dorsoposteriorly) directly anterior to middle of eye about half the distance from edge of orbit to edge of groove separating upper lip from rest of snout; posterior nostril diagonally upward and posterior to anterior, roughly semicircular, without a rim, and large, the greatest diameter of opening about as great as distance between nostrils, 6.4 in orbit diameter of holotype.

Scales ctenoid; no auxillary scales; head, including mandible, scaled except throat, gill membranes, lips, extreme front of snout, and a broad zone of snout from level of lower edge of eye to above nostrils; spinous dorsal fin without scales, soft dorsal fin with scales on basal half to quarter; anal fin with scales on approximately basal half; caudal fin with small scales extending close to posterior margin; pectoral fins scaled on about basal third; pelvic fins scaled on medial surface, the scales on first ray extending for about length of pelvic spine.

Lateral line a little more strongly arched than dorsal body contour, reaching highest point below about the sixth dorsal spine; last pored scale of lateral line approximately above posterior edge of hypural plate.

Origin of dorsal fin vertically above upper end of gill opening; third dorsal spine prolonged in females (4.93-6.04 in SL in three Philippine females), more prolonged in males (3.77 in SL in holotype, 4.29-4.74 in SL in two other Philippine males), with distal fleshy filament, longer in males; posterior parts of dorsal and anal fins with prolonged rays in males and adult females, rays relatively more prolonged in males, extending just posterior to a vertical through hind edge of hypural plate in holotype; origin of pectoral fins below third or fourth dorsal spine, the fins extending (when placed horizontally) to a vertical through first or second soft dorsal ray; origin of pelvic fins immediately below lower margin of pectoral fin base, first and second soft pelvic rays longest, reaching close to anal fin origin; caudal fin lunate, the lobes filamentous in larger specimens.

Colour in alcohol: overall pale, the scales on dorsal half of body dark basally. Colour of male holotype in life and up to 2 hours after death: a narrow violet stripe from predorsal region along dorsal fin base; remainder of dorsal body contour orange, each scale faintly greenish basally; a diffuse violet band from upper hind margin of eye to centre of caudal peduncle bordered immediately below by a conspicuous bright red band extending from top of snout through eye and upper half of pectoral fin base to lower part of caudal peduncle; tip of snout and ventral part of body pinkish-violet, more intense anteriorly, with a diffuse red stripe running from isthmus to anal fin origin. Iris reddish-violet. Pectoral fins pinkish hyaline; pelvic fins red-orange anteriorly, blood red posteriorly, with a violet anterior margin and a large bright bluish-violet central region; anal fin anterior to third or fourth soft rays bright red with a violet distal margin, posteriorly bright bluish-violet; distal margin of dorsal fin posterior to fourth spine, basal part of anterior soft dorsal rays, and three posteriormost dorsal rays violet; remainder of dorsal fin deep red, becoming orange on anterior half of spinous portion, the first three spines with violet tinges; caudal fin violet, the lobes slightly reddish. Two to three hours after death, the banding began to fade, and the body tended towards an overall bright red colour. Colour of 56.7 mm SL female paratype in life and shortly after death: dorsal body contour orange, shading to reddish-orange with violet tinges ventrally; scales on upper half of body faintly greenish basally; snout yellow-orange. Iris orange, violet ventrally. Pectoral fins pinkish hyaline; pelvic fins pinkish hyaline, anterior margin with violet tinges; anal fin orange, spinous portion and distal margin with violet tinges; dorsal fin orange with violet distal margin, anterior three spines with violet tinges; caudal fin yellow-orange.

Habitat and Distribution

The present species has been collected in the Philippine Islands, Molucca Islands, Palau Islands, and Marshall Islands, living in caves or on vertical drop-offs at depths of 30-68 m.

In the Philippines it was relatively common, and on one occasion several hundred individuals were observed together in a large cave off Marigondon, Mactan Island. At Marigondon, and also at Baring, Olango Island and Caubyan Daku Island, *A. randalli* did not appear to share its habitat with any other anthiines. At Apo Island in the north Mindanao Sea, a small cave was found containing both *A. randalli* and *A. bicolor* Randall; at Pescador Island in the Tañon Strait, *A. randalli* was found on a vertical drop-off also inhabited by *A. fasciatus* (Kamohara), *A. squamipinnis* (Peters), and *A. tuka* (Herre & Montalban). The bright colours of male *A. randalli* rendered them particularly conspicuous underwater.

At the Palau Islands, off Bairakaseru Island, it was frequently encountered in small aggregations adjacent to a vertical cliff at depths ranging between about 40 and 68 metres. The fish were observed chiefly around the bases of large colonies of black coral (*Antipathes*).

Remarks

This species is closest to an as yet undescribed species from the western Indian Ocean (J. Randall, pers. comm.); it bears only a superficial resemblance to other known species of *Anthias*, and may be distinguished using the diagnosis above.

We provisionally place *A. randalli* in the subgenus *Pseudanthias* Bleeker. In spite of the slight thickening of the upper lip of males, the species appears to share fewer characters with the subgenus *Mirolabrichthys* Herre and Montalban as defined by Randall and Lubbock (in press) than with *Pseudanthias.* Unfortunately the exact limits of the latter subgenus remain unclear.

As in other *Anthias* investigated, the males of *A. randalli* are larger and more brightly coloured than females. The gonads of this and several other species of *Anthias* are currently being examined histologically by Shapiro and Lubbock.

The Philippine population of *A. randalli* appears to reach a significantly larger size than those examined from other localities. Marked size differences according to geographical range are known in other *Anthias*. In the collections of Shapiro (1977), for example, *A. squamipinnis* from the Gulf of Aqaba reached a maximum length of 93 mm SL, while *A. squamipinnis* from the central Red Sea were not larger than 75 mm SL.

The present species is named after Dr J.E. Randall, who was the first to collect it, and who kindly provided us with specimens.

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PETROGALE BURBIDGEI (MARSUPIALIA, MACROPODIDAE), A NEW ROCK WALLABY[1] FROM KIMBERLEY, WESTERN AUSTRALIA

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ABSTRACT

A new species of rock wallaby, *Petrogale burbidgei* is described from the Kimberley. It is distinguishable from other species of rock wallaby (*Petrogale* and *Peradorcas*) on the basis of external morphology and on dental measurements. Its discovery emphasises the need for a revision of the separate status of these genera.

Introduction

In historical times rock wallabies of the genus *Petrogale* have occupied steep rocky country over most of mainland Australia, excluding the greater part of Victoria, southeastern South Australia and the forested southwestern corner of Western Australia. They are also found on a number of islands off the coasts of South and Western Australia, Northern Territory and Queensland. Calaby (1971) comments that 'the highly discontinuous nature of *Petrogale* distribution has resulted in a great variation of size and colour, and the taxonomy is confused'. Although many forms have been described from tropical northern Australia (see Iredale and Troughton 1934, and Tate 1948) both Ride (1970) and Calaby (1971) consider that there are probably

[1] The suggested vernacular name is Warabi, the name used for this rock wallaby by the Wunambal-speaking people (Bobby Koodbin to I. Crawford, pers. comm.).

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only two species, the Short-eared (*P. brachyotis*) and Brush-tailed (*P. penicillata*) in the Kimberley.

In the ranges southwest of Cooktown Godman's Rock Wallaby (*P. godmani*) is found. Calaby (1971) considers that this may be only another subspecies of *P. penicillata.*

The other genus of rock wallaby, *Peradorcas*, was originally placed in *Petrogale* by Gould (1842). It was distinguished from that genus by Thomas (1904) principally on the basis that individuals have the development of supplementary molars behind M^4_4. *Peradorcas* is a monotypic genus of which three subspecies have been recognised: *P. concinna concinna*, *P. concinna monastria* and *P. concinna canescens* — these are confined to the northern Kimberley and adjacent part of the Northern Territory and northwestern Arnhem Land (Ride 1970, Calaby 1971). Tate (1948) retained the subspecific names for *Peradorcas* although he doubted their validity.

Holotype

M15830, Western Australian Museum (WAM), adult female in alcohol with skull removed, collected by Donald T. Kitchener, 2 November 1976, shot at 2000 hrs in crevice in King Leopold Sandstone in fringing vegetation at the edge of Crystal Creek, weight 1400 gm, field number 7M.37, carrying an unfurred pouch young weighing 51.0 gm.

Type locality

Crystal Creek, Mitchell Plateau, Western Australia (14°30′00″S, 125°47′20″E). Locality described in Kitchener *et al.* (in prep.).

Paratypes

Mitchell Plateau, Kimberley

M15827 (WAM); adult female; in alcohol — skull removed; collected near Surveyors Pool (14°40′30″S, 125°43′40″E) by N.L. McKenzie on 22 October 1976; shot at 2200 hrs in open low woodland dominated by *Owenia vernicosa* and *Eucalyptus* spp., *over* open low scrub, *over* hummock grass, on rugged King Leopold Sandstone; weight 1360 gm; field number WS56; carrying a furred pouch young weighing 85.0 gm.

M15832 (WAM); adult female; skeleton and 'puppet' skin; collected at Crystal Creek (14°30′00″S, 125°47′20″E) by D.J. Kitchener on 3 November 1976; shot at 2100 hrs amongst sandstone boulders; weight 1150 gm; field number 7M.44; carrying a furred pouch young weighing 77.0 gm.

Prince Regent River Reserve, Kimberley

M12402 (WAM); adult female; in alcohol — skull removed; collected 13 km NE Mt York (15°26′12″, 125°36′42″) by A.A. Burbidge and A. Chapman on 18 August 1974, shot at 2030 hrs on King Leopold Sandstone scree slope on the south bank of Wyulda Creek at site E4. This site is described in Miles *et al.* (1975); weight 1300 gm; field number E4/19; carrying a pouch young weighing 48.0 gm.

Bigge Island, Bonaparte Archipelago, Kimberley
(14°31′40″S, 125°09′20″E)

M5978 (WAM); adult, skull and dentaries, collected by I. Crawford on 20 September 1963.

M9312 (WAM); juvenile female; in alcohol — skull removed; collected by L.A. Smith and J. Dell on 3 June 1972; trapped; weight 480 gm; field number DAM10.

M9313 (WAM); adult male; in alcohol — skull removed; collected by A.A. Burbidge on 3 June 1972; shot about 1800 hrs; weight 1200 gm; no field number.

M9314 (WAM); subadult male; in alcohol — skull removed; collected by A.A. Burbidge on 3 June 1972; shot about 1800 hrs; weight 980 gm; no field number.

M9359 (WAM); subadult male; skeleton and flat skin (in formalin); collected by A.A. Burbidge on 3 June 1972; shot 1800 hrs; weight 920 gm; field number DAM12.

M9361 (WAM); adult female; skeleton and 'puppet' skin; collected by A.A. Burbidge on 3 June 1972; shot about 1800 hrs; weight 1400 gm; field number DAM11; carrying an unfurred pouch young weighing 18.5 gm.

M15417 (WAM); adult male; in alcohol — skull removed; collected by A.A. Burbidge and P. Fuller on 22 July 1977; shot about 2100 hrs; weight 960 gm; field number FW376.

M15418 (WAM); adult male; in alcohol — skull removed, collected by A.A. Burbidge and P. Fuller on 22 July 1977; shot about 2100 hrs; weight 1430 gm; field number FW377.

Katers Island, Bonaparte Archipelago, Kimberley
(14°28′00″S, 125°31′20″E)

M9334 (WAM); juvenile male; in alcohol — skull removed; collected by A.A. Burbidge on 9 June 1972; shot at 1800 hrs; weight 185 gm; field number 61/62.

M9335 (WAM); juvenile female; in alcohol — skull removed; collected by A.A. Burbidge on 9 June 1972; shot about 1800 hrs; weight 520 gm; field number 63/64.

M9358 (WAM); juvenile female; skeleton and 'puppet' skin; collected by J. Dell; shot; weight not recorded; field number 65/66.

M9362 (WAM); adult male; skeleton and 'puppet' skin; collected by J. Dell; shot; weight 1200 gm; field number 67/68

Boongaree Island, Bonaparte Archipelago, Kimberley
(15°04′00″S, 125°12′00″E)

M10351 (WAM); juvenile male; in alcohol — skull removed; collected by W.K. Youngson on 4 July 1973; shot; weight 750 gm; field number RM127.

McKenzie *et al.* (in prep.) report that the specimens from islands in the Bonaparte Archipelago were collected from rugged King Leopold Sandstone country with low open woodlands of *Eucalyptus* spp. and *Owenia vernicosa* over hummock grassland (*Plectrachne* spp.).

Diagnosis

Very small rock wallaby, 1-1.5 kg; with short ears (less than 35 mm long) and short hind foot (less than 93 mm long); with large, well developed, permanent premolars and four molars; without sharply contrasting pelage markings; it has a faint dark central facial, occipital and shoulder stripe, and lighter lateral facial stripes. It is distinguished from other rock wallabies of the genus *Petrogale* by its small size, inflated tympanic bullae and large ratio between length of permanent premolar and length of first molar (1.59-1.82), and from *Peradorcas* by the presence of permanent premolars.

Description

Where it is thought helpful, comparisons are drawn with *Peradorcas concinna concinna* (Gould, 1842), *P. concinna monastria* Thomas, 1926, *Petrogale brachyotis brachyotis* Gould, 1841, and *Petrogale penicillata* Griffith, Smith & Pidgeon, 1827 and *Peradorcas concinna canescens* Thomas, 1909 from Northern Territory.

Petrogale burbidgei is a very small rock wallaby. Dimensions of the skull, dentition and external body measurements are presented for *P. burbidgei* in Tables 1 and 2. Skull and dental measurements are summarised in Table 3 for adult (dental notation $M\frac{4}{}$ 1.0) *P. burbidgei* and are listed alongside comparative measurements from adult *Peradorcas concinna*, the species most easily confused with *P. burbidgei*. All *Petrogale* (excluding *Peradorcas*, see Remarks below) are easily separable from *P. burbidgei* on their greater size. The skull and dentary of the holotype are illustrated in **Fig. 1**. The notation of molar eruption stage used in Tables 1 and 2 is as follows: a tooth not erupted above the surface of the maxilla is rated at zero, while a tooth that is fully erupted is rated at 1.0. Thus if the fourth upper molar is half erupted, this would be designated as $M\frac{4}{-}$ 0.5.

(a) Skull and dental characters: *P. burbidgei* has the typical narrow rostrum and fragile posterior palatal structure of *Peradorcas* and *Petrogale*. Possibly its most pronounced cranial character is the size of the tympanic bullae mesial to the post-glenoid process. These are considerably inflated in comparison with *P. concinna*, *P. brachyotis* and *P. penicillata* (see **Figs 3 & 4**). The alisphenoid bullae are narrow and only slightly inflated. There is a slight crest forming the anterior border of the ovale foramen and the external lateral border of the pterygoid cavity. As with *P. concinna* and *P. brachyotis*, there is little of the petrosal emergent from the eustachian canal compared to *P. penicillata*. Both the glenoid and mastoid processes, viewed laterally, curve forward to about the same degree as *P. concinna* and more so than in the petrogales examined. The median ridge on the basioccipital is low, as with the other species examined. The nuchal crest is pronounced as it also is in *P. concinna*, and accentuates the supraoccipital depressions on either side of it. The length of the rostrum as a proportion of the length of the skull is similar to the other species examined, although the rostrum is narrower anteriorly than the other species. The incisive foramina are small and elongate with the labial foramina behind. The labial foramina are on the ridge at the edge of the palate on the premaxillary — maxillary suture. The nasals are similar in shape to *P. concinna* being hastate in outline (see **Fig. 2**), relatively much more expanded posteriorly than *P. penicillata* and slightly more so than *P. brachyotis*. The inferior lacrimal tuberosity is moderate as with *P. concinna* but the superior is slightly reduced relative to the other petrogales examined. The dorsal crest of the zygomatic process of the squamosal curves down only slightly as is the case with the other species examined.

The upper and lower incisors closely resemble other *Petrogale* species with $I\frac{1}{-} > I\frac{3}{-} > I\frac{2}{-}$ and $I\frac{3}{-}$ having the typical lateral fold which divides the spade-shaped tooth into two distinct lobes. In specimen number M9334, which has $M\frac{1}{-}$ almost in place, $I\frac{3}{-}$ is only about a quarter erupted, while $I\frac{3}{-}$ is fully erupted in specimen number M9335 which has $M\frac{2}{-}$ three-quarters erupted. The milk molar $DP\frac{4}{-}$, on the notation of Thomas (1888), is similar in shape to the upper molars and like them is similar in shape to other species examined. The forelink is very weak and the midlink is not well

Table 1: Skull and dental measurements (in mm) of *Petrogale burbidgei.*

No.	M15827	M15830 (Holotype)	M15832	M5978	M9312	M9313	M9314	M9359	M9361	M15417	M15418	M9334	M9335	M9358	M9362	M10351	M12402
Sex	♀	♀	♀	?	♀	♂	♂	♂	♀	♂	♂	♂	♀	♀	♂	♂	♀
Locality (Kimberley)	Mitchell Plateau	Mitchell Plateau	Mitchell Plateau	Bigge Island	Bigge Island	Bigge Island	Bigge Island	Bigge Island	Bigge Island	Bigge Island	Bigge Island	Katers Island	Katers Island	Katers Island	Katers Island	Boongaree Island	Prince Regent River Reserve
Molar eruption stage	M^{4} 1.0	M^{4} 0.8	M^{4} 0.1	M^{4} 1.0	M^{2} 0.2	M^{4} 1.0	M^{3} 0.8	M^{3} 0.4	M^{4} 1.0	M^{4} 1.0	M^{4} 1.0	M^{1} 0.9	M^{2} 0.8	M^{2} 0.7	M^{4} 1.0	M^{2} 1.0	M^{4} 0.1
Greatest length	79.9	75.5	72.3	71.8	58.5	72.5	67.1	67.2	73.1	70.4	—	49.1	59.9	61.4	75.7	67.1	71.3
Condylobasal length	69.0	67.4	63.0	62.1	49.5	63.1	58.4	57.6	64.2	61.1	—	40.2	50.8	51.9	65.3	57.4	63.1
Nasal length	33.0	30.1	29.3	29.4	20.8	29.0	26.1	—	29.4	30.2	—	14.8	22.5	24.4	32.6	27.2	27.8
Nasal breadth	15.8	14.1	13.0	13.9	9.5	14.6	11.1	—	12.9	12.7	14.3	13.0	10.2	10.4	12.5	10.0	14.7
Diastema	13.5	15.1	15.3	12.0	10.0	11.2	13.4	11.2	10.7	11.6	—	12.0	10.5	10.8	13.2	11.3	14.8
Rostrum length	35.0	34.0	31.4	31.7	23.2	31.5	28.4	27.7	31.5	29.8	—	13.9	24.4	25.9	34.6	28.2	30.3
Mastoid breadth	30.0	29.2	29.4	28.4	25.4	30.1	27.8	27.5	28.7	26.0	31.2	21.8	—	24.1	29.1	28.4	31.0
Least interorbital width	15.9	14.0	14.2	13.2	11.6	14.1	12.4	12.4	13.1	11.5	11.8	10.1	10.6	12.5	13.8	12.6	13.7
Zygomatic breadth	42.0	40.4	40.4	41.0	34.3	41.4	38.3	37.2	40.7	38.9	42.7	30.6	33.9	34.9	40.4	38.1	40.4
Ant. palatal foramen length	4.2	3.2	3.9	3.2	3.0	3.9	3.1	3.2	3.5	3.6	4.3	2.2	2.5	3.0	3.7	3.0	3.3
P^{3} (length x width)	—	—	—	—	4.5x2.6	—	—	4.6x2.8	—	—	—	4.2x2.7	4.2x2.6	4.8x2.9	—	4.9x2.6	—
DP^{4} (length x width)	—	—	—	—	4.0x3.1	—	—	3.7x3.3	—	—	—	3.8x3.2	3.8x3.4	3.9x3.3	—	4.2x3.5	—
P^{4} (length x posterior width)	6.1x3.1	6.7x3.1	6.4x3.2	6.0x2.6	—	6.5x2.9	6.4x3.4	—	7.0x3.2	6.2x3.0	6.7x3.2	—	—	—	6.4x3.3	—	6.2x2.9
P^{4} to P^{4} breadth (buccal surfaces)	15.4	16.2	16.2	15.5	—	15.9	16.5	—	14.4	15.2	—	—	—	—	—	—	16.5
I^{3} to I^{3} breadth (buccal surfaces)	9.3	8.9	7.8	8.6	3.0	8.7	9.1	8.4	9.1	8.7	—	7.2	7.8	8.0	8.6	8.4	8.3
M^{1} length	—	3.8	—	3.3	4.3	—	—	3.9	—	3.5	3.9	—	3.9	4.1	—	—	3.9

developed. X-rays of *P. burbidgei* mandibles and crania indicate that there are no supplementary molars behind M^4_4. The protolophid of $DP_{\overline{4}}$ is not well developed and the anterior cingulum is rudimentary. The lower molars are similar to other species examined.

The deciduous premolar, $P^{\underline{3}}$, of *P. burbidgei* is similar in shape to $P^{\underline{4}}$ and ranges in length from 4.2 to 4.9 mm. It is larger than those for *P. concinna* listed in Thomas (1904) and Tate (1948) and four specimens examined, none of which exceed 4.1 mm in length. $P_{\overline{3}}$ is smaller but similar in shape to $P_{\overline{4}}$.

Table 2: Body measurements (mm) of *Petrogale burbidgei*. (From specimens preserved in alcohol (A), as 'puppet' skins (P), and flat skins (F). Weights (gm) recorded in the field.)

No.	Preservation	Sex	Locality (Kimberley)	Molar eruption stage	Weight (gm)	Head and body length	Tail length	Ear length	Radius length	Tibia length	Pes length
M15827	A	♀	Mitchell Plateau	$M^{\underline{4}}$ 1.0	1360	305.5	269.3	33.0	54.5	120.2	91.0
Holotype M15830	A	♀	Mitchell Plateau	$M^{\underline{4}}$ 0.8	1400	310.0	322.0	36.0	57.9	125.5	94.5
M15832	P	♀	Mitchell Plateau	$M^{\underline{4}}$ 0.1	1150	321.0*	273.0*	32.8	—	—	87.5*
M9312	A	♀	Bigge Island	$M^{\underline{2}}$ 0.2	480	218.5	—	28.5	38.7	88.3	77.0
M9313	A	♂	Bigge Island	$M^{\underline{4}}$ 1.0	1200	309.3	277.0	31.9	53.2	113.7	90.0
M9314	A	♂	Bigge Island	$M^{\underline{3}}$ 0.8	980	277.5	271.4	32.0	48.8	107.1	82.8
M9359	F	♂	Bigge Island	$M^{\underline{3}}$ 0.4	920	307.0*	262.0*	33.0*	49.0*	105.0	81.0*
M9361	P	♀	Bigge Island	$M^{\underline{4}}$ 1.0	1400	328.0*	282.0*	33.0*	54.0*	—	90.0*
M15417	A	♂	Bigge Island	$M^{\underline{4}}$ 1.0	960	319.0	264.0	29.9	49.0	91.0	81.5
M15418	A	♂	Bigge Island	$M^{\underline{4}}$ 1.0	1430	352.7	—	32.0	58.5	121.3	92.1
M9334	A	♂	Katers Island	$M^{\underline{1}}$ 0.9	185	155.3	154.9	25.2	32.8	68.2	62.0
M9335	A	♀	Katers Island	$M^{\underline{2}}$ 0.8	520	215.1	214.5	30.8	40.9	87.2	74.2
M9358	P	♂	Katers Island	$M^{\underline{2}}$ 0.7	—	246.0	228.0	32.0*	41.0*	—	76.1
M9362	P	♂	Katers Island	$M^{\underline{4}}$ 1.0	1200	315.0*	290.0*	33.0*	62.0*	—	85.0*
M10351	A	♂	Boongaree Island	$M^{\underline{2}}$ 1.0	750	252.3	256.1	29.6	45.5	11.2	82.7
M12402	A	♀	Prince Regent R. Reserve	$M^{\underline{4}}$ 0.1	1300	289.6	251.9	35.0	54.4	—	91.9

* Field measurements

Table 3: Comparison between (a) skull and dental measurements (mm) and (b) body measurements (mm) of adult (M^4_4 fully erupted) *Petrogale burbidgei* and *P. concinna.*

(a) Skull/Dental	*P. burbidgei* (4 ♂♂, 2 ♀♀, 1?) Mean (range) N	*P. concinna* (5 ♂♂, 2 ♀♀) Mean (range) N
Greatest length	73.9 (70.4-79.9) 6	76.0 (73.2-76.9) 7
Condylobasal length	64.1 (61.0-69.0) 6	67.3 (65.0-69.0) 7
Nasal length	30.6 (29.0-33.0) 6	32.5 (30.1-35.2) 7
Nasal breadth	13.8 (12.5-15.8) 7	15.4 (13.2-19.5) 7
Diastema	12.0 (10.7-13.5) 6	16.7 (14.6-19.0) 6
Rostrum length	32.4 (29.8-35.0) 6	32.9 (31.3-34.4) 7
Mastoid breadth	29.1 (26.0-31.2) 7	30.9 (28.5-33.4) 6
Least interorbital width	13.3 (11.5-15.9) 7	11.7 (10.0-13.7) 7
Zygomatic breadth	41.0 (38.9-42.7) 7	42.7 (41.3-43.6) 7
Ant. palatal foramen length	3.8 (3.5- 4.3) 7	3.8 (3.3- 4.4) 7
I^3– I^3– breadth (buccal surfaces)	8.8 (8.6- 9.3) 6	9.9 (9.5-10.9) 5
(b) Body		
Weight (gm)	1258.3 (960-1430) 6	1394 (1200-1600) 5
Head and body length	321.7 (306- 353) 6	331.2 (308- 365) 5
Tail length	276.4 (264- 290) 5	305.2 (258- 335) 5
Ear length	32.1 (29.9-33.0) 6	42.7 (41.0-45.2) 5
Pes length	88.3 (81.5-92.1) 6	99.5 (95.2-105.0) 5

The sectorial permanent premolar, P^4_4, is very large in relation to the cheek teeth. P^4– tends to be in line with the molar row. It has three vertical labial and lingual grooves that are separated by two vertical ridgelets. The posterior lingual groove is wider than the others and has a tendency to be further subdivided by a reduced vertical ridgelet. The width of P^4– is less anteriorly than in the other petrogales examined, and the postero-lingual cusp is not so enlarged. The postero- and anterolabial cusps on P^4– are approximately the same size. P^4– of *P. burbidgei* is considerably longer than the five *P. concinna* teeth available for study which range from 4.3-5.0 mm (WAM, M12401, 5.0; Monash University No. 4408, 4.5; Monash No. 4409, 4.3; Monash No. 4406, 4.8; Monash No. 4407, 4.6). P^4– ranges in length from 6.0 to 6.7 mm and is large relative to the size of the skull. The ratio of the length of P^4– to M^1– in *P. burbidgei* is also large compared with other species listed below:

Species	N	Mean	Range
P. burbidgei	5	1.73	1.59-1.82
P. brachyotis	8	1.33	1.36-1.58
P. penicillata	6	1.24	1.19-1.29
P. concinna	5	1.16	1.05-1.25

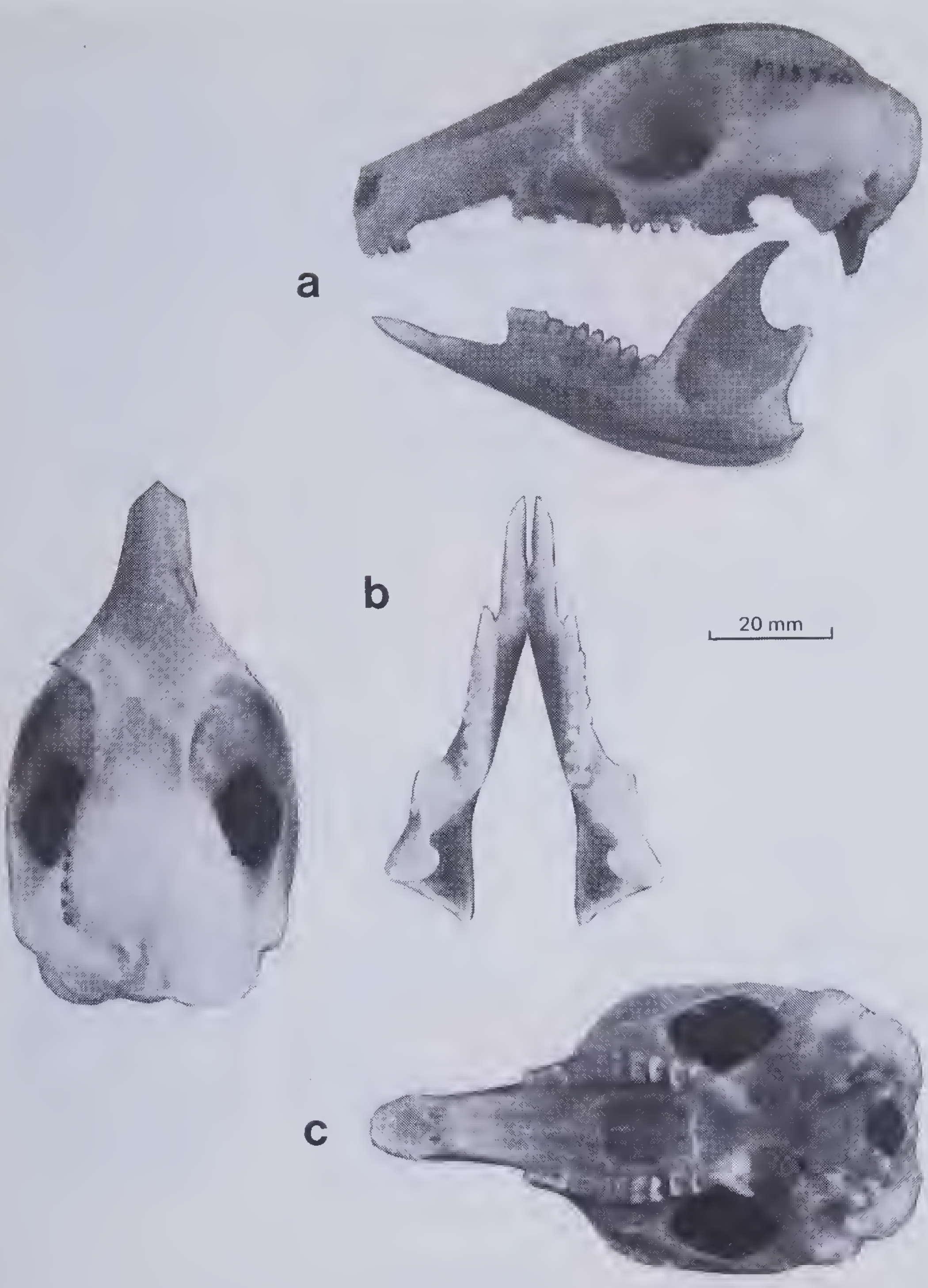

Fig. 1: Skull and dentary of the holotype (WAM M15830) of *Petrogale burbidgei* from (a) lateral, and (b) dorsal, and (c) ventral view.

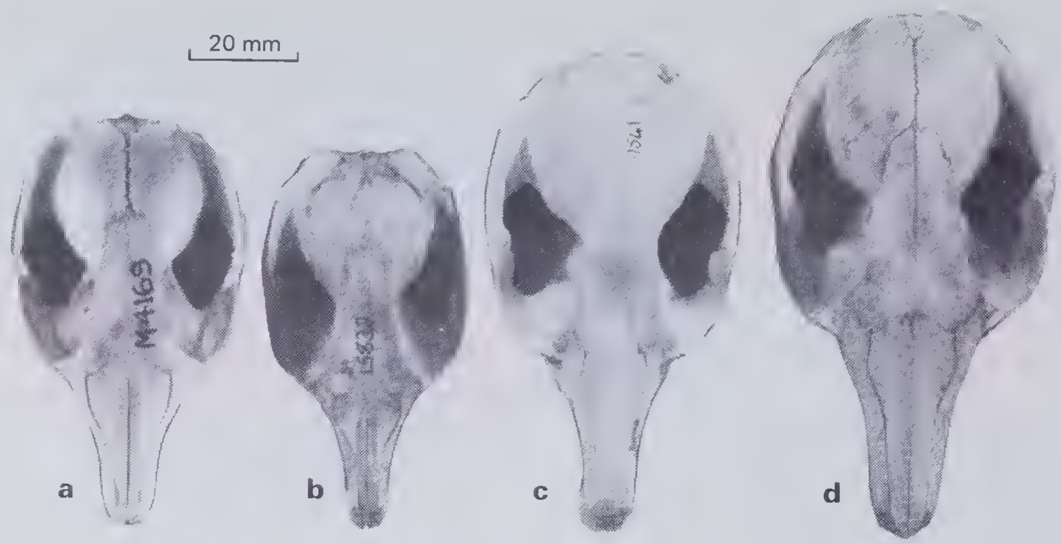

Fig. 2: Dorsal view of the skull of

(a) *Peradorcas concinna monastria* (WAM M4169),
(b) *Petrogale burbidgei* sp. nov. (WAM M15832),
(c) *Petrogale penicillata* (WAM 11541), and
(d) *Petrogale brachyotis brachyotis* (WAM M15355).

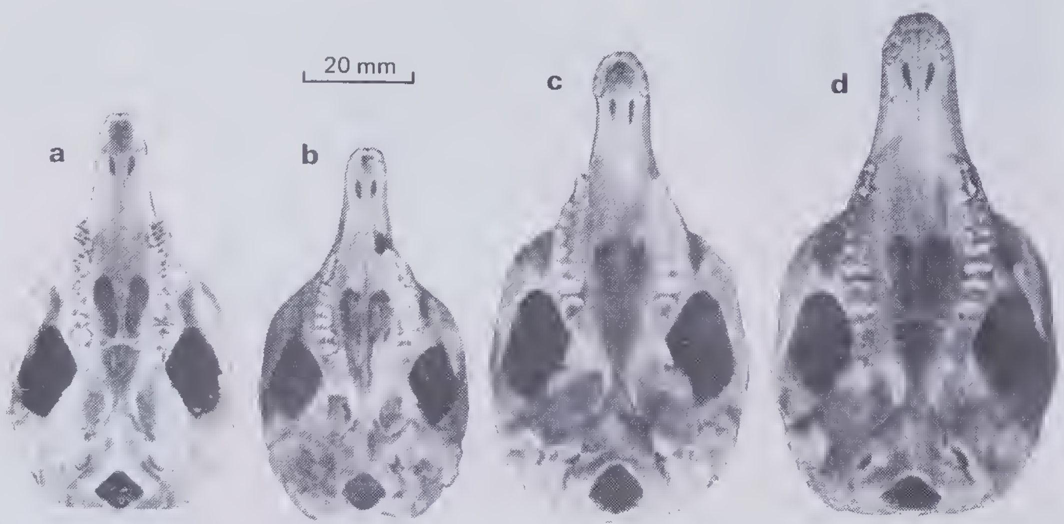

Fig. 3: Ventral view of the skull of

(a) *Peradorcas concinna monastria* (WAM M4169),
(b) *Petrogale burbidgei* sp. nov. (WAM M15832),
(c) *Petrogale penicillata* (WAM 11541), and
(d) *Petrogale brachyotis brachyotis* (WAM M15355).

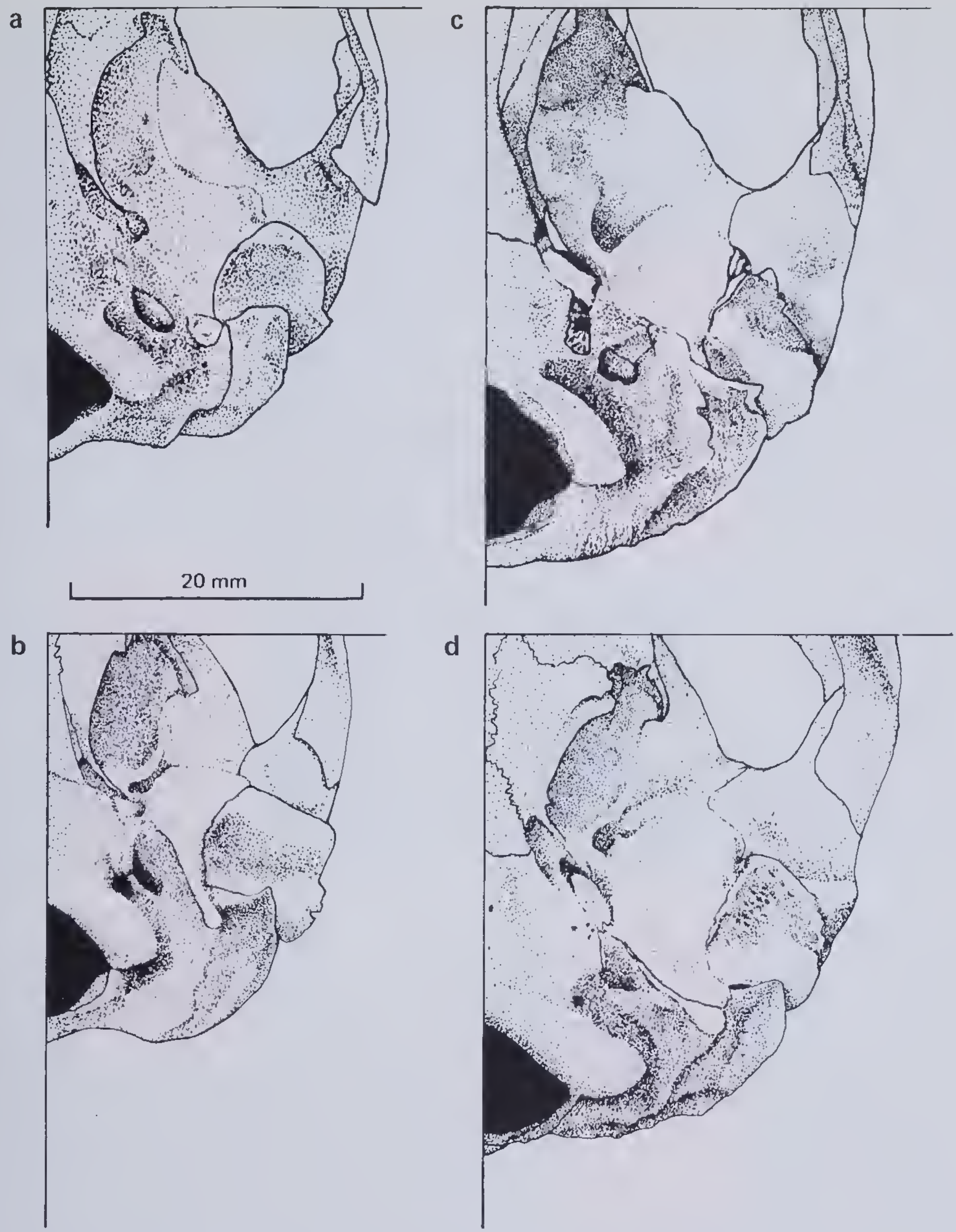

Fig. 4: Ventral view of the basicrania drawn from Fig. 3 photographs to show the region of the bulla of

(a) *Peradorcas concinna monastria* (WAM M4169),
(b) *Petrogale burbidgei* sp. nov. (WAM M15832),
(c) *Petrogale penicillata* (WAM 11541), and
(d) *Petrogale brachyotis brachyotis* (WAM M15355).

$P_{\overline{4}}$ is shorter and narrower than $P^{\underline{4}}$ and is like other petrogales. P^4_4 erupts early and in M9314 is in place before $M^{\underline{3}}$ is half erupted. Compared to the other species examined, *P. burbidgei* has dentaries which have condyles which are arcuate and more nearly anteroposteriorly aligned, incisors which are more procumbent, and the anterior border of the coronoid more nearly vertical. The length of $P_{\overline{4}}$ ranges from 5.1 to 5.8 mm and width from 1.7 to 2.2 mm. $P_{\overline{3}}$ ranges in length from 3.7 to 4.1 mm and in width from 1.8 to 2.0 mm. $DP_{\overline{4}}$ ranges in length from 3.5 to 3.8 mm and in width from 2.3 to 2.6 mm.

(b) External characters: Colours are described following Ridgway's (1912) colour code. The face is predominantly Clay with a Chamois horizontal stripe passing from the snout through the eye to the base of the ear. There is a central indistinct Light Grayish Olive facial and occipital stripe. The lips and throat are Pale Olive Buff. The rhinarium is furred above and a naked Fuscous Black in the front. The ears are Fuscous Black with a Pale Olive Buff patch behind and at the side. The neck and shoulders are Ochraceous Tawny. There is a darker patch behind the arm of Deep Neutral Gray tipped with Pale Olive Buff. The back has a Deep Olive-Buff/Ochraceous Tawny/Fuscous Black marbling. The tail is a Light Grayish Olive, the longer hairs which form a brush on the distal one-third, are tipped with Fuscous Black. The flanks are Deep Olive Buff. The under-surface is Ivory Yellow. The arm is Chamois. The paws and feet are Light Grayish Olive with Fuscous Black under-surface. The colour at the base of the fur over much of the body is Light Neutral Gray and Neutral Gray.

Remarks

The new species has similar karyotypic and blood serum properties to *Petrogale concinna canescens* (Professor G.B. Sharman and Dr D.A. Briscoe, pers. comm.). As already pointed out it is easily confused with *P. concinna* with which it is possibly closely allied. *Pcradorcas*, however, was very clearly distinguished from *Petrogale* by Thomas (1904) as 'General characters as in *Petrogale*, but the molars increased in number, seven at least on each side and probably, more, falling out in front and renewed behind as in the Manatee (*Trichechus*)' (p. 226). Pending major revisions of the two genera it would be unwise to redefine the genus *Peradorcas* to include the new species, which must therefore be placed in *Petrogale*. Another possibility is that the genus *Petrogale* should be redefined to include *Peradorcas* as an aberrant species; *P. burbidgei* could be a representative of the population from which *P. concinna* diverged.

Prior to the discovery of *P. burbidgei*, the only other rock wallabies recorded from the Kimberley Division, Western Australia, were *Peradorcas concinna concinna*, *P. concinna monastria*, *Petrogale penicillata* and *Petrogale brachyotis brachyotis*. *P. burbidgei* is not easy to distinguish from *P. concinna* in the field because they are of similar size and have similar pelage markings. The general body colour of *P. burbidgei* most obvious to an observer in the field, is Deep Olive-Buff of the dorsal pelage and the Fuscous Black furred tip to the tail. These colours contrast with those of *P. concinna concinna* and *P. concinna monastria* which have a dorsal pelage that is predominantly seen as Grayish Olive, and a tail which is shorter and has more lightly coloured hairs on its tip. *P. concinna canescens* skins examined had a much lighter coloured dorsal pelage as a result of a pronounced Cream colour flecking; the hairs on the tip of the tail are coloured and furred similarly to *P. burbidgei*. Apart from colour, *P. burbidgei* is best distinguished externally by its ears and hind feet which are considerably shorter than in *P. concinna*. The skull and dentary differences between *P. burbidgei* and *P. concinna* are marked. *P. burbidgei* has P^4_4 in place early; supplementary molars behind M^4_4 are not developed as is the case with *P. concinna*. Further P^4_4 and P^3_3 are longer and the ratio of their lengths with M^1_1 is greater in *P. burbidgei* than *P. concinna*. It may still be possible to confuse subadult *P. burbidgei* with *P. concinna* which have only $P^{\underline{3}}$ erupted and $P^{\underline{4}}$ still erupting. Excavation of $P^{\underline{4}}$ from the crypt would immediately resolve the problem. The most notable skull difference between these two species is the greater inflation of the tympanic bullae and the narrower rostrum anteriorly in *P. burbidgei*.

P. burbidgei is easily distinguished from the other two Kimberley *Petrogale* on size, pelage colour and markings, and cranial and dental characters. There are several nominal species of small *Petrogale* in the Northern Territory: *P. longmani* Thomas, 1926; *P. venustula* Thomas, 1926 and *P. wilkinsi*, Thomas, 1926. These are also easily separable from *P. burbidgei* in that they all have brightly contrasting shoulder markings and were included by Ride (1970) within *P. penicillata*. Further, the smallest of these (*P. venustula*) is larger than the *P. burbidgei* reported herein. For example, measurements of the type of *P. venustula* in Thomas (1926) show it to have a body length, tail length, hind foot, and greatest skull length some 15.9, 7.0, 7.9 and 3.9% larger than the maximum corresponding measurements for *P. burbidgei*. Further, the shape of skulls of *P. venustula* examined by us is similar to *P. brachyotis* and shows no inflation of the tympanic bullae; the ratio of $P^{\underline{1}}$: $M^{\underline{1}}$ lengths (mean 1.42, range 1.38-1.45, N = 6) is also less than *P. burbidgei*.

An adult male *Petrogale brachyotis brachyotis* sympatric with *P. burbidgei* was shot in March 1977 at Crystal Creek, Mitchell Plateau by A. Chapman, within several hundred metres of where the holotype of *P. burbidgei* was collected. Testes preparation from this specimen were sent to Professor G. Sharman, Macquarie University, New South Wales, who is currently examining the taxonomy of rock wallabies in Australia using serological and chromosomal techniques. Professor Sharman concluded (pers. comm.) that this specimen 'is not chromosomally different, so far as can be ascertained, from *Petrogale brachyotis* from western Northern Territory, *Petrogale brachyotis signata, Petrogale longmani venustula* from Arnhem Land or *Petrogale longmani* from Groote Eylandt'.

The three *P. burbidgei* females collected at Mitchell Plateau between 22 October and 3 November 1976 (M15827, M15830 and M15832) had small pouch young weighing 51.0, 77.0, and 85.0 gm. The collection of a female from Prince Regent River Reserve on 18 August with a pouch young weighing 48 gm and one from Bigge Island on 3 June 1972 with a pouch young weighing 18.5 gm suggests that this species has a protracted period of births.

It was interesting to note that the expedition to the Bonaparte Archipelago reported in McKenzie *et al.* (in prep.) collected *P. burbidgei* from Bigge, Katers and Boongaree Islands, but not from Augustus or Borda Islands where they captured *Peradorcas concinna.* These authors have considered the distribution of these two species on these islands and cannot elucidate obvious differences between the islands which may account for the distribution on them of *P. burbidgei.* Their general conclusion was that *P. burbidgei* inhabits King Leopold Sandstone with an open woodland of *Owenia vernicosa* and *Eucalyptus* spp.; they were not recorded from the Warton sandstones. The Mitchell Plateau specimens came from similar habitat. *P. burbidgei* and *P. concinna* have been collected from the mainland from localities separated by distances as little as 15 km. Description of these localities (sites E2 and E4) are in Miles *et al.* (1975); they indicate that *P. burbidgei* was collected on King Leopold Sandstone (E4) which support a low open woodland of *Eucalyptus* sp. and *Owenia vernicosa, Ficus* and *Acacia* sp. over spinifex hummock grasses interspersed with areas of 'Sorghum type' grass. The *P. concinna* were collected from site E2 which was also King Leopold Sandstone, similarly vegetated to site E4.

In summary, the new rock wallaby, *Petrogale burbidgei*, is distinguishable from all species of rock wallaby (*Petrogale* and *Peradorcas*) on the basis of external morphology (hind foot and ear lengths) and on dental measurements. Like other *Petrogale* it does not possess supernumary molars behind

M^4_4 (as do *Peradorcas*) yet it is not distinguished from *Peradorcas* by chromosome morphology or serological characters. Its discovery emphasises the need for a revision of the separate status of these genera.

Other Material Examined

Peradorcas concinna concinna

WAM: M9286, adult female, skin and skull, Augustus Island, Kimberley; M9288 subadult female, skin and skull, Augustus Island, Kimberley; M9346 subadult female, alcohol — skull removed, Borda Island, Kimberley; M9360 subadult male, skin and skull, Borda Island, Kimberley; M12400 adult male, alcohol — skull removed, Prince Regent River Re erve, Kimberley; M12401 subadult female, alcohol — skull removed, Prince Regent River Reserve, Kimberley.

Peradorcas concinna monastria

WAM: 10444, adult female, skull only, Napier Broome Bay, Kimberley; 10445 adult male, skull only, Napier Broome Bay, Kimberley (these two specimens are topotypes and were collected by G.F. Hill in 1910; they have collector Nos 7 and 8. The holotype collected by Hill at that time had collector No. 14); M4168 adult male, skin and skull, Kalumburu, Kimberley; M4169 adult male, skin and skull, Kalumburu, Kimberley.

Peradorcas concinna canescens

C.S.I.R.O.: CM8767, adult male, skin and skull, Mt Borrodaile, N.T.; CM8768 adult male, skin and skull, Mt Borrodaile, N.T.; CM8766 subadult female, skin and skull, Mt Borrodaile, N.T.; CM8783 subadult female, skin and skull, Mt Borrodaile, N.T.

Petrogale venustula

C.S.I.R.O.: CM7012, adult male, skull, Mt Brockman Ra., N.T.; CM7015 adult male, skull, Mt Brockman Ra., N.T.; CM7082 subadult male, skull, Mt Brockman Ra., N.T.; CM7083 subadult male, skull, Mt Brockman Ra., N.T.; CM7923 subadult male, skull, Deaf Adder Creek, N.T.; CM7927 subadult female, skull, Deaf Adder Creek, N.T.; CM7933 adult female skull, Cannon Hill, N.T.; CM7935 adult male, skull, Cannon Hill, N.T.; CM7972 adult male, skull, Cannon Hill, N.T.; CM7988 adult female, skull, Nourlangie Rock, N.T.

Petrogale penicillata

(All skin and skull collected from Mungi, 13 km SE Mt Alexander, West Kimberley.)

WAM: 11539, subadult male; 11540 adult male; 11541 subadult male; 11542 adult female; 11543 subadult male; 11544 subadult male.

Petrogale brachyotis brachyotis

WAM: M11598, adult male, skin and skull, Ord River, Kimberley; M11602 adult male, skin and skull, Ord River, Kimberley; M11603 adult female, skin and skull, Ord River, Kimberley; M11641 adult female, skin and skull, Ord River, Kimberley; M12398 adult female, skin and skull, Prince Regent River Reserve, Kimberley; M14321 adult female, skin and skull, Drysdale River National Park, Kimberley; M15355 adult male, skin and skull, Mitchell Plateau, Kimberley.

ACKNOWLEDGEMENTS

Petrogale burbidgei is named after A.A. Burbidge, Western Australian Department of Fisheries and Wildlife, who instigated much of the recent mammal survey work in the Kimberley. We are indebted to D. Merrilees, Western Australian Museum, for drawing our attention to the possible importance of the *P. burbidgei* material in our collections.

We are also most grateful to A. Chapman and J. Henry, Western Australian Museum, who returned to Mitchell Plateau in March 1977 in an attempt to obtain blood and testes preparations from *P. burbidgei*, and to D. Merrilees, and G.M. Storr, Western Australian Museum, who offered critical advice during the preparation of this manuscript. J. Calaby, C.S.I.R.O., kindly allowed us to use his field measurements for *Peradorcas concinna canescens* and *Petrogale venustula*. We are indebted to A. Muller and J. Chambel-Gaspar, Western Australian Museum, for the drawings and photographs, respectively, and last but not least to the typist, Mrs Maureen Wallis.

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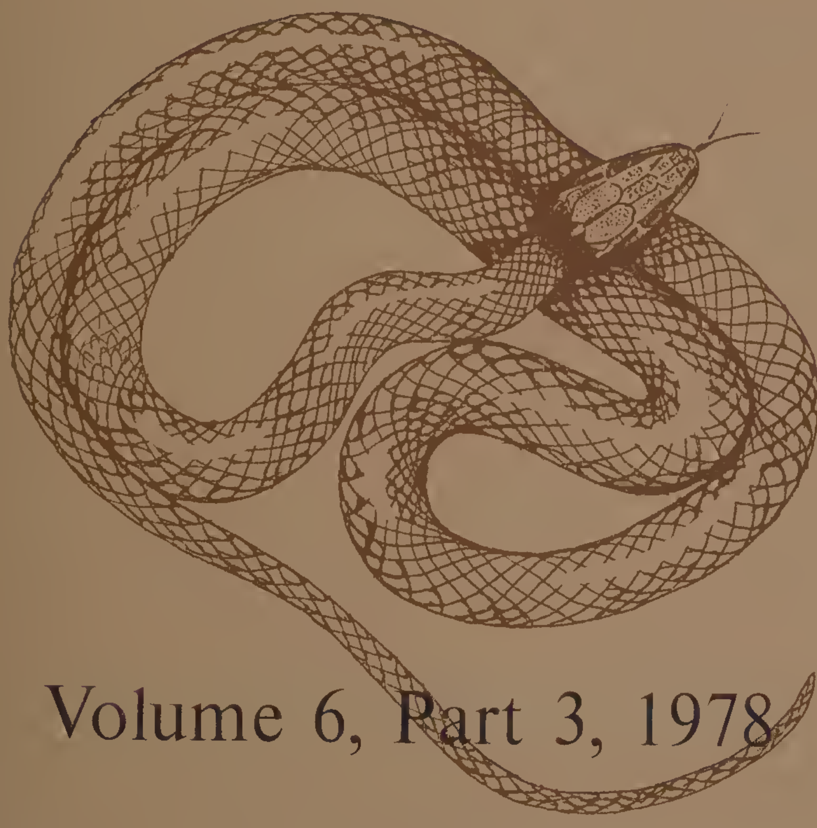

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Cover: A whip snake (*Demansia olivacea calodera*), drawn by Martin Thompson, Western Australian Museum. This beautiful little snake is confined to the mid-west coast of Western Australia.

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WHIP SNAKES (*DEMANSIA*, ELAPIDAE) OF WESTERN AUSTRALIA

G.M. STORR*

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ABSTRACT

The eight taxa inhabiting Western Australia are described and keyed, viz. *Demansia simplex* nov., *D. olivacea olivacea* (Gray), *D. olivacea rufescens* nov., *D. olivacea calodera* nov., *D. reticulata reticulata* (Gray), *D. reticulata cupreiceps* nov., *D. atra* (Macleay) and *D. papuensis melaena* nov. A lectotype is designated for *D. reticulata* (Gray).

INTRODUCTION

McDowell (1967) restricted the genus *Demansia* to the whip snakes after transferring the brown snakes and their allies to *Pseudonaja*. This return to a pre-Boulengerian concept of *Demansia* has probably been delayed by Loveridge's contention (1934:277) that the whip snakes comprised a single polytypic species, *Demansia psammophis*. Loveridge rightly questioned the reliance placed by Boulenger and other workers on such variable characters as relative height of rostral and relative length of internasal, but his series were too short for revealing the small but constant differences between species in coloration, body size and number of ventrals and subcaudals.

This revision is based on material lodged in the Western Australian Museum.

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GENUS *DEMANSIA* GRAY

Demansia Gray, 1842, The zoological miscellany, p.54. Type species: *Lycodon reticulatus* Gray.

Diemansia Günther, 1858, Catalogue of colubrine snakes in the collection of the British Museum, p.254. Emendation of *Demansia* Gray.

Diemenia Günther, 1863, Ann. Mag. nat. Hist. (3)12: 350. Emendation of *Demansia* Gray.

Elapocephalus Macleay, 1878, Proc. Linn. Soc. N.S.W. 2: 221. Type species: *Elapocephalus ornaticeps* Macleay [= *Demansia olivacea olivacea* Gray].

Elapocranium Macleay, 1885, Proc. Linn. Soc. N.S.W. 9: 560. New name for *Elapocephalus* Macleay, not *Elapocephalus* Gray.

Diagnosis

Small to moderately large, slender, long-tailed, large-eyed elapid snakes with anal and subcaudals divided; dorsal scales smooth, in 15 rows at mid-body, reducing to 13 well before level of cloaca; canthus rostralis sharp; temporals 2 + 2.

Distribution

Greater part of Western Australia but not far south or sandy deserts. Extralimital in eastern Australia and southern New Guinea.

Description (based on western taxa)

Snout-vent length 136-1143mm. Tail 24-36% of SVL.

Rostral triangular, about as high as wide. Internasals 0.3-0.6 times as long as prefrontals. Frontal long and narrow (in *D. atra* 2.0-2.4 times as long as wide, sides straight and strongly oblique so that scale much wider anteriorly than posteriorly; in *D. o. olivacea* 2.5-3.5 times as long as wide, sides usually concave so that scale not or only a little wider anteriorly than posteriorly; condition intermediate in other taxa). Nasal long and narrow, completely divided by nostril (except in *D. simplex*), almost always in short or point contact with preocular, which is almost always separated from frontal. Postoculars normally two, lower larger. Lower primary temporal much the largest and descending between last two labials almost to lip; secondary temporals subequally smallest and usually smaller than scale ('upper tertiary temporal') immediately behind upper secondary. Upper labials 6. Ventrals

142-220 (fewer than 171 only in *D. simplex*). Subcaudals 51-105 (fewer than 63 only in *D. simplex*). Ventrals plus subcaudals 197-322 (fewer than 241 only in *D. simplex*).

Dorsal coloration varying from coppery red through reddish brown, yellowish brown, greyish brown, leaden grey, olive grey, pale green to blackish brown and black; concealed skin between dorsals white. Pattern simple to very complex; several taxa sharing a pale-edged dark rostral line running transversely from nostril to nostril, a pale-edged dark comma-like mark around eye (consisting of a narrow circumorbital ring, extending infero-posteriorly as a narrowing tail to or towards angle of mouth), and a dark longitudinal streak on each side of chin. Ventrally white, yellowish or grey.

KEY

1. Dorsals not black; ventrals yellowish or white 2
   Dorsals black; ventrals mostly dark grey 7
2. Dorsals green, brown, reddish or grey, usually margined or spotted with black or dark brown; ventrals yellowish or white, more than 160; transrostral and circumorbital markings usually well developed 3
   Dorsal coloration dark grey, ventral coloration uniformly white, the two colours sharply demarcated; no transrostral or chin markings; circumorbital markings variable; ventrals fewer than 160 ... ... *D. simplex*
3. Dorsals brownish, greyish or reddish (dark pigment concentrated at base of scale); snout and temples often spotted with dark brown 4
   Dorsals bright pale green, edged with black (dark pigment concentrated at apex of scale); snout, anterior labials and temples seldom or never spotted 6
4. No dark nuchal bar (or if present, not white-edged); dark transrostral line seldom reaching back to orbit; anterior labials usually spotted with dark brown (spots irregular in shape and often pale-edged) 5

Pale-edged dark nuchal bar (barely discernible in largest specimens); transrostral line usually reaching back to orbit; anterior labials washed with greyish brown ... ... *D. olivacea calodera*

5. Dorsals reddish or reddish brown ... ... *D. olivacea rufescens*

Dorsals brownish or greyish ... ... *D. olivacea olivacea*

6. Head pale coppery brown ... ... *D. reticulata cupreiceps*

Head olive green ... ... *D. reticulata reticulata*

7. Free edge of anterior ventrals margined with black; head dark brown, usually not spotted; ventrals plus subcaudals fewer than 275 ... ... *D. atra*

Free edge of anterior ventrals not margined with black; head brown, spotted with dark brown; ventrals plus subcaudals more than 275 *D. papuensis melaena*

SPECIES AND SUBSPECIES

DEMANSIA SIMPLEX SP. NOV.

Holotype

R13841 in Western Australian Museum, collected by Mr A.M. Douglas and Dr G.F. Mees in July 1960 at Kalumburu, Western Australia, in 14° 17′ S, 126° 40′ E.

Diagnosis

A small dark grey *Demansia* with relatively short, thick body; little or no pattern apart from circumorbital markings; low number of ventrals and subcaudals; and nostril not dividing nasal.

Distribution

North-west Kimberley.

Description

Snout-vent length (mm): 156-430 (N 5, mean 270.6). Length of tail (% SVL): 24.3-33.2 (N 4, mean 27.5). Ventrals 141-149 (N 5, mean 144.0).

Subcaudals 51-65 (N 4, mean 59.5). Ventrals plus subcaudals 197-207 (N 4, mean 202.7).

Upper surface dark brownish grey, sharply demarcated from white lower surface. Usually some indication of circumorbital markings (dark brown 'comma' with short tail, broadly margined with yellow).

Paratypes

Kimberley Division (W.A.): Kalumburu (28074); Mitchell Plateau in 14° 40′ S, 125° 46′ E (56143) and in 14° 42′ S, 125° 50′ E (56367); Drysdale River National Park in 14° 48′ S, 126° 57′ E (50508).

DEMANSIA OLIVACEA OLIVACEA

Lycodon olivaceus Gray, 1842, The zoological miscellany, p.54. Port Essington, N.T. (J. Gilbert). [For clarification of type locality, see Cogger & Lindner (1974: 90).]

Elapocephalus ornaticeps Macleay, 1878, Proc. Linn. Soc. N.S.W. 2: 221. Darwin, N.T. (E. Spalding).

Diemenia angusticeps Macleay, 1888, Proc. Linn. Soc. N.S.W. (2) 3: 417. King Sound, W.A. (W.W. Froggatt).

Diagnosis

A moderately small, greyish or brownish *Demansia*, usually with snout, temples and anterior labials spotted and transrostral, circumorbital and chin markings well developed; distinguishable from *D. o. rufescens* by non-reddish coloration of body, and from *D. o. calodera* by absence of white-edged dark bar on nape. All subspecies of *D. olivacea* distinguishable from all subspecies of *D. reticulata* by absence of pale green coloration on body, concentration of dark pigment at base (not apex) of dorsals, and tail of comma long and usually reaching lip or nearly so.

Distribution

Kimberley Division, south to Anna Plains and the Gardiner Range; also Koolan I. Extralimital in Northern Territory.

Description

Snout-vent length (mm): 178-658 (N 27, mean 396.8). Length of tail (% SVL): 26.3-35.4 (N 23, mean 30.4). Ventrals 171-210 (N 22, mean

188.2). Subcaudals 71-102 (N 22, mean 83.5). Ventrals plus subcaudals 251-303 (N 19, mean 271.8).

Yellowish brown, dark brown, greyish brown or olive brown above, sometimes darker and reddish on neck; dorsals with or without a dark spot at base (which may spread over most of scale) and a black anterolateral edge. Dark brown spots and other marks on snout and anterior labials usually white-edged. Dark circumorbital markings broadly edged with white. Temples and sides of throat usually spotted with blackish brown. Usually a grey longitudinal streak on each side of chin; rest of under surface white, yellowish white, buffy white or greyish white.

Material

Kimberley Division (W.A.): Kalumburu (13649); Old Theda (55867); Mitchell Plateau (29687); Careening Bay (44007); 18 km E of Kuri Bay (40419); Koolan I. (28071); Ivanhoe (8794); Lake Argyle (42809, 55900-1); Mt House (45688); Derby (13829, 20297); Mowanjum (13842); 37 km SSE of Derby (20357); Liveringa (10565); Halls Creek (28072); Granny Soak, Gardiner Range (51236); Lagrange (28068); Frazier Downs (28067, 28069); Anna Plains (47729).

Northern Territory: Casuarina, Darwin (47589); Darwin (40834) and 56 km SE (23287); Katherine (21937, 24928); Kildurk (31054).

DEMANSIA OLIVACEA RUFESCENS SUBSP. NOV.

Holotype

R52747 in Western Australian Museum, collected by Mr W.H. Butler on 2 May 1976 at Marandoo minesite, near Mt Bruce, Western Australia, in 22° 40′ S, 118° 10′ E.

Diagnosis

A small, short-tailed subspecies of *D. olivacea*, distinguishable from *D. o. olivacea* by reddish body, and from *D. o. calodera* by absence of white-edged nuchal bar.

Distribution

Pilbara region, including Dolphin and Barrow Is.

Description

Snout-vent length (mm): 162-520 (N 13, mean 311.4). Length of tail

(% SVL): 24.7-32.3 (N 12, mean 27.0). Ventrals 182-198 (N 11, mean 191.3). Subcaudals 70-83 (N 10, mean 75.7). Ventrals plus subcaudals 256-275 (N 9, mean 267.4).

Dorsals reddish or reddish brown, dark basal spot often spreading over much of scale. Head and neck dark grey or olive grey; snout paler, with or without dark spots. Transrostral line, circumorbital markings and grey mental streaks variably developed but usually weaker than in other subspecies of *D. olivacea.* Lower surface white, except where red of dorsal surface extends briefly on to free edge of ventrals.

Fig. 1: Map of northern Western Australia showing location of specimens of three subspecies of *Demansia olivacea.*

Paratypes

North-west Division (W.A.): Barrow I. (28070, 51634); Dolphin I., Dampier Archipelago (14279); Roebourne (15064); Port Hedland (16504); Shaw River (15058); Marble Bar (536); Python Pool, Mt Herbert (26154); Mt Stuart (45088); Tom Price (42992); Marandoo (55965); Mt Newman (28929).

DEMANSIA OLIVACEA CALODERA SUBSP. NOV.

Fig. 2: Holotype of *Demansia olivacea calodera* photographed in life by G. Harold.

Holotype

R54992 in Western Australian Museum, collected by Messrs G. Harold and M. Peterson on 29 August 1976 at Tamala, Western Australia, in 26° 42′ S, 113° 42′ E.

Diagnosis

A small subspecies of *D. olivacea* with a pale-edged dark bar on neck.

Distribution

Upper west coast and hinterland from North West Cape south to Carnarvon, inland to Marilla, Wandagee and Callagiddy. Mid-west coast: Edel Land, Peron Peninsula and Bernier and Dirk Hartog Is.

Description

Snout-vent length (mm): 136-476 (N 29, mean 358.2). Length of tail (% SVL): 23.8-34.2 (N 23, mean 30.2). Ventrals 174-193 (N 25, mean 181.2). Subcaudals 65-87 (N 24, mean 75.2). Ventrals plus subcaudals 241-272 (N 22, mean 257.0).

Upper surface olive grey or olive brown, dorsals usually spotted basally with black, and snout occasionally spotted with blackish brown. Blackish brown transrostral line extending back through nostril to narrow blackish brown circumorbital ring whose tail extends to or towards angle of mouth; dark markings broadly edged with creamy white. Bottom of rostral and greater part of first three labials dark greyish brown. Temporal blotch dark greyish brown. Nuchal bar black, dark grey or dark brown, narrowing as it descends side of neck, edged with white or brownish white. Occasionally indication of longitudinal streak on each side of chin; rest of lower surface creamy white.

Geographic variation

The northern population differs from those of the Shark Bay islands and peninsulas mainly in its greater size (SVL 199-476, N 14, mean 393; *vs* 136-439, 15, 326) and more numerous ventrals and subcaudals (sum 255-272, N 9, mean 264.3; *vs* 241-260, 13, 252.0).

Paratypes

North-west Division (W.A.): Vlaming Head (22510-11); 3 km N of Yardie HS (55888); Yardie Creek (51027); Ningaloo (32027-8); Cardabia (16966); Marilla (4751, 5322); Wandagee (14055); Quobba Point (17320-1); Carnarvon (22830); Callagiddy (45650); Bernier I. (11241, 13283); Dirk Hartog I. (42378, 44237, 44546); Tamala (6530, 54991); Monkey Mia (54831); Peron HS (54817-8); Denham (22433) and 25 km S (54587); Eagle Bluff (22432, 55098).

DEMANSIA RETICULATA CUPREICEPS SUBSP. NOV.

Holotype

R34555 in Western Australian Museum, collected by Mr J. Bywater in

September 1969 at Callagiddy, Western Australia, in 25° 02′ S, 114° 01′ E.

Diagnosis

A moderately large green *Demansia* with reticulate dorsal pattern, coppery tail, and well-developed transrostral and circumorbital markings; distinguishable from *D. r. reticulata* by coppery rather than olive head.

Distribution

West Kimberley from Yampi Sound and Manning Creek south to Derby. Western arid zone from Mundabullangana and Marble Bar south to Wooramel, Karalundi and Cosmo Newbery. Far eastern arid zone from Warburton Range south nearly to the Nullarbor Plain (and adjacent parts of Northern Territory and South Australia).

Description

Snout-vent length (mm): 186-764 (N 49, mean 550.4). Length of tail (% SVL): 23.3-33.5 (N 44, mean 28.9). Ventrals 179-205 (N 45, mean 191.3). Subcaudals 63-91 (N 42, mean 77.2). Ventrals plus subcaudals 250-288 (N 40, mean 269.1).

Head, hind part of body and tail coppery brown, except for occasional specimens with head and nape blackish. Rest of back and sides bright pale green, posterolateral edges of scales black (margin widest at apex). Transrostral line dark brown, margined with yellow. Narrow dark brown circumorbital ring with short grey tail, broadly margined with yellow. Faint longitudinal streak occasionally discernible on each side of chin. Throat yellow; rest of under surface yellowish white, except where black of dorsal reticulation extends briefly on to free edge of ventrals.

Paratypes

Kimberley Division (W.A.): Wotjulum (12359); Manning Creek (32067); Derby (144, 13751).

North-west Division (W.A.): Mundabullangana (15059); Spearhill, Shaw River (30957); Marble Bar (42); Mt Edgar (15057); Woodstock (13059, 55898); north end of Chichester Range (31145); Onslow (8283-4); Wittenoom (47728); Hamersley Iron (41913); Marandoo minesite (52714); 32 km W of Roy Hill (45888); Mundiwindi (45089); North West Cape (14023); Exmouth (31421-2, 34705); Learmonth district (8659, 11491); Marilla (5039); Winning Pool (14164); Manberry (22948); Wandagee (9412-3); Booloogooro (55899); Carnarvon (24018-9) and 16 km E (13309); Callagiddy (37644, 39778, 40676, 40681-2); Wooramel (54599); Yinnietharra (40656-7); Kumarina (22704-5); 32 km N of Beyonde (23941); Karalundi (42651).

Eastern Division (W.A.): Yandil (2227); Warburton Range (15156, 22072); Cosmo Newbery (13850); Maloora Rockhole (15066).

Northern Territory: 2 km E of Docker River Settlement (34303).

South Australia: 37 km NE of Maralinga (36637).

DEMANSIA RETICULATA RETICULATA

Lycodon reticulatus Gray, 1842, The zoological miscellany, p.54. Australia.

Lectotypes

Mr A.F. Stimson of the British Museum (Natural History) kindly sent me two of Gray's syntypes, one of which (1946. 1. 19. 79) I designate holo-lectotype. It and the paralectotype (1946. 1. 19. 78) were purchased by the British Museum from G. Krefft in 1838. Both specimens have an olive head.

Diagnosis

A moderately large green *Demansia*, distinguishable from *D. r. cupreiceps* by olive rather than coppery head.

Distribution

West coast and hinterland from Dirk Hartog I. south to Harvey, inland to Yuna, Morawa and Beacon.

Description

Snout-vent length (mm): 219-700 (N 60, mean 545.4). Length of tail (% SVL): 24.2-36.1 (N 58, mean 29.4). Ventrals 172-201 (N 50, mean 187.8). Subcaudals 67-88 (N 55, mean 75.1). Ventrals plus subcaudals 244-279 (N 48, mean 262.7).

Head pale to moderately dark olive green, except for occasional specimens with blackish head and nape. Rest of coloration as in *D. r. cupreiceps*.

Material

North-west Division (W.A.): Dirk Hartog I. (42377, 44238, 45839); 10 km S of Carrarang (54725); 5 km SW of Tamala (37576).

South-west Division (W.A.): Kalbarri (24195, 34141) and 6 km E (33527)

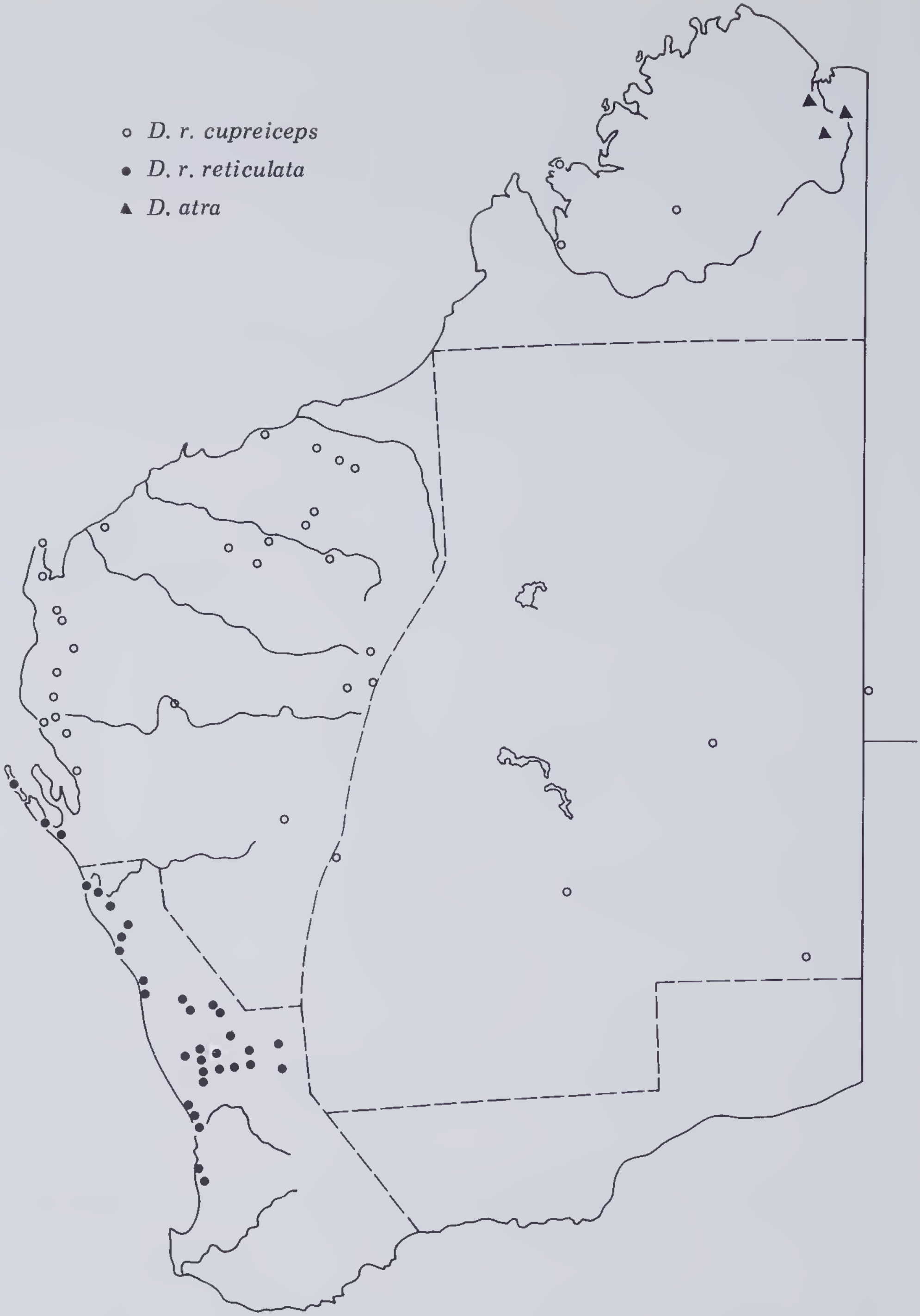

Fig. 3: Map of Western Australia showing location of specimens of *Demansia atra* and two subspecies of *D. reticulata*.

and 23 km ESE (33836) and 5 km S (33931); Binnu (25222); Yuna (28269); East Chapman (4524); Geraldton (22863); Bookara (26610); Port Denison (23331); 21 km E of Yandanooka (29577); 18 km W of Morawa (29715); Three Springs (7546-7); Caron (28885); Bunjil (15063, 22990); Coorow (9244); Wubin (13769); Watheroo (2084); 14 km NNE of Badgingarra (26167, 32084); Coomberdale (5704, 9992, 21717); Miling (5733); Burakin (26514); Kulja (26515); Beacon (29403); Bencubbin (31154); Cadoux (31641); Wongan Hills (47343); Piawaning (23332-3); Moora (1602, 37959-60); Mogumber (5203); Yanchep (1960); 16 km N of Wanneroo (26074); Whitfords Beach (21724); Sorrento (24022); Scarborough (6145); Midland Junction (797); Perth (791); Kings Park (579, 593); Hollywood (4479); Nedlands (6671); Melville (6379); Applecross (4599, 4887, 6043); Carlisle (15065); Queens Park (4956); Cannington (7468); Forrestdale (5177); Mandurah (57233); 17 km NW of Harvey (57774).

DEMANSIA ATRA

Diemenia atra Macleay, 1885, Proc. Linn. Soc. N.S.W. 9: 549. Ingham, Qld (J.A. Boyd).

Diagnosis

A large blackish *Demansia*, distinguishable from *D. papuensis melaena* by its black-edged anterior ventrals, unspotted head, dark-sutured temporals, lesser size and fewer ventrals and subcaudals.

Distribution

East Kimberley, about the lower Ord. Extralimital in far north of Northern Territory, northern and eastern Queensland and southern New Guinea.

Description

Snout-vent length (mm): 530-863 (N 8, mean 723.1). Length of tail (% SVL): 24.2-33.0 (N 7, mean 29.7). Ventrals 176-197 (N 8, mean 184.1). Subcaudals 70-88 (N 7, mean 79.1). Ventrals plus subcaudals 257-270 (N 7, mean 263.0).

Head moderately dark coppery brown, not spotted but sometimes blotched posteriorly with dark brown. Back black, becoming blackish brown or dark reddish brown posteriorly. Tail dark reddish brown, becoming paler distally. No transrostral line. Occasionally a trace of circumorbital markings. Lips, chin, throat and subcaudals pinkish or buffy white. Rest of under surface pale grey, dark grey or brownish grey, darkest at sides.

Geographic variation

The above description is based on the Northern Territory-Kimberley population, which is probably separable subspecifically from that of Queensland. The western population has more ventrals and subcaudals, lacks yellow pigment ventrally and seems to be larger.

Material

Kimberley Division (W.A.): Wyndham (13448) and 60 km SSE (25089); Kimberley Research Station, N of Kununurra (22347-8, 29914).

Northern Territory: Milingimbi (13532-3); Yirrkala (13509).

Queensland: 30 km E of Georgetown (55849); Townsville (55615); near Laura (57865).

DEMANSIA PAPUENSIS MELAENA SUBSP. NOV.

Holotype

R47590 in Western Australian Museum, collected by Mr G.F. Gow on 18 July 1974 at Katherine, Northern Territory, in 14° 28′ S, 132° 16′ E.

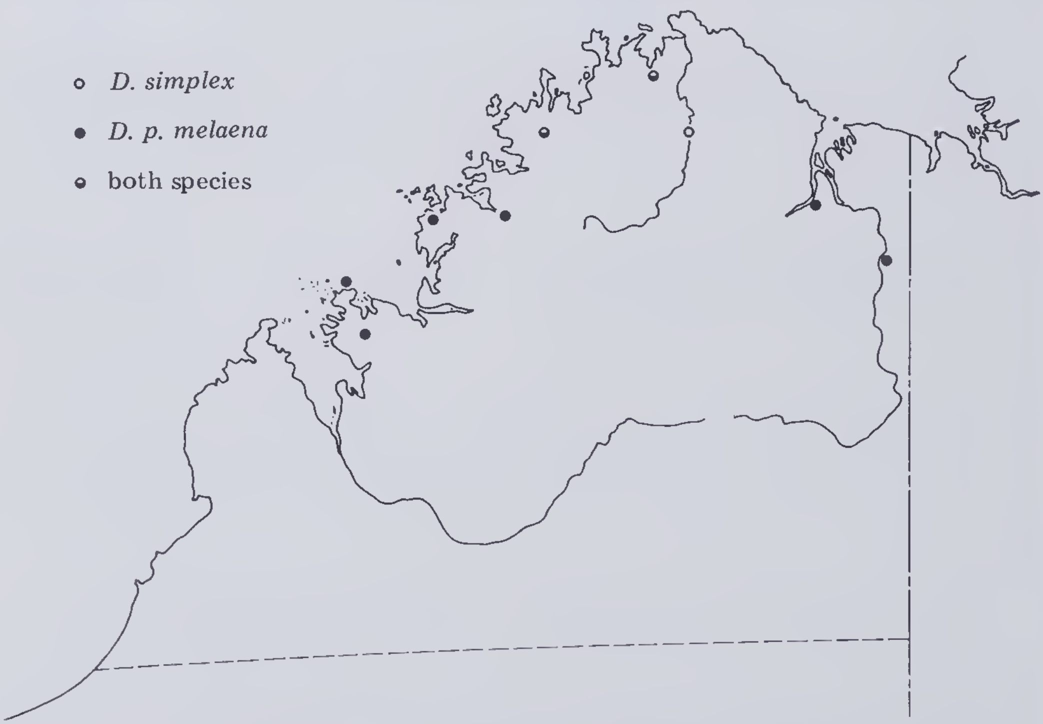

Fig. 4: Map of Kimberley Division showing location of specimens of *Demansia simplex* and *D. papuensis melaena*.

Diagnosis

A very large blackish *Demansia*, distinguishable from *D. p. papuensis* (Macleay) of southern New Guinea by its darker coloration, fewer ventrals and lesser size, and from *D. atra* by its greater size, more numerous ventrals and subcaudals, head paler and spotted, and anterior ventrals and temporals not dark-edged.

Distribution

North Kimberley, south to the Yampi Peninsula and Lake Argyle; also Koolan I. Extralimital in far north of Northern Territory.

Description

Snout-vent length (mm): 501-1143 (N 19, mean 894.7). Length of tail (% SVL): 25.8-32.6 (N 17, mean 28.6). Ventrals 192-220 (N 19, mean 208.0). Subcaudals 78-105 (N 18, mean 87.9). Ventrals plus subcaudals 281-322 (N 17, mean 295.7).

Head pale to moderately dark coppery brown, dotted or spotted with dark brown or blackish brown. Back black, blackish grey or blackish brown, becoming paler on hind back and tail. No transrostral or circumorbital markings. Lips, chin, throat and under tail white. Rest of under surface grey, except occasionally for a ragged median strip of greyish white.

Paratypes

Kimberley Division (W.A.): Kalumburu (13286-8, 22425, 28073); Mitchell Plateau (53714); Prince Regent River Reserve (46834); Kuri Bay (22923); Koolan I. (47684); Kimbolton Spring (51202); Wyndham (13648); Lake Argyle (55865-6).

Northern Territory: Cape Don (26673); Katherine (16509, 23893-4, 26347).

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TAXONOMIC NOTES ON THE REPTILES OF THE SHARK BAY REGION, WESTERN AUSTRALIA

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ABSTRACT

Two new pygopodid lizards (*Pletholax gracilis edelensis* and *Aprasia haroldi*) and two new skinks (*Lerista planiventralis decora* and *Menetia amaura*) are described. *Ctenotus youngsoni*, *C. alleni* and *C. mimetes* are redescribed. Additional data are provided for *Amphibolurus maculatus badius*, *Lerista macropisthopus*, *L. lineopunctulata*, *L. nichollsi* and *Vermicella littoralis*.

INTRODUCTION

A generous grant from Mr and Mrs W.H. Butler enabled the Western Australian Museum to send two collectors, Messrs G. Harold and M. Peterson to the Shark Bay region for four weeks in August and September 1976. The grant also covered Mr Harold's expenses in the laboratory during the registration of the collection.

Strangely, less was known of the fauna of the Shark Bay mainland than of the adjacent islands. Harold and Peterson therefore concentrated on sampling all major habitat types on Edel Land, the Peron Peninsula and the coastal plains south and east of Hamelin Pool. Their 751 specimens were distributed among 74 species and subspecies as follows:

Leptodactylidae — *Arenophryne rotunda* (1)
Hylidae — *Litoria rubella* (4)
Cheluidae — *Chelodina steindachneri* (2)
Gekkonidae — *Crenadactylus ocellatus* (28), *Diplodactylus alboguttatus* (40), *D. michaelseni* (7), *D. pulcher* (2), *D. spinigerus* (29), *D. squarrosus*

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(5), *D. strophurus* (12), *D. ornatus* (9), *Gehyra variegata* (59), *Heteronotia binoei* (85), *Nephrurus levis occidentalis* (17), *Phyllurus milii* (12)

Pygopodidae — *Aprasia haroldi* (9), *A. smithi* (3), *Delma nasuta* (4), *D. tincta* (3), *Lialis burtonis* (11), *Pletholax gracilis edelensis* (5), *Pygopus lepidopodus* (4), *P. nigriceps* (2)

Agamidae — *Amphibolurus inermis* (5), *A. maculatus badius* (6), *A. m. maculatus* (23), *A. minor* (15), *A. parviceps butleri* (10), *A. reticulatus* (24), *A. scutulatus* (5), *Moloch horridus* (5), *Physignathus longirostris* (2)

Scincidae — *Cryptoblepharus carnabyi* (9), *Ctenotus fallens* (6), *C. lesueurii* (1), *C. mimetes* (3), *C. p. pantherinus* (2), *C. severus* (5), *C. youngsoni* (2), *Egernia depressa* (1), *Lerista connivens* (11), *L. elegans* (5), *L. lineopunctulata* (39), *L. macropisthopus* (26), *L. muelleri* (17), *L. nichollsi* (13), *L. p. planiventralis* (6), *L. p. decora* (2), *L. praepedita* (52), *Menetia amaura* (1), *M. greyii* (9), *M. surda* (13), *Morethia butleri* (1), *M. lineoocellata* (12), *M. obscura* (4), *Omolepida branchialis* (23), *Sphenomorphus richardsonii* (3), *Tiliqua occipitalis* (3), *T. rugosa* (5)

Varanidae — *Varanus caudolineatus* (2), *V. eremius* (1)

Typhlopidae — *Typhlina leptosoma* (2), *T. nigroterminata* (1)

Boidae — *Liasis childreni* (1)

Elapidae — *Demansia olivacea calodera* (7), *D. r. reticulata* (1), *D. r. cupreiceps* (1), *Denisonia monachus* (3), *Pseudechis australis* (1), *Pseudonaja modesta* (2), *P. nuchalis* (1), *Vermicella bertholdi* (1), *V. bimaculata* (2), *V. littoralis* (3).

In a later paper ecological and distributional data from this collection will be combined with those of earlier collections, to give a picture of the rich herpetofauna of Shark Bay. Before this can be done certain taxonomic revisions are necessary. Some of these have already been published (Storr, 1977a and 1977b). In the present paper four new species and subspecies are described and eight species and subspecies are fully or partly redescribed.

I am grateful to Mr Harold for assistance in the preparation of this paper.

PYGOPODIDAE

PLETHOLAX GRACILIS EDELENSIS SUBSP. NOV.

Holotype

R54627 in Western Australian Museum, collected by Messrs G. Harold and M. Peterson on 24 August 1976 at 4 km S of Useless Loop, Western Australia, in 26° 10′ S, 113° 25′ E.

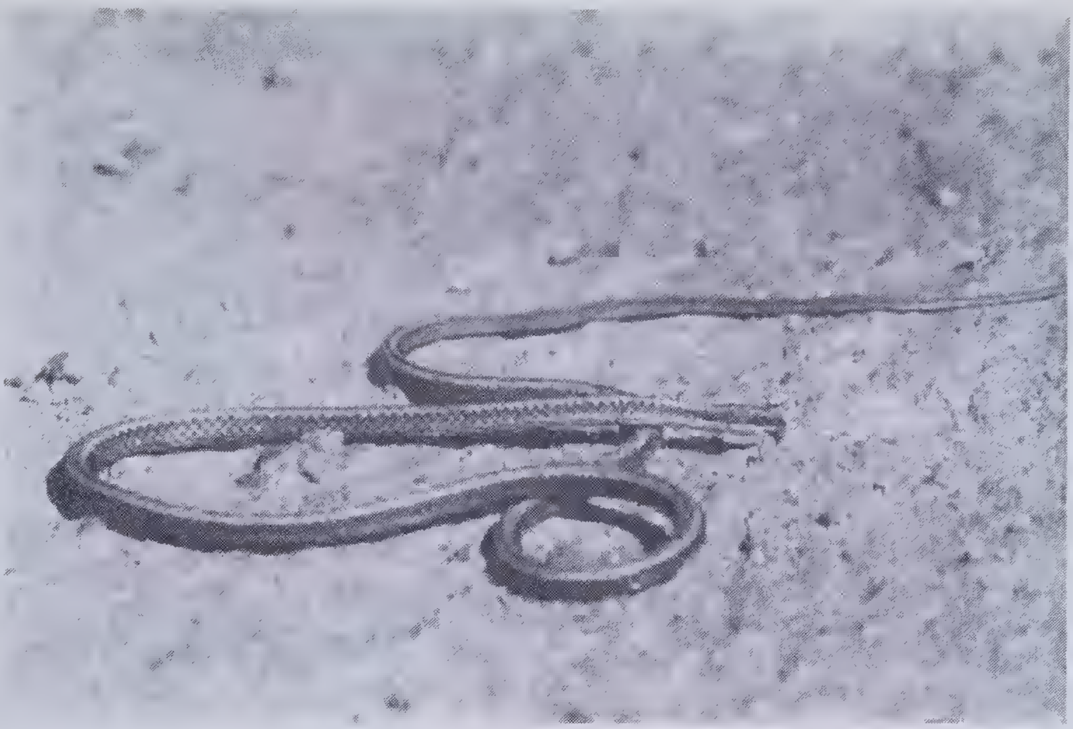

Fig. 1: Holotype of *Pletholax gracilis edelensis* photographed in life by G. Harold.

Diagnosis

Distinguishable from *P. g. gracilis* by its greater size, subequal supraoculars, small first supraciliary, more numerous postoculars and fewer anterior temporals.

Distribution

Edel Land, mid-west coast of Western Australia.

Description

Snout-vent length (mm): 69-90 (N 5, mean 81.2)[57-83 in *P. g. gracilis*, N 10, mean 65.5]. Length of tail (%SVL): 302-340 (N 4, mean 316) [258-346 in *P. g. gracilis*, N 8, mean 295].

Supraoculars 2, subequal in size [second much the larger in *P. g. gracilis*]. Supraciliaries 2, second much the larger [first much the larger in *P. g. gracilis*]. Anterior temporals 2, except in one specimen with 3/4 [3 in *P. g. gracilis*]. Midbody scale rows 16.

Upper and lateral surfaces pale grey except for dark grey upper lateral streak. Upper lateral streak most pronounced anteriorly, flecked with dark

Fig. 2: Map of south-western Western Australia, showing location of specimens of *Pletholax gracilis edelensis* and *P. g. gracilis.*

brown and bordered above and below by a series of angular blackish spots. Chin, throat and upper labials pale yellow. Rest of under surface white.

Remarks

The nominate subspecies of *P. gracilis* occurs on the lower west coast of Western Australia from Eneabba south to Mandurah, inland to Coomberdale and Red Hill. Useless Loop is 450 km north of Eneabba. As much of the intervening country has been well worked by naturalists, it would seem that *P. g. edelensis* is really isolated from the rest of the species.

Paratypes

North-west Division: 10 km NW of Useless Loop (55085); 4 km S of Useless Loop (54814, 54863); 5 km S of Useless Loop (54755).

APRASIA HAROLDI SP. NOV.

Holotype

R54766 in Western Australian Museum, collected on 27 August 1976 by Messrs G. Harold and M. Peterson on Parrot Isle, 5 km N of Carrarang, Western Australia, in 26° 20′ S, 113° 30′ E.

Diagnosis

A narrow-headed, long-snouted member of the *Aprasia repens* super-species, distinguishable from *A. repens* by 14 (rather than 12) midbody scale rows, and from both *A. repens* and *A. rostrata* by 4 (rather than 5) upper labials. *A. haroldi* is the only *Aprasia* in which the prefrontal is in contact with the subocular labial.

Distribution

Edel Land, mid-west coast of Western Australia.

Description

Snout-vent length (mm): 56-106 (N 8, mean 85.5). Length of tail (% SVL): 55-65 (N 3, mean 60.7).

Head scutellation as in *A. repens* except that rostral (as seen from above) is slightly narrower than long (rather than slightly wider), and the second upper labial of *A. repens* is missing so that the prefrontal is in broad contact with first labial and in narrow contact with second (subocular) labial.

Pale brownish grey above, obscurely marked with dark brownish grey; markings tending to take form of dark-edged longitudinal streaks of ground colour. Markings on head including a wavy streak from temples to snout. Streaks on back and sides short, one in middle of each scale. Lips and chin yellowish white; under tail creamy white; rest of under surface pale greyish brown.

Remarks

This lizard is named after Mr Gregory Harold, in appreciation of his skill as a collector of fossorial reptiles.

Paratypes

North-west Division: Parrot Isle, Carrarang Station (54765); False Entrance Well, Carrarang Station (54847, 54891-5).

AGAMIDAE

AMPHIBOLURUS MACULATUS BADIUS

Amphibolurus maculatus badius Storr, 1965, *J. Proc. R. Soc. West. Aust.* 48: 46. 25 km SE of Cardabia, W.A. (Storr & Clay).

Remarks

Harold and Peterson's six specimens from between Carnarvon and Wooramel have the rich coloration of typical *badius* (i.e. from north of the Gascoyne) but are a little larger (SVL of 2 males 52, 56; 3 females 49-54). They are still smaller than the Shark Bay specimens of the nominate subspecies, females of which have SVL ranging up to 60 mm.

SCINCIDAE

CTENOTUS YOUNGSONI

Ctenotus youngsoni Storr, 1975, *Rec. West. Aust. Mus.* 3: 227. Dirk Hartog I., W.A. (A.A. Burbidge).

Diagnosis

A large dark member of the *C. labillardieri* group with unbroken pale dorsolateral line; legs dark olive brown with or without blackish flecks or spots. Further distinguishable from *C. lancelini* by more numerous midbody scale rows (28-30, *vs* 24).

Distribution

Mid-west coast of Western Australia: Dirk Hartog I. and adjacent mainland (Edel Land).

Description

Snout-vent length (mm): 48-84 (N 4, mean 66.0). Length of appendages (% SVL): foreleg 22-28 (N 4, mean 24.0); hindleg 37-45 (N 4, mean 40.8); tail 155-177 (N 2).

Nasals narrowly separated or in short contact. Prefrontals narrowly separated. Supraoculars 4, first 2 in contact with frontal. Supraciliaries 7, first much the largest. Palpebrals 9-11 (N 4, mean 10.0). Second loreal 1.4-1.9 (N 4, mean 1.65) times as wide as high. Presuboculars 3. Upper labials 8. Upper secondary temporal much larger than subequal primary and lower secondary. Ear lobules 3, acute or subacute, first or second largest. Nuchals 2-4 (N 4, mean 3.2). Lamellae under fourth toe 21-23 (N 4, mean 22.2), widely callose.

Dorsally olive grey. Very wide black laterodorsal stripe enclosing a series of pale dots (ground colour). Pale dorsolateral line from level of foreleg to level of hindleg, sometimes extending forward as a series of dots half way to brow. Upper lateral zone grey, flecked with black. Pale midlateral stripe poorly developed (indistinct and not reaching forward to foreleg) or absent. Lower lateral zone pale grey flecked with black. Lips barred (owing to dark sutures between labials). Tail almost patternless olive grey above, merging on sides with greyish white of subcaudals.

Additional material

North-west Division: False Entrance Well, Edel Land (54800, 54825).

CTENOTUS ALLENI

Ctenotus alleni Storr, 1974, *J. Proc. R. Soc. West. Aust.* 56: 89. 18 km N of Galena, W.A. (N.T. Allen).

Diagnosis

A large member of the *C. leonhardii* group with white midlateral stripe, unspotted black laterodorsal stripe, little or no trace of dark vertebral stripe, nasals separated, and prefrontals forming a median suture. Most like *C. mimetes*, from which it is distinguishable by its greenish back, midlateral stripe seldom extending forward beyond forelegs, streaked legs, and white upper lateral dots not clumping into large subrectangular spots.

Distribution

Northern interior of the South-west Division of Western Australia, in the Ajana and Yuna districts.

Description

SVL 46-93 (N 19, mean 79.7). Length of appendages (% SVL): foreleg 24-32 (N 19, mean 27.0), hindleg 44-57 (N 19, mean 50.0), tail 212-276 (N 15, mean 254.7).

Nasals separated from each other and from second labial; occasionally weakly grooved. Prefrontals forming a median suture. Supraoculars 4, first 3 in contact with frontal, first usually not much narrower than second. Supraciliaries 7 or 8 (N 17, mean 7.2). Upper labials 8-9 (mostly 8, N 18, mean 8.1). Ear lobules 4-7 (N 15, mean 6.0), long and acute in adults, obtuse or subacute in juveniles, third or fourth usually largest. Nuchals 3-5 (N 20, mean 3.8). Midbody scale rows 24-28 (N 18, mean 25.5). Lamellae under fourth toe 27-34 (N 17, mean 29.4), each with a narrow to moderately wide callus.

Dorsally olive, darkest on head, palest on tail. Occasionally a black vertebral line on nape. Black laterodorsal stripe unspotted, narrow to moderately wide. Conspicuous narrow white dorsolateral stripe from orbit to base of tail. Black upper lateral zone usually with two series of dots anteriorly and one series posteriorly. Legs brown, longitudinally streaked with black.

Remarks

Because of their greenish backs and rather wide subdigital calli, and despite their compressed toes and relatively large first supraocular, the type specimens of *C. alleni* were wrongly placed in the *lesueurii* group instead of the *leonhardii* group. The close relationship of *C. alleni* to *C. mimetes* was not appreciated, and the best characters for distinguishing them were not discerned, resulting in my later mistaking four specimens of *C. mimetes* for *C. alleni*, viz. 47699 from Hamelin, 47739 from 30 km SE of

Yuna, and 47736-7 from 29 km N of Tenindewa. The first of these misidentifications wrongly extended the range of *C. alleni* northwards to the Shark Bay region, and all of them vitiated my redescription of *C. alleni* (Storr, 1975: 220), hence the need for the present redescription of *alleni* and a listing of all the material on which it is based.

C. alleni and *C. mimetes* are closely related to *C. regius* of eastern Australia, in which species the unusual tendency for the nasal to be grooved is more strongly developed. These three species could be informally associated as the *mimetes* sub-group.

Material

South-west Division: 18 km N of Galena (33602); 29, 32, 42 and 45 km NE of Yuna (26499, 56926-31, 56977-9); East Yuna Reserve, 30 km ESE of Yuna (47738, 47740-1, 48228, 48259, 55913-6).

CTENOTUS MIMETES

Ctenotus mimetes Storr, 1969, *J. Proc. R. Soc. West. Aust.* 51: 103. 20 km E of Paynes Find, W.A. (D.A. Richards).

Diagnosis

A moderately large member of the *C. leonhardii* group with white midlateral stripe, unspotted blackish laterodorsal stripe, little or no trace of dark vertebral stripe, nasals usually separated, prefrontals usually forming a median suture. Most like *C. alleni*, from which it is distinguishable by its brown back, midlateral stripe extending forward to lores, spotted legs, and pale upper lateral dots tending to clump into large subrectangular spots.

Distribution

Western arid and semiarid zones of Western Australia from the Ashburton drainage, south to the central Wheat Belt, west to Hamelin, Ajana and Carnamah, and east to Youanmi and Merredin.

Description

Snout-vent length (mm): 33-82 (N 26, mean 67.5). Length of appendages (% SVL): foreleg 22-30 (N 26, mean 25.4), hindleg 44-56 (N 26, mean 50.2), tail 174-280 (N 13, mean 228.2).

Nasals usually separated (touching in one specimen); in contact with second labial or narrowly separated; occasionally weakly grooved. Prefrontals usually in contact (narrowly separated in three specimens). Supraoculars 4, first three in contact with frontal, first about as wide as second. Supraciliaries 5-8 (usually 7, N 22, mean 6.9). Second loreal 1.0-1.9 times as wide as high (N 24, mean 1.43). Upper labials 7-9 (mostly 8, N 24, mean 8.0). Ear lobules 3-6 (N 24, mean 4.4); acute, subacute or truncate in adults; obtuse in juveniles. Nuchals 3-5 (N 26, mean 3.5). Midbody scale rows 26-32 (N 26, mean 27.2). Lamellae under fourth toe 23-31 (N 25, mean 26.9), each with a narrow to moderately wide callus.

Dorsally pale to dark brown, duller on head, paler and redder on tail. Dark vertebral stripe usually absent, occasionally represented by a line on nape, less commonly extending to base of tail. Blackish, unspotted laterodorsal stripe usually narrow. Conspicuous narrow white dorsolateral stripe from orbit to middle of tail. Blackish upper lateral zone with a series of large, narrowly separated, pale subrectangular spots or 2 or 3 narrowly separated series of white dots or short dashes that tend to align vertically and form large, pale, narrow subrectangular spots. Legs pale brown; dark brown streaks breaking up into spots, short bars or a loose reticulum.

Material

North-west Division: Wyloo (13211); Callagiddy (40765); Hamelin (47699) and 7 km W (55053-4); 6 km N of Wannoo (52060-1) and 3 km N (54842); 68 km SW of Youanmi (19119); 70 km NE of Paynes Find (ERP 10006) and 20 km E (17991); Lochada (45692).

South-west Division: 3 km W of Ajana (30321); 'Bunya Bunya', 19 km ESE of Yuna (8303, 9027); East Yuna Reserve, 30 km ESE of Yuna (47739, 49924); Bindoo Hill Reserve, 29 km N of Tenindewa (47736-7); Carnamah (407); 40 km N of Beacon (48327, 48330-1); Merredin (1265-6) and 5 km E (52059).

LERISTA PLANIVENTRALIS PLANIVENTRALIS

Rhodona planiventralis Lucas & Frost, 1902, *Proc. R. Soc. Vict.* 15: 78. Western Australia (B.H. Woodward).

Diagnosis

A medium-sized *Lerista* with ventrolateral keel, digits 2 + 3, eyelid movable, and temporals normally 1 + 1. Distinguishable from *L. p. decora* by more numerous midbody scale rows, darker head and narrower upper lateral stripe.

Distribution

Upper west coast of Western Australia from North West Cape south to Carnarvon; also Bernier I. and Edel Land.

Description

Snout-vent length (mm): 31-72 (N 21, mean 55.3). Length of appendages (% SVL): foreleg 6-10 (N 21, mean 7.8), hindleg 20-29 (N 21, mean 25.4), tail 77-106 (N 7, mean 87.9), snout to foreleg 24-31 (N 21, mean 27.0).

Nasals widely separated. Prefrontals widely separated. Frontoparietals forming a median suture (only touching in one specimen), usually much shorter than interparietal. Nuchals 0-4 (N 20, mean 1.8). Supraoculars 3, first two in contact with frontal. Supraciliaries 5; third and fourth moderately high and penetrating between supraoculars; second and fifth smallest. Upper labials 6. Occasionally a small lower secondary temporal. Midbody scale rows 22-24 (N 20, mean 22.2). Lamellae under longest toe 12-17 (N 18, mean 14.2).

Upper surface brownish grey (Edel Land) or olive grey (Bernier Island), becoming dark grey on head and buffy on tail. Hind part of head with or without obscure blackish bars or spots. Four series of small blackish brown or greyish brown spots on back; inner series extending on to tail; outer series ending on hind back. Narrow to moderately wide, ragged or sharp-edged greyish brown or blackish brown upper lateral stripe, usually much less than a scale wide, usually running through centre of one longitudinal series of scales, occasionally through contact between two adjacent series of scales; extending forward through orbit to nasal. Lower lateral and ventral surfaces white.

Geographic variation

The above colour description applies to southern specimens (12 from Edel Land and one from Bernier I.). Specimens from North West Cape south to at least Warroora have the back coppery brown, the stripes and lines of spots moderately dark brown, the head greyish and without dark spots, and the sides of body pink.

Material

North-west Division: Neds Creek, North West Cape (27916); 35 km SSE of Cardabia (51016); Warroora (8158); Carnarvon (360-1); Bernier I. (old series 11247-8, 11250; R20505); 10 km NW of Useless Loop (54711); Steep Point (54791); False Entrance Well, 22 km NW of Carrarang (39014-8, 55090-3).

Fig. 3: Map of mid-western Western Australia, showing location of specimens of *Lerista p. planiventralis* and *L. p. decora*.

LERISTA PLANIVENTRALIS DECORA SUBSP. NOV.

Holotype

R54707 in Western Australian Museum, collected by Messrs G. Harold and M. Peterson on 1 September 1976 after digging beneath reptile tracks on white coastal dunes at Denham, Shark Bay, Western Australia, in 25° 55′ S, 113° 22′ E.

Diagnosis

Distinguishable from *L. p. planiventralis* by fewer midbody scale rows, ground colour of head same as back, and wider upper lateral stripe.

Distribution

Mid-west coast of Western Australia and near-coastal sandplains, from Peron Peninsula south nearly to Jurien Bay, inland to Lockwood Spring and Watheroo.

Description

Snout-vent length (mm): 41-62 (N 6, mean 53.1). Length of appendages (% SVL): foreleg 7-8 (N 5, mean 7.3), hindleg 21-28 (N 5, mean 24.2), tail 95-100 (N 2), snout to foreleg 26-28 (N 5, mean 27.1).

Nasals widely separated. Prefrontals widely separated. Frontoparietals forming a median suture in northern specimens, separated in Padbury specimen, and fused in Watheroo specimen; much shorter than interparietal. Nuchals 1-4 (N 6, mean 2.4). Supraoculars 3, first two in contact with frontal. Supraciliaries 5; third and fourth moderately high and penetrating between supraoculars; second and fifth smallest. Upper labials 6. Temporals 2, secondary much larger than primary. Midbody scale rows 20 (N 6). Lamellae under longest toe 12-18 (N 5, mean 14.8).

Head, back and tail very pale brown. Short blackish-brown bars and angular spots on middle and hind part of head. Four series of short dark brown bars or spots on back, running through centres of dorsal scales; inner (paravertebral) series largest and darkest, extending back to middle of tail; outer series fading out on hind back. Wide, sharp-edged, blackish brown upper lateral stripe, occupying half of scale of two adjacent series of scales; extending forward through orbit to nasal and back on to tail (where it breaks up into a series of spots). Lower lateral and ventral surfaces white.

Paratypes

North-west Division: Denham (54706).

South-west Division: Lockwood Spring, 32 km ESE of Kalbarri (33473-4); 5 km W of Padbury (48453); Watheroo (796).

LERISTA MACROPISTHOPUS

Lygosoma (Rhodona) macropisthopus Werner, 1903, *Zool. Anz.* 26: 246.

Remarks

During my revision of this species (Storr, 1972: 65), before any material was available from the Shark Bay region, specimens with 5 supraciliaries were rarely encountered. Harold and Peterson collected 26 specimens at Wooramel and Hamelin; 18 of them had 5 supraciliaries, seven had 1 + 3, and one had 0 + 3. Digits were 2 + 3 except for three specimens with a single finger on one side. In this population the head is blackish brown back to level of eyes and down to centre of upper labials; the rest of the upper surface is brown, with or without a purplish tinge.

LERISTA LINEOPUNCTULATA

Brachystopus lineo-punctulatus Duméril & Bibron, 1839, Erpétologie générale 5: 779.

Remarks

Harold and Peterson's collection from the Shark Bay mainland reveals a discordant mixture of northern and southern characters (cf. Storr, 1972: 67). All 16 specimens from Peron Peninsula have two toes, but in only one of them the back is spotted. All 17 specimens from Carrarang Station on Edel Land have only one toe, and five of them have a spotted back. Further south at Tamala all five specimens have one toe (except one with two toes on one side) and none of them is spotted. Only on Dirk Hartog Island is there correlation between these characters; our three unspotted specimens have a single toe and the single spotted specimen has two toes.

LERISTA NICHOLLSI

Rhodona nichollsi Loveridge, 1933, *Occ. Pap. Boston Soc. Nat. Hist.* 8: 87. Dalgaranga, W.A. (G.E. Nicholls).

Remarks

Two of three specimens recently collected at 17 km S of Gascoyne Junction show some tendency towards *L. connivens petersoni* from Yinnietharra (120 km to north-east). One of them (55971) has snout-vent length 67 mm, well beyond the range (31-61 mm) previously recorded for *nichollsi*, and another specimen (55975) has the second loreal not fused to prefrontal, a condition that is rare in *nichollsi*. All three specimens have 20 midbody scale rows and immovable eyelids. It seems then that *petersoni* is closer to *nichollsi* than to *connivens*. Until more is learnt of the status of *petersoni*, it is best to treat *connivens* binomially.

MENETIA AMAURA SP. NOV.

Holotype

R54724 in Western Australian Museum, collected by Messrs Harold and Peterson on 20 August 1976 at False Entrance Well, Carrarang Station, Western Australia, in 26° 23′ S, 113° 19′ E.

Diagnosis

A dark *Menetia* with only one supraciliary. Further distinguishable from *M. greyii* by 5 (rather than 4) small scales in outer arc between largest supraciliary and penultimate labial, lack of ear aperture, and absence of lateral stripes, and from *M. surda* by single presubocular (rather than 2), longer first supraocular, and no enlarged upper circumocular granule.

Distribution

Edel Land, mid-west coast of Western Australia.

Description (based on holotype, the only available specimen)

Snout-vent length 25 mm. Tail 1.65 times as long as SVL.

Nasals separated. Prefrontals separated moderately narrowly. First supra-ocular much more than twice as long as wide. Parietal on one side divided. Supraciliary single (as if first and second of *M. greyii* were fused). Upper labials 6 (5 on one side owing to fusion of fourth and fifth). One nuchal on each side. Midbody scale rows 22, smooth. Subdigital lamellae 15.

Dorsally blackish brown, becoming paler on tail and sides owing to pale brown fleck on each scale. Lips pale, flecked dark brown. Under surface pale.

Remarks

Since my revision of *Menetia* (Storr, 1976), Mr P.R. Rankin of the Australian Museum has drawn my attention to the importance of presuboculars in this genus. Checking our material, I found that *M. surda* has two presuboculars and the other western species one.

ELAPIDAE

VERMICELLA LITTORALIS

Vermicella bertholdi littoralis Storr, 1967, *J. Proc. R. Soc. West. Aust.* **50:** 84. 11 km S of Geraldton, W.A. (R. Vollprecht).

Remarks

Since my revision of *Vermicella* '*bertholdi*' (Storr, *supra cit.*), many additional specimens have been received, but none of them can be considered intermediate between the three 'subspecies'. It has therefore become clear that these 'subspecies' are in fact three parapatric species, *V. bertholdi*, *V. littoralis* and *V. anomala.*

When describing *littoralis*, I mentioned the possibility of its proving divisible into northern and southern subspecies, mainly on the basis of number of body rings: 16-22 in the north and 24-34 in the south. Since then seven specimens have been collected in the geographically intermediate region (Edel Land and the Kalbarri National Park); predictably they have an intermediate number of rings (19-27). However, the count on Dirk Hartog Island is anomalously high (two specimens with 32 rings).

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NOTES ON THE *CTENOTUS* (LACERTILIA, SCINCIDAE) OF QUEENSLAND

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ABSTRACT

Full or partial descriptions are given for *C. pantherinus acripes* Storr, *C. robustus* Storr, *C. spaldingi* (Macleay), *C. inornatus* (Gray), *C. lateralis* nov., *C. essingtonii* (Gray), *C. schevilli* (Loveridge), *C. pulchellus* nov., *C. hebetior* nov. and *C. striaticeps* nov.

INTRODUCTION

Regional revisions of *Ctenotus* (Storr 1969, 1970, 1971, 1974, 1975) cover Western Australia, the Northern Territory and South Australia, and one of them (Storr 1971) virtually covers Victoria and inland New South Wales. Queensland thus remains the biggest gap in our knowledge of the genus.

Recent collections in western and northern Queensland, notably by Messrs G. Harold, M. Peterson and J.R. Ford, have brought to light four new species, have extended the known range of two western taxa eastwards into Queensland, and have permitted the redescription of certain little-known species.

These notes are based on material in the Western Australian Museum (registered numbers without prefix) and specimens loaned on previous occasions by the National Museum of Victoria (registered numbers prefixed with NMV), Queensland Museum (QM); South Australian Museum (SAM); Macleay Museum, Sydney (MM); CSIRO Wildlife Section, Darwin (NTR); and Arid Zone Institute, Alice Springs (NTM).

I am grateful to Gregory Harold for photographs of the new species and for information on their habitat preferences.

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Ctenotus pantherinus acripes Storr, 1975, Rec. West. Aust. Mus. 3: 216. Barrow Island, W.A. (W.H. Butler).

Diagnosis

Differing from other subspecies of *C. pantherinus* by the combination of black nails, sharply keeled subdigital lamellae, spiny plantars, and high number of midbody scales.

Distribution

Arid and semi-arid northern interior of Queensland and adjacent parts of Northern Territory, in spinifex (*Triodia* and *Plectrachne*) on sandy, gravelly or stony soils. Also Barrow Island, off northwest coast of Western Australia.

Description

Snout-vent length (mm): 50-63 (N 4, mean 58.5). Length of appendages (% SVL): foreleg 29-34 (N 4, mean 31.0); hindleg 45-48 (N 4, mean 46.8); tail 176-195 (N 3, mean 183.0).

Nasals strongly grooved and in long median contact. Prefrontals in moderately long median contact. Supraoculars 4, first three in contact with frontal. Supraciliaries 7 (N 4). Second loreal 1.1-1.4 (N 4, mean 1.25) times as wide as high. Presuboculars 2 (N 4). Upper labials 8 (N 4). Temporals 1 + 2, upper secondary much the largest. Ear lobules 3-5 (N 4, mean 4.2); first, second or third largest. Nuchals 2 or 3 (N 4, mean 2.3). Midbody scale rows 38-40 (N 4, mean 39.5). Lamellae under fourth toe 20-23 (N 4, mean 21.2), each bearing a fine, sharp, dark keel. Plantars sharply conical, proximal scales not greatly enlarged.

Dorsal and lateral surfaces olive brown, darkest on head, palest on tail and sides, with *ca* 10 longitudinal series of black-edged white spots, mid-lateral series tending to form a black-edged white stripe on tail. Posterior upper labials posteriorly edged with dark brown. Legs dark brown; hindleg with one or two longitudinal series of indistinct ocelli. Under surface white, flecked with pale grey. Culmen of nails blackish brown.

Remarks

It is strange that these specimens should be so like those of distant Barrow Island. Perhaps *C. p. acripes* was formerly widespread in the northern interior of Western Australia and the Northern Territory but has recently been replaced by *C. p. ocellifer*.

Other subspecies of *C. pantherinus* could reach Queensland, especially *C. p. calx*, which has been collected in the Northern Territory half of the Nicholson River drainage.

Material

Queensland: 10 km SW of Pentland (55637); Fermoy (55668) and 5 km NW (55672).

Northern Territory: Barkly Highway (NTM 5334).

CTENOTUS ROBUSTUS

Ctenotus robustus Storr, 1970, J. Proc. R. Soc. West. Aust. 52: 100. Northern Territory (Spencer & Gillen).

Diagnosis

A very large member of the *lesueurii* group with 4 supraoculars, nuchals usually 3 or 4, upper labials 7 or 8, black vertebral stripe wide and white-edged, small pale upper lateral spots indistinct and not confluent with white midlateral stripe.

Distribution

Eastern Queensland, north to Trinity Bay and inland to Pentland, Muttaburra and Cunnamulla. Extralimital in far north of Western Australia and Northern Territory and in southeastern Australia.

Description

See Storr (1970, 1971, 1975).

CTENOTUS SPALDINGI

Hinulia spaldingi Macleay, 1877, Proc. Linn. Soc. N.S.W. 2: 63. Endeavour River, Queensland (Chevert Expedition).

Lygosoma dorsale Boulenger, 1887, Catalogue of the lizards in the British Museum (Natural History) 3: 226. Fly River, Papua (S. Macfarlane).

Diagnosis

A large member of the *lesueurii* group with 3 supraoculars, sharp brow tending to hide supraciliaries, nuchals usually 2 or 3, upper labials usually 7, large pale upper lateral spots confluent with white midlateral stripe.

Distribution

North Queensland from Badu Island (Torres Strait) south to beyond Hughendon (Cameron Downs). Extralimital in south New Guinea and far north of Northern Territory.

Description

Snout-vent length (mm): 33-102 (N 42, mean 69.0). Length of appendages (% SVL): foreleg 19-29 (N 42, mean 24.1); hindleg 37-55 (N 42, mean 44.8); tail 190-234 (N 21, mean 212.9).

Nasals separated (occasionally in short contact). Prefrontals in contact (occasionally very narrowly separated). Supraoculars 3, first two in contact with frontal. Supraciliaries 8-13 (N 35, mean 10.1), third or fourth to penultimate considerably smaller than others and often hidden by brow. Second loreal 1.1-2.3 times as wide as high (N 41, mean 1.77). Presuboculars 2. Upper labials 7 or 8 (N 41, mean 7.3). Temporals 1 + 2, upper secondary much the largest. Ear lobules 2-6 (N 42, mean 4.3); obtuse in juveniles, subacute or acute in adults; second or third usually largest. Nuchals 2-4 (N 40, mean 2.8). Midbody scale rows 26-32 (N 41, mean 29.6). Lamellae under fourth toe 18-25 (N 41, mean 21.0), widely callose.

Dorsally pale olive brown (more reddish in life). Narrow to moderately wide black vertebral stripe usually pale-edged and extending to hind back or base of tail in south; sometimes completely absent in north but usually represented by a narrow stripe on fore back, with or without a pale margin. Narrow black or dark brown laterodorsal stripe in south, absent or represented only anteriorly in north. Narrow white dorsolateral stripe from last supraocular to base of tail. Dark brown upper lateral zone with a series of squarish white blotches, inferiorly confluent with midlateral stripe. White midlateral stripe from lores to tail, sometimes represented anteriorly only by a subocular streak. Pale ventrolateral stripe present or absent.

Material

Queensland: Cape York (QM J1697, 1701-4); Edward River Station (NMV D13152-3); Strathgordon (NMV D13151); Endeavour River (MM 418-21, syntypes); 3 km SE of Wrotham Park (55889); 25 km ESE of Torwood (55880-1); 32 km NNW of Mt Garnet (55890); 6 km E of Croydon (55862); 21 km W of Torrens Creek (55481-3) and 6 km S (55635-6); Mornington Island (SAM R9343-56; NMV D8433-6); 'North Queensland' (NMV D2033); 'Queensland' (NMV D1456).

CTENOTUS INORNATUS

Hinulia inornata Gray, 1845, Catalogue of the lizards in the British Museum, p. 78. Port Essington, N.T. (*fide* Storr, 1975: 221).

Diagnosis

A moderately small, long-tailed member of the *lesueurii* group, *inornatus* sub-group, with colour pattern tending to disappear with age, 4 supraoculars, 8 upper labials and seldom more than 3 nuchals.

Distribution

Southern Carpentarian drainages of northern Queensland, east to Gilberton; also Mornington Island. Extralimital in far north of Western Australia and Northern Territory.

Description

See Storr (1970, 1975).

CTENOTUS LATERALIS SP. NOV.

Plate 1: Holotype of *Ctenotus lateralis* photographed in life by G. Harold.

Holotype

J28372 in Queensland Museum, formerly R55485 in Western Australian Museum, collected by Messrs G. Harold and M. Peterson on 20 November 1976 at 14 km N of Mt Isa, Queensland, in 20° 37′S, 139° 32′E.

Diagnosis

A long-tailed, long-legged member of the *lesueurii* group, *inornatus* subgroup, with pale upper lateral spots wholly or mainly replaced by a broad stripe.

Distribution

Stony hills and ridges of arid and semi-arid zones of northern Queensland.

Description

Snout-vent length (mm): 48-88 (N 14, mean 69.0). Length of appendages (% SVL): foreleg 23-31 (N 14, mean 25.8); hindleg 39-52 (N 14, mean 44.0); tail 219-262 (N 7, mean 237.6).

Nasals narrowly separated (just touching in one specimen, moderately widely separated in another). Prefrontals usually forming a short to moderately long suture (narrowly separated in two specimens). Supraoculars 4, first three in contact with frontal, first a little to considerably narrower than second. Supraciliaries 7 (8 in two specimens), either forming a graded series or with fourth to penultimate considerably smaller than others. Second loreal 1.2-2.0 times as wide as high (N 14, mean 1.69). Presuboculars 2. Upper labials 8 (9 in one specimen). Ear lobules 3-5 (N 14, mean 4.5); obtuse in juveniles, usually subacute in adults; first usually very small, second or third largest. Nuchals 2-4 (usually 2 or 3, N 14, mean 2.8). Midbody scale rows 28-32 (N 14, mean 30.1). Lamellae under fourth toe 20-25 (N 14, mean 22.1), each with a wide dark-brown callus.

Dorsally greyish brown, reddish brown or olive brown, becoming greyer on tail. Narrow black vertebral stripe from nape to base of tail, indistinctly edged with greyish white or brownish white (pale margins tending to disappear with age). White or whitish dorsolateral stripe from orbit to proximal half of tail, edged above with black (i.e. a narrow laterodorsal stripe). Upper lateral zone black (becoming brown on tail), bisected by a wide greyish white or brownish white stripe. Narrow to moderately wide greyish white midlateral stripe, extending back nearly to end of tail and forward to ear aperture, thence more narrowly and less distinctly to lores. Lower lateral zone greyish, occasionally bisected by a pale stripe. Legs reddish brown streaked with black.

Paratypes

Queensland: 30 km E of Georgetown (55893); Julius Dam, Leichhardt River (55379); 72 km NNE of Mt Isa (55345); 13 km NW of Mt Isa (55444); 10 km NW of Fermoy (41069); 8 km NW of Fermoy (55553, 55613); 5 km NW of Fermoy (55612, 55565-6); Fermoy (55587, 55607); 19 km E of Fermoy (55567).

CTENOTUS ESSINGTONII

Tiliqua essigntonii Gray, 1842, The zoological miscellany, p. 51. Port Essington, N.T. (J. Gilbert).

Diagnosis

A member of the *essingtonii* group with little or no indication of black vertebral stripe, dark upper lateral zone unspotted, separated nasals, separated prefrontals, 4 supraoculars, 7 upper labials, ear lobule very large and obtuse, 24 midbody scale rows, and toes slightly compressed with 17-24 dark, widely callose lamellae.

Distribution

Southern Carpentarian drainages of northern Queensland, south to Mt Isa, north to the Edward River and east to Wrotham Park. Extralimital in far north of Northern Territory.

Description

See Storr (1970).

CTENOTUS SCHEVILLI

Sphenomorphus schevilli Loveridge, 1933, Occ. Pap. Boston Soc. nat. Hist. 8: 96. Army Downs, 55 km N of Richmond, Qld (W.E. Schevill).

Diagnosis

A moderately large *Ctenotus* with more than 36 midbody scale rows and pattern consisting mainly of white dots.

Distribution

Arid northern interior of Queensland from the Richmond district south to the Boulia and Aramac districts.

Description

Snout-vent length (mm): 65-84 (N 5, mean 76.0). Length of appendages (% SVL): foreleg 24-28 (N 5, mean 25.4); hindleg 39-44 (N 5, mean 41.3); tail 159-168 (N 3, mean 163. 0).

Nasals usually in contact. Prefrontals separated or in contact. Supraoculars 4, first three in contact with frontal. Supraciliaries 6-8 (N 5, mean 7.2). Palpebrals 12-13 (N 5, mean 12.2). Second loreal 0.8-1.4 (N 5, mean 0.99) times as high as wide. Upper labials 8. Temporals 2 + 2 (four specimens) or 1 + 2 (one specimen). Ear lobules 6-7 (N 5, mean 6.1); acute or subacute; central lobules largest. Nuchals 0-6 (N 5, mean 3.8). Midbody scale rows 37-44 (N 5, mean 41.2). Lamellae under fourth toe 22-26 (N 5, mean 23.6), slightly compressed, widely to moderately narrowly callose.

Dorsally pale reddish brown (sharply demarcated from darker reddish brown of upper lateral zone) or olive brown. Median dorsal zone of dark spots and pale flecks, dark markings on hind back and/or proximal third of tail tending to coalesce into an irregular vertebral stripe. Temples and side of body and base of tail densely covered with white dots; dots of upper lateral zone, and sometimes of lower lateral zone, arranged in vertical series. Legs pale brown with little pattern. Under surface white.

Material

Queensland: Paton Downs (NTR 351); Army Downs (QM J5805, holotype); 25 km SE of Muttaburra (NMV D13899-901).

CTENOTUS PULCHELLUS SP. NOV.

Holotype

J28375 in Queensland Museum, formerly R55577 in Western Australian Museum, collected by Messrs G. Harold and M. Peterson on 21 November 1976 at 72 road km NNE of Mt Isa, Queensland, in 20°19′S, 139°47′E.

Diagnosis

A small slender member of the *leonhardii* group with five dark stripes on back, contiguous nasals and separated prefrontals, distinguishable from *C. militaris* of east Kimberley by its blackish upper lateral zone sharply demarcated from orange-red lower lateral zone and complete absence of white midlateral stripe. (In my original description of *C. militaris* I failed to mention that in most specimens there is some indication posteriorly of a white midlateral stripe.)

Plate 2: Holotype of *Ctenotus pulchellus* photographed in life by G. Harold.

Distribution

Stony hills of arid northwestern interior of Queensland, in spinifex (*Triodia* and *Plectrachne*).

Description

Snout-vent length (mm): 46-60 (N 6, mean 52.2). Length of appendages (% SVL): foreleg 26-31 (N 6, mean 29.2); hindleg 48-55 (N 6, mean 52.2); tail 192-225 (N 5, mean 209.8).

Nasals in long median contact. Prefrontals separated (usually widely). Supraoculars 4, first three in contact with frontal, first usually wider than second. Supraciliaries 7 (5 specimens) or 8 (one specimen), third to penultimate considerably smaller than others. Second loreal 1.3-1.8 (N 6, mean 1.53) times as wide as high. Presuboculars 2. Upper labials 8. Ear lobules 5 or 6 (N 5, mean 5.3), obtuse or subacute (acute in one specimen), third or fourth largest. Nuchals 3-5 (N 5, mean 3.9). Midbody scale rows 30-34 (N 5, mean 32.4). Lamellae under fourth toe 23-27 (N 5, mean 25.6), compressed, each with a narrow to moderately wide, dark callus.

Dorsally reddish brown. Back with five blackish brown stripes: vertebral widest, extending from back of head to base of tail; laterodorsal from brow to base of tail; and between them a dorsal, narrowest and least extensive and tending to fade on fore back. White dorsolateral stripe from orbit to base of tail. Blackish brown upper lateral zone with 1-3 irregular series of white dots, extending on to tail as a dark brown stripe. Face and lower lateral zone orange with 3-5 irregular series of white dots that tend to be dark-edged. Legs reddish brown streaked with blackish brown. Under surface opalescent white, becoming pinkish buff under limbs and tail.

Remarks

This beautiful skink is so like *C. militaris* that it could prove to be only subspecifically distinct. At present the known ranges of *pulchellus* and *militaris* are separated by 1200 km.

Paratypes

Queensland: 72 road km NNE of Mt Isa (55452); 8 km N of Mt Isa (55323); 2 km E of Fermoy (41070); 16 km E of Fermoy (41068, 41071).

CTENOTUS HEBETIOR SP. NOV.

Plate 3: Holotype of *Ctenotus hebetior* photographed in life by G. Harold.

Holotype

J28374 in Queensland Museum, formerly R55673 in Western Australian Museum, collected by Messrs G. Harold and M. Peterson on 8 November 1976 at 5 km NW of Fermoy, Queensland, in 23°09′S, 143°00′E.

Diagnosis

A small stout member of the *leonhardii* group with 5 dark stripes on back. Most like *C. militaris* of east Kimberley but differing from that species and *C. pulchellus* by its smaller nasals, larger prefrontals, fewer midbody scale rows, and vertebral stripe narrower than laterodorsal stripe. Further distinguishable from *C. pulchellus* by its paler and duller coloration without sharp demarcation between upper and lower lateral zones (apart from midlateral stripe).

Distribution

Arid northern interior of Queensland, on grassy flats (including *Triodia*).

Description

Snout-vent length (mm): 47-58 (N 6, mean 52.3). Length of appendages (% SVL): foreleg 26-30 (N 6, mean 28.7); hindleg 45-55 (N 6, mean 50.3); tail 172-208 (N 2).

Nasals narrowly separated (4 specimens) or in short contact (2 specimens). Prefrontals in short contact (4 specimens) or very narrowly separated (2 specimens). Supraoculars 4, first three in contact with frontal, first usually wider than second. Supraciliaries 7 (2 specimens) or 8 (4 specimens), forming a graded series (3 specimens) or with third to penultimate considerably smaller than others. Second loreal 1.3-1.9 (N 6, mean 1.60) times as wide as high. Presuboculars 2. Upper labials 8. Temporals normally 3, uppermost largest. Ear lobules 4 or 5 (N 6, mean 4.3); obtuse or subacute; first, second or third largest. Nuchals 2-5 (N 6, mean 3.3). Midbody scale rows 30 (N 6). Lamellae under fourth toe 23-27 (N 6, mean 24.7).

Dorsally pale greyish brown or buffy brown. Five dark stripes from back of head or nape to base of tail or beyond: inner (vertebral and two dorsals) narrow and indistinct; outer (two laterodorsals) darker, wider, more conspicuous and extending further back on tail. White dorsolateral stripe from above temples to base of tail. Upper lateral zone dark reddish brown anteriorly (including temples and lores), more greyish posteriorly, bearing two irregular series of white dots or a series of white spots. Narrow white midlateral stripe absent or moderately well-developed posteriorly (i.e. from hindleg half-way forward to foreleg). Lower lateral zone pale reddish brown anteriorly, more greyish posteriorly, with two or more irregular series of inconspicuous pale dots. Legs buffy brown. Under surface opalescent white.

Paratypes

Queensland: 21 km W of Torrens Creek (55484, 55530); 21 km S of Winton (55678); 5 km NW of Fermoy (55542, 55573).

CTENOTUS STRIATICEPS SP. NOV.

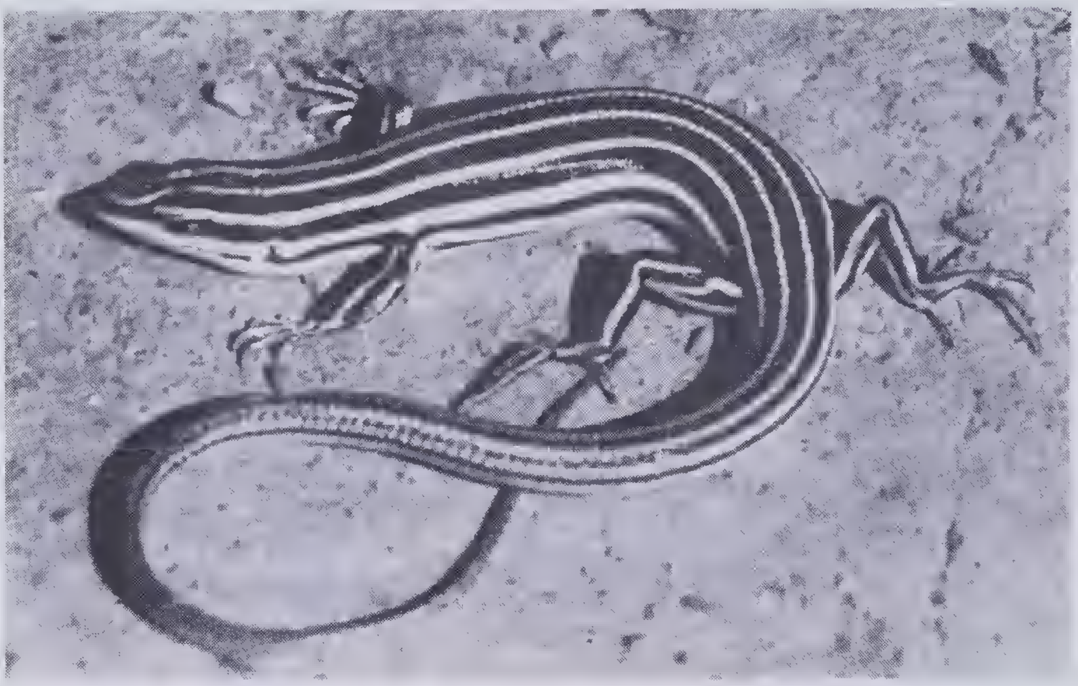

Plate 4: Holotype of *Ctenotus striaticeps* photographed in life by G. Harold.

Holotype

J28373 in Queensland Museum, formerly R55420 in Western Australian Museum, collected by Messrs G. Harold and M. Peterson on 21 November 1976 at 72 road km NNE of Mt Isa, Queensland, in 20°19′S, 139°47′E.

Diagnosis

A member of the *colletti* group with 8 white stripes on a blackish ground and large opercle-like upper ear lobule. Most like *C. colletti* but distinguishable by its widely separated prefrontals, more numerous midbody scale rows, wider and whiter stripes, and extension of dorsal pattern forward to snout.

Distribution

Stony hills of arid northwestern interior of Queensland.

Description (of holotype, the only available specimen)

Snout-vent length (mm): 44. Length of appendages (% SVL): foreleg 26; hindleg 42; tail 193.

Nasals in long median contact. Prefrontals widely separated. Supraoculars 4, first three in contact with frontal, first wider than second. Supraciliaries 7, third to penultimate smallest. Second loreal 1.65 times as wide as high. Presuboculars 2. Temporals 3, uppermost largest. Upper labials 7. Ear lobules 2; upper very large, obtuse, covering nearly half of aperture; lower very small. Nuchals 3 or 4. Midbody scale rows 28. Lamellae under fourth toe 25-27, compressed, each bearing a fine, weak, mucronate keel (keels weakest or absent on proximal lamellae).

Dorsal and lateral surfaces blackish brown with 8 broad white stripes: on each side of paravertebral extending back nearly to end of tail and forward to frontonasal where it joins its opposite number; dorsolateral from brow to distal part of tail; midlateral from lores to middle of tail; and ventrolateral from foreleg to hindleg. Limbs white with three blackish brown longitudinal streaks. Anterior upper labials, lower half of rostral and entire lower surface white.

Alternatively it could be described as white with 9 blackish brown stripes: wide vertebral extending forward to centre of frontonasal; and on each side a wide laterodorsal forward to head, curving through centre of supraoculars down to wide upper lateral, which extends forward to nostril; lower lateral forward to ear aperture, thence narrowly and faintly along bottom of posterior upper labials; and narrow lateroventral from hindleg to foreleg. Vertebral, laterodorsal and upper lateral stripes extending back nearly to end of tail, on which they become narrower and paler. Lower lateral extending faintly and very narrowly to middle of tail.

DISCUSSION

Ctenotus is essentially a genus of arid climates and/or sandy or stony habitats. It is therefore not surprising that the deserts and stony ranges of western Queensland are much richer in species than the well-watered and well-wooded northern and eastern parts of the State or the grassy plains that usually lie between these two extreme habitat types.

Ten species are now known from stony and sandy habitats in the arid and semi-arid zones of Queensland: *C. pantherinus* of the *pantherinus* group, *C. inornatus* and *C. lateralis* of the *inornatus* subgroup, *C. essingtonii* of the *essingtonii* group, *C. pulchellus* and *C. hebetior* of the *leonhardii* group, *C. piankai* of the *taeniolatus* group, *C. striaticeps* of the *colletti* group, and *C. strauchii* and *C. brooksi* of the *schomburgkii* group. All but one of these groups or subgroups are confined to the western three-quarters of Australia, and the exceptional group (*taeniolatus*) has only a single representative in the east.

In the north the grassy plains of the Barkly Tableland and upper Georgina constitute a barrier to the eastward dispersal of arid stony-country and spinifex-inhabiting species. The arid Queensland representative of the highly successful *inornatus* subgroup is a very distinct species (*C. lateralis*), as is the sole Queensland representative of the *colletti* group (*C. striaticeps*). However, the two members of the *leonhardii* group (*C. pulchellus* and *C. hebetior*) are closely related to each other and to *C. militaris* of east Kimberley; they could have derived from the double invasion of a single western stock.

Only one species, *C. schevilli*, has been found on the grassy plains of arid northern Queensland, but *C. joanae* of the Barkly Tableland and upper Georgina of the Northern Territory could well extend to similar country in far western Queensland. *C. regius* has been collected on Mitchell grass plains near Cunnamulla in semi-arid southwestern Queensland.

To date only three species of *Ctenotus* have been recorded from the humid and subhumid zones of northern and eastern Queensland, namely *C. robustus* and *C. spaldingi* of the *lesueurii* group and *C. taeniolatus*. Moreover the first two of these species seem to have mutually exclusive ranges, *C. robustus* only occurring to the south and east of *C. spaldingi*.

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Rec. West. Aust. Mus., 1978, 6 (3)

CTENOTUS RUBICUNDUS, A NEW SCINCID LIZARD FROM WESTERN AUSTRALIA

G.M. STORR*

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INTRODUCTION

In a revision of the *Ctenotus* of the Kimberley and North-west Divisions (Storr 1975), I included in *C. helenae* four anomalous specimens from the Pilbara tableland. Since then I have examined two more specimens from that region and have become convinced that all six specimens belong to a new species. In this paper I describe that species and correct my description of *C. helenae*.

CTENOTUS RUBICUNDUS SP. NOV.

Holotype

R57257 in Western Australian Museum, collected by Messrs G. Harold and G. Barron on 13 July 1977 under a slab of rock at Mt Herbert, W.A., in 21°20′S, 117°12′E.

Diagnosis

A large stout *Ctenotus* completely without pattern, differing from *C. helenae* in its more numerous midbody scale rows (34-36, vs 26-32), contiguous nasals, slightly compressed toes with narrower calli, tubercular plantars, second supraocular not much wider than third and usually narrower than first (in *C. helenae* and *C. grandis* the second is much wider than third and usually wider than first).

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Plate 1: Holotype of *Ctenotus rubicundus*, photographed in life by G. Harold.

Distribution

Rocky hills in the interior of the Pilbara (northwestern Western Australia).

Description

Snout-vent length (mm): 42-101 (N 6, mean 71.3). Length of appendages (% SVL): foreleg 25-30 (N 6, mean 27.3); hindleg 33-47 (N 6, mean 39.7), tail 141-208 (N 3, mean 179).

Nasals contiguous (contact usually short). Prefrontals in short to moderately long contact. Supraoculars 4, first three in contact with frontal. Supraciliaries 6 or 7 (N 6, mean 6.7), fourth to penultimate smaller than others. Palpebrals 11 or 12 (N 4, mean 11.3). Second loreal 1.7-2.1 (N 6, mean 1.87) times as wide as high, upper side flat (i.e. not gabled as in *C. grandis*). Presuboculars 2. Upper labials 8. Ear lobules 3-5 (N 6, mean 4.2); usually obtuse, occasionally subacute or truncate; second or third largest. Nuchals 3 (2 on one side of one specimen) (N 6). Midbody scale rows 34 or 36 (N 4, mean 34.5). Lamellae under fourth toe 19-22 (N 6, mean 20.3), calli moderately narrow (not much wider than in *leonhardii* group). Plantar scales subconical, each with a small round apical callus.

Head, back, sides and forelegs reddish (at least in adults), becoming brownish on snout and paler on face and sides. Tail and extreme posterior part of back olive brown. Hindlegs grey. Under surfaces white.

Remarks

Although this species has been confused with *C. helenae*, I do not consider their relationship especially close. Indeed, it is doubtful whether *C. rubicundus* is even a member of the *lesueurii* group, for its second supraocular is relatively small (as in the *leonhardii* group) and there is no marked disparity in size between the anterior and posterior supraciliaries.

In view of its great size, stout habit and high number of midbody scales, *C. rubicundus* could be related to *C. grandis* and more distantly to *C. pantherinus*. All three of these species share a superficial resemblance to members of the genus *Egernia*. In particular, *C. rubicundus* resembles *E. pilbarensis*, which is also endemic to rocky habitats in the Pilbara.

Paratypes

North-west Division (W.A.): Daniels Well (17252); Tambrey (20234-5); Cockeraga River (37706); Marble Bar (11340). All in the Western Australian Museum.

CTENOTUS HELENAE

Partial Re-description

Snout-vent length (mm): 42-95 (N 24, mean 73.2). Length of appendages (% SVL): foreleg 19-28 (N 24, mean 23.7), hindleg 34-48 (N 23, mean 40.4), tail 200-235 (N 7, mean 216).

Nasals usually separated, touching in one specimen (N 23). Prefrontals usually forming a median suture, just touching in one specimen (N 23). Supraciliaries 6-8 (N 23, mean 7.2), fourth to penultimate markedly smaller than others. Palpebrals 9-13 (N 22, mean 10.7). Nuchals 2 or 3 (N 23, mean 2.5). Midbody scale rows 26-32 (N 22, mean 29.4). Lamellae under fourth toe 17-25 (N 23, mean 21.7).

REFERENCE

STORR, G.M. (1975)—The genus *Ctenotus* (Lacertilia, Scincidae) in the Kimberley and North-west Divisions of Western Australia. *Rec. West. Aust. Mus.* 3: 209-243.

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SEVEN NEW GEKKONID LIZARDS FROM WESTERN AUSTRALIA

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ABSTRACT

Two new subspecies and five new species of gecko are described from northern Western Australia, viz. *Crenadactylus ocellatus naso*, *C. o. rostralis*, *Diplodactylus mcmillani*, *D. wombeyi*, *D. fulleri*, *Gehyra nana* and *G. xenopus*.

INTRODUCTION

The terminology in the following descriptions is generally that of Kluge (1967), except that his 'anterior nasal' is here called 'prenasal'. Contrary to Bustard's usage (1965), my counts of subapical lamellae in *Gehyra* do not include the distal azygous scale on the expanded pad of the fourth toe.

All cited specimens are lodged in the Western Australian Museum.

NEW TAXA

CRENADACTYLUS OCELLATUS NASO SUBSP. NOV.

Holotype

R56206 in Western Australian Museum, collected on 2 November 1976 by Messrs L.A. Smith and R.E. Johnstone at Crystal Creek, Western Australia, in 14° 30′S, 125° 47′E.

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Diagnosis

A striped subspecies of *C. ocellatus*; distinguishable from *C. o. rostralis* by rostral entering nostril, and from *C. o. horni* by flatter head, longer snout, shallower rostral (3.8 or more times as wide as deep, vs 3.8 or less times as wide as deep), more numerous internasals (3-4, vs 0-2), more numerous interorbitals (usually more than 24, vs usually fewer than 24), and more numerous loreals (12 or more, vs 11 or fewer).

Distribution

Subhumid northwest Kimberley, including Heywood Island, in *Triodia* growing on sandstone.

Description

Snout-vent length (mm): 26-31 (N 9, mean 28.1). Tail (% SVL): 68-100 (N 4, mean 88).

Rostral quadrangular, 3.8-5.0 (N 9, mean 4.3) times as wide as deep; median groove extending down 0-30% of scale. Nostril surrounded by first labial, rostral, two supranasals (anterior larger), and 2-3 (N 9, mean 2.9) postnasals. Internasals 3-4 (N 9, mean 3.2). Interorbitals 22-29 (N 8, mean 26.1). Loreals 12-17 (N 8, mean 13.7). Upper labials 9-10 (N 7, mean 9.3), 7-9 (N 8, mean 7.9) to middle of eye. Preanal pores 2 or 3 on each side, forming a continuous curving series (bowed slightly forwards); each pore located in notch at rear of squarish scale, scales increasing in size towards midline.

Dorsally and laterally pale olive brown, with 5 pale longitudinal stripes, each edged with dark brown: vertebral stripe from nape to base of tail, very slightly paler than ground colour and thus barely discernible; white dorso-lateral line from snout to middle of tail; wide, slightly wavy midlateral stripe from eye and angle of mouth to base of tail, partly interrupted by hindleg, somewhat paler than ground colour and thus more conspicuous than vertebral stripe. Labials blotched with dark brown. Under surface white, usually dotted sparsely with brown.

Remarks

This gecko was found in the same tussocks of spinifex as *Diplodactylus mcmillani* but seemed to be much less plentiful than that species (L.A. Smith, pers. comm.).

For description and distribution of the populations of *C. ocellatus* from south of the Kimberley Division, see Dixon & Kluge (1964). Their segments

3 and 5 comprise the striped subspecies *C. o. horni* (Lucas & Frost) of arid Western Australia and Central Australia, and segments 1, 2 and 4 the spotted subspecies *C. o. ocellatus* (Gray) of southwestern Western Australia.

Paratypes

Kimberley Division: Crystal Creek, Port Warrender (56185-7); Mitchell Plateau in 14°57′S, 126°00′E (43220-1, 43224); Heywood I. (41373-4).

CRENADACTYLUS OCELLATUS ROSTRALIS SUBSP. NOV.

Holotype

R32154 in Western Australian Museum, collected in April 1968 by Mr W.H. Butler at Geikie Gorge, Western Australia, in 18°07′S, 125°39′E.

Diagnosis

A striped subspecies of *C. ocellatus*, distinguishable from all other subspecies by prenasal widely excluding rostral from nostril.

Plate 1: Holotype of *Crenadactylus ocellatus rostralis.*

Fig. 1: Map of Kimberley Division, Western Australia, showing location of specimens of *Crenadactylus ocellatus naso* (solid circles) and *C. o. rostralis* (hollow circles).

Distribution

Arid and semiarid south and east Kimberley, north to the Napier Range, Geikie Gorge and Lake Argyle, in *Triodia* growing on stony hills and gravelly plains.

Description

Snout-vent length (mm): 22-32 (N 18, mean 26.7). Tail (% SVL): 84-100 (N 10, mean 93).

Rostral quadrangular, 3.2-5.0 (N 18, mean 4.0) times as wide as deep; median groove extending down 0-20% of scale. Nostril surrounded by first labial, a large prenasal, a supranasal, and 2-3 (N 14, mean 2.7) postnasals. Internasals 1-3 (N 16, mean 2.1). Interorbitals 19-23 (N 13, mean 21.8). Loreals 10-14 (N 16, mean 12.2). Upper labials 8-11 (N 14, mean 9.1), 6-9 (N 16, mean 7.4) to middle of eye. Preanal pores as in *C. o. naso*.

Coloration at Lake Argyle much the same as in *C. o. naso*, except for the dorsolateral stripe being no paler or narrower than the midlateral stripe; but elsewhere the pale stripes are so wide as to leave no ground colour and to be separated only by their dark margins.

Coloration elsewhere. Head brown. Back and sides pale olive brown with 4 brown longitudinal stripes: on each side a paravertebral back to middle of tail, diverging from its opposite number on nape and occiput and terminating above eye; and an upper lateral extending back to middle of tail and forward to snout. Lower labials blotched with dark brown. Lower surface olive white with up to 5 indistinct longitudinal brown stripes: a medioventral, and on each side two lateroventrals.

Remarks

There is considerable geographic variation. Colour pattern in the north approaches that of *C. o. naso*; in the south it approaches that of *C. o. horni*. In the west (Napier Range and Mt Anderson) the head is almost as flat and the snout almost as long as in *C. o. naso*; in the far southeast (Wolf Creek) they are much the same as in *C. o. horni*, and the number of internasals (1-2) is fewer than elsewhere (2-3).

Paratypes

Kimberley Division: Lake Argyle (56441-5); Napier Range (26824-6); Mt Anderson (27388-92); 10 km E of Margaret River HS (46115); 45 km SE of Halls Creek (23058); near Wolf Creek Meteorite Crater (46058-9).

DIPLODACTYLUS MCMILLANI SP. NOV.

Holotype

R43230 in Western Australian Museum, collected by Messrs L.A. Smith and R.E. Johnstone on 20 February 1973 on the Mitchell Plateau, Western Australia, in 14°57′S, 126°00′E.

Diagnosis

A large, short-tailed, moderately stout *Diplodactylus* of the *michaelseni* group with prenasal as large or nearly as large as first upper labial and broadly excluding rostral from nostril. Further distinguishable from *D. taeniatus* and *D. michaelseni* by more numerous nasals (6-8, usually 7; vs 3-6, mostly 4 or 5) and in lacking a pale streak along canthus rostralis.

Distribution

Subhumid northwest Kimberley, in *Triodia* growing on sandstone.

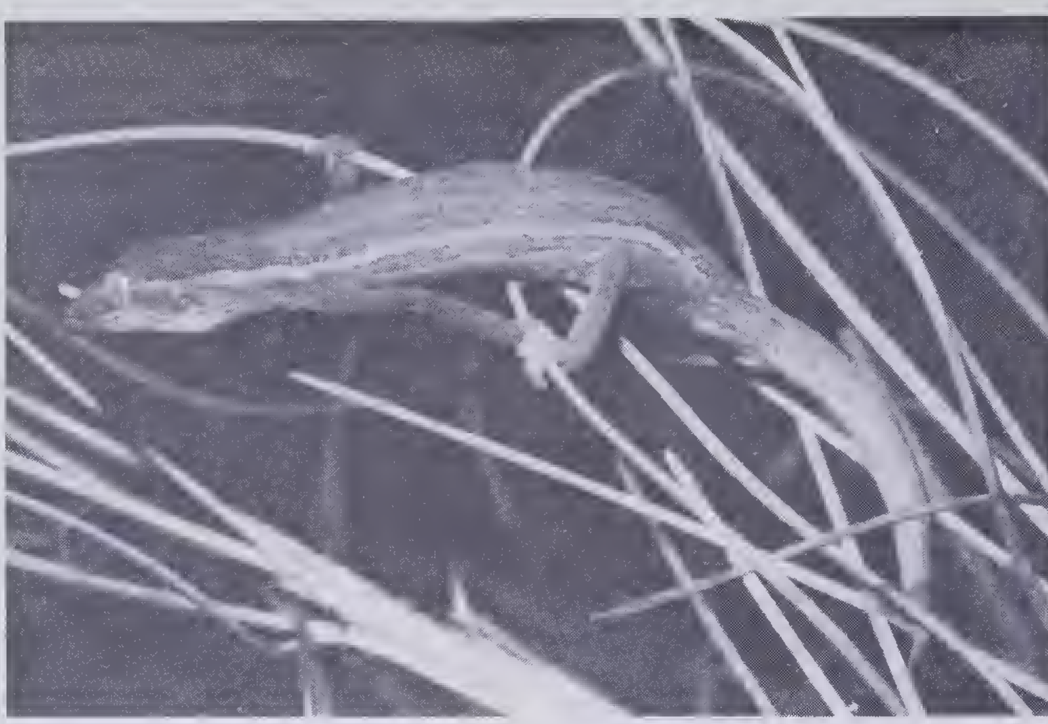

Plate 2: A *Diplodactylus mcmillani* from Crystal Creek, photographed by R.E. Johnstone.

Description

Snout-vent length (mm): 37-53 (N 39, mean 44.4). Tail (% SVL): 52-74 (N 29, mean 61.0).

Rostral hexagonal or hemi-elliptic, 2.4-3.8 (N 38, mean 2.9) times as wide as deep; median groove extending down 25-55% of scale. Nostril surrounded by first labial, prenasal, 2-3 (usually 2) supranasals, and 3-5 (usually 4, rarely 5) postnasals. Internasals 0-5 (N 28, mean 2.5). Interorbitals 29-34 (N 18, mean 31.8). Loreals 15-20 (N 27, mean 17.6). Upper labials 12-17 (N 39, mean 13.8), 9-14 (N 37, mean 11.2) to middle of eye. Lamellae under fourth toe 6-9 (N 26, mean 7.5), distal 3-6 (N 26, mean 4.1) undivided.

Dorsally and laterally olive grey with or without 4 lines of dark brown dots along back (presumably the margins of obsolete stripes). White upper lateral stripe, edged with a series of dark brown dots, from eye to end of tail. Greyish-white dark-edged ventrolateral stripe from foreleg to hindleg. Faint dark-edged dorsolateral stripe and faint midlateral line usually just discernible (in 37696 the stripes are so suffused with ground colour that they are less discernible than their dark margins).

Remarks

This species is named after Mr R.P. McMillan, an Honorary Associate of the Western Australian Museum and generous donor of many reptile and other specimens.

In its size, relatively robust habit, short tail, coloration, less flattened facial and dorsal granules, and high number of upper labials, loreals and interorbitals, *D. mcmillani* is unexpectedly more like the distant *D. michaelseni* than adjacent *D. taeniatus* (which reaches south and east Kimberley). For description and distribution of *D. michaelseni* and *D. taeniatus*, see Storr & Ford (1967).

Paratypes

Kimberley Division: Crystal Creek, Port Warrender (43039-41, 43064-5, 43076-8, 56188-205); Mitchell Plateau in 14°40′S, 125°40′E (43125-6) and 14°57′S, 126°00′E (43222-3, 43225-9); King Edward River (presumably in 14°52′S, 126°12′E) (28186); Old Theda (57323); Drysdale River National Park in 15°03′S, 126°45′E (50536); Manning Creek (47696).

Fig. 2: Map of Kimberley Division, Western Australia, showing location of specimens of *Diplodactylus mcmillani*.

DIPLODACTYLUS WOMBEYI SP. NOV.

Holotype

R36747 in Western Australian Museum, collected on 18 June 1970 by Mr J.C. Wombey on the Cockeraga River, Western Australia, in 22°05′S, 118°48′E.

Diagnosis

A *Diplodactylus* of the *stenodactylus* group with moderately large apical plates and rostral entering nostril; apices of digits more strongly dilated than in other members of group, and subdigital granules larger, flatter and mostly arranged in pairs. Most like *D. alboguttatus* but lacking large white spots on flanks and limbs.

Distribution

Chichester Range, southern Pilbara.

Description

Snout-vent length (mm): 20-49 (N 6, mean 36.2). Tail (% SVL): 77-100 (N 5, mean 87).

Plate 3: A paratype of *Diplodactylus wombeyi*.

Rostral quadrangular, 2.0-3.1 (N 6, mean 2.6) times as wide as deep; median groove extending down 30-45% of scale. Nostril surrounded by first labial, rostral, 1-2 (mostly 2) supranasals, and 2-3 postnasals. Internasals absent, except in one specimen with one. Interorbitals 26-33 (N 6, mean 29.2). Loreals 14-18 (N 6, mean 15.8). Upper eyelid differentiated. Upper labials 9-11 (N 6, mean 10.7), 9-10 (mean 9.7) to middle of eye. Dorsal granules about as large as ventrals. Scales between cloaca and caudal constriction much larger than other caudals. One preanal pore on each side. Cloacal spur comprising 1-4 (usually 2) small spinose scales. 'Lamellae' under fourth toe 10-13 (N 6, mean 11.5).

Dorsal and upper lateral surfaces pale to moderately dark reddish brown with variable dark reddish brown markings; latter usually in form of irregular broken cross-bands, sometimes in form of reticulum. Canthus rostralis and upper labials sometimes whitish. Sides of body and upper surface of limbs usually dotted white.

Remarks

This species is named after Mr John C. Wombey of the CSIRO Division of Wildlife Research, who collected the entire type series. Four of the specimens were found under rocks, and one under a sheet of iron.

Paratypes

North-west Division: Cockeraga River (36597, 37061-4).

DIPLODACTYLUS FULLERI SP. NOV.

Holotype

R31331 in Western Australian Museum, collected in May 1968 by Mr M. De Graaf at 5 km W of the mouth of Savoury Creek, Western Australia, in 23°20'S, 122°40'E.

Diagnosis

A large robust *Diplodactylus* of the *stenodactylus* group with very small apical plates and rostral entering nostril. Most like *D. maini* but larger and with shorter tail, more numerous loreal granules and postanal tubercles, and fewer subdigital and interorbital granules.

Distribution

Arid interior of Western Australia, in vicinity of Lake Disappointment.

Plate 4: Holotype of *Diplodactylus fulleri.*

Description (of holotype, the only available specimen)

Snout-vent length (mm): 51. Tail (% SVL): 63.

Rostral quadrangular, 2.3 times as wide as deep; median groove extending half-way down scale. Nostril surrounded by first labial, rostral, 2 supranasals (anterior very large and forming long median suture with its opposite number), and 2-3 postnasals. No internasal. Interorbitals 23. Loreals 14-15. Upper labials 9, 8 back to middle of eye. Dorsal granules slightly larger than ventrals but much smaller than caudals, which are moderately large, rectangular, and strongly arranged in whorls. No preanal pores. Five large postanal tubercles. 16-17 transverse series of conical granules under fourth toe.

Back and sides pale reddish brown with an indistinct reticulum of darker reddish brown. Tail dark reddish brown, irregularly cross-banded with pale reddish brown. Under surface whitish.

Remarks

This gecko is named after Mr Phillip J. Fuller, who has donated numerous reptiles to the Western Australian Museum.

GEHYRA NANA SP. NOV.

Holotype

R28214 in Western Australian Museum, collected on 8 June 1965 by Dr A.K. Lee at the King Edward River, Western Australia, presumably in 14°52′S, 126°12′E.

Diagnosis

A small, spotted, reddish *Gehyra* with divided lamellae on subapical pads. Of the Kimberley species of *Gehyra*, most like *pilbara* but distinguishable by its smaller size, longer snout, less deep head, fewer subapical lamellae (mostly 6 or 7 under fourth toe, vs mostly 7 or 8), postnasal usually smaller (rather than larger) than posterior supranasal, scales above second and third labials not so greatly enlarged, absence of dark longitudinal streaks on side of head (*pilbara* has one through top of eye and one through middle of eye), pale dorsal spots smaller than dark dorsal spots (in *pilbara* they are absent or larger), and dark spots on tail not so clearly aligned into narrow cross-bands.

Plate 5: Holotype of *Gehyra nana.*

Distribution

North Kimberley, south to the Prince Regent River, Drysdale River National Park and Lake Argyle; also offshore from the Sir Graham Moore Is southwest to Melomys I.

Description

Snout-vent length (mm): 23-54 (N 95, mean 42.8). Tail (% SVL): 87-124 (N 28, mean 109.3).

Rostral 1.3-2.1 (N 90, mean 1.8) times as wide as deep; top very slightly to moderately dented; median groove extending down 30-65% of scale. Nostril surrounded by rostral, first labial, postnasal and two supranasals (anterior much the larger). Internasals 0-3 (N 91, mean 1.0). Upper labials 7-10 (N 91, mean 8.1). Lamellae on each side of subapical pad 5-8 (N 94, mean 6.6), usually in medial contact with their opposite number, but in 24% of specimens proximal 1-2 pairs of lamellae separated by a granule. Preanal pores 13-22 (N 30, mean 18.1); 14-16 femoral pores on each side of three Prince Regent River specimens.

Fig. 3: Map of Kimberley Division, Western Australia, showing location of specimens of *Gehyra nana*.

Dorsally and laterally reddish brown. Dorsal surfaces (including limbs) spotted with dark reddish brown and pinkish white; pale spots usually smaller and more numerous than dark spots. Spots on back and tail tending to be transversely elongate and to be aligned in transverse rows, a row of dark spots alternating with one or two rows of pale spots. Rostral and upper labials dark brown, except for their pale lateral margins. Under surfaces white.

Paratypes

Kimberley Division: Anjo Point (44075); Pago (43559-62); Kalumburu (27750-2, 27757-62, 56639); Crystal Creek (14°30′S, 125°47′E) (43062-3, 43079-81, 56167, 56211-2); Mitchell Plateau in 14°52′S, 125°50′E (40469-71, 43147, 43157); 2 km E of Mitchell River Falls (56357); King Edward River (28187, 28213, 28215-8); Prince Regent River Reserve in 15°07′S, 125°33′E (46883-4), in 15°20′S, 124°56′E (46831-2, 46837-8), in 15°25′S, 125°37′E (46710), and in 15°28′S, 125°59′E (46668-72, 46706-7); Drysdale River National Park (50330-2, 50400-3, 50414, 50465, 50507, 50675, 50783, 50797, 50802, 50811); 13 km NNE of Argyle Downs (42704); Sir Graham Moore Is (44051-5, 44065-6); South-west Osborne I. (44110); Bigge I. (41455); Boongaree I. (44088); St Andrew I. (44144); Augustus I. (40441); Darcy I. (41391); Heywood I. (41371-2); Champagny I. (41428-31); Kingfisher I. (44157-65); Melomys I. (44195).

GEHYRA XENOPUS SP. NOV.

Holotype

R56429 in Western Australian Museum, collected on 6 November 1976 by Mr R.E. Johnstone in a sandstone cave near the Port Warrender road crossing of the King Edward River, Western Australia, in 14°52′S, 126°12′E.

Diagnosis

A very large, spotted, greyish *Gehyra* with flat head, large eyes and long, somewhat retroussé snout (all making its profile crocodilian); subapical pads with divided lamellae, of which only the distal pairs are in median contact, the remainder being separated by a wedge-shaped patch of granules.

Distribution

Massive sandstone of subhumid northwest Kimberley, from Kalumburu southwest to the Prince Regent River; also offshore from Borda I. southwest to Champagny I.

Plate 6: A *Gehyra xenopus* from Crystal Creek, photographed by R.E. Johnstone.

Description

Snout-vent length (mm): 39-79 (N 67, mean 68.3). Tail (% SVL): 106-130 (N 38, mean 116.4).

Supranasal region swollen. Rostral 1.7-2.3 (N 63, mean 1.9) times as wide as deep; top slightly to strongly dented medially; median groove extending down 10-60% of scale. Nostril surrounded by rostral, first labial, postnasal and two supranasals (anterior much the larger). Internasals 1-3 (N 64, mean 1.7). Upper labials 8-11 (N 62, mean 9.3). Lamellae on each side of subapical pad 8-11 (N 66, mean 9.6), of which the distal 2-5 pairs (N 65, mean 3.7) are medially contiguous, the remainder separated by 1-4 granules (the gap widening towards base of toe). Preanal pores 9-18 (N 28, mean 13.0).

Upper surface greyish brown or dark brown, spotted with brownish white and flecked with blackish brown. Spots on head small; spots on back fairly large and tending to be dark-edged and arranged transversely. Lower lips and chin brown. Rest of under surface white.

Fig. 4: Map of Kimberley Division, Western Australia, showing location of specimens of *Gehyra xenopus*.

Paratypes

Kimberley Division: Kalumburu (27753-5); Crystal Creek in 14°30′S, 125°47′E (43042-3, 43069-70, 56163-6, 56180-1); 2 km E of Mitchell River Falls (43177, 56356, 56417); King Edward River in 14°52′S, 126°12′E (56428, 56430); Prince Regent River Reserve in 15°19′S, 125°35′E (46775-7, 46779-80, 46796-8), in 15°20′S, 124°56′E (46818-9, 46822, 46830), and in 15°49′S, 125°33′E (46986-7); Borda I. (41488); South-west Osborne I. (44107-9, 44111, 44126); Katers I. (41468-70); Wollaston I. (41463); Boongaree I. (44086-7); Bat I., off Cape Brewster (44077); St Andrew I. (44143); Uwins I. (44136); Augustus I. (41283-4); Darcy I. (41392-6); Byam Martin I. (44152-3); Champagny I. (41432-3).

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Cover: Scissor-tail Sergeant (*Abudefduf sexfasciatus*), a colourful species of damselfish which inhabits northern coral reefs of Western Australia and is also distributed throughout the tropical Indo-West Pacific region.

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A REVIEW OF THE ARCHERFISHES (FAMILY TOXOTIDAE)

GERALD R. ALLEN*

[Received 16 July 1977. Accepted 27 September 1977. Published 31 December 1978.]

ABSTRACT

The six species of *Toxotes* which constitute the fish family Toxotidae are reviewed. This group, commonly known as archerfishes, is renowned for its ability to knock down insects from overhanging vegetation with squirts of water ejected from the mouth. The habitat consists of mangrove-lined estuaries and freshwater streams of southeast Asia, northern Australia and the islands of the western Pacific in the Indonesia-New Guinea-Philippines region. A brief diagnosis, illustrations, and tables of counts are presented for each of the following species (approximate distributions indicated in parentheses): *blythi* (Burma), *chatareus* (widespread from India eastward to northern Australia and New Guinea), *jaculator* (widespread from India to the New Hebrides), *lorentzi* (northern Australia and New Guinea), *microlepis* (Thailand, Sumatra, and Borneo), *oligolepis* (eastern Indonesia, New Guinea, and northern Australia). A generic diagnosis and key to the species are also provided.

INTRODUCTION

The perciform family Toxotidae is comprised of a single genus, *Toxotes*, which contains six species: *T. blythi* Boulenger, *T. chatareus* (Hamilton), *T. jaculator* (Pallas), *T. lorentzi* Weber, *T. microlepis* Günther, and *T. oligolepis* Bleeker. These fishes exhibit one of nature's most remarkable feeding adaptations which has been the subject of papers by Zolotnisky (1902), Gill (1909), Smith (1936 and 1945), and Allen (1973). When suitable prey, usually a small insect, is sighted the fish rises to the surface and ejects an aqueous 'bullet' by forcefully compressing the gill covers, thus propelling a jet of water from the mouth. The aim is uncannily accurate to a

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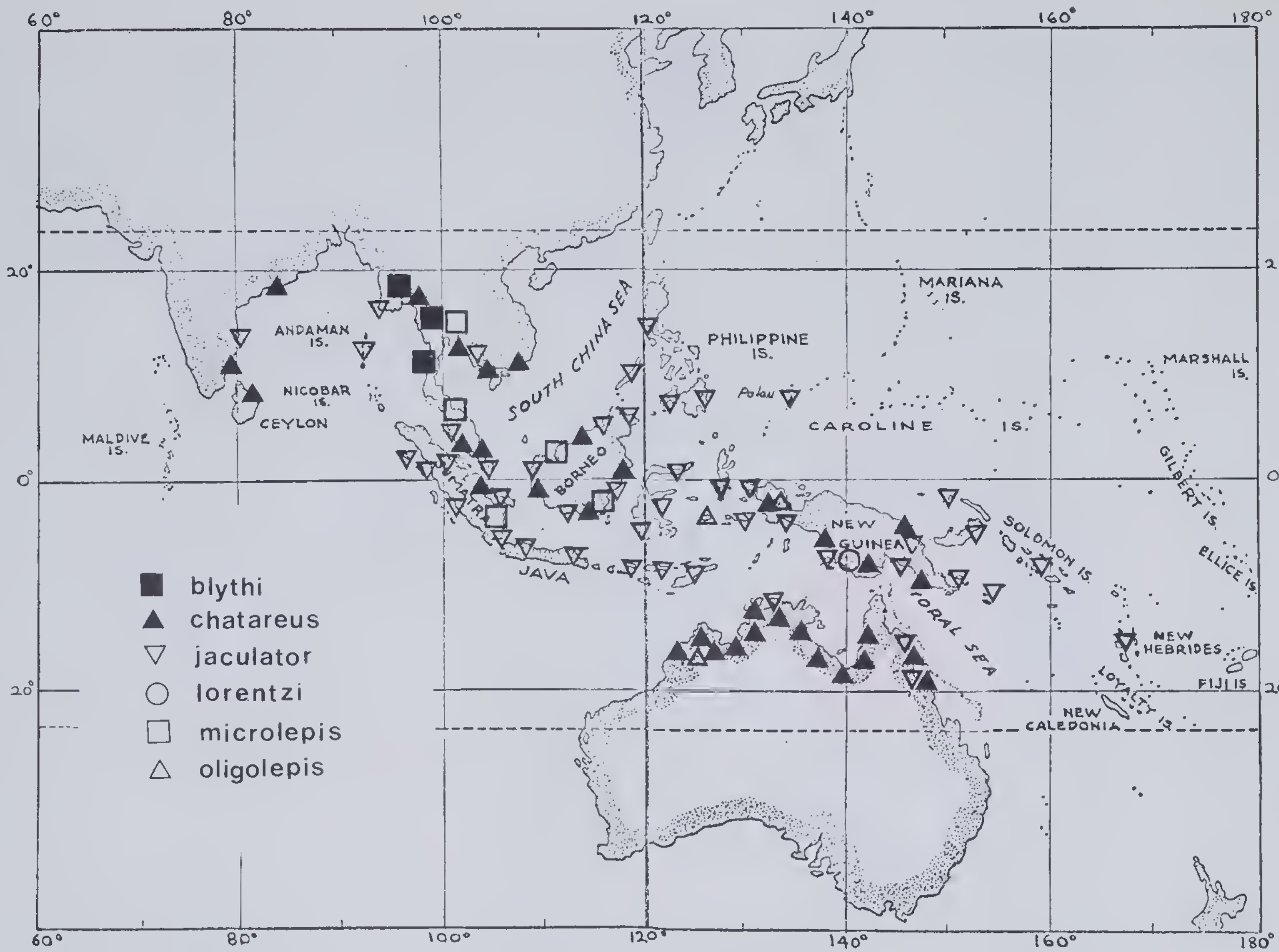
distance of several feet and in most cases the victim is knocked into the water and devoured. The special adaptation of the oral cavity was described in detail by Smith (1945). According to his description the palate contains a deep longitudinal groove which is converted to a tube when the tongue is pressed against the roof of the mouth. When the gill covers are suddenly compressed water is forced from the pharynx into this palatine canal, and with the tip of the tongue acting as a valve, the flow of water, under pressure, is regulated.

Toxotes chatareus and *T. jaculator* are the most widespread members of the family occurring over a large area extending from Sri Lanka and the east coast of India eastward through the tropics to the Palau Islands, New Guinea, Solomon Islands, and the New Hebrides. A summary of the distribution of the six species is shown in **Map 1**. *T. jaculator* is normally found in brackish water in the vicinity of mangroves; the other species are frequently encountered in freshwater and several of these probably breed there. However, there is little published information on the reproductive habits. According to Smith (1945) the newly hatched young of *T. jaculator* are seen in the Bangkok region during May and by the first week of July a total length of 13 to 15 mm is attained. The maximum length recorded for *Toxotes* is approximately 40 cm (see remarks section for *T. chatareus*) and in some localities they are netted for food or caught by sport anglers.

The stimulus for the present study was my initial lack of success in identifying a species of *Toxotes* recently collected in the extreme northern section of Western Australia. It did not correspond with any of the species currently recognised from Australia, nor with several others which are generally accepted as junior synonyms. Eventually it was identified as *T. oligolepis*, a poorly known species described by Bleeker (1876) from the Molucca Group of Indonesia.

The family has not been reviewed previously on a comprehensive basis, although Fowler and Bean (1929), and Weber and de Beaufort (1936) included all the species except *T. blythi* in their respective monographs of the fishes of the Indo-Australian Archipelago and the Philippine Islands. In addition, Bleeker (1876 and 1877) reviewed the known species and provided illustrations of *chatareus*, *jaculator*, *microlepis*, and *oligolepis*. Sanders (1934) described a fossil species, *Toxotes beauforti*, from the early Tertiary of Central Sumatra. It is remarkably similar to modern *Toxotes* except for the possession of six instead of four or five dorsal spines.

Fowler and Bean (1929) gave a brief account of *'Toxotes' squamosus* Hutton from New Zealand, but Weber and de Beaufort (1936) have shown



Map 1: Distribution of *Toxotes*.

that this species is a bramid and therefore unrelated. Bleeker (1876) had previously included it in a new monotypic genus, *Amblytoxotes.* Whitley (1968) listed this species as *Lepidotus squamosus* in the family Lepidotidae. *'Toxotes' antiquus* Agassiz is a fossil species, which according to Eastman (1914) is not a toxotid, but rather a labrid, which he placed in a new genus, *Gillidia.*

During the present study *Toxotes* were observed in the field at the Palau Islands (Micronesia), Madang (New Guinea), Cairns (Queensland), Northern Territory and the far north of Western Australia. In addition, specimens were examined at the following institutions: Australian Museum, Sydney (AM); British Museum (Natural History), London (BMNH); Fisheries Office, Department of Agriculture, Stock, and Fisheries, Konedobu, Papua (DASF); Museum National d'Histoire Naturelle, Paris (MNHN); Rijksmuseum van Natuurlijke Histoire, Leiden (RMNH); National Museum of Natural History, Smithsonian Institution, Washington, D.C. (USNM); Western Australian Museum, Perth (WAM); and Zoologisch Museum, Universiteit van Amsterdam (ZMA).

Proportional measurements were taken with dial calipers to the nearest 0.5 mm. The height of the tallest dorsal spine was measured from the level of the basal articulation. The interorbital width refers to the least width, measured between the anterior portion of the eyes. The caudal peduncle depth is the least depth of the tail base. The abbreviation SL refers to standard length, measured from the tip of the upper jaw to the tail base, as indicated by the line of flexure.

TAXONOMY

GENUS *TOXOTES* CUVIER

Toxotes Cuvier, 1817: 338 (type species, *Sciaena jaculatrix* Pallas by monotypy).

Trompe Gistel, 1848: 109 (type species, *Sciaena jaculatrix* Pallas; proposed as a replacement name for *Toxotes* Cuvier).

Diagnosis

Dorsal rays IV to VI,11 to 14; anal rays III,15 to 18; pectoral rays 11 to 15; scales in lateral line 25 to 47; horizontal scale rows above lateral line 3 to 7, below lateral line 8 to 15; gill rakers on lower limb of first branchial arch 2 to 8. Greatest body depth 1.8 to 2.5, head length 2.3 to 3.2, both in standard length. Snout 3.2 to 4.2, eye 2.9 to 4.9, interorbital 2.7 to 3.8, caudal peduncle depth 2.3 to 3.4, pectoral fin length 1.0 to 1.8, pelvic fin length 1.8 to 2.5, all in head length. Penultimate dorsal spine usually the longest, 1.3 to 2.3 in head length. Colour in preservative generally uniform tan or brown, or with a pattern consisting of a series of dark bars, large spots, or irregular stripes on a light ground.

Remarks

Gistel (1848) did not give a reason for his substitution of *Trompe* for *Toxotes*. The latter name has otherwise been generally accepted as the valid generic designation since the description by Cuvier.

KEY TO THE SPECIES OF *TOXOTES*

1a. Dorsal spines 4; series of 4 or 5 black bars on upper sides (widespread, India to the New Hebrides) ... ... *T. jaculator*

1b. Dorsal spines normally 5; colour variable with either series of bars, spots, or irregular stripes on sides, or colour uniform without markings 2

2a. Lateral line scales usually less than 38 3

2b. Lateral line scales usually 39 to 50 6

3a. General coloration uniform tan or brown without markings (may have about 10 faint, narrow bars on upper sides in life); pectoral rays usually 14 (occasionally 15); lateral line running in a straight course; gill rakers on lower limb of first branchial arch 2 to 4 (usually 3) (northern Australia and New Guinea) ... ... *T. lorentzi*

3b. General coloration consisting of a series of dark bars or relatively large spots on a light ground; pectoral rays usually 13 (rarely 11, 12, or 14); lateral line arched over pectoral region; gill rakers on lower limb of first branchial arch 5 to 8 4

4a. Colour pattern consisting of a series of 6 or 7, alternating large and small black spots (except in small juveniles, see Plates 2-6) (widespread, India to New Guinea and N. Australia ... ... *T. chatareus*

4b. Colour pattern consisting of a series of 4 or 5, wedge-shaped black bars or saddles without intervening small spots (see Plates 10 and 11) (Molucca Islands, W. New Guinea, Kimberley region of W. Australia, and possibly Philippine Islands ... ... *T. oligolepis*

5a. Colour pattern consisting of a series of irregular horizontal dark stripes on a light ground (see Plate 1) (Burma) ... ... *T. blythi*

5b. Colour pattern consisting of a series of 4 or 5 rounded dark spots along back (see Plate 9) (Thailand, Sumatra, and Borneo) ... ... *T. microlepis*

TOXOTES BLYTHI BOULENGER

(Plate 1; Tables 1 and 2)

Toxotes blythi Boulenger, 1892: 143 (type locality: Tenasserim, Burma).

Toxotes microlepis (non Günther) Day, 1875: Plate 30, Fig. 1 (Irrawaddi River, Burma).

Diagnosis

Dorsal rays V,12 to 14; anal rays III,16 to 18; pectoral rays 13; scales in lateral line 41 to 47; horizontal scale rows above lateral line 5 to 6, below lateral line 14 to 15; gill rakers on lower limb of first branchial arch 2 to 6 (usually 5 or 6). Greatest body depth 2.2 to 2.3, head length 2.6 to 2.9, both in standard length. Snout 3.2 to 3.6, eye 3.1 to 3.5, interorbital 3.0 to 3.4, caudal peduncle depth 2.6 to 2.9, pectoral fin length 1.3 to 1.5, pelvic fin length 1.9 to 2.0, all in head length. Fourth dorsal spine the longest, about 1.5 in head length.

Colour in alcohol: ground colour yellowish, but with silvery metallic sheen; a series of dark brown to blackish spots and longitudinal markings on sides and fins (see Plate 1); dorsal and anal fins dusky to yellowish; caudal, pelvic, and pectoral fins yellowish.

Plate 1: *Toxotes blythi*, paralectotype, 91.5 mm SL, Tenasserim, Burma.

Distribution

T. blythi is known only from the Andaman Sea drainage of Burma between the Irrawaddi River system and Tenasserim. The latter location represents the type locality and is on the upper part of the Malay Peninsula, about 250 km southwest of Bangkok.

Remarks

Day's (1875-8) illustration of *T. microlepis* from the Irrawaddi River actually represents *T. blythi.* The colour pattern of the latter species is very different from other *Toxotes* and it is difficult to understand the basis for Day's confusion, except for the similarity in scale size.

Apparently there are very few specimens of *T. blythi* in museum collections. I have examined the syntypes, 7 specimens, 61 to 131 mm SL which are deposited at BMNH (register number 1891.11.30.20-26). The specimens are in good condition and the largest is here designated as the lectotype. In addition, a specimen, 74 mm SL, from Kokurit, Burma was examined at RMNH.

TABLE 1

Fin ray and gill raker counts for species of *Toxotes*.

	Dorsal Rays							Anal Rays				Pectoral Rays					Lower Limb Gill Rakers						
	IV	V	VI	11	12	13	14	15	16	17	18	11	12	13	14	15	2	3	4	5	6	7	8
blythi		8			3	4	1		4	3	1			8			1			2	5		
chatareus	2	93	1		33	41	22	10	65	20		1	7	82	6					2	65	29	
jaculator	37	1		2	29	7		2	28	8			3	35						2	18	18	
lorentzi		13				3	10	1	10	2					10	3	1	11	1				
microlepis		21				14	7	2	7	12				9	11	1					11	9	1
oligolepis	1	39			26	14		24	9	4			2	35	3						5	27	7

TABLE 2

Lateral line scale counts for species of *Toxotes*.

	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
blythi																	2	1	1	2	1		1
chatareus					18	18	13	12	14	7	7	5	1										
jaculator		8	11	7	10	2																	
lorentzi															4	2	1	2		2	1	6	3
microlepis																		5	3	3	2		
oligolepis	1			1	5	10	18	3	2														

TOXOTES CHATAREUS (HAMILTON)

(Plates 2-6; Tables 1-3)

Coius chatareus Hamilton, 1822: 101 and 370 (type locality: mouth of Ganges River, India).

Toxotes carpentariensis Castelnau, 1878: 47 (type locality: Norman River, Gulf of Carpentaria).

Toxotes dorsalis Whitley, 1950: 242 (type locality: Flinders River, near Hughenden and Richmond, Queensland).

Toxotes ulysses Whitley, 1950: 243 (type locality: Townsville, Queensland).

Diagnosis

Dorsal rays IV to VI (usually V),12 to 14; anal rays III,15 to 17 (usually 16); pectoral rays 11 to 14 (usually 13); scales in lateral line 29 to 37 (usually 29 to 32); horizontal scale rows above lateral line 3 to 5, below lateral line 9 to 11; gill rakers on lower limb of first branchial arch 5 to 7. Greatest body depth 1.9 to 2.4, head 2.5 to 3.0, both in standard length. Snout 3.3 to 4.1, eye 3.5 to 4.9, interorbital 2.7 to 3.7, caudal peduncle depth 2.4 to 3.2, pectoral fin length 1.0 to 1.3, pelvic fin length 1.8 to 2.4, all in head length. Fourth dorsal spine usually the longest (sometimes third is the longest), 1.3 to 2.3 in head length.

Colour in alcohol: there is a certain amount of variation in the colour pattern which is related to the developmental stage and geographic location (see **Plates 2-6**). The basic pattern of specimens in excess of about 70 mm SL is as follows: ground colour whitish to dusky grey or tan, sometimes with silvery sheen; a series of 6 or 7 black spots on upper side of body; spinous dorsal fin dusky or blackish; soft dorsal fin dusky or blackish, frequently with pale central band; caudal fin whitish or yellowish to very dusky; anal fin similar to soft dorsal or pale basally grading to blackish on outer half of fin; pelvic fins whitish to yellowish grading to dusky on outer portion; pectoral fins usually pale, but sometimes upper rays dusky, particularly in larger specimens. Nearly all of the specimens from freshwater possess a series of alternating light and dark horizontal bands (approximately one per scale row) on the sides which are of variable intensity, but are usually most prominent on the ventral body region. Several specimens collected in the Kimberley region of Western Australia by J.B. Hutchins are extremely dusky over the entire body, thus obscuring the characteristic spots. According to the collector these fish were normal coloured, but assumed the dusky pattern shortly after death. The juvenile colour pattern is illustrated in Plate 5.

Plate 2: *Toxotes chatareus*, juvenile specimen, 40 mm SL, Parry Creek (freshwater), near Wyndham, Western Australia.

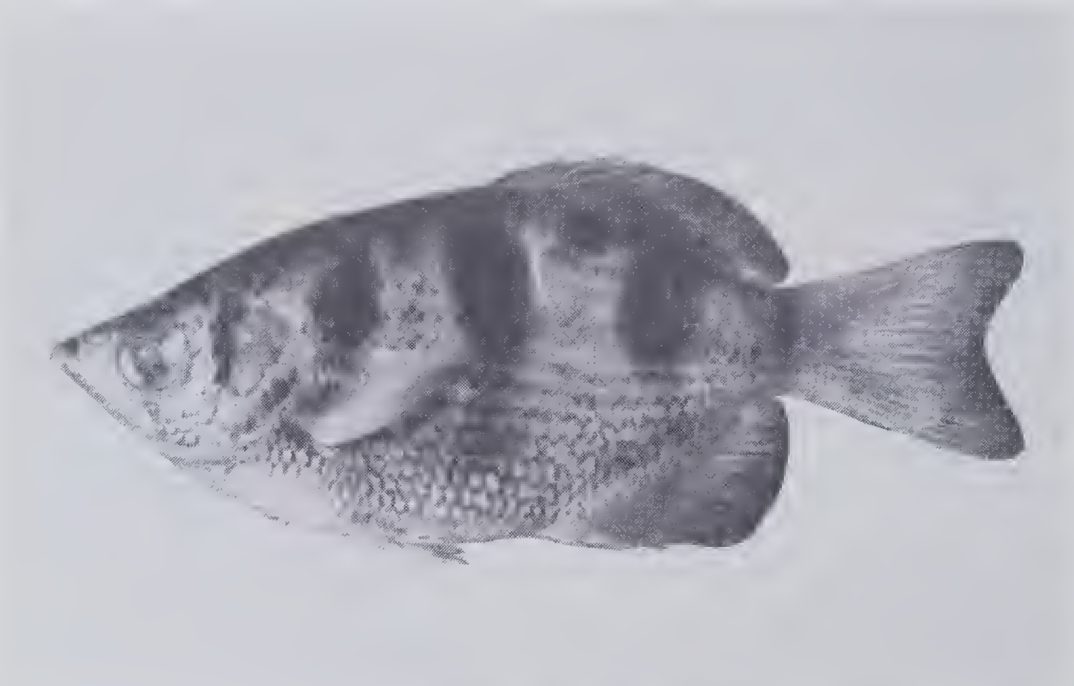


Plate 3: *Toxotes chatareus*, 91 mm SL, Lawley River (freshwater), Western Australia.

Plate 4: *Toxotes chatareus*, 84 mm SL, Behn River (freshwater), Western Australia.

Plate 5: *Toxotes chatareus*, juvenile specimen, 21 mm SL, Cairns, Queensland (brackish water).

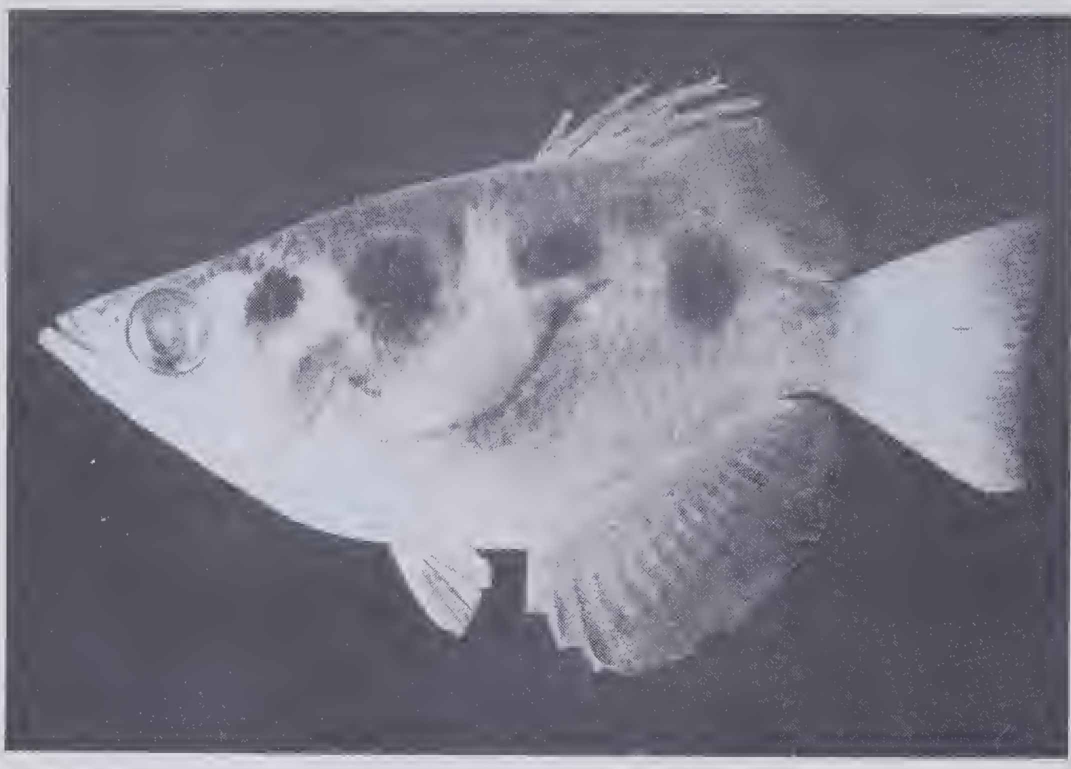


Plate 6: *Toxotes chatareus*, 74 mm SL, Cairns, Queensland (brackish water).

Distribution

T. chatareus has a relatively widespread distribution. Weber and de Beaufort (1936) recorded it from the following localities: India, Malay Peninsula, Thailand, Vietnam, Singapore, Sumatra, Borneo, New Guinea and northern Australia. In addition, Smith (1945) and Munro (1955) recorded it from Burma and Sri Lanka respectively.

The coastal population of *T. chatareus* in northern Australia extends approximately between Derby in Western Australia and Townsville on the Pacific coast of Queensland. Freshwater populations are distributed throughout far northern Australia and New Guinea in river systems flowing into the Timor and Arafura Seas and the Gulf of Carpentaria. I have examined specimens from the following rivers (progressing eastward): *Western Australia* — King Edward, Carson, Lawley, Durack, Pentacost, and Ord; *Northern Territory* — Victoria, Darwin, South Alligator, East Alligator, and Roper; *Queensland* — O'Shannassy, Gregory, Flinders, Saxby, and Archer; *New Guinea* — Bensbach, Morehead, Fly (including Lake Murray), Sepik, and Laloki.

T. chatareus exhibits considerable variation with regard to maximum body depth and dorsal spine structure. These characters are influenced by growth, geographic locality and environmental conditions. Judging from the examination of gonads and the capture of small juveniles, breeding populations are present in both brackish and pure freshwater. On the basis of certain morphological features it seems likely that divergence is occurring amongst the various populations in the Australia-New Guinea region. For example, specimens from freshwater in northern Australia are generally more slender in shape and have a significantly lower spinous dorsal fin composed of relatively weak spines in comparison with specimens from brackish water. The dorsal spine difference was dramatically demonstrated in specimens which I collected from the Victoria River, Northern Territory during October and December 1977. Individuals taken from brackish water near Timber Creek had very robust spines, with the longest of these significantly taller than the overall height of the soft dorsal fin. A subsequent collection from freshwater, approximately 100 km upstream at the Victoria Highway Bridge, yielded specimens which were virtually identical in appearance except the dorsal spines were relatively feeble and the tallest ones were about equal in height to the soft dorsal rays. Perhaps the stronger, taller spines are due to an increased calcium intake amongst fish living in brackish water. *Toxotes* are easily kept in captivity, therefore it would be worthwhile to conduct an experiment to determine the effect of different salinities on the spine morphology. Although the number of New Guinea specimens examined during this study was insufficient, freshwater populations from this region are generally deeper bodied and have a higher spinous dorsal in comparison with their freshwater relatives from northern Australia. A summary of data comparing dorsal spine height and body depth is presented in Table 3.

T. chatareus is capable of penetrating well inland. Lake (1971) reported its occurrence above Riversleigh Station, some 200 km up the Gregory River in northern Queensland. During the present study it was collected from distances ranging up to 175-200 km upstream on the Roper, Edith, and King Rivers. in the Northern Territory. Dr Tyson Roberts (pers. comm.) recently collected it from the Fly River of New Guinea at localities 509 and 859 km upstream from the sea. Specimens as small as 8 mm SL were taken at both locations, thus indicative of a freshwater breeding population. Dr Roberts also collected the largest known *Toxotes*, a specimen of *T. chatareus* 400 mm SL, from the Upper Fly River. The previous record was 270 mm SL reported for *T. chatareus* by Weber and de Beaufort (1936).

T. carpentariensis was distinguished by Castelnau on the basis of a dorsal spine count of six compared with four or five spines in other members of the genus. I have examined the holotype at MNHN and conclude that it is synonymous with the Australian freshwater form of *T. chatareus*, but apparently the dorsal count represents an anomaly. The specimen is otherwise morphologically similar to numerous individuals examined from the Kimberley region of Western Australia and the Gulf of Carpentaria drainage system, which possess five dorsal spines. It is a dried specimen, 173 mm SL, in relatively poor condition and overall yellow-brown in colour without distinctive markings.

I have examined 193 specimens, 13-207 mm SL, from New Guinea and northern Australia. This includes Whitley's types of *T. dorsalis* (AM I.13056-13058) and *T. ulysses* (AM IA.2220), which represent specimens from freshwater and brackish water respectively. According to Hora (1924), Hamilton (sometimes cited as Hamilton-Buchanan) did not keep collections of the numerous fishes he described; therefore a type specimen for *T. chatareus* does not exist. However, the illustration which accompanies the original description of this species is clearly diagnostic.

TABLE 3

Comparison of the height of the spinous dorsal fin and body depth of *Toxotes chatareus* with relation to size, locality, and habitat (expressed in percent of standard length).

	Height of Spinous Dorsal		
	$\overline{X}$ (N indicated in parentheses)		
Size Class (mm SL)	Australia-New Guinea Brackish Water	Australia Freshwater	New Guinea Freshwater
20-59	25.1 (29)	20.3 (24)	24.0 (2)
60-99	26.0 (5)	19.1 (35)	23.7 (7)
100-149	25.9 (4)	16.9 (10)	20.4 (2)
150+	26.1 (4)	16.9 (4)	23.8 (5)
	Body depth		
20-59	47.9 (28)	45.5 (23)	49.9 (2)
60-99	48.1 (5)	46.2 (36)	49.0 (7)
100-149	49.1 (4)	45.6 (10)	47.1 (3)
150+	48.6 (4)	46.2 (5)	46.9 (7)

TOXOTES JACULATOR (PALLAS)

(Plate 7; Tables 1 and 2)

Sciaena jaculatrix Pallas, 1767: 186 (type locality: Batavia [Jakarta] Java).

Scarus schlosseri Gmelin, 1789: 1228 (based on Pallas' description of *Sciaena jaculatrix*).

Diagnosis

Dorsal rays IV or V,11 to 13 (usually IV,12); anal rays III,15 to 17; pectoral rays 12 or 13 (usually 13); scales in lateral line 26 to 30; horizontal scale rows above lateral line 3 or 4, below lateral line 8 or 9; gill rakers on lower limb of first branchial arch 5 to 7 (usually 6 or 7). Greatest body depth 2.1 to 2.4, head length 2.3 to 2.7, both in standard length. Snout 3.4 to 3.7, eye 3.2 to 3.6, interorbital 2.8 to 3.8, caudal peduncle depth 2.5 to 3.4, pectoral fin length 1.2 to 1.4, pelvic fin length 2.1 to 2.4, all in head length. Third dorsal spine the longest, 1.7 to 1.9 in head length.

Colour in alcohol: ground colour whitish to tan, sometimes with silvery sheen, grading to brown on dorsal surface, a series of 4-5 black bars, primarily on upper sides; dorsal, anal, and pelvic fins blackish; caudal fin pale to dusky; pectoral fins pale.

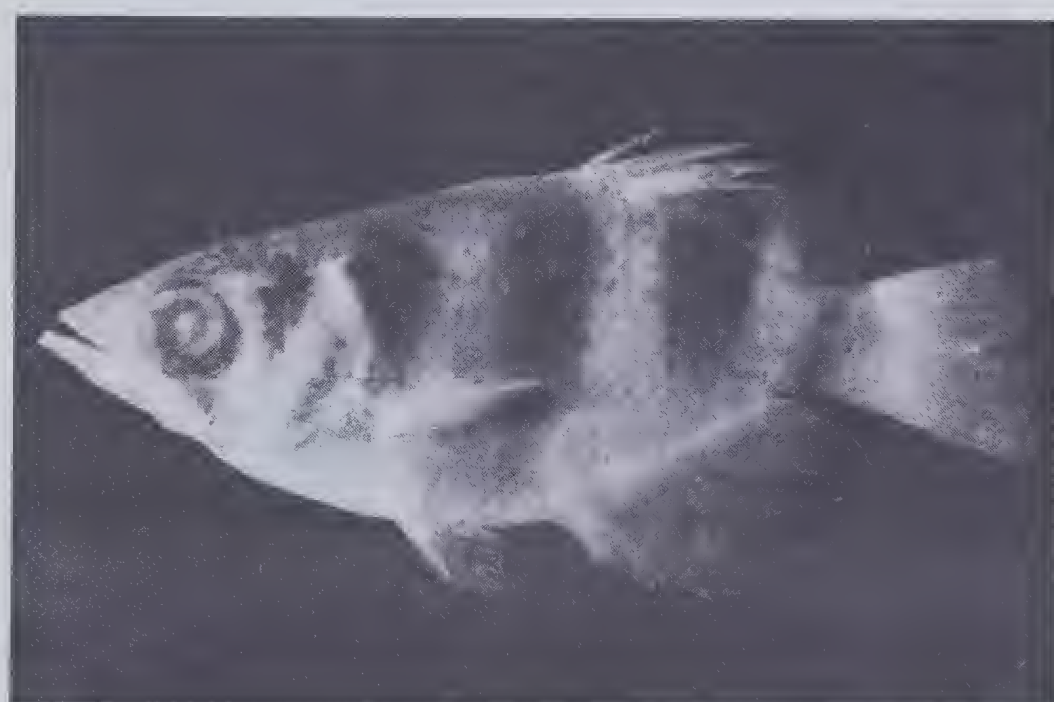


Plate 7: *Toxotes jaculator*, 33 mm SL, Cairns, Queensland.

Distribution

T. jaculator is the most widely distributed member of the family. Weber and de Beaufort (1936) recorded it from the following localities: India, Andaman Islands, Burma, Thailand, Malay Peninsula, Singapore, Vietnam, Philippine Islands, numerous localities throughout the Indonesian Archipelago, New Guinea, northern Australia (Darwin), New Britain, Woodlark Island, Admiralty Islands, Solomon Islands, and the New Hebrides. In addition, Herre (1939) recorded it from the Palau Islands.

There are relatively few specimens available from northern Australia, but I have examined several examples from the northeastern coast of Queensland between Innisfail and Cooktown. It was originally reported from Darwin by Castelnau (1873), but I am unable to verify this record. McCulloch (1929) recorded the species from northwestern Australia and Whitley (1948) also included it in his list of the fishes of Western Australia. However, these records are doubtful and are perhaps based on several old specimens at WAM which are labelled as *T. jaculator*, but were re-identified as *T. chatareus* during the present study.

Remarks

Smith (1945) provided a historical resumé of the nomenclature of *T. jaculator*. There is no type specimen, however, the original description by Pallas was accompanied by a poor, but nevertheless diagnostic illustration. Fortunately this is the only member of the family which possesses four dorsal spines, otherwise it might be confused with other *Toxotes*, particularly *T. oligolepis*.

This species inhabits mangrove estuaries and the lowermost reaches of freshwater streams. I have made collections and observations at the Palau Islands, New Guinea (Madang), Ambon, and Cairns, Australia. In most cases it was encountered in murky, brackish water in the vicinity of mangroves. However, in the Palau Islands around Koror it can be seen in relatively clear water. A series of nocturnal dives at this locality revealed that it remains stationary among dense mangrove roots at this time. During the day solitary individuals or groups of up to about 20 individuals feed continually at the surface. The adults roam considerable distances along the shore, rarely venturing out over deep water. Young fish form small aggregations around half-submerged stumps or logs, and under overhanging branches. Both juveniles and adults feed on a variety of insects and spiders which are 'shot' down or taken as they float on the surface. The stomach of a 20 cm TL specimen collected at Madang, New Guinea was packed full of flower buds and contained several small insects.

From personal experience, more than one species of *Toxotes* is rarely encountered at a given locality. However, *T. jaculator* and *T. chatareus* were collected together from mangrove creeks in the vicinity of the Admiralty Island near Cairns, Queensland.

I have examined 51 specimens, 23-159 mm SL from the Philippine and Palau Islands, Celebes, Ambon, New Guinea, Trobriand Islands, Solomon Islands, and Queensland. One of these, a specimen (DASF FOZ441) 126 mm SL, from the Trobriand Islands has an aberrant dorsal count consisting of five spines.

TOXOTES LORENTZI WEBER

(Plate 8; Tables 1 and 2)

Toxotes lorentzi Weber, 1911: 232 (type locality: freshwater pool near Merauke, South New Guinea [Irian Jaya]).

Diagnosis

Dorsal rays V,13 or 14; anal rays III,15 to 17 (usually 16); pectoral rays 14 or 15 (usually 14); scales in lateral line 39 to 47; horizontal scale rows above lateral line 7, below lateral line 12 or 13; gill rakers on lower limb of first branchial arch 2 to 4 (usually 3). Greatest body depth 2.1 to 2.5, head 2.7 to 3.2, both in standard length. Snout 3.7 to 4.1, eye 3.8 to 4.4, interorbital 3.0 to 3.8, caudal peduncle depth 2.3 to 2.5, pectoral fin length 1.7 to 1.8, pelvic fin length 1.8 to 2.1, all in head length. Fourth dorsal spine the longest, 2.0 to 2.3 in head length.

Colour in alcohol: ground colour dusky brown on back grading to yellowish on ventral surface; dorsal, anal, and caudal fins dusky; pelvic and pectoral fins yellowish.

A colour transparency of a fresh specimen taken by Mr John Lake reveals the presence of approximately 10 faint, narrow bars on the upper sides extending to slightly below the midline. The sides are silvery and the pectoral base is dark.

Distribution

T. lorentzi is known from the Merauke River and vicinity of Balimo (8°01'S, 142°57'E) in the central portion of southern New Guinea. It has also been reported from the Northern Territory, Australia at Yam Creek (Daly River system) by Whitley (1950) and at Sawcut, Deaf Adder, and Baroalba Creeks (South Alligator River system) by Pollard (1974).

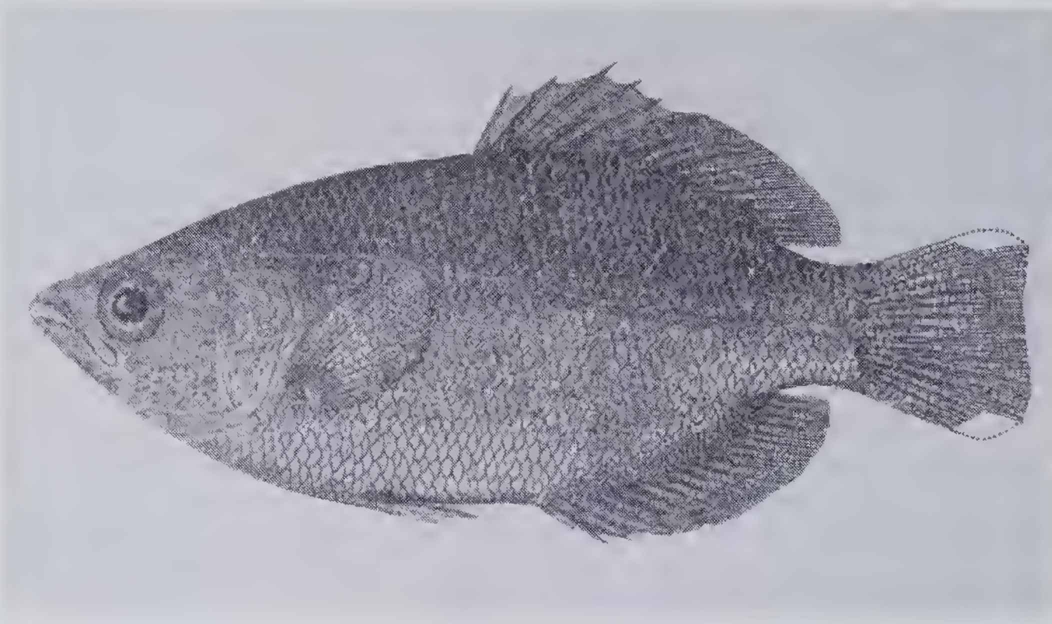


Plate 8: *Toxotes lorentzi*, approximately 77 mm SL, New Guinea (drawing from Weber and de Beaufort, 1936).

Remarks

Weber and de Beaufort (1936) and Whitley (1950) suggested that *T. lorentzi* is the most primitive species of archerfish because of its lack of distinctive markings, small scale size, straight course of the lateral line, the more anterior position of the dorsal, and the less elevated body. Furthermore, Whitley (1950) erected the genus *Protoxotes* for this species on the basis of these features. However, I agree with Taylor (1964), who regarded it as a synonym of *Toxotes*. None of the characters listed above seem to offer conclusive evidence of a more primitive state.

I have examined 13 specimens, 69-150 mm SL, including the two syntypes, 85 and 96 mm SL which are deposited at ZMA (register number 112.449). The largest syntype is here designated as the lectotype.

TOXOTES MICROLEPIS GÜNTHER

(Plate 9; Tables 1 and 2)

Toxotes microlepis Günther, 1860: 68 (type locality: Siam [Thailand]).

Diagnosis

Dorsal rays V,13 to 14; anal rays III,15 to 17; pectoral rays 13 to 15 (usually 13 or 14); scales in lateral line 42 to 45; horizontal scale rows above lateral line 6 to 7, below lateral line 14 to 15; gill rakers on lower limb of first branchial arch 6 to 8. Greatest body depth 1.8 to 2.1, head length 2.6 to 2.8, both in standard length. Snout 3.5 to 3.8, eye 2.9 to 3.8, interorbital 3.0 to 3.2, caudal peduncle depth 2.7 to 3.0, pectoral fin length 1.4 to 1.6, pelvic fin length 1.9 to 2.1, all in head length. Fourth dorsal spine the longest, 1.4 to 1.6 in head length.

Colour in alcohol: ground colour yellowish; a series of 4 or 5 rounded dark brown spots along back from upper part of gill opening; a narrow dark bar sometimes present across caudal peduncle; dorsal fin white to yellowish except with black spot near posterior edge and a second one sometimes on anterior soft rays; remainder of fins white to yellowish except pelvics and outer edge of anal fin dusky.

Plate 9: *Toxotes microlepis*, 120 mm SL, Borneo.

Distribution

T. microlepis has been reported from Thailand, Sumatra (near Palembang), and Borneo. Smith (1945) stated that it is a river fish in Thailand and seems to penetrate further inland than *T. jaculator* and *T. chatareus*. He reported it as being common in the lower Menam Chao Phya and also examined specimens from the Nakon Nayok, one of the tributaries of the Bangpakong. Weber and de Beaufort (1936) reported a number of Borneo localities including Bandjermasin, Tepoe, Sintang, Smitau, and Sanggan.

Remarks

The record of *T. microlepis* from Burma by Fowler and Bean (1929) is erroneous and actually refers to *T. blythi.* Day (1875) is responsible for this error as he incorrectly identified specimens of *blythi* from the Irrawaddi River as *microlepis.* The inclusion of the latter species in his monograph of Indian fishes was apparently based on surmise and is probably inaccurate. There are no further records of *microlepis* from India.

I have examined 21 specimens, 38-123 mm SL, including the three syntypes, 40-123 mm SL, which are deposited at BMNH (register number 1859.7.1.43-45). The largest is here designated as the lectotype.

TOXOTES OLIGOLEPIS BLEEKER

(Plates 10 and 11; Tables 1 and 2)

Toxotes oligolepis Bleeker, 1876: 162 (type locality: probably Buru, Molucca Islands).

Diagnosis

Dorsal rays IV or V,12 or 13 (usually V,12 or 13); anal rays III, 15 to 17; pectoral rays 12 to 14 (usually 13); scales in lateral line 25 to 33; horizontal scale rows above lateral line 3 or 4, below lateral line 9 or 10; gill rakers on lower limb of first branchial arch 6 to 8 (usually 7). Greatest body depth 2.0 to 2.3, head length 2.4 to 3.0, both in standard length. Snout 3.4 to 4.2, eye 3.2 to 3.8, interorbital 3.1 to 3.7, caudal peduncle depth 2.4 to 3.2, pectoral fin length 1.1 to 1.5, pelvic fin length 2.0 to 2.5, all in head length. Fourth dorsal spine the longest, 1.7 to 2.1 in head length.

Colour in alcohol: ground colour whitish to yellow, sometimes with silvery sheen, grading to brown on dorsal surface; a series of five black bars, primarily on upper sides, the last sometimes in the form of a rounded spot mid-laterally on caudal peduncle; dorsal and anal fins dusky, usually with central pale band; caudal fin pale to dusky; pelvic fins pale to slightly dusky; pectoral fins pale with uppermost rays frequently dusky.

Distribution

T. oligolepis is known from the Molucca Islands, Irian Jaya (West New Guinea), and the Fitzroy, Meda, May, and Isdell River systems of the Kimberley region, Western Australia. The only previous reliable record was that of the type (Molucca Islands, probably Buru) although, according to Weber and de Beaufort (1936), Fowler wrote to them stating there were two specimens of *oligolepis* from New Guinea in the U.S. National Museum. However, Fowler and Bean (1929) did not list this extralimital locality in their treatment of Philippine toxotids. During the present study, however, I examined two unregistered lots at RMNH containing eight specimens, 22-93 mm SL, of *T. oligolepis* from Lake Jamoer, Irian Jaya. In addition,

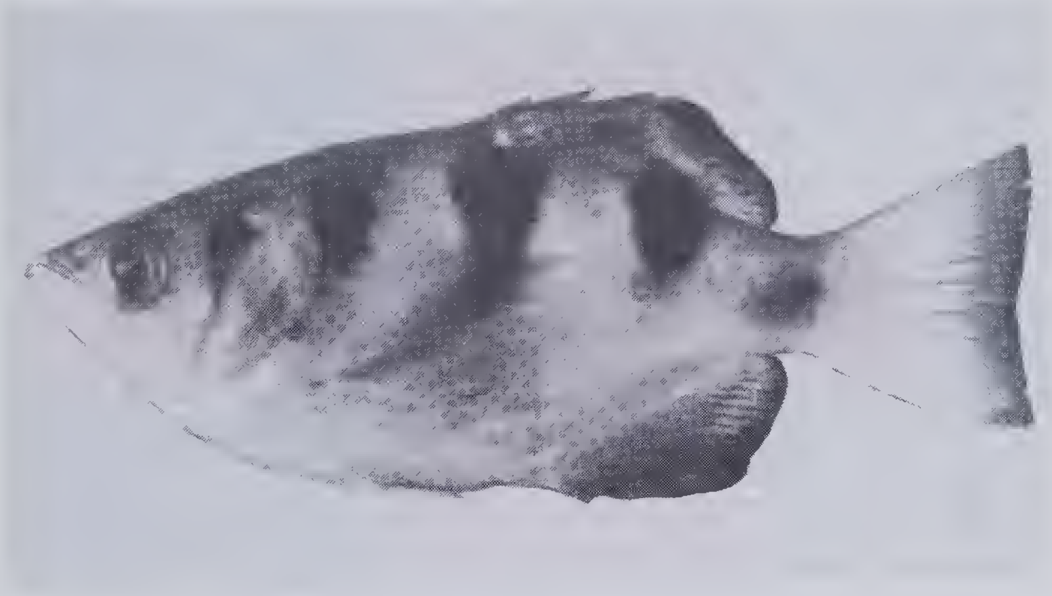


Plate 10: *Toxotes oligolepis*, 95 mm SL, Lennard River, Western Australia.

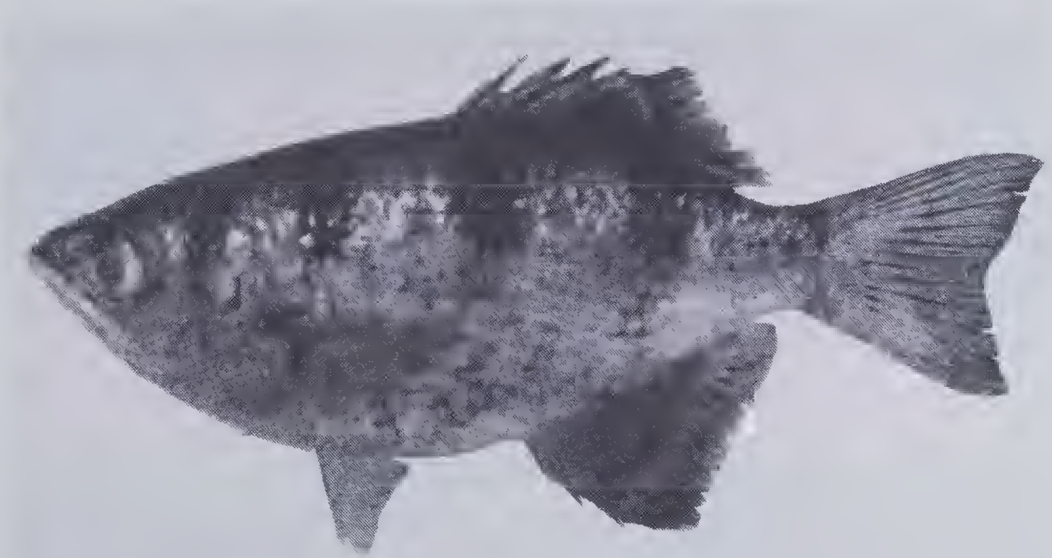


Plate 11: *Toxotes oligolepis*, 126 mm SL, Plain Creek, Western Australia.

Herre (1953) recorded this species from the Pansipit River, Batangas Province, Luzon, Philippine Islands. The specimens were collected by him during 1933-34, but I have not been able to locate them. It is possible they were deposited in the Bureau of Science Collection at Manila, which was subsequently destroyed during World War II.

Remarks

I have examined 48 specimens, 22-127 mm SL, including the type, 112 mm SL, which is deposited at RMNH (register number 5835).

The status of the Western Australian population is uncertain. There is a possibility that it may represent a distinct species or at least a subspecies. The Western Australian specimens are deeper bodied ($\overline{X}$ = 48.5% of the standard length vs. 44% for the type) and possess a higher lateral line scale count. The type specimen has 25 lateral line scales on the right side; the left side is damaged, but counting scale pockets it appears there were approximately 28 scales. The Western Australian specimens usually have 30 or 31 scales, although the counts range between 29-33. Unfortunately the type is the only known specimen from the Molucca Islands and until more material becomes available I must reserve judgement on the status of the Australian population.

There are also differences between the populations known from Western Australia. The specimens from the Isdell system are more slender (average depth 46.7% of SL for seven specimens, 100-127 mm SL) than those from the Fitzroy, Meda, and May Rivers (average depth 50.0% of SL for nine specimens, 64-94 mm SL) and there is also a difference in colour pattern (see Plates 10 and 11).

Whitley (1950) included 'variety from Mandurah' in his key to the toxotids of Australia. I have identified the specimen (AM IB.2156) on which this entry was based as *T. oligolepis*. The specimen was received by the Australian Museum from the Western Australian Museum during the late 1800s. The locality of Mandurah, Western Australia is undoubtedly a mistake as this location, which is situated about 60 km south of Perth, lies well outside the distributional limits of *Toxotes*.

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I thank Mr Barry Hutchins of WAM for his recent collections of *Toxotes* from the Kimberley region of Western Australia. Mr Hutchins' 1975 and 1976 collections and my own in this area during 1974 were made possible because of expeditions organised by the Western Australian Department of Fisheries and Wildlife. These trips were supervised by Dr Andrew Burbidge, Director of the Wildlife Research Centre. Dr Winston Baily of the University of Western Australia assisted with the collection of specimens during 1974. I am also grateful to Drs M.L. Bauchot (MNHN), M. Boeseman (RMNH), D. Hoese (AM), H. Nijssen (ZMA), J. Paxton (AM), V. Springer (USNM), and P. Whitehead (BMNH) for allowing me to examine specimens under their care. Mrs Patricia Kailola, formerly of DASF sent a large and valuable collection of *Toxotes* from New Guinea. Finally, I thank my wife, Mrs Connie Allen, for her careful preparation of the typescript.

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AMBLYELEOTRIS RANDALLI, A NEW SPECIES OF GOBIID FISH LIVING IN ASSOCIATION WITH ALPHAEID SHRIMPS

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and

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ABSTRACT

A new species of *Amblyeleotris* is described based on seven specimens from the tropical western Pacific Ocean. The species lives in association with an alphaeid shrimp, as do many, if not all species of *Amblyeleotris*. The genus is characterised and contrasted with *Cryptocentrus*, a genus which is also associated with alphaeid shrimps. A list of distinctive species of *Amblyeleotris* is given, but does not include numerous undescribed species.

INTRODUCTION

Gobiid fishes are a world-wide group of tropical and temperate fishes occurring in freshwater, estuaries, and in the sea. The group contains about 2,000 species, making it one of the largest families of fishes in the world.

Early workers separated gobiid fishes from the related and more primitive eleotrids by the development of a sucking disc, formed by fusion of the pelvic fins in gobiids. Recent studies (Akihito 1969, Birdsong 1975, Miller 1973) have shown that this character is not adequate to separate the two groups, since many coral reef gobiids have secondarily lost the connection between the pelvic fins. Few true eleotrids occur on coral reef, most being found in freshwater or estuaries. Only four highly specialised eleotrids occur

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on coral reefs; *Calumia*, *Allomicrodesmus*, *Xenisthmus* and an undescribed genus. The genus *Amblyeleotris* has been regarded as an eleotrid, since the pelvic fins are separate, but it is a true gobiid, having 5 branchiostegal rays and a pelvic girdle characteristic of gobiids. Studies of coral reef genera by the senior author indicate that most speciose coral reef genera have species with the disc and others without it. In some species of *Fusigobius*, the degree of connection of the pelvic fins varies geographically and is sometimes sexually dimorphic.

The species of *Amblyeleotris* described here normally lives in association with alphaeid shrimps. Several gobiid species placed in various genera have been recorded living in association with alphaeids; *Cryptocentrus* (Magnus 1967, Klausewitz 1960), *Amblyeleotris* (Harada 1969, Klausewitz 1969, 1974a, Yanagasawa 1976, Polunin and Lubbock 1977), *Vanderhorstia* (Magnus 1967, Klausewitz 1974b), *Ctenogobiops* (Klausewitz 1960), *Lotilia* (Klausewitz 1960) and *Psilogobius* (Baldwin 1972). Studies on *Cryptocentrus cryptocentrus* have shown that the shrimp digs the burrow and the goby serves as a sentry at the burrow entrance (Luther 1958, Magnus 1967, Karplus, *et al.* 1972). Our observations indicate that the gobies feed on organisms in the sand deposited by the alphaeids, but will also forage away from the burrow.

Several problems exist in the classification of gobiids which live in association with alphaeids. Many of the 20 nominal genera involved have not been adequately diagnosed. Consequently, in many cases species have been placed in genera, with which they have little affinity. In some cases, species which do not live with alphaeids have been incorrectly placed in *Cryptocentrus*. A generic diagnosis will be presented in a paper currently in preparation by the senior author. *Cryptocentrus* and *Amblyeleotris* are the two most speciose genera that live in association with alphaeid shrimps. *Cryptocentrus* contains about 40 nominal species and *Amblyeleotris* contains 15 species. Since there is considerable confusion regarding the classification of the group, a generic synonymy for *Amblyeleotris* is presented below.

METHODS

Type specimens are deposited in The Australian Museum, Sydney (AM); the Bernice P. Bishop Museum, Honolulu (BPBM); the British Museum (Natural History), London (BMNH); and the Western Australian Museum, Perth (WAM).

Except as indicated counts and measurements follow those given by Hubbs and Lagler (1958). The head length is taken to the upper attachment of the opercular membrane. In most gobiids the first ray of the second dorsal and anal fins is simple and is included in ray counts in the general discussion. The last ray of these fins, as counted, is branched to the base, but it has been treated as two separate rays by some earlier workers. Bleeker, for example gave both counts, giving a range of counts, even when he had only a single specimen. The longitudinal scale count is taken from the upper attachment of the opercular membrane to the end of the hypural. The ctenoid scale row count is the longitudinal count of the ctenoid scales. Transverse scale counts are taken from the anal origin upward and forward to the first dorsal base (TRF) and from the anal origin upward and backward to the second dorsal fin base (TRB). Since the anterior scales are often crowded and irregularly placed, the TRB count generally shows less variation. Post dorsal scales is a count of the scale rows from the end of the second dorsal fin to the upper base of the caudal fin. The vertebral count includes the urostyle.

The generic synonomy is based on work of the senior author, including examination of types of the nominal genera, except for *Biat*, where only nontype material was examined.

TAXONOMY

AMBLYELEOTRIS BLEEKER

Amblyeleotris Bleeker 1874: 373 (type species: *Eleotris periophthalmus* Bleeker 1853, by original designation).

Biat Seale 1909: 532 (type species: *Biat luzonica* Seale 1909, by original designation).

Pteroculiops Fowler 1938: 133 (type species: *Pteroculiops guttatus* Fowler 1938, by original designation).

Zebreleotris Herre 1953: 191 (type species: *Zebreleotris fasciata* Herre 1953, by original designation).

Cryptocentrops Smith 1958: 152 (type species: *Cryptocentrops exillis* Smith 1958, by original designation).

Fereleotris Smith 1958: 152 (type species: *Amblyeleotris (Fereleotris) delicatulus* Smith 1958, by original designation).

Diagnosis

Cheek with transverse and longitudinal papillae rows; two longitudinal rows, uppermost extends posteriorly from fifth or sixth transverse row

(Fig. 1). Mandibular papillae reduced to a single enlarged papilla on each side of chin, set in a depression. Gill opening broad, extending from the upper opercular attachment below to well before the posterior margin of the preoperculum. Posterior body scales ctenoid, cycloid anteriorly. Second dorsal and anal rays I, 12 to 20. Head compressed, with eyes placed high on sides of head, interorbital much narrower than eye. Head pores present, 2 median unpaired interorbital pores. Pelvic fins connected or separate.

Superficially *Cryptocentrus* is quite similar to *Amblyeleotris*, but differs in several features. In *Cryptocentrus* the upper longitudinal cheek papilla row extends forward to the second or third transverse row, under the eye; the mandibular papillae are arranged in two parallel rows extending posteriorly on the sides of the chin; the gill opening is more restricted, ending below the posterior preopercular margin; scales are normally cycloid, except for 2 or 3 species; dorsal and anal rays vary from I,9 to 12; the pelvics generally are connected into a disc, but are separate in a few species. *Vanderhorstia*, *Ctenogobiops*, *Eilatia* and *Flabelligobius* are also similar in appearance to *Amblyeleotris*, but differ in having longitudinal papillae cheek rows, but no transverse rows.

As recognised here, the genus *Amblyeleotris* contains the following species: *A. fontanesii* (Bleeker), *A. gymnocephala* (Bleeker), *A. exilis* (Smith), *A. periophthalmus* (Bleeker), *A. fasciata* (Herre), *A. guttata* (Fowler), *A. japonica* Takagi, *A. delicatulus* (Smith), *A. steinitzi* (Klausewitz), *A. maculata* Yanagasawa, *A. sungami* (Klausewitz), and *A. aurora* (Polunin and Lubbock).

AMBLYELEOTRIS RANDALLI N. SP.

(Figs 1, 2 and 3)

Diagnosis

Second dorsal and anal I,12, pectoral rays 18-19. Pelvic fins completely separate. Midline of nape naked, sides scaled forward to above middle of operculum. Breast and pectoral base covered with small cycloid scales. Body with 54 to 63 scale rows. TRB 17-21. First dorsal fin with a large ocellated spot posteriorly. Head with 2 narrow transverse orange bands in life. Body with four thin transverse orange bands, sloping obliquely forward ventrally. First dorsal fin elevated.

Description

Based on 7 specimens 35 to 61 mm SL. An asterisk indicates the count of the holotype. The number in parenthesis indicates the number of specimens with a specific count.

First dorsal VI(7)*. Second dorsal I,12(7)*. Anal I,12(7)*. Pectoral 18-18(1), 19-18(2)*, 19-19(3), 20-20(1). Segmented caudal rays 17(7)*. Branched caudal rays 14(7)*. Branchiostegals 5(2).Vertebrae 10+16=26 (1). Longitudinal scale count 58(2), 62(1), 63(3)*, 65(1). Ctenoid scale rows: 42(1), 45(1), 46(1), 48(2)*. Transverse scales: TRB 17(1), 18(1), 20(3), 21(2)*. Circumpenduncular scales 20(3), 21(2)*. Post dorsal scales 11(2)*. Gill rakers on outer face of first arch 2+10(2)*, 3+11(1), 3+12(1)*. Measurements are given in Table 1.

Table 1: Measurements (in mm) of holotype and 4 paratypes of *Amblyeleotris randalli*, all females.

Character	Paratypes				Holotype
	BPBM 17058	AMS I 17901-001	BPBM 9444	WAM P 25235-021	BPBM 20809
Standard length	52.4	34.7	60.6	58.2	73.2
Head length	15.6	10.4	16.8	17.6	20.4
Head width at cheeks	8.4	6.5	–	–	10.6
Head depth at posterior preopercular margin	9.1	6.5	–	11.0	13.4
Body depth at anal origin	10.0	6.6	11.2	11.3	14.9
Caudal peduncle depth	6.0	3.9	6.5	6.6	7.9
Caudal peduncle length	7.7	6.6	9.8	9.7	12.6
Upper jaw length	6.8	4.5	7.8	8.1	8.9
Eye length	3.7	3.3	4.8	4.1	4.7
Snout length	3.8	2.5	4.6	4.1	5.5
Pectoral length	16.8	11.4	18.3	19.3	24.3
Pelvic length	15.8	11.7	17.8	18.3	22.0
Caudal length	17.3	10.4	21.3	20.2	28.9
Depressed dorsal length	18.5	12.7	19.0	18.5	26.0
First dorsal spine length	12.4	8.5	14.9	15.2	21.6
Second dorsal spine length	15.5	12.0	17.9	16.5	22.2
Third dorsal spine length	16.0	12.4	17.7	18.6	22.6
Base of second dorsal fin	16.4	11.0	18.0	16.4	19.8
Snout to anal origin	32.1	21.4	36.2	33.8	44.6

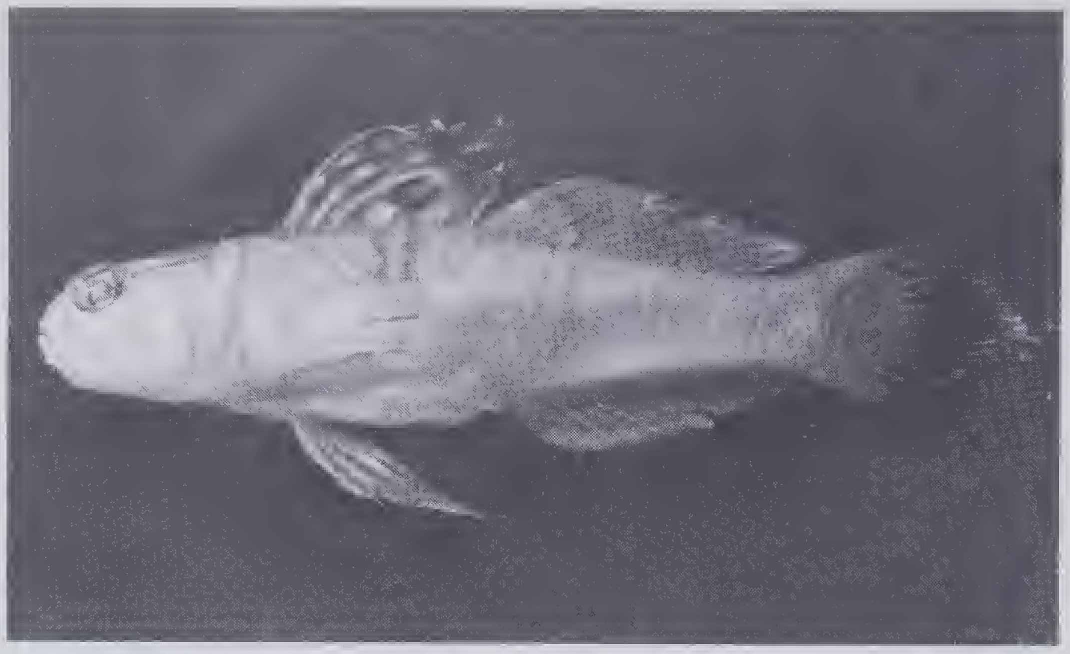

Fig. 1: Paratype of *Amblyeleotris randalli*, WAM P25235-021. Photo G. Allen.

Head moderately compressed, deeper than wide. Cheeks slightly bulbose. Body compressed. Mouth slightly oblique, forming an angle of about 30° with the body axis. Mouth terminal. Jaws extend posteriorly to a point under posterior margin of pupil. Snout steep in lateral view, about equal to eye diameter. Eye elevated slightly above interorbital region, with a very shallow groove behind the dorsoposterior margin of eye. Interorbital narrow, about equal to pupil diameter. Anterior nostril a short tube above upper lip. Posterior nostril a simple pore close to anterior margin of eye. Gill opening extends forward to below peroperculum, ending midway between end of eye and posterior preopercular margin. Gill rakers elongate on outer face of first arch; rakers on inner face of arch and on both faces of other arches, short, about as wide as long. Dorsal and anal rays branched. First dorsal fin higher than body depth, second, third and fourth spines longest and about equal in height. Pectoral fin elongate with pointed tip reaching to above anal origin; all but uppermost and 2 lowermost rays branched. Anal rays slightly more elongate than dorsal rays. Caudal fin assymetrically pointed, upper rays longer than lower rays. Pelvics I,5, soft rays all branched; fourth ray longest, fifth ray about one half length of fourth; interspinal membrane absent; two pelvics partly connected basally (**Fig. 2**).

Head pores: a nasal pore between anterior and posterior nostril; a median anterior and a median posterior interorbital pore; one postocular pore behind each eye; an infraorbital pore on each side of head behind middle of eye; lateral canal extending from posterior end of eye to above preoperculum, with one pore behind eye and a terminal pore above the posterior preopercular margin; a short tube with pores at each end above operculum; three preopercular pores, lowest pore in horizontal line behind end of jaws. Pores and papillae shown in Fig. 3.

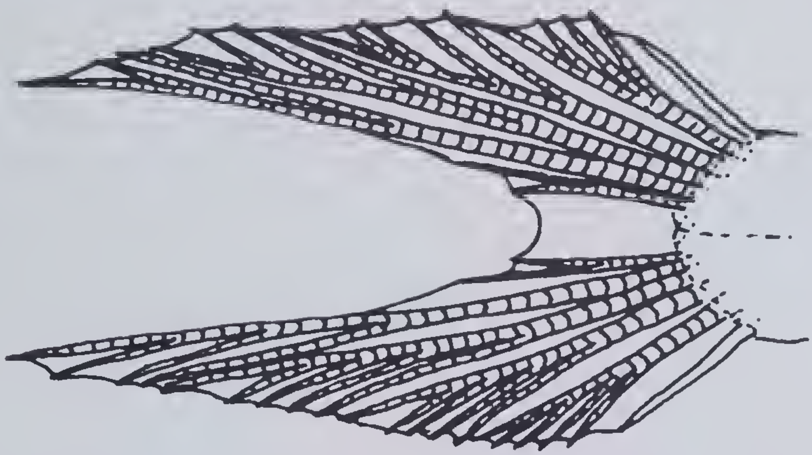

Fig. 2: Ventral view of pelvic fin of *Amblyeleotris randalli*. Drawing by H.K. Larson.

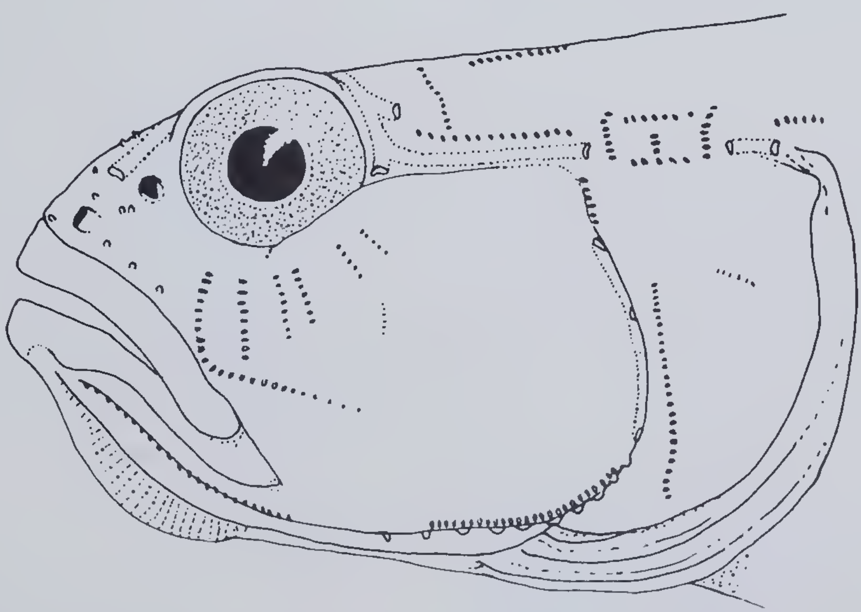

Fig. 3: Head of *Amblyeleotris randalli*, showing head canals and pores and sensory papillae pattern. Drawing by H.K. Larson.

Dentition: No vomerine or palatine teeth. All jaw teeth conical and curved. Upper jaw teeth in 4 rows; teeth in outer row distinctly larger than those in inner rows, largest anteriorly; three inner rows with small inwardly curved teeth, rows tapering posteriorly into one row. Lower jaw with 4 to 5 rows of teeth; outer row composed of 6 to 8 slightly enlarged teeth, confined to anterior margin of dentary; three to four inner rows of smaller teeth anteriorly, tapering posteriorly into a single row, innermost row with 1 or 2 very large teeth on each side, just behind angle of dentary.

Squamation: Body covered with 54 to 63 small scales, ctenoid posteriorly, cycloid anteriorly. Ctenoid scales extending forward in wedge, reaching between a point below second dorsal origin and middle of first dorsal fin. Pectoral base and breast covered with small cycloid scales. Basicaudal scales ctenoid. Belly covered with very small cycloid scales. Sides of head naked. Midline of nape naked, sides scaled forward to above middle of operculum.

Colouration of fresh paratype from Solomon Islands (BPBM 17508): Head and body faint blue, narrow oblique orange bands with dark margins, width of bands about equal to pupil diameter. An oblique band from lower margin of eye to end of jaws. A bar dorsally between eyes. An oblique orange bar from midline of middle of nape extending downward over upper two-thirds of operculum. A band from behind middle of first dorsal fin extending downward and slightly forward onto sides of belly. Two bands below second dorsal. A short band on upper two-thirds of caudal peduncle. A crescent-shaped narrow orange band at base of caudal fin, with extensions along lowermost and uppermost caudal rays. A small orange spot behind middle of eye. Body with small scattered irregularly shaped orange blotches, which form vertical rows. First dorsal black with a white margin, with white spots, about equal in size to pupil diameter, forming distinct rows anteriorly, irregularly placed posteriorly. A large black spot, slightly larger than eye, centred on fifth dorsal spine, surrounded dorsally and laterally with a white rim; ventrally connected to orange band on body. Second dorsal with distal margin blue, covered with small blue spots or blotches forming rows sloping downward and backward. Spots surrounded by narrow orange lines. Caudal fin blue, with some yellow near base. Anal fin bluish white, with bright blue stripe along distal margin; a broad faint yellow stripe proximally; and a third bright blue stripe between second and base of fin. Anal clear or with dusky stripes replacing blue stripes. Pectoral and pelvic dusky.

Distribution and Ecology

Amblyeleotris randalli is known from Indonesia, Palau, the Admiralty Islands, New Britain, Philippines and Solomon Islands. Although specimens have not been taken in Australia, the junior author has photographed this species off Cairns, Queensland.

Randall (pers. comm.) noted that this species occurs in burrows with an olivaceous alphaeid shrimp, with white, short transverse marks. The species in known from depths of 25 to 48 m.

Derivation of Name

The species is named for J.E. Randall, who first brought this species to our attention.

Relationships

Amblyeleotris randalli differs from *A. fontanesii*, *A. gymnocephalus* and *A. sungami* in having fewer dorsal rays and separate pelvic fins. *A. japonicus*, also has higher dorsal ray counts than *A. randalli*. *A. randalli* differs from *A. fasciatus* and *A. guttatus* in lacking predorsal scales. The species is most similar to *A. steinitzi*, *A. maculata*, *A. delicatula*, *A. exilis* and *A. periophthalmus* in fin ray counts, but differs from those species in colouration and in having the pectoral base scaled and in having a higher first dorsal fin.

Superficially, the species is similar to the nominal *Batman insignitus* Whitley (1956). The gill opening in the holotype of *Batman* (AMS I4299) is more restricted, ending under the posterior border of the preoperculum, the scales are cycloid, and there are 13 dorsal and 12 anal rays, all characteristics of the genus *Cryptocentus*. Consequently, we regard *Batman* as a junior synonym of *Cryptocentus*.

Material Examined

Holotype: BPBM, 20809, a 73.2 mm female; Philippine Islands, Samilon Island, 22 m. Paratypes: BPBM 17508, 1(52); Guadacanal, Solomon Islands, 11 km west of Honiara, 48 m. AM I17901-001, 1(35); Guadacanal, Solomon Islands, 11 km west of Honiara, 33 m. BMNH 1977.9.20: 1, 1(37), New Britain, BMNH 1977.9.20: 2, 1(36), Admiralty Islands. BPBM 9444, 1(61), Palau Island, Augulpelu Reef, 33 m. WAM P25235-021, 1(58), Ambon, Molucca Is., Indonesia, 25 m.

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Rec. West. Aust. Mus., 1978, 6 (4)

SYNOPSIS OF THE 'FINLESS' PIPEFISH GENERA (*PENETOPTERYX*, *APTERYGOCAMPUS* AND *ENCHELYOCAMPUS*, GEN. NOV.)

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and
G.R. ALLEN†

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ABSTRACT

Three genera of presumably cryptic pipefishes which, as adults, lack all fins except caudal are diagnosed and compared. *Penetopteryx* Lunel and *Apterygocampus* Weber (removed from the synonymy of *Penetopteryx*) have lateral trunk ridge deflected ventrad near anal ring, whereas lateral ridge ends without deflection in *Enchelyocampus* gen. nov. *Penetopteryx*, including *P. taeniocephalus* (Indo-Pacific) and *P. nanus* (Western Atlantic), is characterized by 17-19 trunk rings and separate bilateral brood-pouch folds which meet or nearly meet on ventral midline. The monotypic *Apterygocampus* (*A. epinnulatus*: Indonesia) has 11 trunk rings and brood-pouch is a closed sac-like structure with anteromesial pore, similar to the brood-pouch configuration of seahorses (Hippocampinae). *Enchelyocampus*, also monotypic (*E. brauni* sp. nov.: Western Australia, Palau), lacks the tubiform snout and terminal mouth common to all other syngnathids and has a spine-like preorbital projection with distinctly separate and inferior mouth. Brood-pouch larvae of *Penetopteryx* and *Apterygocampus* have well developed dorsal, pectoral and caudal fins; mature males and larvae are presently unknown in *Enchelyocampus*. Evidence is presented to suggest that *Mannarichthys pawneei* (Herald) is a protracted planktonic stage of *Penetopteryx nanus*. A key is provided and all species are illustrated.

INTRODUCTION

Recent collection of an unusual pipefish (Syngnathidae), lacking dorsal, pectoral and anal fins, prompted examination of other nominal 'finless'

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species in order to determine its identity and relationships. We soon found that these forms are poorly represented in collections, that descriptions are in part inaccurate, that they have been seldom treated in literature and that one genus (*Apterygocampus* Weber) has been incorrectly synonymized with *Penetopteryx* Lunel.

Absence of fins (except caudal) implies reduced swimming efficiency and available collection data indicate that these are cryptic species which live (as adults) in protected niches within coral or coral rubble. Although occupying similar habitats and exhibiting similar reduction in fins, we find that these 'finless' genera represent convergence in three phyletic lines and that larvae of two (*Penetopteryx* and *Apterygocampus*) have both dorsal and pectoral fins.

We here provide a synopsis of the 'finless' pipefishes and include therein the description of a new genus and species from Western Australia and Palau. Pertinent types have been studied, available museum material has been examined and all species are illustrated. Many unanswered questions remain but present treatment should facilitate future studies on pipefishes which lack dorsal, pectoral and anal fins in adults.

METHODS AND MATERIALS

Counts of trunk rings begin with first complete ring behind gill opening; except where noted, other methods follow Dawson (1977a); SL = standard length; HL = head length.

Abbreviations for repositories of examined materials are: AMNH — American Museum of Natural History, New York; AMS — Australian Museum, Sydney; CAS — California Academy of Sciences, San Francisco; CAS-SU — former Stanford University material now housed at CAS; GCRL — Gulf Coast Research Laboratory Museum; LUZM — Zoological Museum, Lunds Universitets Zoologiska Institute, Lund; MNHN — Muséum National d'Histoire Naturelle, Paris; SIO — Scripps Institution of Oceanography, La Jolla; USNM — National Museum of Natural History, Smithsonian Institution, Washington; WAM — Western Australian Museum; ZMA — Zoölogisch Museum, Universiteit van Amsterdam.

KEY TO SUBADULT AND ADULT PIPEFISHES LACKING DORSAL, PECTORAL AND ANAL FINS

1. Mouth terminal on short but distinct snout; lateral trunk ridge deflected near anal ring 2

   Mouth inferior, located below pointed tip of projecting preorbital; lateral trunk ridge not deflected, ends midlaterally near anal ring ... ... *Enchelyocampus brauni* gen. and sp. nov.

2. Trunk rings 17-19; brood pouch with bilateral fleshy folds which meet or nearly meet on midline of egg-filled pouch 3

   Trunk rings 11; brood pouch a closed sac with restricted pore-like opening anteriad, without separate bilateral folds ... *Apterygocampus epinnulatus*

3. Rings total 59-61; head with broad dark bars, body plain or with irregular rows of brown or black spots; Indo-Pacific ... ... *Penetopteryx taeniocephalus*

   Rings total 48-51; head or both head and body ringed with numerous subvertical narrow brown bands; Western Atlantic ... ... *Penetopteryx nanus*

PENETOPTERYX LUNEL

Penetopteryx Lunel, 1881: 275 (type-species by original designation: *Penetopteryx taeniocephalus* Lunel, 1881).

Diagnosis

Superior trunk and tail ridges continuous (Fig. 1), inferior trunk and tail ridges interrupted at anal ring, lateral trunk ridge deflected near anal ring and confluent with inferior tail ridge. Mouth terminal on snout; snout angled dorsad, somewhat concave in lateral profile; low median dorsal ridge on posterior half or third of snout, not bounded laterad by anterior continuations of supraorbital ridge; snout narrow in front, breadth less than half of eye diameter. Opercle without median longitudinal ridge; median dorsal head ridges obsolete; head not covered with fleshy integument; venter of trunk somewhat V-shaped, without median keel; all body ridges low and

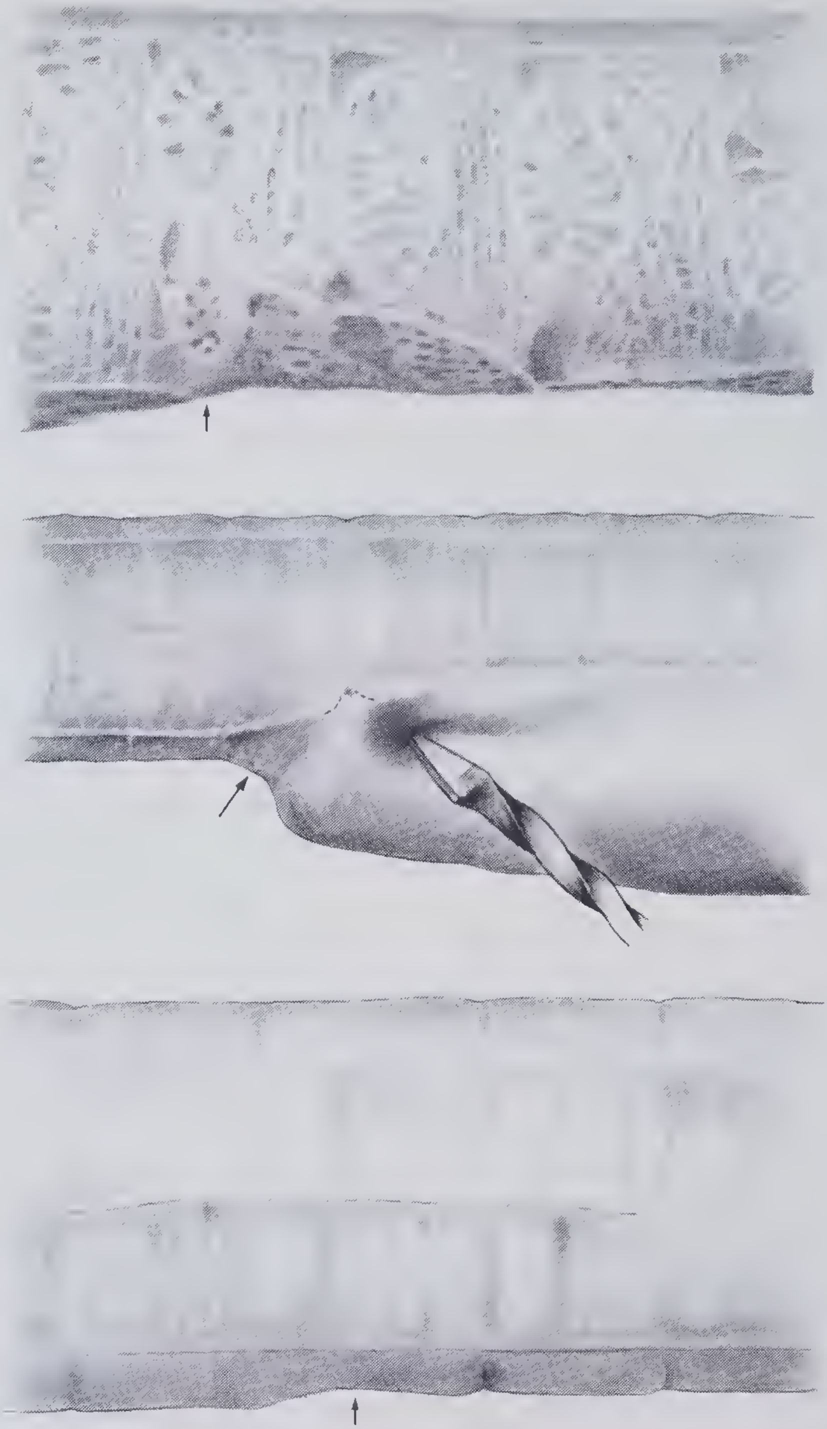

Fig. 1: Section of body illustrating configuration of principal body ridges, general surface ornamentation and anal ring location (arrow) in *Penetopteryx taeniocephalus* (top), *Apterygocampus* (middle) and *Enchelyocampus* (bottom).

indistinct, slightly indented between rings; scutella large, width equals half or more of ring length, ornamented with minute irregular ridges. Caudal-fin rays 10, other fins absent. Brood pouch developed below 12-17 tail rings; pouch plates little enlarged. Brood-pouch eggs in single layer of 2-3 transverse rows, protected by fleshy folds which meet or nearly meet on ventral midline of egg-filled pouch (Fig. 2); eggs not included within a continuous gelatinous matrix. Nares 2-pored bilaterally; head and body without spines, serrations or dermal flaps.

Fig. 2: Ventral aspect of body and brood pouch illustrating the open pouch and separate pouch folds of *Penetopteryx* (top) and closed pouch with restricted anterior pore of *Apterygocampus* (bottom).

Comparisons

Among genera treated here, *Penetopteryx* agrees with *Apterygocampus* in terminal location of mouth on a prolonged tubular snout (mouth inferior, tubiform snout lacking in *Enchelyocampus*). Brood-pouch closure of *Penetopteryx* differs strikingly from the closed sac-like pouch of *Apterygocampus* and clearly indicates separate lineage for these genera. For further discussion, see Remarks under *Apterygocampus*.

Remarks

Although lacking in subadults and adults, dorsal and pectoral fins are present in pouch-larvae. These fins are evidently lost during metamorphosis from a free-swimming planktonic stage to the apparently cryptic subadult or adult form.

As presently understood, *Penetopteryx* includes one Indo-Pacific and one western Atlantic marine species. These are small fishes which probably do not exceed 80 mm SL; both species have been taken in coral rubble at depths of 2.5 metres or less.

PENETOPTERYX TAENIOCEPHALUS LUNEL

(Fig. 3)

Penetopteryx taeniocephalus Lunel, 1881: 275 (original description, Mauritius).

Penetopteryx fowleri Whitley, 1933: 65 (original description, New Hebrides).

Diagnosis

Rings 18-19 + 41-43 = 59-61; head with 4-6 irregular broad brown bars and broad pale interspaces, body plain or with rows of small dark spots. Larvae with about 30 dorsal-fin rays and dorsal-fin origin on tail.

Description

Measurements (mm) of 60.0 mm SL male syntype (MNHN 90-49) follow: HL 5.0, snout length 1.3, snout depth 1.0, diameter of orbit 1.2, trunk depth 2.5, anal ring depth 1.8. Proportional data based on 9 specimens 52.0-64.5 mm SL are: HL in SL 10.6-13.1 ($\overline{X}$ = 12.1), snout length in HL 3.6-4.1 (3.8), snout depth in snout length 1.2-1.4 (1.3), trunk depth in HL 1.6-2.4 (2.0), anal ring depth in HL 1.8-3.3 (2.6). Opercle crossed by 25 or more low radiating striae in adults, other head surfaces largely ornamented by minute irregular ridges.

Ground colour in alcohol brownish, markings dark brown to nearly black. Males with about 5 broad irregular dark bars ringing head; dark bars separated by rather broad pale bars or blotches, the last infringing on 1st trunk ring; each of anterior 3-6 trunk rings with 1-4 small blackish spots surrounded by pale reticulations on either side of ventral midline, these rings elsewhere without conspicuous markings; sides of 3rd-6th through 11th-14th rings usually with 3 dark spots on each ring, one above and two below lateral ridge; two irregular rows of similar spots usually present above lateral ridge on 14th-16th through 18th rings; 2-3 irregular rows of spots continued on anterior $^1/_2$-$^2/_3$ of tail, distal portion plain. Females with similar bars on head but last dark bar on opercle diffuse, and opercle marked with subvertical row of 4-7 small blackish spots; remainder of body usually without conspicuous markings, occasionally with irregular diffuse brownish spots.

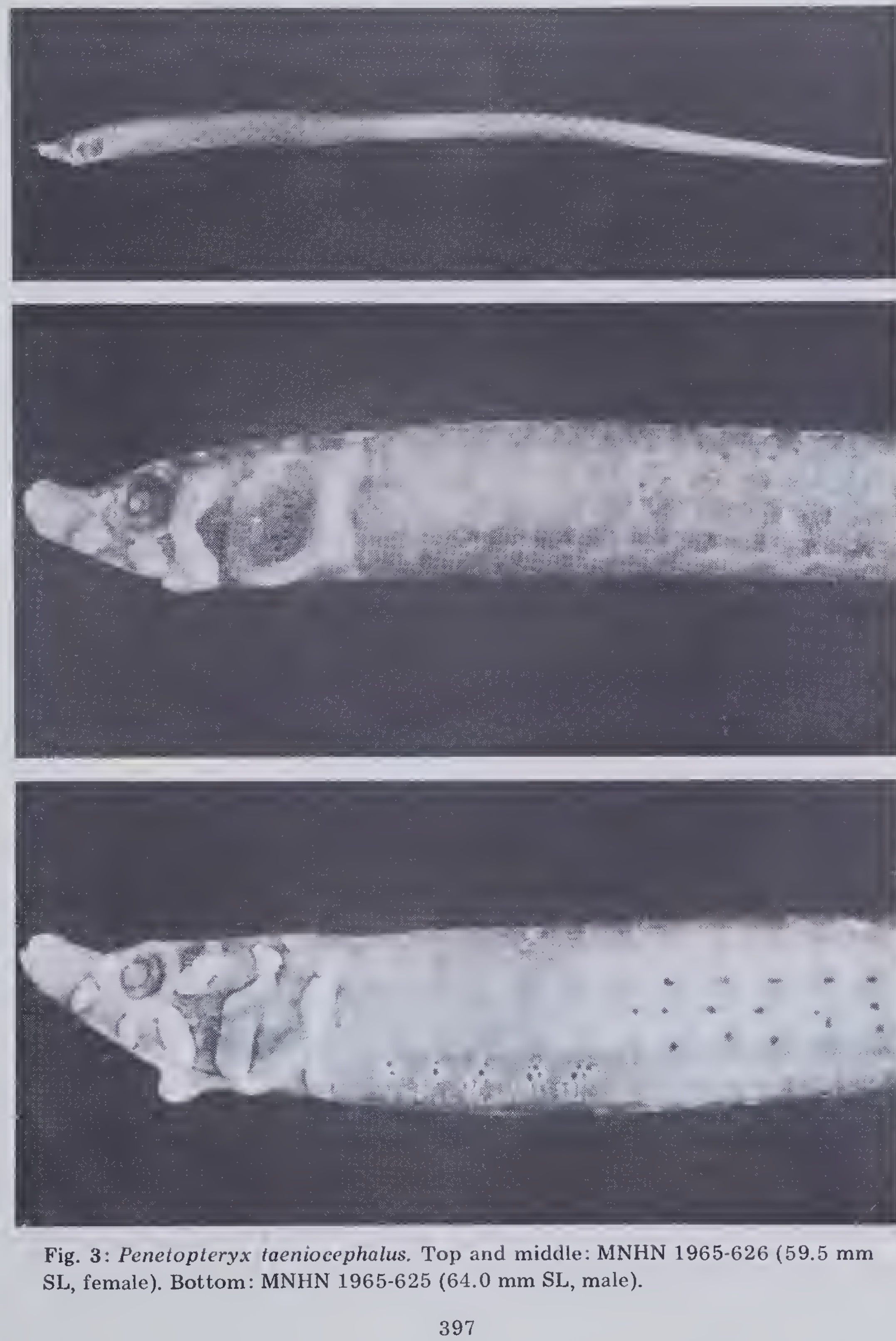

Fig. 3: *Penetopteryx taeniocephalus.* Top and middle: MNHN 1965-626 (59.5 mm SL, female). Bottom: MNHN 1965-625 (64.0 mm SL, male).

Comparisons

Penetopteryx taeniocephalus differs from its only known congener by characters in key and diagnoses.

Remarks

Ten examined egg-bearing males with brood pouch developed beneath 12-14 tail rings; pouch plates little enlarged but angled somewhat laterad; brood-pouch folds usually fail to meet on midline of egg-filled pouch; folds margined bilaterally by short dermal flap which is turned outward throughout length of pouch; type of pouch closure uncertain and outfolded margins do not agree with any configuration reported by Herald (1959). Brood-pouch eggs usually in two longitudinal rows but an incomplete 3rd present in one specimen examined; eggs separated by low membranous partitions lining dorsum of pouch and upper portions of pouch folds; a 64 mm SL male had 47 eggs in 14 ring pouch.

Several examined pouch-larvae with well developed dorsal, pectoral and caudal fins; one larva (*ca* 4.9 mm SL) with 30 dorsal-fin rays and dorsal-fin origin on 1st or 2nd tail ring; examined larvae without brownish bars but sprinkled with microchromatophores. A 56.5 mm SL male (CAS-SU 68329) retains a vestigial dorsal fin beginning on 1st-2nd tail ring; fin-rays are obsolete or poorly ossified and impossible to count.

Whitley (1933) described the holotype and only known specimen of *P. fowleri* (AMS IA.781) as having 20 + 44 rings. We find 19 + 41 rings in this specimen and this count, together with characteristic residual colour pattern and other features, shows *P. fowleri* to be conspecific with *P. taeniocephalus*. The Line Islands specimen mentioned by Herald (1961) is a 72.5 mm SL female (CAS 24854) which agrees with other material in ring count (18 + 41) and persistent colouration. Among examined materials we find no evidence of clinal variation in meristic features or colouration.

Available data show *P. taeniocephalus* to have been collected among 'gravel' and coral rubble at depths of 0.1-1.5 m. The species is known from Madagascar, Mauritius, the Philippines, New Hebrides and Christmas Is.

Material examined

Thirty-four subadults or adults (including one syntype) and several pouch-larvae, *ca.* 4.9-72.5 mm SL.

Syntype

MNHN 90-49 (60.0 mm SL, male), Mauritius.

Other material

Madagascar: CAS 24024; GCRL 15710; MNHN 1965-625, 1965-626; SIO 66-587. Philippines: CAS-SU 68329; GCRL 15711. New Hebrides: AMS IA.781 (*ca.* 62 mm SL, damaged male, holotype of *P. fowleri*). Line Islands, Christmas Is.: CAS 24854.

PENETOPTERYX NANUS (ROSÉN)

(Fig. 4)

Nannocampus nanus Rosén, 1911: 50 (original description; Andros Is., Bahamas).

Penetopteryx nanus Herald, 1942: 131 (new combination, compiled in key).

Diagnosis

Rings 17-18 + 31-33 = 48-51; head or both head and body circled with with numerous narrow brown bands and narrow pale interspaces. Larvae with about 28 dorsal-fin rays and dorsal-fin origin on trunk.

Description

Measurements (mm) of 31.7 mm SL female syntype (largest known specimen) follow: HL 2.6, snout length 0.8, snout depth 0.6, diameter of orbit 0.5, trunk depth 1.4, anal ring depth 1.2. Opercle without radiating striae, a few minute rounded diagonal ridges on suborbital, head surfaces otherwise without ornamentation.

Ground colour in alcohol tan. Female syntypes ringed with continuous series of narrow brown bars and subequal pale interspaces, about 15 dark bars on head and 5-7 on each ring. Two males (*ca.* 22 mm SL) with similar pattern of alternating bars on head; body of one essentially plain; dorsum of other with 11 pale blotches (1-2 rings wide) spaced 2-5 rings apart, blotches continued a short distance ventrad on trunk whereas some completely encircle tail; the latter specimen also marked with 9-10 irregular, vertically oriented, narrow pale blotches more or less equally spaced along upper portion of brood-pouch folds.

Comparisons

See key and diagnoses.

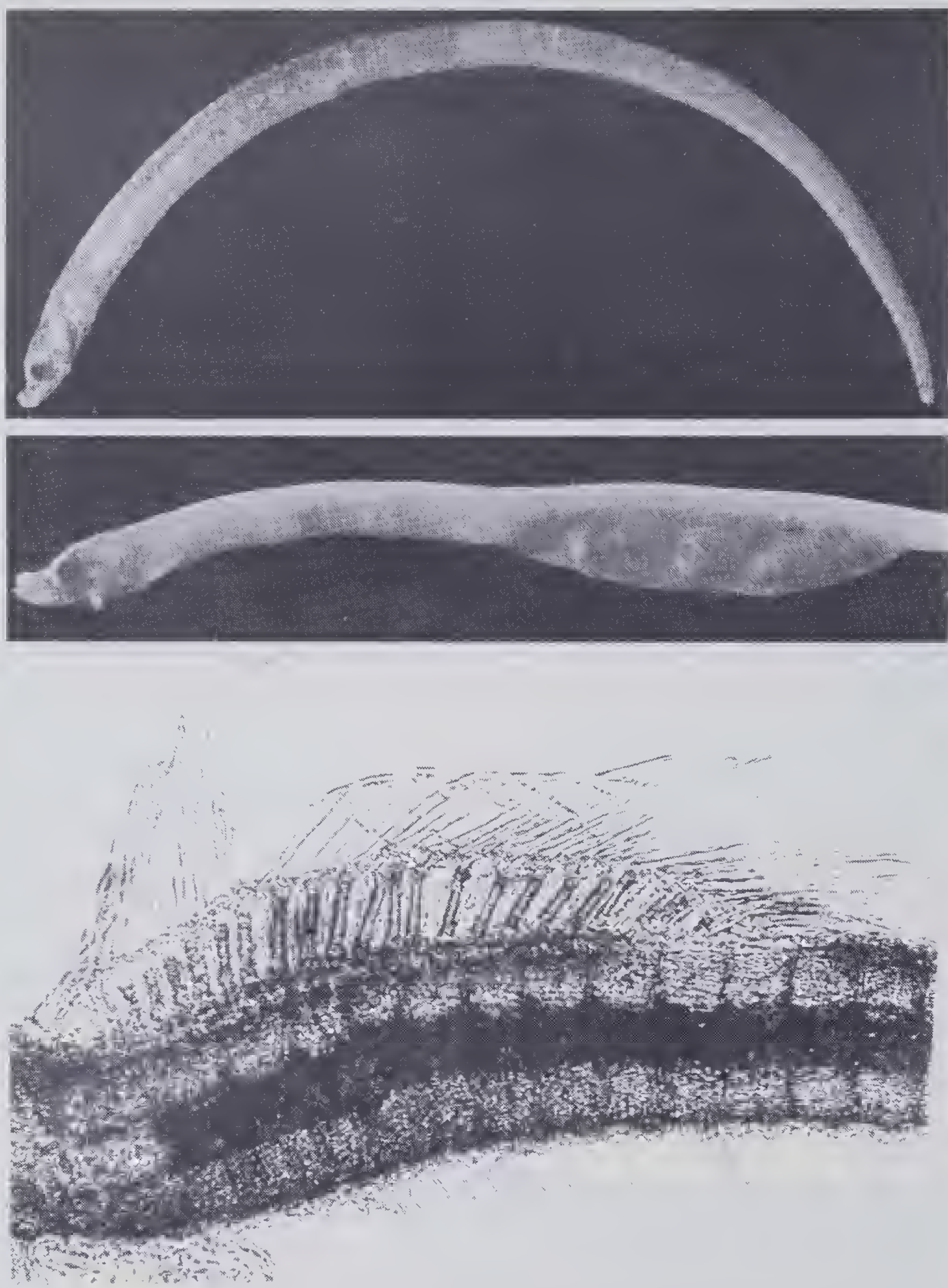

Fig. 4: *Penetopteryx nanus.* Top: LUZM uncat. (31.7 mm SL, female, syntype). Middle: AMNH 26032 (22.1 mm SL, male). Bottom: GCRL 15709 (*ca.* 3.8 mm SL, pouch-larva), section of body showing dorsal-fin rays and pterygiophores.

Remarks

The only examined egg-bearing male (22.1 mm SL) had about 20 membranous egg compartments in two longitudinal rows beneath 17 tail rings and about 10 larvae remained in pouch; margins of pouch folds meet on midline of partially filled pouch but type of closure is indeterminate; pouch folds of a male without eggs (21.6 mm SL) are rolled inward bilaterally through much of pouch length.

Several examined pouch-larvae have well developed dorsal, pectoral and caudal fins and there is a low finfold on venter of tail (Fig. 4); one larva (*ca.* 3.8 mm SL) had 28 dorsal-fin rays, dorsal-fin origin on penultimate trunk ring and there appeared to be about 11 subdorsal rings. Pouch-larvae marked on dorsum with about 10 rather broad brownish bars separated by subequal pale interspaces.

Presence of dorsal and pectoral fins in larval *Penetopteryx nanus* suggests a solution to one of the current enigmas among western Atlantic pipefishes. Herald (1950) described *Ichthyocampus pawneei* (provisionally referred to *Mannarichthys* by Dawson, 1977b) from an immature fish taken in a surface dipnet or plankton collection. To date, there are 5 known specimens of *pawneei*, all small (18-22 mm SL), all from separate surface nightlight or plankton collections (evidently over depths of 12-75 m) and all are from inshore Bahamian localities. The species is characterized by the presence of dorsal, pectoral and caudal fins, absence of anal fin, 18 + 31-32 rings, continuous superior trunk and tail ridges, interrupted inferior ridges, lateral trunk ridge confluent with inferior tail ridge and presence of vestigial opercular ridge. Morphology of head and body essentially replicates that of *Penetopteryx nanus* and, except for the presence of opercular ridge and dorsal and pectoral fins, *pawneei* agrees closely with adult *nanus* in treated characters. The opercular ridge is a variable feature in some pipefishes; it may be present in juveniles and obsolete in adults or it may occur only in late juveniles and adults. Dorsal-fin rays are 26-28 and subdorsal rings are 1.0-1.5 + 9.25-10.0 = 10.75-11.0 in *pawneei*, and these counts agree with those of the examined larva of *nanus*. Persistence of larval or postlarval characters in planktonic young or adults of benthic organisms is well known and has been recorded for the pipefish genus *Corythoichthys* (Dawson 1977a). Agreement in meristic features, ridge configuration and gross morphology, together with apparent absence of adult *pawneei* and sympatric Bahamian distribution, provides strong evidence that the 'finned' *pawneei* represents a protracted planktonic form of the 'finless' *Penetopteryx nanus*.

Although a substantial case can be presented for synonymizing *Mannarichthys pawneei* with *Penetopteryx nanus*, we retain their separate status pending further study.

Rosén (1911) collected the five syntypes from 'among dead corallines along the beach'. The other two known collections were with rotenone in depths of 0.6 to 2.4 m in the vicinity of coral rubble, coral and coralline algae.

Material examined

Four adults and several pouch-larvae, *ca.* 3.8-31.7 mm SL, including two female syntypes; all from the Bahamas.

Syntypes

LUZM uncat. (31.7 mm SL) and USNM 113615 (23.0), Andros Is., Mastic Point, 16 January 1909.

Other material

Ragged Islands: AMNH 26032 (Hog Cay), AMNH 35969 (Nurse Cay), GCRL 15709 (3 pouch-larvae from AMNH 26032).

APTERYGOCAMPUS WEBER

Apterygocampus Weber, 1913: 115 (type-species by original designation: *Apterygocampus epinnulatus* Weber, 1913).

Diagnosis

Superior trunk and tail ridges continuous (Fig. 1); inferior trunk and tail ridges not clearly interrupted at anal ring; lateral trunk ridge deflected near anal ring, reaches to but not clearly confluent with inferior ridge. Mouth terminal on snout; snout not angled dorsad and but slightly concave in lateral profile; short, moderately elevated, ridge on middle third of snout flanked postero-laterad by raised anterior continuations of supraorbital ridges; snout broad in front, breadth about equal to eye diameter. Opercle without median longitudinal ridge; median dorsal head ridges obsolete; head without thick fleshy integument; venter of trunk somewhat V-shaped, without median keel; all body ridges low and indistinct, slightly indented between rings; scutella moderate, width equals about half of ring length, faintly ornamented with indistinct ridges. Caudal-fin rays 10, other fins absent. Brood pouch developed below 11 tail rings; pouch plates somewhat enlarged; pouch developed as a closed sac, formed by continuous dermal envelope without trace of median suture, with mesial slit-like pore anteriad (Fig. 2). Nares 2-pored bilaterally; head and body without spines, serrations or dermal flaps.

Comparisons

Characters in key and diagnosis distinguish *Apterygocampus* from other syngnathid genera lacking dorsal, pectoral and anal fins in adults.

Remarks

Brood-pouch larvae with well developed dorsal, pectoral and caudal fins.

Without examining specimens, Duncker (1915) synonymized *Apterygocampus* with *Penetopteryx* despite described differences in configuration of principal body ridges and brood pouch. Although seldom treated in subsequent literature, other authors (Weber and de Beaufort 1922) have followed Duncker and pertinent types have never been examined critically.

Inferior trunk and tail ridges are not clearly interrupted in the holotype of *Apterygocampus epinnulatus* and lateral trunk ridge deflects rather abruptly to meet or nearly meet the continuous inferior ridge (Fig. 1).

The sealed or sac-like brood pouch of *Apterygocampus* is atypical of pipefishes and has previously been thought to occur only in the Hippocampinae (seahorses). These forms have prehensile tail without caudal fin; dorsal, pectoral and anal fins are present; head is at an angle to principal body axis; lateral tail ridge is present (*Hippocampus*) or absent (*Acentronura*) and pouch plates are present (*Acentronura*) or absent (*Hippocampus*). Herald (1959) proposed a phylogeny for urophorine (tail-pouch) syngnathids based on configuration of principal body ridges and type of brood-pouch closure. He noted that ridge pattern of *Penetopteryx* agreed with those of *Acentronura* and *Ichthyocampus filum* (referred to *Lissocampus* by Dawson 1977) and suggested that *Acentronura* may have been derived from an *Ichthyocampus*-like ancestor.

Herald was most certainly unaware of the sealed pouch of *Apterygocampus* and that ridge pattern is here most similar to that of *Ichthyocampus* (type-species: *Syngnathus carce* Hamilton Buchanan). We do not comment on the validity of Herald's phylogeny, but ridge configuration of *Apterygocampus* does not argue against his suggested *Ichthyocampus-Acentronura* lineage. The closed brood pouch clearly crosses subfamilial lines between the Syngnathinae and Hippocampinae, but general morphology and majority of examined characters indicate that *Apterygocampus* is best retained in the Syngnathinae (pipefishes).

Apparently a monotypic marine Indo-Pacific genus.

APTERYGOCAMPUS EPINNULATUS WEBER

(Fig. 5)

Apterygocampus epinnulatus Weber, 1913: 116 (original description; Indonesia).

Penetopteryx epinnulatus Duncker, 1915: 102 (new combination).

Diagnosis

Diagnostic characters are those of the genus.

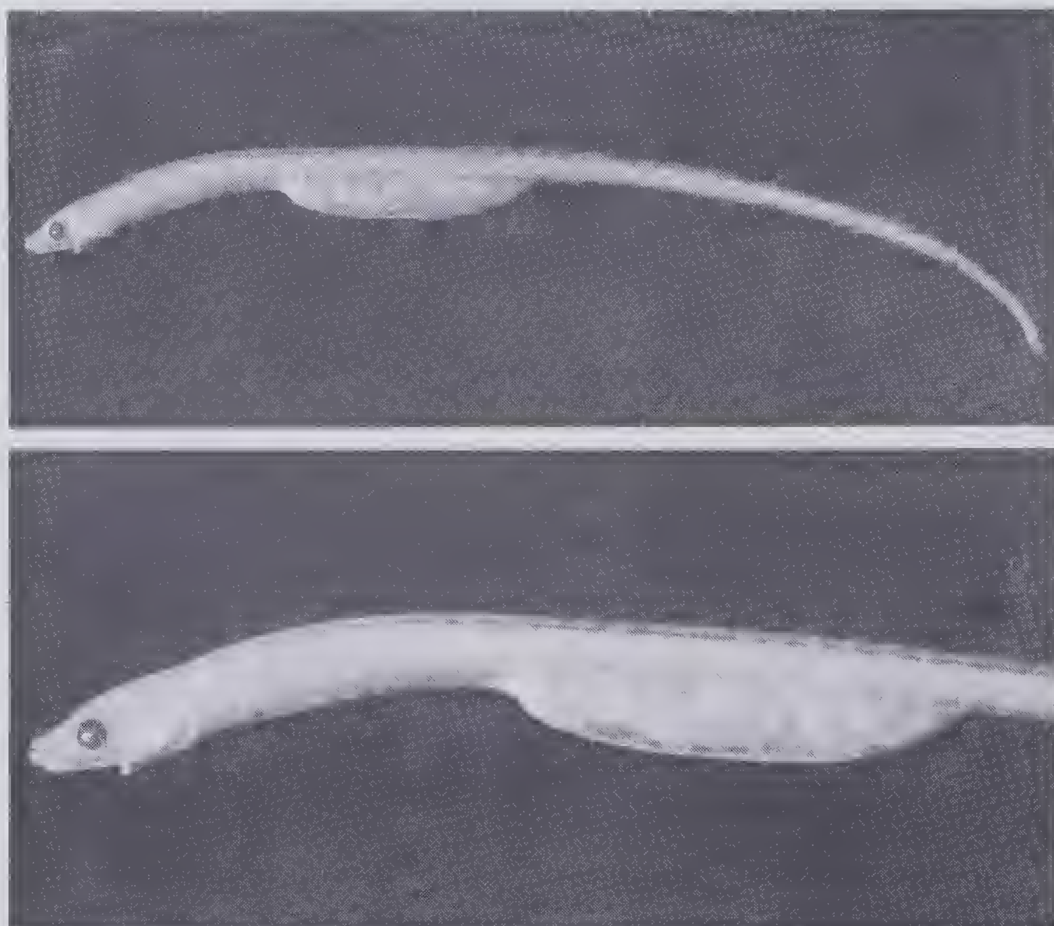

Fig. 5: *Apterygocampus epinnulatus.* ZMA 112.621 (27.4 mm SL, male, holotype).

Description

Rings 11 + 38. Measurements of 27.4 mm SL male holotype follow: HL 2.4, snout length 0.7, snout depth 0.6, trunk depth 1.2, anal ring depth

1.1. Opercle minutely pitted between low radiating striae, head elsewhere largely ornamented with minute irregular ridges.

Except for persistent brown pigmentation of eyes, the holotype is now a very light tan without conspicuous markings. Weber (1913) reported colour in alcohol as yellowish with a white spot on every 2nd ring and with bands of spots between eyes, on opercle and below eyes.

Comparisons

This species has no known congeners. From other adult pipefishes lacking dorsal, pectoral and anal fins, it is best distinguished by characters in key.

Remarks

Brood-pouch plates somewhat enlarged and angled laterad; about 20 rather well developed larvae visible through the translucent pouch integument. Three pouch-larvae, removed through a midlateral incision in side of pouch, all have well developed dorsal, pectoral and caudal fins. One larva, *ca.* 5.5 mm SL, had 18 dorsal-fin rays, dorsal-fin origin on 5th tail ring and 6.5 subdorsal rings.

The holotype and only known adult was collected on a 'reef', presumably in shallow water.

Material examined:

Holotype

ZMA 112.621 (27.4 mm SL, mature male), Indonesia, Gisser (= Gesser) Island, off Ceram, reef, Siboga Expdn Sta. 172, 26-28 August 1899, M. Weber coll.

Other material

GCRL 15724 (3, pouch-larvae, *ca.* 5.0-5.5 mm SL), removed from holotype.

ENCHELYOCAMPUS GEN. NOV.

Type-species: *Enchelyocampus brauni* sp. nov.

Diagnosis

Superior and inferior trunk ridges continuous with their respective tail ridges (Fig. 1); lateral trunk ridge terminates midlaterally, without deflection, near anal ring. Mouth inferior, not terminal on projecting tubular snout as in other syngnathids; snout separate, superior, represented by a hook-like preorbital projection which narrows to a bony point in front (Figs 6 and 7). Gape large, its breadth about $^1/_3$ greater than eye diameter; upper lip a broadly rounded fleshy fold, lower lip much thinner and with a shallow median emargination; suborbital crossed by a prominent rounded fleshy protuberance extending from angle of gape to slightly beyond rear margin of eye. Superior portion of orbital ridge rather distinct, other head ridges obsolete or concealed beneath fleshy integument covering remainder of head; greatest head breadth near angle of gape, slightly more than breadth at opercle. Gill opening a simple pore located dorso-laterad above posterior angle of opercle, its diameter about $^1/_4$ that of eye. Venter of trunk V-shaped, without median keel; venter of tail and dorsum of body somewhat convex; body ridges rather distinct, elevated slightly above surface of body and indented faintly between rings; scutella inconspicuous, poorly defined at X60 magnification, evidently occupy less than half of ring length; ring surfaces elsewhere ornamented with a few low subvertical ridges. Caudal fin present; other fins absent. Brood pouch presumably subcaudal. Nares 2-pored bilaterally, located on preorbital on level of horizontal through upper third of eye. Except for pointed preorbital, head and body devoid of spines, serrations and dermal flaps.

Etymology

Enchelyocampus, derived from the Greek *enchelys* (eel) and *kampos* (sea-animal), in allusion to the eel-like appearance and swimming behaviour of the type-specimen.

Comparisons

The absence of tubiform snout with terminal mouth immediately distinguishes *Enchelyocampus* from other syngnathid fishes. Whereas snout may be very short in some forms (e.g. *Apterygocampus* and certain species of *Micrognathus*), the mouth is never inferior nor is it provided with fleshy lips as in *Enchelyocampus*. The principal body ridge configuration of *Enchelyocampus* replicates a pattern common to several pipefish genera (see Dawson 1977a), but differs from the deflected lateral ridge configurations found in *Penctopteryx* and *Apterygocampus*. Although sharing loss of dorsal, pectoral and anal fins with these genera, *Enchelyocampus* clearly represents a different phyletic lineage of presently unknown relationships.

ENCHELYOCAMPUS BRAUNI SP. NOV.

(Figs 6 and 7)

Diagnosis

Diagnostic features are those of the genus.

Description

Rings 16 + 45-46. Measurements (mm) of 54 mm SL holotype are followed by those of 51.5 mm paratype in parentheses: HL 3.6 (3.2), snout length (to tip of preorbital spine) 0.6 (0.5), diameter of pigmented eye 0.5 (0.5), maximum head breadth 2.2 (1.3), trunk depth 2.2 (2.0), anal ring depth 1.7 (1.2). Holotype with ventral surface of preorbital projection V-shaped distally and somewhat concave or depressed; head surfaces without distinct sculpturing or other ornamentation; lateral trunk ridge ends without deflection near posterior margin of 1st tail ring; tail rings 45.

The holotype is near white in alcohol, without markings except for eye which is black. A colour photograph of holotype before preservation permits the following colour notes: ground colour brownish, darker anteriad shading to near tan on distal part of tail; buccal region and preorbital white; eye with black pupil surrounded by red; middle of opercle with a more or less oval, dusky brown blotch; remainder of head and body sprinkled with minute white dots, 13-14 in irregular vertical series on anterior trunk rings, dots fewer and less distinct caudad; principal trunk ridges lined faintly with pale.

Etymology

Named after the collector, Mr J. Braun, who recognized the fish as unusual and brought the living holotype to the Western Australian Museum.

Comparisons

See this section under generic diagnosis.

Remarks

Although caudal fin is well developed (*ca.* 0.8 mm long) in the holotype, it has been distorted in preservation and fin-ray count cannot be made without damaging or destroying the fin; there is no evidence of regeneration or other anomalous development. The paratype (preserved in isopropyl alcohol) is somewhat dehydrated, partially cleared and without conspicuous markings; caudal fin-rays 10. As seen through the translucent integument, the preorbital is a deflected V-shaped process, the apex formed by the exposed preorbital spine, each arm margined with 8-9 serrations and with bony preorbital somewhat depressed between; integument crossing dorsum of head with several rows of short, narrow, plate-like dermal thickenings or ossifications.

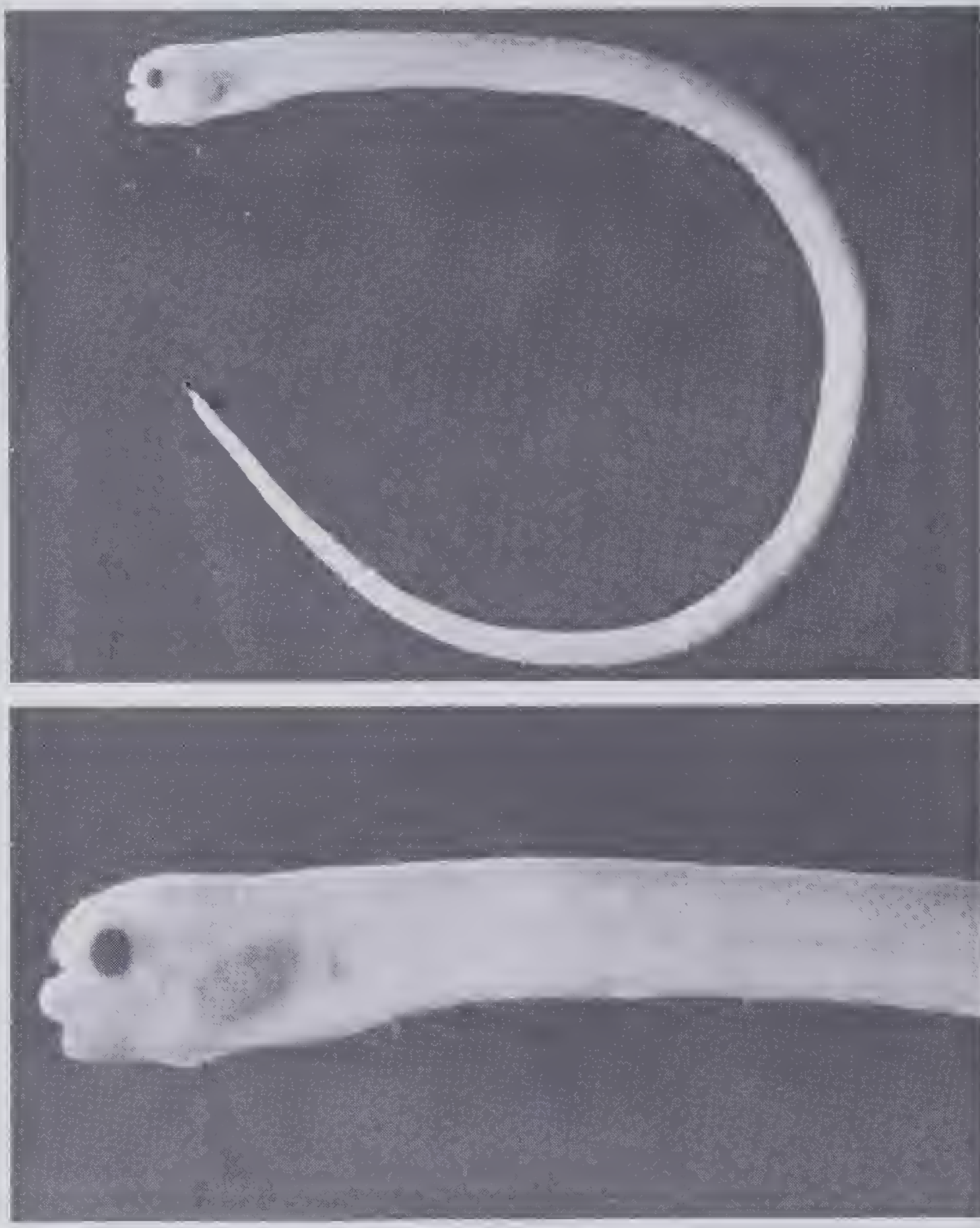

Fig. 6: *Enchelyocampus brauni*. WAM P.25800-001 (54 mm SL, holotype).

Fig. 7: *Enchelyocampus brauni.* WAM P.25800-001 (holotype). Lateral and dorsal aspects of head and anterior trunk rings.

Neither holotype nor paratype shows evidence of brood-pouch development and both specimens are assumed to be subadult or adult females. The holotype exhibited an undulating swimming motion and was initially thought to be an eel; it was found to be a syngnathid only on close examination after preservation.

Material examined

Holotype

WAM P.25800-001 (54 mm SL, immature or female), Western Australia, North West Cape, off Tantabiddi Creek (21°55′S, 113°56′E), outer reef, among dendrophyllid coral, 10 m, 5 Nov. 1976, J. Braun coll.

Paratype

CAS 17789 (51.5 mm SL, immature or female), Palau Is., Iwayama Bay, E side of mouth of Kaki-suido, from submarine cave, 0.6-4.6 m, 'found among protruding calicles of *Galaxea musicalis*', 22 Oct. 1955 (GVF Sta. 220A), R.R. Harry and party.

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Rec. West. Aust. Mus., 1978, 6 (4)

DESCRIPTION OF A NEW WESTERN AUSTRALIAN PIPEFISH (*CHOEROICHTHYS LATISPINOSUS*), WITH NOTES ON *SYNGNATHUS TUCKERI* SCOTT AND *NANNOCAMPICHTHYS* HORA AND MUKERJI

C.E. DAWSON*

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ABSTRACT

Choeroichthys latispinosus (characterized by a spiny anterolateral process on snout, short and deep snout, and hyaline dorsal fin) is described from South Murion Is., Western Australia; a revised key to the genus is provided. Published data on *Syngnathus tuckeri* Scott are emended, records from Twofold Bay, N.S.W. extend the known range from Tasmania to continental Australia and notes are given on generic relationships. *Nannocampichthys* Hora and Mukerji (type-species: *N. gigas*) is found to be a junior synonym of *Entelurus* Duméril. All treated species are illustrated.

INTRODUCTION

In continuation of studies on Indo-Pacific pipefishes (Syngnathidae), I here describe a new species of *Choeroichthys* Kaup from Western Australia, report on the first known specimen of *Syngnathus tuckeri* Scott from continental Australian waters, and discuss the status of the nominal genus *Nannocampichthys* Hora and Mukerji.

Measurements are in millimetres (mm); proportional data are referred to standard length (SL) or head length (HL); depths are reported in metres (m); other methods follow Dawson (1977). Study materials are deposited in collections of the British Museum of Natural History (BMNH), California Academy of Sciences (CAS), Queen Victoria Museum and Art Gallery, Launceston, Tasmania (QVM), Western Australian Museum (WAM) and Zoological Survey of India, Calcutta (ZSI).

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CHOEROICHTHYS LATISPINOSUS N. SP.

(Fig. 1)

Diagnosis

Snout with bilateral recurved spinous process protruding laterad; scutella not keeled; without knoblike projections below lateral trunk ridge; snout depth 2.8 in snout length; dorsal fin not bicoloured.

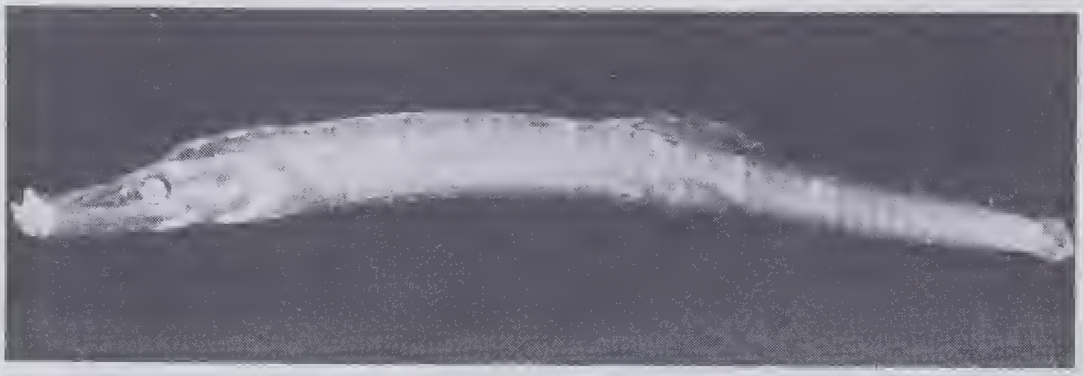

Fig. 1: *Choeroichthys latispinosus* n. sp. WAM P.25815-024, holotype, 27.5 mm SL, female.

Fig. 2: *Choeroichthys latispinosus.* Lateral and dorsal aspects of head and anterior trunk rings; detail illustrates spiny lateral snout ridge. From 27.5 mm SL holotype, WAM P.25815-024.

Description

Dorsal-fin rays 22; rings 19 + 20; subdorsal rings 5.5 + 0.25 = 5.75; pectoral-fin rays 20; anal rays 4; caudal rays 10. Measurements (mm) of holotype: standard length (SL) 27.5, head length (HL) 6.6, snout length 3.1, snout depth 1.1, length of dorsal-fin base 3.6, anal ring depth 1.6, trunk depth 2.2, pectoral-fin length 1.0, length of pectoral-fin base 0.8.

Side of snout (Fig. 2) with a protruding spiny ridge between verticals from tip of upper jaw and origin of median dorsal snout ridge; spines (10 on left side, 8 on right) conical; ridge and spines distally free from snout and recurved posteriad. Median lateral snout ridge slightly arched, originates behind spiny anterior lateral ridge; median dorsal snout ridge begins on anterior third of snout, its height extends well above level of nares behind; supraopercular and supraorbital ridges continuous, confluent in front with superior lateral snout ridge, ridges somewhat expanded laterad above opercle and eye; interorbital and internarial region flat, depressed well below ridge margins; prenuchal, nuchal and frontal ridges moderately elevated; suborbital narrow, without prominent ridges; opercle with distinctly elevated median longitudinal ridge, a single reduced ridge above and four below; pectoral-fin base with two prominent longitudinal ridges. Median ventral trunk ridge distinct but not keel-like; inferior ridges of 1st trunk ring enlarged, expanded somewhat laterad, venter depressed between; principal ridges indented between most rings, notched between last 5-6 tail rings where posterior ring angles are distinctly pointed. Scutella indistinct, without keels; trunk and tail surfaces depressed between principal ridges; margins of head and body ridges entire, other surfaces irregularly sculptured with a few minute ridges. Odontoid processes (Dawson and Fritzsche 1975) not prominent in holotype but 2-3 projections are visible on premaxillae at X60 magnification.

Ground colour brown in alcohol. Jaws with irregular pale mottling, snout elsewhere with a few indistinct pale spots on dorsum and 5-6 pale spots along inferior ridge. Median dorsal head ridges with three pale blotches on midline; dorsum of trunk and tail with indications of 8-9 irregular, narrow, pale blotches which occasionally extend slightly ventrad on superior ridges; side with irregular pale mottling below middle of dorsal fin and a diffuse pale bar across juncture of 1st-2nd tail ring; edges of principal ridges translucent or pale; all fins hyaline.

A colour slide of the fresh holotype shows ground colour to be very dark brown, pale areas are white and dorsal fin is narrowly edged with black or brown.

Etymology

Named from the Latin *latus* (side) and *spinosus* (thorny), in reference to the protruding lateral snout ridge.

Comparisons

The protruding recurved spiny anterolateral snout ridge immediately separates *C. latispinosus* from all congeners. It is most similar to *C. smithi* in gross appearance, both have smooth-edged ridges and ring-counts overlap. In addition to the lateral snout spines, *C. latispinosus* has one more dorsal-fin ray than examined *C. smithi* (22 against 17-21), slightly longer dorsal-fin base (covers 5.75 rings against 3.75-5.25), snout depth in length ratio is somewhat higher (2.8 against an average of 2.3), and dorsal fin is hyaline in preservative (distinctly bicoloured in *smithi*).

Remarks

This unusual *Choeroichthys* requires the following emendation of the generic diagnosis (Dawson 1976): protruding subvertical spiny anterolateral snout ridge present or absent. A revised key to the genus is given below.

Holotype

WAM P.25815-024 (27.5 mm SL, female), Western Australia, South Murion Is., from coral/limestone formation on reef-front slope, 8 m, SCUBA and rotenone, 7 June 1977, Sta. MUR 77-005, J.B. Hutchins and J. Tryndall.

KEY TO THE SPECIES OF *CHOEROICHTHYS*

1a Scutella of trunk and tail keeled; dorsal-fin rays 27-34; subdorsal rings 6.25-8.25 ... ... *C. sculptus* (Günther)

1b Scutella not keeled; dorsal-fin rays 17-26; subdorsal rings 3.75-6.0 2

2a Snout short, its depth less than 3 in length; trunk rings 18-19; with spiny anterolateral snout ridge or dorsal fin bicoloured 3

2b Snout longer, its depth more than 3.5 in length; trunk rings 14-18 (99.6% with 17 or fewer); without spiny snout ridge; dorsal fin not bicoloured 4

3a Snout with protruding, recurved, subvertical spiny anterolateral ridge (Fig. 2); dorsal fin hyaline ... ... *C. latispinosus* n. sp.

3b Snout without spiny anterolateral ridge; dorsal fin distinctly bicoloured, mainly brown in front and pale behind ... ... *C. smithi* Dawson

4a Without knoblike projections below lateral ridge on posterior margins of trunk rings; head length averages about 5 in SL; tail rings 17-20 (fewer than 20 in 93%); trunk plain or with 1-2 rows of small dark spots, without dark bars ... ... *C. brachysoma* (Bleeker)

4b Males (females?) with knoblike projections below lateral ridge on posterior margins of most trunk rings; head length about 4 in SL; tail rings 20-21; body with dark bars (females?) ... ... *C. cinctus* Dawson

SYNGNATHUS TUCKERI

Scott (1942) described *Syngnathus tuckeri* from a single male fish from Bridport, Tasmania and six additional specimens have since been recorded from the northern Tasmanian coast (Scott 1960, 1964, 1975). I have recently examined the holotype (QVM 1971/5/28; 121.5 mm SL), two other Tasmanian specimens (QVM 1975/5/110; 76-99 mm SL), and two (CAS-SU 36427, 133.5-159 mm SL) collected at Twofold Bay, N.S.W., on 3 February 1940 by G. Clark. Counts from the latter (Fig. 3), apparently representing the only records of *S. tuckeri* from continental Australia, are: rings 21 + 41-42; dorsal-fin rays 36 (both fish); pectoral-fin rays 11 (4 counts); subdorsal rings 8.75 + 2.0-2.5 = 10.75-11.25; anal fin apparently with 3 rays; caudal-fin rays 10 (both). The male (133.5 mm) with brood pouch developed below 11 anterior tail rings; pouch plates present but little enlarged; eggs missing but persistent membranous compartments indicate maximum of 6 transverse egg rows and 15 compartments in outer right row. Proportional data (male in parentheses) are: HL in SL 7.9 (7.7); snout length in HL 1.8 (1.9); snout depth in snout length 7.2 (6.6); length of dorsal-fin base in HL 1.0 (both fish); anal ring depth in HL 5.6 (5.8); trunk depth in HL 3.7 (4.7); pectoral-fin length in HL (5.4); length of pectoral-fin base in HL 10.6 (12.4).

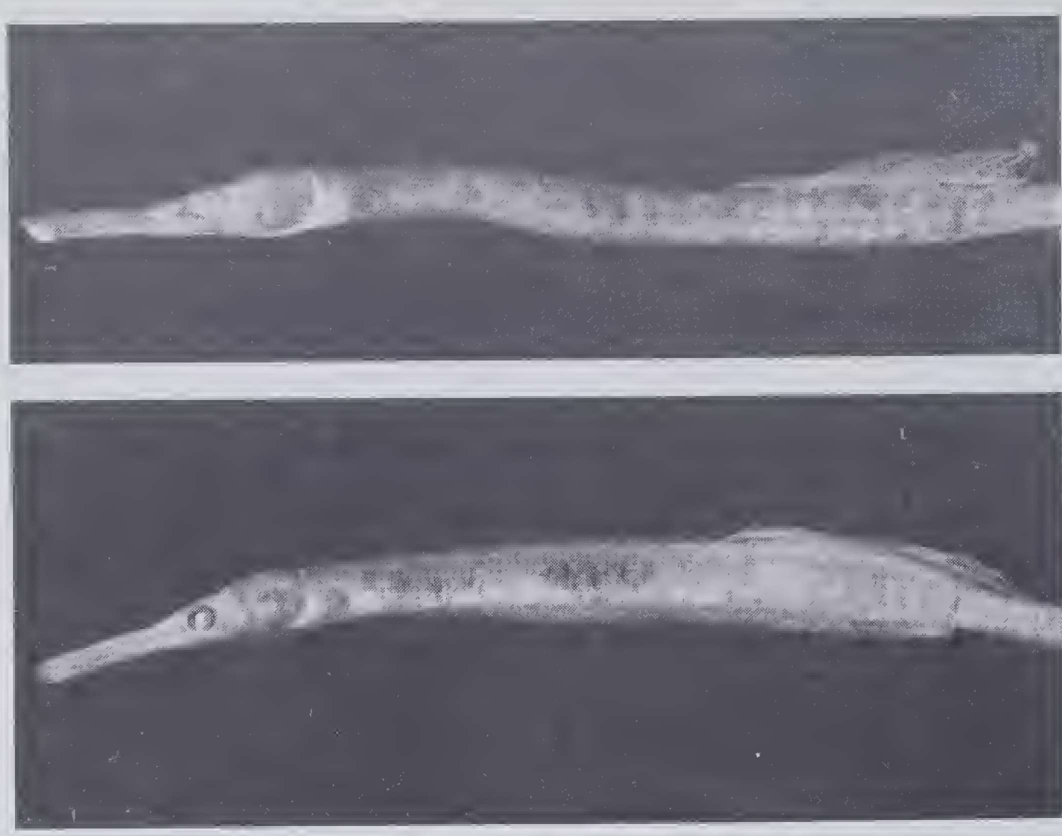

Fig. 3: *Syngnathus tuckeri* Scott. CAS-SU 36427, Twofold Bay, New South Wales. Top — male, 133.5 mm SL. Bottom — female, 159.0 mm SL.

My examination of the holotype shows 41 tail rings and 10 rays in the damaged caudal fin, rather than the originally described respective values of 42 and 5; subdorsal rings total 11.75, rather than 12.0; pouch plates present but little enlarged; pouch closure is the everted type of Herald (1959); an elongate anal fin with at least two rays is present, rather than 'indistinguishable' as described. I also find the following discrepancies in counts reported by Scott (1975) for two other specimens (QVM 1975/5/110): rings 22 + 40-41 (rather than 23 + 43-45), dorsal-fin rays 37-38 (against 36-37), pectoral-fin rays (4 counts) 11-12 (against 13), caudal-fin rays 10 (2 counts) rather than 6, and both fish have elongate 2-3 rayed anal fins. Data from four specimens not examined here (Scott 1960, 1964) together with those treated above show the following meristic values for the 9 known specimens of *S. tuckeri*: rings 20-23 + 40-43 = 60-64; dorsal-fin rays 32-38 (usually 35-38); pectoral-fin rays 11-13 (usually 11-12); subdorsal rings 10.0-8.75 + 1.75-2.5 = 10.75-12.25; caudal-fin rays 10; anal-fin rays 2-3.

Whitley (1948), evidently without examining specimens, referred *Syngnathus tuckeri* to his inadequately diagnosed monotypic genus *Mitotichthys.* Scott (1960, 1975) has followed this treatment or (Scott 1955, 1961, 1964) retained the species in *Syngnathus.* The species was treated (in *Syngnathus*) by Munro (1958) and listed (in *Mitotichthys*) by Whitley and Allan (1958), but I find no other literature citations. *Syngnathus tuckeri* clearly differs from *Syngnathus* Linnaeus (type-species *Syngnathus acus* L.) in a number of features (e.g. convex dorsum of subdorsal rings, dorsal fin location mainly on trunk, everted pouch closure), but recognition of one more monotypic genus seems premature. As implied by Scott (1942), general morphology and meristics suggest that *tuckeri* is related to the poorly defined assemblage of pipefishes now referred to *Histiogamphelus* McCulloch. Pending review of the latter, I deem it best to retain *tuckeri* in the catch-all genus *Syngnathus.*

NANNOCAMPICHTHYS

Hora and Mukerji (1936) described *Nannocampichthys* (type-species *N. gigas*) for the accommodation of a single female pipefish received from Rangoon in a sample of 238 fishes reportedly collected at Maungmagan, Tavoy District, Lower Burma (14°30′N, 97°50′E). The genus was tentatively compiled in the synonymy of *Entelurus* Duméril by Norman (1966), but I am unaware of other references to *Nannocampichthys* and its status has remained in doubt.

The holotype of *Nannocampichthys gigas* (ZSI F.11870-1) has confluent superior trunk and tail ridges; inferior trunk ridge ends at anal ring; lateral trunk ridge confluent with inferior tail ridge; opercle without longitudinal ridge; dorsal-fin rays 40; rings 29 + 62; subdorsal rings 8.75 + 2.5 = 11.25; pectoral and anal fins absent; caudal fin rudimentary with about 9 distorted rays. Measurements (mm) follow: SL 436.5, HL 38.5, snout length 19.9, snout depth 3.7, length of dorsal-fin base 56.2, anal ring depth 8.3, trunk depth 12.7. This fish lacks evidence of fleshy predorsal fold and no distinctive markings persist.

I have compared the holotype (Fig. 4) with several *Entelurus aequoreus* (Linnaeus), including a 440 mm SL female (BMNH 1894.10.22.2) from the eastern North Atlantic, and find no substantive differences in gross morphotogy, counts or proportional characters. I therefore agree with Norman's (1966) treatment of *Nannocampichthys* and find *N. gigas* to be conspecific with *Entelurus aequoreus.*

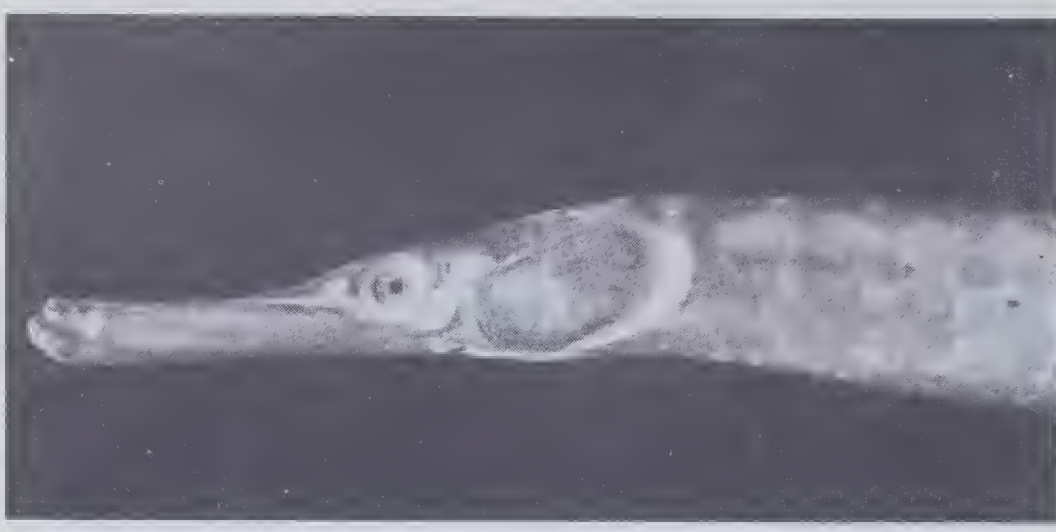

Fig. 4: *Nannocampichthys gigas* Hora and Mukerji [= *Entelurus aequoreus* (Linnaeus)]. ZSI F.11870-1, holotype, 436.5 mm SL, female (head and anterior trunk rings).

Hora and Mukerji (1936) noted that the Rangoon material included single specimens representing five eastern Atlantic taxa (*Ammodytes lanceolatus*, *Blennius pholis*, *Trachinus draco*, *Cottus bubalis*, *Lophius piscatorius*), and that these identifications were subsequently confirmed by J.R. Norman (BMNH). They recognized the highly questionable nature of these extralimital records, but their several attempts to verify the source of these specimens were not completely successful. Available evidence indicates that Atlantic material of unknown origin was included in the Burma collection, and that Hora and Mukerji failed to realize that their single pipefish was also of Atlantic origin.

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I thank W.N. Eschmeyer (CAS), R.H. Green and E.O.G. Scott (QVM), P.K. Talwar (ZSI) and A.C. Wheeler (BMNH) for gifts of specimens or loans of types and other materials in their care. Special thanks are due Mr J.B. Hutchins (WAM) for permitting me to describe the new *Choeroichthys* from his collections. Drawings are by Mrs Nancy Gordon. This study was in part supported by National Science Foundation Grant BMS 75-19502.

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THE UNFIGURED MOLLUSCA OF J. THIELE, 1930 PUBLISHED IN *DIE FAUNA SÜDWEST-AUSTRALIENS*

W.F. PONDER*

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ABSTRACT

The type specimens of 12 species described by Thiele in *Die Fauna Südwest-Australiens* are figured for the first time. Some nomenclatural rectifications are made and descriptions based on translations of the original descriptions are given.

The species included are *Diodora plicifera, D. rugosa, D. nigropunctata* (all synonyms of *D. jukesii* [Reeve]), *D. ovalis* (synonym of *D. singaporensis* [Reeve]), *Calliostoma excellens* (synonym of *C. rubiginosa similarae* [Reeve]), *C. modestum, Cantharidus tristis* (synonym of *C. polychromus* [A. Adams]), *C. sericinus, Turbo menkei* (synonym of *T. haynesi* Preston), *Astraea tentorium, Scala tumidula* and *Phacoides pisiformis.*

INTRODUCTION

Johannes Thiele's (1930) account of the mollusca of Western Australia is the most comprehensive yet published. Many new species were described in this work and, curiously, although Thiele figured nearly all of the new small and minute species most of the larger new species were not illustrated. In the absence of figures it has been almost impossible for Australian malacologists to make an accurate assessment of several of Thiele's species. Consequently, the opportunity was taken during a brief visit to the Museum für Naturkunde, Humbolt-Universität, East Berlin, to photograph the type material of some of Thiele's unfigured Australian species. The remainder of the species are here illustrated with photographs supplied by Dr R. Kilias and one with a drawing from a photograph.

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No attempt is made to redescribe most of the species here dealt with, but a modified translation based on the original description is given under the heading 'Description'. Although comments are made on the taxonomy of some of these species, more detailed discussion on the status of several of the species names is considered to be beyond the scope of this paper. The generic position of most species has been interpreted in the broad sense, generally following the *Treatise on invertebrate paleontology*. For this reason the majority of species are not assigned to subgenera.

The data for the 'stations' referred to in the text are given by Michaelsen and Hartmeyer (1907).

GASTROPODA

FAMILY FISSURELLIDAE

DIODORA PLICIFERA THIELE, 1930: 562

(Plate 1, Figs 1-3)

Description

Sculpture similar to *D. subcalyculata* (Schepman) with 3 very strong posterior radial ribs and 6 weaker anterior ribs. Radial ribs crossed by distinct concentric rings. Form of shell differs from *D. subcalyculata* in being rather depressed, with an oval foramen behind the anterior $^1/_3$. Anterior slope straight, posterior slope somewhat arched. Aperture much longer than broad, internal foramen callus with posterior edge convex and lacks pit behind. Colour white.

Dimensions

Length 14 mm; width 8 mm; height 5 mm.

Locality

Station 1, NW of Middle Bluff, Sharks (= Shark) Bay, north-west Australia, 7-8 m, rocks and coral, (holotype) (reg. no. 67368).

Remarks

This species is a synonym of *Diodora jukesii* (Reeve) (see remarks under *D. nigropunctata*).

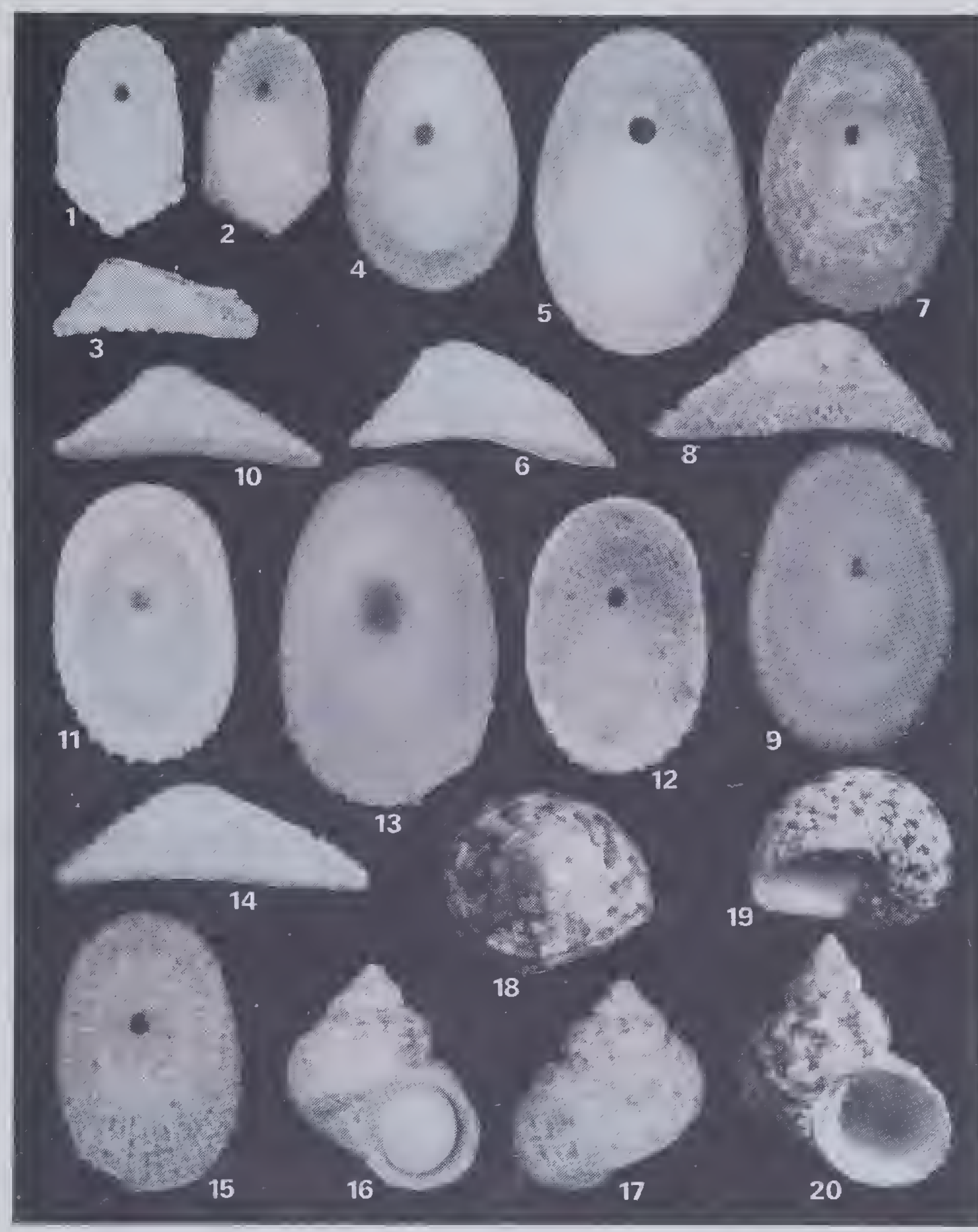


PLATE 1

Figs 1-3, 7-9, 13-15. *Diodora jukesii* (Reeve). 1-3. Holotype of *D. plicifera* Thiele. 7-9. Holotype of *D. rugosa* Thiele. 13-15. Holotype of *D. nigropunctata* Thiele. Figs 4-6, 10-12. *Diodora singaporensis* (Reeve). 4-6. Lectotype of *D. ovalis* Thiele. 10-12. Specimen from Cossack, W. Australia, identified by Thiele as *D. ovalis*. 16-20. *Turbo (Marmarostoma) haynesi* Preston. 16-17. Holotype of *T. menkei* Thiele. 18-20. Holotype of *T. foliaceus haynesi* Preston.

DIODORA RUGOSA THIELE, 1930: 562

(Plate 1, Figs 7-9)

Description

Similar to the eastern Australian *D. lineata* (Sowerby) but the sculpture is not so reticulated. The radial ribbing, which crenulates the shell margin, consists of strong ribs usually alternating with weaker ones. The fine concentric folds form scales at the intersections with the strong radials. Foramen rounded-rectangular, placed anterior to the centre, somewhat inclined forwards. Anterior slope nearly straight, posterior slope somewhat arched. Exterior colour brownish with indistinct broad, darker rays. Shell widest somewhat behind middle, distinctly narrowed anteriorly.

Dimensions

Length 51 mm; width 34 mm; height 20 mm. Foramen 4 mm x 2.5 mm.

Localities

Station 3, *ca* 5 km NW of Denham, Sharks (= Shark) Bay, north-west Australia, sand and rich vegetation (holotype) (reg. no. 67367). A smaller specimen (15 mm long) from station 15, NNE of the northern end of Heirisson Prong, Shark Bay, rocks with coral, 11-12.5 m.

Remarks

This species is also a synonym of *Diodora jukesii* (Reeve) (see remarks under *D. nigropunctata*).

DIODORA NIGROPUNCTATA THIELE, 1930: 563

(Plate 1, Figs 13-15)

Description

Shell with the radial ribs well separated and unequal in strength, especially at the posterior end where some stronger ribs are separated by groups of 3 weaker ribs. The anterior ribs consist of one somewhat stronger rib always alternating with a relatively weaker rib. Foramen a little in front of centre, rectangular. Anterior and posterior slopes hardly arched. White with dispersed black specks, internal callus of foramen blackish.

Dimensions

Length 24 mm; width 15.5 mm; height 7 mm.

Localities

Station 5, Denham, Sharks (= Shark) Bay, north-west Australia (holotype) (reg. no. 67366) and a young specimen from station 7, *ca* 4 km SW of Denham, 3 m, sand and mud with plants.

Remarks

This species, like *D. rugosa* Thiele and *D. plicifera* Thiele is a synonym of *D. jukesii* (Reeve). A large series of specimens from tropical Australia shows Reeve's species to be an extremely variable one. Features such as the strength of the ribbing, the accentuation of a few ribs (as in the types of *D. jukesii* and *D. plicifera*), the degree of scaled or frilled concentric sculpture, the posterior truncation or nontruncation of the internal foramen callus, the base outline, the relative height of the shell and the details of the shape of the foramen are all variable features even within the same population. The purple callus of *D. nigropunctata* is a feature that occurs in some specimens of *D. jukesii* throughout the range of the species and does not appear to be correlated with other shell features. The degree of purple coloration is variable, sometimes being reduced to a narrow line around the callus (as in the type of *Elegidion occiduus* Cotton, another synonym of *D. jukesii*).

A South Australian form, *D. lincolnensis* Cotton, is probably indistinguishable from *D. jukesii*, but insufficient material from intermediate parts of the range (south Western Australia and mid-Western Australia) is available to make a definite decision.

A partial synonymy of *D. jukesii* can be set out as follows:

Diodora jukesii (Reeve, 1849)
- *Fissurella jukesii* Reeve, 1849: Plate 7, Fig. 45
- *Fissurella fimbriata* Reeve, 1849: Plate 14, Fig. 104
- *Fissurella similis* Sowerby, 1862: 194: Plate 241, Fig. 143
- *Diodora plicifera* Thiele, 1930: 562
- *Diodora rugosa* Thiele, 1930: 562
- *Diodora nigropunctata* Thiele, 1930: 563
- *?Diodora lincolnensis* Cotton, 1930: 219
- *Elegidion occiduus* Cotton, 1930: 220; Cotton, 1959: 82: Fig. 41
- *?Austroglyphis lincolnensis.*—Cotton, 1959: 80: Fig. 40

The types of all of the species listed in the above synonymy have been examined by the writer.

DIODORA OVALIS THIELE, 1930: 562

(Plate 1, Figs 4-6, 10-12)

Description

Like *D. singaporensis* (Reeve), but might be separated by its longer shell and its flat ribs. Anterior and posterior slopes nearly straight, sculpture of flat ribs, although these are angular in the middle of the shell, and are alternately broader and narrower and are crossed by weak, concentric folds. Exterior 'colourless' with about 6 weak, grey streaks; interior white (lectotype fawn externally with a few pale brown radial rays).

Dimensions

Length 29.9 mm; width 19 mm; height 12.4 mm; foramen 3.6 mm x 2.7 mm (station 1) (lectotype).

Length 23 mm; width 14 mm; height 7 mm; foramen 1.75 mm x 1.2 mm (station 14) (dimensions given by Thiele).

Length 11 mm; width 7 mm; height 4 mm (specimen from Cossack).

Localities

Stations 1 and 14, Sharks (= Shark) Bay, north-west Australia (2 specimens). Lectotype, station 1 (reg. no. 67369) (Plate 1, Figs 4-6). Station 1, NW of Middle Bluff, 7-8 m, rocks and coral.

Cossack (near Point Samson), north-west Australia, 1 specimen (reg. no. 67400) (Plate 1, Figs 10-12).

Remarks

The specimen measured by Thiele from station 14 in Shark Bay was not located and is not catalogued. In the register an entry written in 1930 lists the specimen from station 1 as the type. This specimen is here designated lectotype. Both the shell and animal are stored in alcohol.

This species is a synonym of *D. singaporensis* (Reeve), falling well within the range of variation exhibited by that species. A partial synonymy is given below:

Diodora singaporensis (Reeve, 1850)
- *Fissurella singaporensis* Reeve, 1850: Plate 14, Figs 100 and 101
- *?Fissurella mus* Reeve, 1850: Plate 16, Fig. 120
- *Fissurella tenuistriata* Sowerby, 1862: 199; Plate 240, Fig. 111
- *Fissurella townsendi* Melvill, 1897: 20; Plate 7, Figs 27 and 27a
- *Diodora ovalis* Thiele, 1930: 562

All of the types of the species in the above synonymy, with the exception of the type(s) of *F. mus*, have been examined by the writer and appear to be conspecific. The type of *D. ovalis* is higher than typical specimens but *D. singaporensis* does show considerable variation in elevation. *F. mus* Reeve, 1850 is possibly conspecific with *D. singaporensis* but was described from unknown habitat from the now missing Metcalfe collection. As first revisor I select the name *singaporensis* for this species because it has existing type material, was described from a known locality and has page priority.

This species is distributed through the central Indo-Pacific and tropical Australia, and can be easily distinguished by its rather large, simple, oval foramen and relatively fine sculpture.

FAMILY TROCHIDAE

CALLIOSTOMA EXCELLENS THIELE, 1930: 565

(Plate 2, Figs 1 and 2)

Description

Similar in size and colour to *C. rubiginosa* (Valenciennes) but differs in not having the lowest 2 (or 3 in some specimens) spiral rows of beads protruding and forming the periphery of the body whorl, but instead the upper row of the 2 peripheral cords is stronger and the two rows do not fuse together as they do in *C. rubiginosa*. In this respect it is similar to *C. similarae* (Reeve) but that species is smaller and more finely sculptured. The whorls have, in addition to the 2 (sometimes 3) peripheral rows of gemmules, 4 or 5 (4-7 in additional material) gemmate spiral cords which have weaker spirals between them. The peripheral cords are visible at the base of each spire whorl. The base has 10 beaded spirals (8-13 in additional material) sometimes with an interstitial thread between each pair. The dorsal surface is whitish with brown blotches and the base is mostly brown with white spots, the central spiral cord (sometimes 2) rose-spotted. Upper peripheral cord spotted with rose and white, lower cord(s) with brown and white (or sometimes also with rose).

Dimensions

Height 26 mm; diameter 23 mm.

Locality

Houtman Abrolhos, Western Australia (holotype) (reg. no. 67364).

PLATE 2

Figs 1-2. *Calliostoma rubiginosa similarae* (Reeve). Holotype of *C. excellens* Thiele.
Figs 3 and 9. *Linga (Bellucina) pisiformis* (Thiele). Holotype.
Fig. 4. *Phasianotrochus sericinus* (Thiele). Holotype.
Figs 5-6. *Calthalotia modesta* (Thiele). Lectotype.
Figs 7-8. *Astralium tentorium* (Thiele). Holotype.
Fig. 10. '*Cantharidus*' *polychromus* (A. Adams). Holotype of *Cantharidus (Jujubinus) tristis* Thiele.

Remarks

Cotton (1959: 152) lists this species as a synonym of *Salsipotens rubiginosus* (Valenciennes, 1846) but repeats Thiele's differentiating characters. On p. 92, however, he lists, under the 'genus' *Laetifautor*, the species names *excellens* and *similaris* (Reeve, 1863). The examination of a range of material of *C. excellens* from north-west Australia shows the differentiating features noted by Thiele to be consistent. The particularly distinctive features of *C. excellens* are the nature of the peripheral ornament, there being a much sharper peripheral keel in *C. rubiginosa*, and the restriction of rose-coloured spots to the peripheral cord(s) and 1 or 2 of the central basal spirals. In *C. rubiginosa* every alternate basal spiral is rose-spotted and the peripheral spirals have no rose-colour, being only brown and white.

Specimens similar to the type of *Calliostoma excellens* are known from north of Houtman Abrolhos and NW of Bluff Point between Shark Bay and Geraldton (99 m) (WAM) through north Western Australia to Darwin (WAM), the Gulf of Carpentaria (AM) and Torres Strait (AM). *Calliostoma rubiginosa* occurs from approximately the vicinity of Fremantle to Bass Strait.

Calliostoma excellens is very similar to *C. similarae* (Reeve) described from Lizard Island, north-east Australia. The type of *C. similarae* has been examined by the author and with other available material it is clear they are part of the same species complex and are here regarded as synonyms. Thiele notes in his description of *C. excellens* that his species is larger and more coarsely sculptured than *C. similarae.* Certainly as far as one can determine from the available material, the north-western specimens tend to be larger than those few available from the north and east but this in itself is not of sufficient importance to separate taxa. The strength of sculpture varies and it is not noticeably stronger in north-western shells than in the other specimens.

The considerable morphological similarity of the shells of *C. rubiginosa* and *C. similarae* (as here interpreted) suggests that these two apparently geographically separated forms could be regarded as subspecies and this course is the one tentatively adopted here. The synonymy of both subspecies is outlined below:

(a) *Calliostoma rubiginosa rubiginosa* (Valenciennes, 1846)
Trochus australis Broderip, 1835: 331; Plate 49, Fig. 3 (*non* Lamarck, 1822)
Trochus rubiginosus Valenciennes, 1846: Plate 4, Fig. 1 (no text issued)

Trochus nobilis Philippi, 1849: 86; Plate 15, Fig. 6, Plate 38, Fig. 1 (*non* Muenster, 1835)
Trochus broderipi Philippi, 1855: 257; Plate 38, Fig. 5 (*nom. nov. pro T. australis* Broderip *non* Lamarck)
?*Zizyphinus splendidus* (Philippi ms) Reeve, 1863: Plate 2, Fig. 11

Distribution: Southern Australia from Fremantle to Bass Strait.

Z. splendidus best matches specimens from Victoria which often have a very weak peripheral keel. This is the form illustrated by Macpherson & Gabriel (1962: Fig. 80) as *Calliostoma (Salsipotens) australe* (Broderip).

(b) *Calliostoma rubiginosa similarae* (Reeve, 1863)
Zizyphinus similaris Reeve 1863: Plate 5, Fig. 32
Calliostoma excellens Thiele, 1930: 565

Distribution: North-western Australia, northern Australia, Torres Strait and the northern Great Barrier Reef.

CALLIOSTOMA MODESTUM THIELE, 1930: 565

(Plate 2, Figs 5 and 6)

Description

Similar to *C. hedleyi* Pritchard & Gatliff in form and sculpture but has a different coloration and less dense spiral sculpture. Colour whitish with irregular grey spots. Body whorl very slightly convex with the periphery angled and with 7 nodulose spiral lirae. Base with about 10 weak, indistinctly nodulose spiral cords.

Dimensions

Height 18 mm; diameter 16 mm (from original description and these dimensions are those of the figured lectotype). Height 15 mm; diameter 15 mm (paralectotype).

Localities

Stations 19 and 28, Sharks (= Shark) Bay, north-western Australia ('a few specimens'). Only two specimens located, both from station 28 (reg. no. 67363). Station 28, Dirk Hartog, 2-4.5 m, sand with vegetation.

Remarks

The specimen illustrated is here chosen as the lectotype. This species is somewhat similar to, and obviously congeneric with, *Calthalotia arruense* (Watson, 1880) from northern Australia. The Shark Bay specimens differ from typical *C. arruense* mainly in their shorter spire and more heavily developed columellar callus. Thiele (1930) remarked that his new species was similar to *Calliostoma hedleyi* and Cotton (1959) suggested that it was a probable variant of that species. *C. hedleyi* however, belongs to the subgenus *Fautor* (of *Calliostoma*) and is quite distinct from Thiele's species. *Calthalotia* Iredale, and *Prothalotia* Thiele, are probably very closely related groups but radular studies are required before their relationships can be more accurately assessed.

Specimens of this species have been examined from N of Delambre Is., Dampier Archipelago, north-western Australia, in 40-42 m (WAM); E end of Mary Ann Passage, Onslow, north-western Australia, in 13 m (WAM) and Ningaloo, S of North West Cape, north-western Australia, on beach (AM).

CANTHARIDUS (JUJUBINUS) TRISTIS THIELE, 1930: 567

(Plate 2, Fig. 10)

Description

Shell elongate conical, marbled with blackish-brown on a light background, sculpture of dense, fine spiral lirae, indistinct on upper spire whorls. Sides of spire straight, periphery of body whorl acutely angled, base flat.

Dimensions

Height 10.5 mm; diameter 7 mm.

Locality

Station 3, *ca* 5 km NW of Denham, Sharks (= Shark) Bay, north-western Australia, 3 m, sand with rich vegetation (holotype) (reg. no. 67360).

Remarks

Hedley (1907) recorded this species as *Calliostoma polychroma* (A. Adams) from Queensland and in a manuscript note made in June 1912, he records that an examination of the probable types of *Ziziphinus polychromus* A. Adams and *Z. picturatus* A. Adams, both from the Philippine Islands and both held in the British Museum (Natural History), shows them to be identical and the same as the Queensland species. An examination of Adam's type material and material from the central Indo-Pacific indicates that this synonymy appears to be correct.

The tentative synonymy of this species can therefore be listed as follows:

'Cantharidus' polychromus (A. Adams, 1853)
Ziziphinus polychromus A. Adams, 1853: 168; Reeve, 1863: Plate 6, Fig. 40
Ziziphinus picturatus A. Adams, 1853: 168; Reeve, 1863: Plate 7, Fig. 53
Cantharidus (Jujubinus) tristis Thiele, 1930: 567

The generic location of this and related species is questionable. They appear to fall between *Cantharidus* Montfort, 1810 (s.l.) and *Jujubinus* Monterosato, 1884 in shell features. A more definite location, however, must await a detailed revision.

The Australian distribution of this species is from the southern Barrier Reef and Lord Howe Island northwards and westwards to Shark Bay, Western Australia. In Western Australia it appears to overlap in distribution with *'Cantharidus' lepidus* (Philippi, 1846) a closely related species common in south-western Australia and extending at least as far north as North West Cape. The typical form of *lepidus* differs from *polychromus* in its larger, broader shell and often darker coloration with a more complex colour pattern, but some specimens from the overlapping part of the range are difficult to place in either species. *'Cantharidus' lepidus* has been figured as *Calliostoma interrupta* (Wood, 1828) by Hodgkin *et al.* (1966: 19, Plate 4, Fig. 3) but that species name was given to a specimen from Ireland and the original illustration does not closely resemble *'C.' lepidus.* Wood's name is probably a synonym of *Cantharidus exasperatus* (Pennant, 1777), a common European species. *'Cantharidus' fournieri* (Crosse, 1863), *'C.' crenelliferus* (A. Adams, 1853) and *'C.' artensis* (Fischer, 1878) from New Caledonia also appear to be closely related to *'C.' polychromus.*

CANTHARIDUS SERICINUS THIELE, 1930: 567

(Plate 2, Fig. 4)

Description

Similar in form to *C. rutilus* (A. Adams), its 7 whorls slightly convex, glossy, and finely and densely spirally striated. Body whorl with angled periphery; base slightly convex. Colour of brownish spots on a pale greenish background, the spots bigger on the upper whorls, small and rather regularly arranged on the body whorl. A green nacreous layer inside aperture.

Dimensions

Height 10.5 mm; diameter 7 mm.

Locality

Station 48, northern side of Port Royal (= Careening Bay), 14.5-18 m, mud and algae, Cockburn Sound, Western Australia (holotype) (reg. no. 67361).

Remarks

The type specimen is a sub-adult specimen of a species of *Phasianotrochus*. It is, as Thiele indicates, closest to *P. rutilus* (A. Adams, 1851) from Victoria and Tasmania. The only species seen by the writer from Cockburn Sound and its vicinity are *P. bellulus* (Dunker, 1845), *P. apicinus* (Menke, 1843), *P. irisodontes* (Quoy & Gaimard, 1834) and *P. eximius* (Perry, 1811). *Phasianotrochus irisodontes* is similar in shape and sculpture to *C. sericinus* but the examination of hundreds of specimens has shown that it always has a very characteristic colour pattern of fine red axial lines quite different from the essentially spiral arrangement of the brownish spots exhibited by Thiele's specimen. *Phasianotrochus apicinus* has a much more sharply angled periphery than Thiele's specimen when it is the same size and also has fine reddish axial lines. *Phasianotrochus bellulus* is smooth and has a very distinct colour pattern and *P. eximius* has a more sharply angled periphery and distinct, rather widely spaced spiral grooves. Although the real status of *C. sericinus* will have to await further work it is possible that it represents a chance introduction of *P. rutilus* or a mislocalized specimen.

FAMILY TURBINIDAE

TURBO (MARMAROSTOMA) MENKEI THIELE, 1930: 568

(Plate 1, Figs 16-20)

Description

Shell similar to *T. intercostalis* Menke in form and colour, but the operculum is totally different. The sculpture, although similar to that of *T. circularis* Reeve, does not totally agree and the form and coloration are different in that species. The shell is higher than wide, pale with green spots and of about 6 convex whorls which are sculptured with heavy, weakly nodulose lirae which are alternately stronger and weaker. Spiral lirae on base rather weak and close, those at umbilical region merge to form a rather broad, white, nodulose pad. Aperture subcircular. Operculum white, convex at columellar side, with a weakly granulated surface and 2 distinct concentric furrows at the external edge.

Dimensions

Height 35 mm; diameter 29 mm.

Localities

Stations 3 and 21, Sharks (= Shark) Bay, north-western Australia ('a few' specimens). Only one specimen was located (reg. no. 67370), and this was labelled 'type'. It is not known from which of the two stations the type was taken.

Remarks

This species is conspecific with *Turbo foliaceus haynesi* Preston, 1914. The types of Preston's species of *Turbo* were examined in The National Museum of Wales, Cardiff and are here refigured for comparison (Plate 1, Figs 18-20). The synonymy is thus:

Turbo (Marmarostoma) haynesi Preston, 1914
Turbo foliaceus haynesi Preston, 1914: 15; Fig. (on p. 15)
Turbo (Marmarostoma) menkei Thiele, 1930: 568

Although this is a common species which appears to be endemic to tropical Australia it does not appear to have received an earlier name. It ranges northwards and westwards from Hervey Bay, south Queensland to at least as far south as Geraldton, Western Australia.

ASTRAEA TENTORIUM THIELE, 1930: 569

(Plate 2, Figs 7 and 8)

Bellastraea tentorium Hodgkin *et al.*, 1966: 23; Plate 6, Fig. 6

Description

Similar to the eastern Australian species *A. tentoriiformis* (Jonas) but differs in the characters of the operculum and the umbilical region. The shell is conical, with a sharp periphery, the whole dorsal surface covered by a chalky coating. Base flat, with dense spiral lirae. Adjoining the concave columella is a narrow, violet basal callus which has, on its lower part a short groove. Operculum brilliant violet, centre fairly depressed, lighter in colour in lower part, being more rose-red, whereas the upper part is indigo-coloured.

Dimensions

Height 30 mm; diameter 40 mm.

Locality

Station 25, Surf Point, Outer Bar, at entrance to South Passage, Sharks (= Shark) Bay, north-western Australia, 0.5-3.5 m, sand and rocks with coral (holotype) (reg. no. 67358).

Remarks

This species is restricted to Western Australia, ranging from Cockburn Sound to Bernier Island off Shark Bay (Ponder 1975). The genus *Astralium* is considered to be the most appropriate location for this species. The reasons for the use of this name as a full genus will be discussed in detail elsewhere.

FAMILY EPITONIIDAE

SCALA TUMIDULA THIELE, 1930: 578

(Text Fig. 1)

Description

Shell probably immature, colourless, imperforate; protoconch of 3 smooth whorls and teleoconch of 3 rapidly increasing, strongly convex whorls. Sculpture of rather dense, striae-like ribs which have close, delicate spiral threads between them. Body whorl relatively large, base without a cord; aperture oval, columellar edge rather broad, somewhat concave.

Dimensions

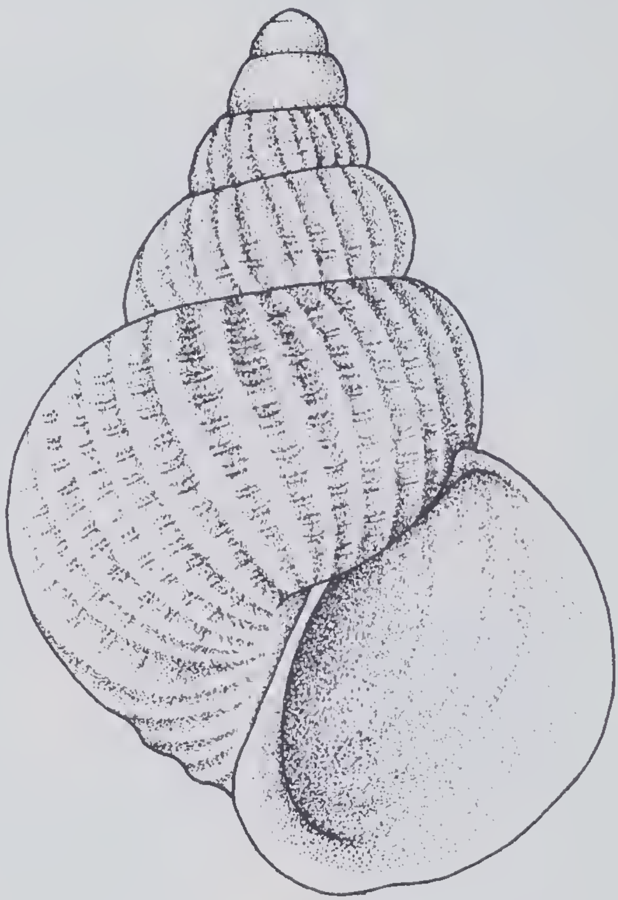
Height 1.9 mm; diameter 1.3 mm.

Locality

Station 3, *ca* 5 km NW of Denham, Sharks (= Shark) Bay, north-west Australia, 3 m, sand with rich vegetation (holotype) (reg. no. 67496).

Remarks

The unique specimen is a juvenile shell of uncertain species relationship. It is, however, an *Epitonium* in the broad sense and could not be included in *Berthais* Melvill, 1904, which Thiele suggests as a possibility.



Text Fig. 1: *Epitonium tumidula* (Thiele). Holotype.

FAMILY APLYSIIDAE

APLYSIA ANNULIFERA THIELE, 1930: 586

Remarks

This species was not examined, but Eales (1960: 307) has listed it in the synonymy of *Aplysia (Varria) dactylomela* Rang, 1828.

BIVALVIA

FAMILY LUCINIDAE

PHACOIDES (PARVILUCINA) PISIFORMIS THIELE, 1930: 592

(Plate 2, Figs 3 and 9)

Description

Differs from *P. eucosmia* (Dall, 1901) (= *pisum* [Reeve, 1850] *non* Sowerby, 1836) by its considerably denser, undulating concentric rings, by its more rounded form and presumably also by its smaller size. Dorsal margin concave anterior to beaks, but then suddenly becomes convex; posterior to beaks margin first weakly concave, then convex. Hinge and sculpture otherwise similar to the above species (left valve only).

Dimensions

Length 3 mm; width 2.9 mm.

Locality

Station 3, 5 km NW of Denham, Sharks (= Shark) Bay, north-west Australia, 3 m, sand with rich vegetation (holotype) (reg. no. 67726).

Remarks

Chavan (1969) lists *Bellucina* Dall, 1901 (type species, by original designation, *Parvilucina eucosmia* Dall) as a subgenus of *Linga* de Gregorio, 1884; further, Dall's species is synonymised with *Lucina semperiana* Issel, 1869.

ACKNOWLEDGEMENTS

I would particularly like to acknowledge the assistance of Dr R. Kilias of the Museum für Naturkunde, East Berlin for his kindness and considerable assistance during my visit to that institution and for providing photographs of several of the species included in this work. I am also indebted to Mr P.E. Schwerin for translating Thiele's work and to my wife for her help in recording information and for photographing several of the type specimens dealt with in this paper. Dr J. Chatfield kindly made facilities available in the National Museum of Wales. Mrs S. Slack-Smith, Mr G.W. Kendrick and Dr B.R. Wilson, all of the Western Australian Museum, made many valuable comments on the manuscript.

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ABBREVIATIONS

AM — Australian Museum, Sydney, WAM — Western Australian Museum, Perth.

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NEOAPLOACTIS TRIDORSALIS, A NEW GENUS AND SPECIES OF FISH FROM THE GREAT BARRIER REEF, AUSTRALIA (SCORPAENIFORMES: APLOACTINIDAE)

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and

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ABSTRACT

Neoaploactis tridorsalis is described as a new genus and species of the fish family Aploactinidae. The species is known from one specimen collected at One Tree Island at the southern end of the Great Barrier Reef, Australia. It differs from all other aploactinids in having the initial four dorsal spines forming a separate fin and in having peculiar scales composed of a spinous flange or shelflike projection at right angles to the body, supported by an elongate diamond-shaped base embedded in the skin.

INTRODUCTION

The fish fauna at One Tree Island, Capricorn Group, near the southern end of the Great Barrier Reef, has been collected regularly over the period 1966-1975 by ichthyologists of the Australian Museum and associates from other institutions. In 1973, one of us (G.R.A.) collected a small fish taken in a rotenone poison station in 3 to 4 metres depth; it appeared to be referable to the family Aploactinidae. Despite rather intensive collection at One Tree, this specimen to our knowledge is the only aploactinid that has been collected there.

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Members of the family Aploactinidae occur in the Indo-West Pacific faunal region, and most are poorly known. Whitley (1933) reviewed the species known at that time. Subsequent descriptions (including Eschmeyer and Dor, in press) in scattered references bring the total number of nominal species in this family to 33 (Poss and Eschmeyer, 1978). It was readily apparent that the One Tree Island specimen differed from all known species in having the initial four dorsal spines forming a separate fin, the fourth and fifth spines being separated by scales. A deep notch between the eleventh and twelfth spines gives the impression of three dorsal fins. It further differed in having very unusual scales: a diamond-shaped base supporting a prominent flange or shelf that projects at right angles to the body. In other features, especially head spination, general body shape and origin of the dorsal fin on the cranium, the specimen resembled other aploactinids. It does not appear closely related to any known species, and we describe it below as a new species in a new genus.

NEOAPLOACTIS ESCHMEYER & ALLEN, NEW GENUS

Type species

Neoaploactis tridorsalis Eschmeyer & Allen.

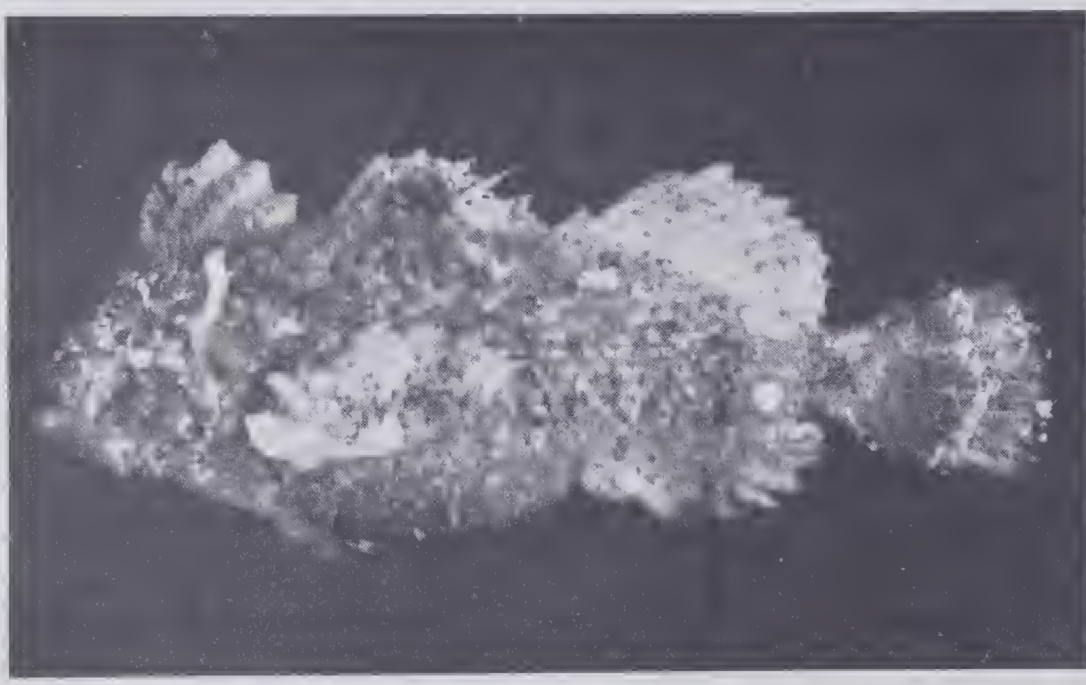

Fig. 1: *Neoaploactis tridorsalis*, holotype, WAM P25529-001, 34 mm SL, photo taken from the fresh specimen.

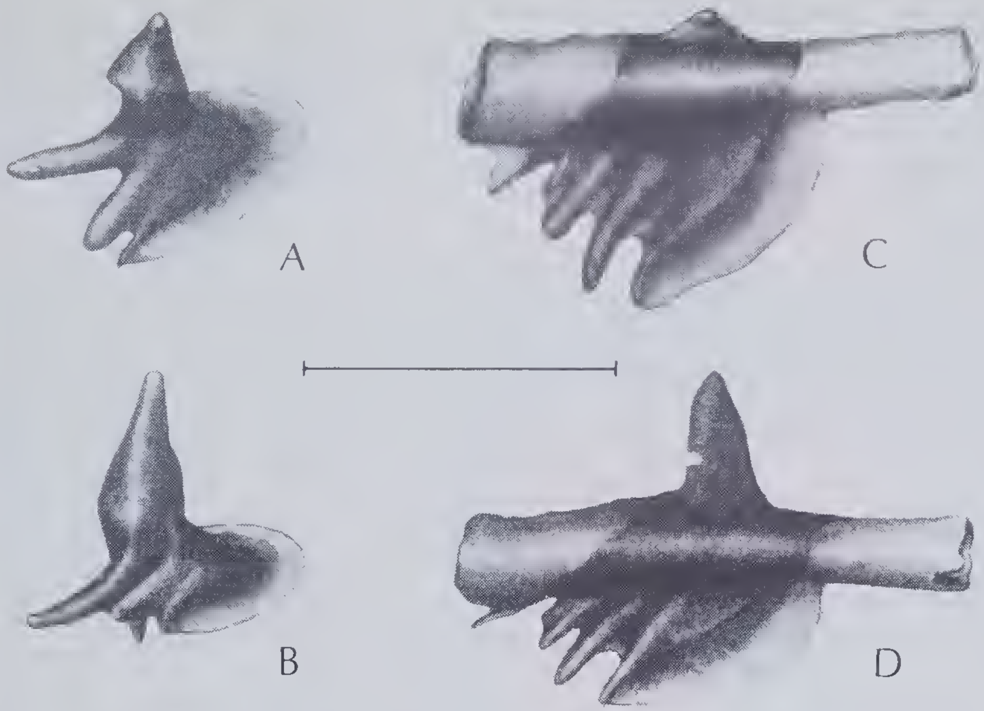

Fig. 2: Scales in holotype of *Neoaploactis tridorsalis.* (A) Dorsal view and (B) oblique view of body scale from vicinity of fourth lateral line scale on right side. (C) Dorsal view and (D) oblique view of fourth lateral line scale on right side. Camera lucida drawings; line is 1 mm; anterior to right; darker areas more heavily ossified. (See text for description of scales.)

Diagnosis

A genus of aploactinid fishes that is uniquely characterized by the presence of three dorsal fins and by peculiar ridged scales. See also the description below of *N. tridorsalis*, the only known member of the genus.

Name

The genus is named *Neoaploactis*, from *neo* (new) + *aploactis*, with reference to its newness and uniqueness in relation to other aploactinids.

Neoaploactis tridorsalis Eschmeyer & Allen, new species.

No literature applies to this species.

Holotype

WAM P25529-001, 34.0 mm SL, 42.3 mm TL, Great Barrier Reef off Queensland, Australia, One Tree Island, Capricorn Group, 3-4 m, rotenone station, G.R. Allen, 15 Jan. 1973.

Diagnosis

Dorsal IV + VII + I,9; anal II,8; pectoral 12; pelvic I,3; caudal 16. First 4 dorsal spines as a separate fin separated by scales from succeeding spines; strong notch between spines 11 and 12. Scales highly modified, with a strong median shelflike projection.

Description

A compressed fish having the general physiognomy of an aploactinid. The first dorsal spine originates over the middle of the eye. Second spine longest. Initial 4 spines form a separate fin separated by scales from the fifth spine. Fifth through eleventh spines form a separate rounded fin, separated from the succeeding spine by a nearly complete notch. Twelfth spine about same length as ninth spine and at the leading edge of the soft dorsal fin. Soft dorsal fin rays long, about equal in length to second spine. Soft rays unbranched, total 9, last apparently single and not a double ray as in some aploactinids. Two short anal spines, about $^1/_2$ length of first anal soft ray; anal soft rays 8, unbranched, last ray single. Total caudal ray count 16, including 1 short ray both above and below, all unbranched. Pectoral rays unbranched, total rays 12, longest at middle of fin. Pelvic fin with one spine and 3 soft rays, second soft ray moderately longer than first soft ray, third soft ray short, about $^1/_2$ length of first soft ray. Vertebrae 26. Gill rakers on outside of first arch rudimentary, difficult to count, total 14 (left side).

Body covered with longitudinal rows of highly modified scales (Fig. 2), rows somewhat irregular. Scale base elongate, diamond-shaped, embedded in thick skin; exposed part of scale a broad, flat projection at right angle to body. Most with 2 points at edge of projection. Lateral line scales (Fig. 2C, D) tubed, but with a similar lateral shelflike projection; 11 lateral line scales on each side. Each scale separated from nearby scales by skin. Scales moveable in a horizontal plane, more easily depressed rearward than anteriorly. Similar scales, but smaller, on belly and breast and on the cheek and opercle; remainder of head unscaled. About 20 scale rows on body between last dorsal spine and first anal spine. Most ridges and spines on the underside of the head and the pectoral fin covered with small rounded skin projections; similar but more elaborate skin flaps on dorsal spines. Anterior nostril with a long tube; posterior nostril with a short tube, about $^1/_2$ the length of anterior one. Pores of head lateralis system large, especially those of lower jaw.

Head spination similar to that of most aploactinids. Lachrymal bone (infraorbital 1) with 2 prominent diverging spines, a spinous lump anterior to first spine, a second lateral lump at base of diverging spines, a small lump and ridge extending to front of orbit, and 2 more lumps anterior to these. Suborbital ridge (infraorbitals 2-3) with 2 knobby lumps, first under anterior part of eye, second under rear of orbit. Preopercle with 5 spines, first longest and reaching nearly across opercle, remainder shorter and more knobby, fifth nearly imperceptible. Nasal bones moveable, ridgelike, with 2 lumps posteriorly. Frontal ridges fairly well developed, with a channel or depression between, ending posteriorly at right angles to a ridge which crosses the head at level of midorbits. A large spine at upper posterior border of orbit, preceded by a smaller lump over midorbit. A strong parietal ridge present, with a pterotic ridge at midorbit level behind eye. Strong supra-cleithral ridge above opercle. Two low, knobby opercular spines. Cleithral spine elongate, pointing out from body.

Colour in preservative similar to that in Figure 1 of the fresh specimen. Body tan with paler large spots. Melanophores contracted, appearing as dots under magnification. Head darker brown, marbled and spotted with clear areas; most prominent feature a clear vertical stripe behind the eye. Small clear bars radiate from eye. Fins nearly transparent, with dusky smudges. Colour in life not recorded at capture.

Measurements in mm are as follows: standard length 34.0, total length 42.3, head 11.2, snout 3.7, orbit 3.0, interorbital width 3.0, jaw 3.7, post-orbital 4.5, predorsal-fin 6.1, body depth at pelvic base 11.8, greatest body depth 12.4, anal fin height (anterior base to posterior tip of fin) 11.3, caudal fin 8.8, pectoral fin (upper base to apex) 10.1, pelvic fin 6.4, first dorsal spine 5.6, second dorsal spine 6.3, fifth dorsal spine 3.8, twelfth dorsal spine 2.5, first anal spine 2.2, second anal spine 2.8, dorsal fin base (1st spine to end of soft dorsal) 26.1, anal fin base 8.1.

Name

The specific name *tridorsalis* refers to the presence of 3 dorsal fins in this species.

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HERPETOFAUNA OF THE SHARK BAY REGION, WESTERN AUSTRALIA

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[Received 22 April 1977. Accepted 5 May 1977. Published 31 December 1978.]

ABSTRACT

The 13 families, 43 genera and 97 forms (92 species, 5 of which are represented by two subspecies) of amphibians and reptiles inhabiting the Shark Bay region are listed with notes on their local distribution, relative abundance and habitat preferences. The region is located on the west coast of Australia between latitudes 24°40′ and 26°45′S and is divisible into three longitudinal zones: (1) the western, with waterless white sandy soils, relatively cool summers and wet winters, and a predominantly southwestern fauna and several endemic forms; (2) the central, with waterless red sandy soils, intermediate climate and somewhat depauperate southwestern fauna; and (3) the eastern, with red loamy and clayey soils, hot summers, less winter and more summer rain than other zones, some surface water, and a fauna rich in arid-zone elements. Only 14 species are shared by all three zones, indicating that regional diversity is largely due to the juxtaposition (without blending) of distinct faunas. The region is especially rich in fossorial reptiles (e.g. *Lerista* and *Vermicella* spp.).

INTRODUCTION

Knowledge of the herpetofauna of Shark Bay began in a small way early last century with the visits of the French navigators Baudin and Freycinet and the naturalists who accompanied them, notably Péron, Quoy and Gaimard. Generally their collections were too small and too poorly localised to give even a hint of the richness of the region.

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Next to visit Shark Bay were the German zoologists Michaelsen and Hartmeyer in 1905. Although their specimens were accurately localised, well annotated, and carefully studied by F. Werner, the leading German herpetologist of the day, such was the backward state of reptile taxonomy that one can only wonder what species Werner (1909) was referring to when he listed *Aprasia pulchella* and *Delma fraseri*, only to mention the pygopodids in his report.

In the last two decades, the tempo of collecting in the region has increased enormously, yielding for the first time material adequate for research into the taxonomy of Shark Bay reptiles. Until recently more work had been done on the islands than the mainland. Led by W.D.L. Ride, an expedition to Bernier and Dorre Islands collected reptiles in July 1959 (Douglas & Ride, 1962); in the previous May W.H. Butler visited Faure Island. G.M. Storr collected on Bernier Island in May 1963 and on several small islands in Freycinet Estuary in August 1965. A.A. Burbidge and associates visited Dirk Hartog Island on several occasions between September 1972 and April 1977, Bernier Island in April 1969 and Dorre Island in December 1973.

During the same period many reptiles were collected on the Shark Bay mainland. However, collections tended to be opportunistic rather than systematic and were usually made by naturalists travelling to and from areas further north. Exceptional were J.R. Ford's work in the country between Hamelin and Tamala in December 1964 (when he rediscovered the gecko *Diplodactylus michaelseni*) and the visits of A. Baynes to Edel Land in December 1968 and August 1970 (on the second of which he discovered a new genus of frogs, *Arenophryne*).

Imbalance between islands and mainland was more than corrected in August and September 1976 when G. Harold and M. Peterson, financed by a grant from Mr and Mrs W.H. Butler, collected amphibians and reptiles on Edel Land, Peron Peninsula and the coastal plains south and east of the Hamelin Pool gulf. This collection (itemised in Storr, 1977) and others lodged in the Western Australian Museum form the basis of the following accounts.

Finally we would like to acknowledge all the people (in addition to those mentioned above) whose specimens have contributed to this report; they are J.L. Bannister, G. Barron, D.G. Bathgate, M.G. Brooker, J. Bywater, E.J. Car, B.T. Clay, P. Cowley, J. Estbergs, P.J. Fuller, T.M.S. Hanlon, B. Harty, G. Kendrick, N. Kolichis, O. Lipfert, A.R. Main, K. Malcolm, G.F. Mees, H. Merrifield, R.L. Pink, W. and W. Poole, R.D. Royce, S. St John, T.C. Scott, R. Slack-Smith, P. Slater, T.A. Smith, A.G. Wells, B.R. Wilson

and J. Wombey. We exclude E.L. Grant Watson from this list, for we believe that his specimens of several species, e.g. the agamid lizards *Amphibolurus cristatus*, *Tympanocryptis cephala* and *Moloch horridus*, could not have come from Bernier Island.

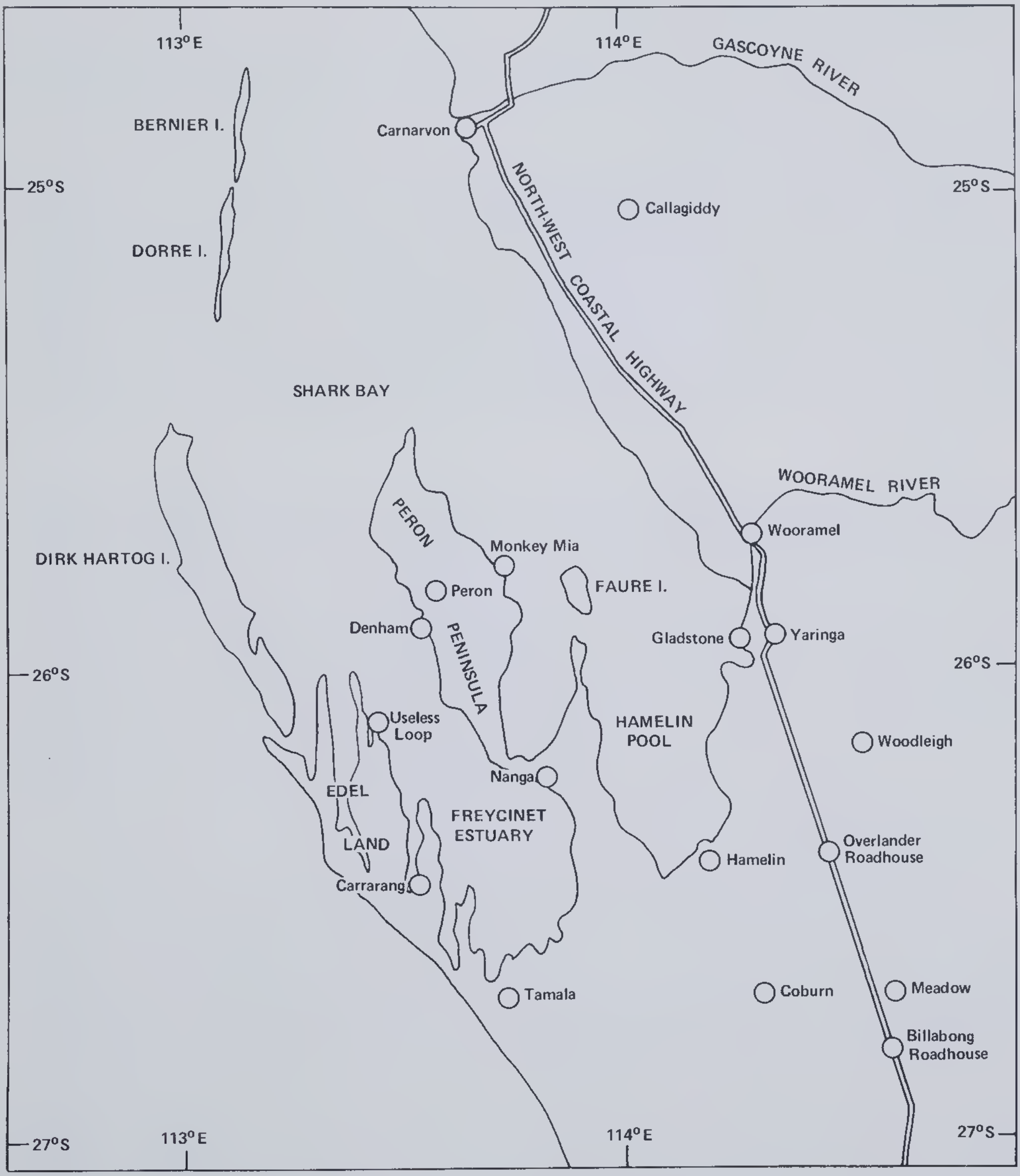

Fig. 1: Map of Shark Bay region, Western Australia.

The Shark Bay region can be divided longitudinally into three zones:

(1) the western, comprising the large islands Dirk Hartog, Dorre and Bernier, the Edel Land peninsula and the small islands in Freycinet Estuary,

(2) the central, comprising Peron Peninsula, Faure Island and the southern hinterland of Freycinet Estuary,

(3) the eastern, comprising the coastal plains south and east of the Hamelin Pool gulf, north to the Gascoyne River and east to about the North-west Coastal Highway.

Though it is the most humid of the three, the western zone (like the central) is almost completely devoid of surface fresh water. Annual rainfall averages about 30 cm, most of it falling in winter. The soils are predominantly white sands. Coastal dunes are vegetated with the coarse grass *Spinifex longifolius* and shrubs such as *Olearia axillaris* and *Myoporum insulare.* Where the limestone is outcropping or shallowly covered with sand the vegetation is more varied and includes *Triodia* and several species of tall and low shrubs.

The central zone consists mainly of Peron Peninsula and similar country around the bottom of Freycinet Estuary southwestwards nearly to Tamala. Annual rainfall varies from 23 cm in the north to 20 cm in the far southeast and 28 cm in the far southwest. The soils are reddish and range in texture from sands to sandy loams. In the south the dunes and interdunes are densely wooded with small trees and shrubs of *Acacia*, *Eucalyptus*, *Melaleuca*, *Banksia*, *Hakea*, *Grevillea*, *Conospermum*, *Gyrostemon*, *Codonocarpus* and *Brachychiton*, interspersed with open belts of soft spinifex *(Plectrachne).* The central sector consists mainly of rolling plains of *Triodia* and *Atriplex*, which give way to samphires in low-lying areas. In the north, open scrubs of *Acacia* are common.

Apart from a few mesas between Overlander and Yaringa, the eastern zone is level and low-lying. Annual rainfall ranges from 19 to 23 cm, more of it falling in summer than further west (see Table 1). Less affected by oceanic influences, this zone is markedly hotter and more arid than the others; nevertheless, it alone is endowed with seasonal surface waters. In the south the shallow red loams over limestone support open scrubs dominated by *Acacia* (several species), *Eremophila* and *Cassia.* North of the Wooramel the soils are heavier and deeper and support little shrubbery except where they are crossed by low ridges of lighter soil. Towards the coast the plains of *Atriplex*, *Kochia*, *Carpobrotus* and grasses are successively replaced by samphire and mangrove swamps. Two intermittent streams, the Gascoyne and Wooramel Rivers, traverse the zone; they are fringed with *Eucalyptus camaldulensis.* Claypans, especially in the northern half, fill with fresh water after good rains.

In the following list of species and subspecies we briefly describe the local distribution, relative abundance and habitat preferences of each form.

Table 1: Mean monthly and yearly rainfall (mm) at Dirk Hartog HS (western zone), Denham (central zone) and Brick House (eastern zone).

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Dirk Hartog	6	10	14	16	56	90	63	36	14	6	2	2	315
Denham	11	13	17	17	37	61	39	19	9	4	2	2	231
Brick House	25	22	15	15	36	46	43	15	8	6	0	2	230

ANNOTATED LIST

Leptodactylidae

Arenophryne rotunda Tyler

Endemic to Edel Land. Only known from white coastal dunes in the vicinity of False Entrance Well, 22 km NW of Carrarang HS. Harold and Peterson's specimen was collected on 27 August (almost the same date as the type series).

Neobatrachus centralis (Parker)

Restricted to claypans in eastern zone. Collected at 64 km SSE of Carnarvon (and on nearby Callagiddy Station).

Neobatrachus wilsmorei (Parker)

Presumably occurring in eastern zone. (M.G. Brooker found one on 13 June 1972 on Callagiddy Station after rain in sandy country without permanent water.)

Hylidae

Litoria rubella (Gray)

Eastern zone, on and near the Gascoyne and Wooramel Rivers.

Cheloniidae

Caretta caretta (Linnaeus)

Loggerheads have been collected at Denham and Bernier Island.

Chelonia mydas (Linnaeus)

A Green Turtle has been collected at Carnarvon. Turtles, presumably of this species, nest in summer on the beaches of Bernier and Dorre Islands (Douglas & Ride, 1962: 119).

Cheluidae

Chelodina steindachneri Siebenrock

Eastern zone. Harold and Peterson collected two specimens in a bore drain 8 km N of Wooramel HS on 11 September 1976.

Gekkonidae

Crenadactylus ocellatus horni (Lucas & Frost)

Large islands (Bernier, Dorre and Dirk Hartog), Edel Land and Peron Peninsula. Common. Mainly spinifex *(Triodia* and *Plectrachne)* and limestone.

Diplodactylus alboguttatus Werner

Common in far north of Peron Peninsula on red sand with *Triodia* and open *Acacia;* also found in similar habitats near Nanga HS. Much less plentiful on Edel Land, where it is confined to far north of peninsula (collected at 4 km S of Useless Loop on brown soil with low open *Acacia* and dense *Triodia* and in coastal dunes 8 km SE of Steep Point).

Diplodactylus michaelseni Werner

Far south of Peron Peninsula. Common. Red sands with soft spinifex *(Plectrachne)* and open *Acacia* and other shrubs and low trees.

Diplodactylus ornatus Gray

Large islands (Bernier, Dorre and Dirk Hartog), Edel Land (including Baudin Island) and Peron Peninsula. Moderately common. On Peron Peninsula mainly on red sands with open to moderately dense *Acacia* scrub; elsewhere mainly in sparsely vegetated white coastal dunes and limestone.

Diplodactylus pulcher (Steindachner)

Mainly on the red loams and clays of eastern zone; also in sand-dune country with wattle scrub at base of Peron Peninsula. Uncommon.

Diplodactylus spinigerus Gray

Large islands (Bernier, Dorre and Dirk Hartog) and Edel Land. Common. In *Spinifex longifolius* and bushes on white coastal dunes and on pale brown soils with *Triodia* and open *Acacia.*

Diplodactylus squarrosus Kluge

Eastern zone. Moderately common. Red soils with open *Acacia.*

Diplodactylus strophurus (Duméril & Bibron)

Moderately common on Peron Peninsula in low open *Acacia* and other bushes and low trees growing on red sands; occurring in narrow belts of similar habitat in eastern zone near Carnarvon. Found on Bernier Island in *Olearia* and other bushes (dead or alive) growing in white coastal dunes.

Gehyra variegata (Duméril & Bibron)

Very common throughout region, including several islands (Bernier, Dorre, Dirk Hartog, Three Bays, Salutation and Faure). Mainly in small *Acacia* trees but also among rocks, especially coastal limestone.

Heteronotia binoei (Gray)

Very common throughout region, including several islands (Bernier, Dorre, Dirk Hartog, Freycinet, Double, Mary Anne, Baudin, Three Bays and Salutation).

Nephrurus levis occidentalis Storr

Large islands (Bernier, Dorre and Dirk Hartog), Edel Land and north of Peron Peninsula. Common. On Peron Peninsula and in northeast of Edel Land (4 km S of Useless Loop) on red and brown sands with *Triodia* and open *Acacia;* elsewhere in white coastal dunes. Possibly also occurring on the narrow belts of red sandy soil traversing northern half of eastern zone, in view of its presence further inland (e.g. at Ellavalla and Mooka).

Phyllurus milii Bory

Large islands (Bernier, Dorre and Dirk Hartog) and Edel Land. Common. Mainly in coastal limestone.

Rhynchoedura ornata Günther

Confined to heavy soils of eastern zone. Rare. Collected at Overlander (and a little further inland at Ellavalla, Towrana and Woodleigh).

Pygopodidae

Aprasia haroldi Storr

Endemic to Edel Land. Moderately common. White coastal sands.

Aprasia smithi Storr

Far south of Edel Land. One record: three specimens collected by Harold and Peterson at 1 km S of Tamala on 29 August 1976.

Delma fraseri Gray

Far south of Edel Land. One record: specimen collected by G. Barron and T.M.S. Hanlon at 1 km S of Tamala on 7 February 1977.

Delma nasuta Kluge

Three specimens collected by Harold and Peterson in *Triodia* on reddish sandy loam 25 km S of Denham and four collected by Fisheries and Wildlife Department on Dirk Hartog Island.

Delma tincta DeVis

Eastern zone (collected at Carnarvon, Wooramel and Hamelin). Scarce. Red clay loams with open *Acacia.*

Lialis burtonis Gray

Islands (Bernier, Dorre, Dirk Hartog and Salutation), Edel Land and eastern zone (from Carnarvon south to Coburn), but not yet recorded from Peron Peninsula. Moderately common in *Spinifex longifolius* and low shrubbery of white coastal sands and in *Triodia* and/or low open *Acacia* on pale brown loams near east coast of Edel Land; scarce elsewhere.

Pletholax gracilis edelensis Storr

Endemic to Edel Land, in vicinity of Useless Loop. Moderately common. Mainly in dense *Triodia* growing on pale brown loam; also in *Spinifex longifolius* on white coastal dunes.

Pygopus lepidopodus (Lacépède)

Dirk Hartog Island, Edel Land and Peron Peninsula. Uncommon. Sandy country, especially with *Triodia.*

Pygopus nigriceps (Fischer)

Moderately common in eastern zone, but only two specimens from elsewhere (Tamala and 8 km S of Nanga). Mainly red loams with open *Acacia.*

Agamidae

Amphibolurus inermis (DeVis)

Confined to eastern zone (unless provenance of a specimen from Tamala can be confirmed). Common. Sparsely wooded red sandy loams and clay loams and salt flats.

Amphibolurus maculatus badius Storr

Northern half of eastern zone (south to 16 km N of Wooramel). Moderately common. Scattered low ridges of red sandy loam with low open *Acacia* and other bushes.

Amphibolurus maculatus maculatus (Gray)

Large islands (Bernier, Dorre and Dirk Hartog), Edel Land and Peron Peninsula. Red or white sands with spinifex *(Plectrachne* or *Triodia)* and low open *Acacia* and other shrubs.

Amphibolurus minor Sternfeld

Dirk Hartog Island, Edel Land, Salutation Island, Peron Peninsula and eastern zone. Moderately common. All habitats from coastal heath on whitish sand to open *Acacia* scrub on red clay loam.

Amphibolurus parviceps butleri Storr

Edel Land. Common. White coastal dunes and pinkish sandplains with low open vegetation.

Amphibolurus parviceps parviceps (Storr)

Large islands (Bernier and Dirk Hartog). Common. White coastal dunes with *Spinifex longifolius, Olearia axillaris* and other low open vegetation.

Amphibolurus reticulatus (Gray)

Islands close to mainland (Dirk Hartog, Baudin and Faure), Edel Land, Peron Peninsula and eastern zone. Common. Coastal limestone and all well-vegetated habitats.

Amphibolurus scutulatus Stirling & Zietz

Eastern zone. Common in southern quarter of zone, around Hamelin, Overlander and Wannoo, but scarce on heavier soils and more sparsely wooded country further north (they seem to be more plentiful inland, where the soil is generally lighter, e.g. at Brick House, Callagiddy and Woodleigh).

Moloch horridus Gray

Peron Peninsula (southwest to 8 km NE of Tamala) and eastern zone. Uncommon. Reddish loams and sands vegetated with open *Acacia* and other shrubs, with or without a lower storey of *Plectrachne* or *Atriplex*.

Physignathus longirostris Boulenger

Eastern zone, south to Gladstone. Common. River gums and other trees along and near the Gascoyne and Wooramel Rivers and in coastal thickets along east shore of Hamelin Pool.

Scincidae

Cryptoblepharus carnabyi Storr

Islands (Bernier, Dorre, Dirk Hartog, Wilds and Three Bays), northern Edel Land and southern shore of Hamelin Pool. Moderately common. Mainly in coastal limestone; also in trees and shrubs of coastal dunes and shell beds.

Cryptoblepharus plagiocephalus (Cocteau)

Far south of Edel Land. One record: a specimen collected by J.R. Ford at 8 km S of Tamala (the vegetation here is moderately tall *Melaleuca* and *Acacia* on sand over limestone — G.M.S.).

Ctenotus fallens Storr

Large islands (Bernier, Dorre and Dirk Hartog), Edel Land and southern Peron Peninsula (north to Eagle Bluff). Scarce on Peron Peninsula; moderately common elsewhere. In coastal limestone, *Spinifex longifolius* on coastal dunes, and *Triodia* and open *Acacia* on brown sandy loams.

Ctenotus lesueurii (Duméril & Bibron)

Large islands (Bernier, Dorre and Dirk Hartog) and northern Edel Land. (Record from Carnarvon requires confirmation.) Moderately common on islands but scarce on Edel Land. Mainly white coastal dunes with *Spinifex longifolius;* also pinkish sands with low open *Acacia* and heath.

Ctenotus mimetes Storr

Southern quarter of eastern zone (around Hamelin and Wannoo). Uncommon. Open *Acacia* and other shrubs on red loam over limestone. (Inland from the heavy, sparsely wooded coastal soils it occurs much further north, e.g. at Callagiddy.)

Ctenotus pantherinus pantherinus (Peters)

Southern quarter of eastern zone (two specimens from 7 km W of Hamelin). Scarce. Open *Acacia* on red loam. (Inland it occurs much further north, e.g. at Callagiddy.)

Ctenotus schomburgkii (Peters)

Edel Land (one specimen from 2 km S of Useless Loop) and southern quarter of eastern zone (one specimen from Overlander). Scarce.

Ctenotus severus Storr

Southern half of eastern zone (five specimens from Wooramel). Scarce. Red loam with open *Acacia*.

Ctenotus youngsoni Storr

Endemic to Dirk Hartog Island and Edel Land (False Entrance Well). Scarce (known from five specimens). White coastal dunes.

Egernia depressa (Günther)

Eastern zone. Uncommon. Lightly wooded country, sheltering in hollow logs, beneath loose bark of trees and under boulders of laterite on scree slopes of mesas.

Egernia multiscutata bos Storr

Bernier Island. Common. Burrowing in sparsely vegetated sandplains.

Egernia stokesii aethiops Storr

Endemic to Baudin Island in Freycinet Estuary. Common. Sheltering under slabs of coastal limestone.

Egernia stokesii badia Storr

Dirk Hartog Island and possibly the eastern zone (one specimen from nearby Callagiddy).

Lerista connivens Storr

Islands in Freycinet Estuary (Freycinet, Mary Anne, Salutation and Three Bays) and far south of Edel Land (1 km S of Tamala). Common. Under limestone on islands and in reddish brown sand beneath *Acacia rostellifera* on mainland.

Lerista elegans (Gray)

Bernier Island, northern Edel Land (near Useless Loop), northern Peron Peninsula (Monkey Mia) and far north of eastern zone (56 km SSE of Carnarvon). Moderately common on Bernier Island and Edel Land; scarce elsewhere. White coastal dunes with *Olearia* and reddish sands with open *Acacia.*

Lerista lineopunctulata (Duméril & Bibron)

Large islands (Bernier and Dirk Hartog), Edel Land and Peron Peninsula. Common. Red dunes with open *Acacia* and white coastal dunes.

Lerista macropisthopus (Werner)

Eastern zone. Common. Red loams and sands, usually with open *Acacia.*

Lerista muelleri (Fischer)

Far south of Edel Land (Tamala), southern quarter of Peron Peninsula, and southern quarter of eastern zone about Hamelin (inland it occurs much further north, e.g. at Callagiddy). Moderately common. Reddish sands and loams with open to moderately dense *Acacia.*

Lerista nichollsi (Loveridge)

Eastern zone. Moderately common. Red sands and loams with open *Acacia.*

Lerista planiventralis decora Storr

Peron Peninsula (two specimens from Denham). White coastal dunes.

Lerista planiventralis planiventralis (Lucas & Frost)

Bernier Island and Edel Land. Moderately common. White coastal dunes.

Lerista praepedita (Boulenger)

Larger islands (Bernier, Dirk Hartog and Salutation), Edel Land, Peron Peninsula and far north of eastern zone (56 km SSE of Carnarvon). Very common. White coastal dunes and red sands.

Menetia amaura Storr

Edel Land. Only known from holotype, which was collected by Harold and Peterson under a slab of limestone at False Entrance Well at inland edge of white coastal dunes.

Menetia greyii Gray

Far south of Edel Land (Tamala), northern half of Peron Peninsula (including Faure Island) and southern quarter of eastern zone about Hamelin and Yaringa (inland much further north, e.g. at Callagiddy). Moderately common in eastern zone but scarce further west. Loamy and sandy soils.

Menetia surda Storr

Bernier Island and Peron Peninsula. Moderately common. Spinifex *(Triodia* and *Plectrachne)* on white, brown or red sands.

Morethia butleri (Storr)

Eastern zone. One record: a specimen collected by Harold and Peterson on 6 September 1976 on red stony loam with open *Acacia* 7 km NW of Hamelin.

Morethia lineoocellata (Duméril & Bibron)

Large islands (Bernier, Dorre and Dirk Hartog), Edel Land, Peron Peninsula (at Denham and 25 km S) and eastern zone (at Gladstone and 40 km N of Carnarvon). Common in coastal dunes and coastal limestone; also in open *Triodia* on red sand on Peron Peninsula.

Morethia obscura Storr

Edel Land (at 19 km N of Carrarang) and southern Peron Peninsula (at 15 and 17 km SE of Nanga). Uncommon. Coastal limestone (Edel Land) and *Acacia* scrub (Peron Peninsula).

Omolepida branchialis (Günther)

Large islands (Bernier and Dirk Hartog), Edel Land (including Baudin Island) and Peron Peninsula. Common. In spinifex *(Triodia* and *Plectrachne)* on red, brown and white sands, in coastal limestone and on coastal dunes (especially with *Spinifex longifolius*).

Sphenomorphus richardsonii (Gray)

Eastern zone. Rare. Three specimens collected by Harold and Peterson at and near Wooramel.

Tiliqua occipitalis (Peters)

Northern Peron Peninsula (Peron HS) and extreme north of eastern zone (Carnarvon and 16 km E). Reddish sandy loams with low open *Acacia.*

Tiliqua rugosa (Gray)

Large islands (Bernier, Dorre and Dirk Hartog), Edel Land, northern half of Peron Peninsula and extreme north of eastern zone (about the lower Gascoyne). Moderately common. Mainly low open *Acacia* scrub on sandy soils.

Varanidae

Varanus caudolineatus Boulenger

Eastern zone, west to 15 km E of Hamelin. Uncommon. Open *Acacia* scrub on red loam.

Varanus eremius Lucas & Frost

Northern Peron Peninsula (Peron HS) and eastern zone. Scarce. Red sands and sandy loams with open *Acacia.*

Varanus giganteus (Gray)

Eastern zone. One record: observation by G.M. Storr on the lower Wooramel on 2 August 1961.

Varanus gouldii (Gray)

Large islands (Bernier, Dorre, and Dirk Hartog) and far north of eastern zone. Uncommon.

Typhlopidae

Typhlina leptosoma (Robb)

Eastern zone. Two specimens collected by Harold and Peterson under cement slabs at Wooramel HS.

Typhlina nigroterminata (Parker)

Eastern zone. One found (but later lost) by Harold and Peterson in red loam with open *Acacia* at 7 km W of Hamelin on 6 September 1976.

Boidae

Liasis childreni Gray

Northern islands (Bernier and Dorre) and eastern zone. Moderately common.

Elapidae

Demansia olivacea calodera Storr

Large islands (Bernier and Dirk Hartog), far south of Edel Land (Tamala), northern half of Peron Peninsula and extreme north of eastern zone. Moderately common.

Demansia reticulata cupreiceps Storr

Eastern zone, south to Wooramel. Uncommon. Red loams with open *Acacia*.

Demansia reticulata reticulata (Gray)

Dirk Hartog Island and Edel Land. Uncommon. White coastal sands.

Denisonia fasciata Rosén

Eastern zone. One record: a specimen collected by P.J. Fuller at 8 km N of Overlander (apparently more plentiful further inland — specimens from Ellavalla and Woodleigh).

Denisonia monachus Storr

Southern half of Peron Peninsula (specimen from 15 km SE of Nanga) and eastern zone. Uncommon. Mainly red loams with open *Acacia*.

Pseudechis australis (Gray)

Large islands (Bernier, Dorre and Dirk Hartog), Edel Land and eastern zone. Moderately common.

Pseudonaja modesta (Günther)

Eastern zone. Moderately common. Red loams with open *Acacia*.

Pseudonaja nuchalis Günther

Northern Peron Peninsula (Denham and vicinity) and eastern zone. Common.

Vermicella bertholdi (Jan)

Eastern zone. Uncommon. Red loams with open *Acacia*.

Vermicclla bimaculata (Duméril, Bibron & Duméril)

Far south of Edel Land. One record: two specimens collected by Harold and Peterson in reddish brown sandy loam with open *Acacia* at 1 km S of Tamala.

Vermicella fasciolata fasciolata (Günther)

Peron Peninsula. One record: specimen collected at 7 km E of Denham.

Vermicella littoralis Storr

Large islands (Bernier, Dorre and Dirk Hartog), Edel Land and Peron Peninsula (including Faure Island). Moderately common on islands; uncommon on mainland. White coastal sands.

Vermicella semifasciata semifasciata (Günther)

Eastern zone. One record: specimen collected by W.H. Butler at 16 km S of Overlander in December 1966.

Hydrophiidae

Aipysurus laevis pooleorum L.A. Smith

Endemic to Shark Bay. Common.

Emydocephalus annulatus Krefft

One record: a mounted specimen from Cape Peron brought into the W.A. Museum for identification (L.A. Smith, pers. comm.).

Ephalophis greyii M.A. Smith

One record: a specimen collected by K. Malcolm at Carnarvon in May 1968.

Hydrophis elegans (Gray)

Common in seas of Shark Bay region. Two specimens of *H. elegans* and eight of *H. major* were taken by fishermen east of Koks Island in June 1970 when trawling for prawns at 18-22 fathoms.

Hydrophis major (Shaw)

Very common. Judging from number of specimens in W.A. Museum this is the commonest sea-snake in the Shark Bay region.

Pelamis platurus (Linnaeus)

One record: a specimen collected at Shark Bay in April 1972.

DISCUSSION

The 43 genera and 97 species and subspecies of amphibians and reptiles listed for the region are distributed among 13 families as follows:

Leptodactylidae (2 genera, 3 species)
Hylidae (1 genus, 1 species)
Cheloniidae (2 genera, 2 species)
Cheluidae (1 genus, 1 species)
Gekkonidae (7 genera, 13 species)
Pygopodidae (5 genera, 9 species)
Agamidae (3 genera, 10 species and subspecies)
Scincidae (9 genera, 32 species and subspecies)
Varanidae (1 genus, 4 species)
Typhlopidae (1 genus, 2 species)
Boidae (1 genus, 1 species)
Elapidae (5 genera, 13 species and subspecies)
Hydrophiidae (5 genera, 6 species)

It is not surprising that frogs only account for 4% of the fauna. One of them, *Arenophryne rotunda*, seems to have no need for surface water, but the others depend on claypans and river-pools that fill after summer rains, habitats that are found in only a small part of the region, namely the northern half of the eastern zone.

Most reptile families are well represented, some extremely well. To a large extent this diversity is due to the location of Shark Bay at the meeting point of Western Australia's three main natural regions, (1) the south-western with its relatively cool summers and rainy winters, (2) the northern with its hot rainy summers and warm winters, and (3) the eremaean with its hot summers, cold winters and low irregular rainfall.

Many southern reptiles have their northern limit in the Shark Bay region, e.g. the geckos *Diplodactylus alboguttatus, D. michaelseni, D. spinigerus* and *Phyllurus milii*, the pygopodid lizards *Delma fraseri* and *Pygopus lepidopodus*, the skinks *Ctenotus lesueurii, C. p. pantherinus, Egernia multiscutata bos, Lerista planiventralis decora, L. praepedita, Morethia obscura, Tiliqua occipitalis* and *T. rugosa*, and the elapid snake *Demansia r. reticulata*. Southern taxa are almost confined to the western and central zones.

The northern component in the herpetofauna includes the hylid frog *Litoria rubella*, the pygopodid lizard *Delma tincta*, the agamid lizard *Physignathus longirostris*, the blind-snake *Typhlina nigroterminata*, the elapid snake *Demansia reticulata cupreiceps*, and all the marine turtles and sea-snakes.

Several taxa characteristic of the arid interior reach the coast in the Shark Bay region, e.g. the geckos *Diplodactylus squarrosus*, *D. strophurus* and *Rhynchoedura ornata*, the pygopodid *Pygopus nigriceps*, the agamids *Amphibolurus scutulatus* and *Moloch horridus*, the skinks *Ctenotus mimetes*, *C. severus*, *Egernia depressa*, *E. stokesii badia*, *Lerista macropisthopus*, *Menetia surda* and *Morethia butleri*, the monitors *Varanus caudolineatus* and *V. eremius*, and the elapid *Denisonia monachus*. The eremaean component is almost confined to the eastern zone.

Another source of diversity are the large islands, peninsulas and gulfs of the region. They provide a refuge for eight relict or endemic taxa, namely the leptodactylid *Arenophryne rotunda*, the pygopodids *Aprasia haroldi* and *Pletholax gracilis edelensis*, the agamid *Amphibolurus parviceps butleri*, the skinks *Ctenotus youngsoni*, *Egernia stokesii aethiops* and *Menetia amaura*, and the sea-snake *Aipysurus laevis pooleorum*. Almost restricted to Shark Bay are another three species that extend south only to the mouth of the Murchison: the pygopodid *Aprasia smithi*, the skink *Lerista connivens* and the blind-snake *Typhlina leptosoma*.

Of the 89 terrestrial and freshwater amphibians and reptiles listed for the Shark Bay region, 52 have been recorded in the western zone, 35 in the central and 55 in the eastern (the eastern zone total probably exceeds 60, for some of the additional species known from the country immediately north and east of Carnarvon, viz. *Cyclorana maini*, *C. platycephala*, *Amphibolurus clayi*, *Caimanops amphiboluroides*, *Ctenotus helenae*, *C. leonhardii*, *Varanus brevicauda* and *Typhlina australis*, could well extend to the eastern zone). Nineteen taxa are locally restricted to the western zone, 3 to the central and 27 to the eastern. Only 14 species are found in all three zones.

The region is rich in old Australian elements, e.g. 11 species of diplodactyline geckos, 9 species of pygopodid lizards and 12 species of elapid snakes. It is especially rich in fossorial species, viz. the endemic frog *Arenophryne rotunda*, two species of the pygopodid genus *Aprasia* (one endemic, the other almost so), six species of the scincid genus *Lerista*, two blind-snakes *(Typhlina)* and five species of the elapid genus *Vermicella*.

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Manuscripts

Manuscripts must be submitted in duplicate, typewritten, double spaced with wide margins. Positions of text figures and tables must be indicated. Authors may include an abstract for publication as part of a paper. The Committee may require an author to submit an abstract if no abstract is submitted and it considers that an abstract would be useful.

Illustrations

Papers may be illustrated by black and white line drawings or black and white photographs. One set of illustrations will be required. Photographs should be printed on white glossy paper, showing a full range of tones and good contrast. Top and bottom should be clearly indicated. Line drawings should be no more than three times the maximum size for publication, which is 19 cm x 12.5 cm, including caption. Authors should indicate their preferred degree of reduction. Numbering and lettering should be done lightly in blue pencil. Composite illustrations are to be submitted separately, with a sketch of authors' requirements. Final illustrations will be produced by the Western Australian Museum's display artists.

Footnotes

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