VOL. 111, PARTS 1 & 2
29 MAY, 1987

Transactions of the
Royal Society of South Australia
Incorporated

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PUBLISHED AND SOLD AT THE SOCIETY'S ROOMS
SOUTH AUSTRALIAN MUSEUM, NORTH TERRACE, ADELAIDE, S.A. 5000

TRANSACTIONS OF THE

ROYAL SOCIETY
OF SOUTH AUSTRALIA

INCORPORATED

VOL. 111, PART 1

TRANSACTIONS OF THE ROYAL SOCIETY OF SOUTH AUSTRALIA INC.

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SEED DISPERSAL BY BIRDS AND DENSITIES OF SHRUBS UNDER TREES IN ARID SOUTH AUSTRALIA

BY MARK TESTER[1], D. C. PATON†, NICK REID*[2] & R. T. LANGE**

Summary

The frequencies of nine species of shrub under *Acacia papyrocarpa* trees, under *Myoporurn platycarpum* trees and in the spaces between trees were measured in a South Australian arid zone woodland. All nine species were at least as common under the trees as they were in the open, and five species had significantly higher frequencies under the trees. Three species with higher frequencies under trees, *Chenopodiurn gaudichaudianum, Enchylaena tomentosa* and *Rhagodia spinescens*, produce fleshy fruits that are consumed by birds. Their seeds would tend to be disseminated under trees in which the birds perch. Enchylaena tomentosa was equally abundant under both three species, but *R. spinescens* and *C. gaudichaudianum* were more abundant under *A. papyrocarpa* than under M. platycarpurn. Traps set under the canopies of the two tree species collected similar though highly variable numbers of seeds. This suggests that rates of seed germination or seedling survival for *R. spinescens* and *C. gaudichaudianum* are higher under *A. papyrocarpa* than *M. platycarpum*. The distribution of these two shrubs cannot be explained solely by the pattern of seed dispersal by birds. For Enchylaena tomentosa, seed dispersal by birds may provide an adequate explanation for its distribution.

KEY WORDS; Chenopodiaceae, seed dispersal, plant distribution, birds, fleshy fruits.

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Summary

TESTER, M., PATON, D. C., REID, N. & LANGE, R. T. (1987) Seed dispersal by birds and densities of shrubs under trees in arid South Australia. *Trans. R. Soc. S. Aust.* 111(1),1-5, 29 May, 1987.

The frequencies of nine species of shrub under *Acacia papyrocarpa* trees, under *Myoporum platycarpum* trees and in the spaces between trees were measured in a South Australian arid zone woodland. All nine species were at least as common under the trees as they were in the open, and five species had significantly higher frequencies under the trees. Three species with higher frequencies under trees, *Chenopodium gaudichaudianum*, *Enchylaena tomentosa* and *Rhagodia spinescens*, produce fleshy fruits that are consumed by birds. Their seeds would tend to be disseminated under trees in which the birds perch. *Enchylaena tomentosa* was equally abundant under both three species, but *R. spinescens* and *C. gaudichaudianum* were more abundant under *A. papyrocarpa* than under *M. platycarpum*. Traps set under the canopies of the two tree species collected similar though highly variable numbers of seeds. This suggests that rates of seed germination or seedling survival for *R. spinescens* and *C. gaudichaudianum* are higher under *A. papyrocarpa* than *M. platycarpum*. The distribution of these two shrubs cannot be explained solely by the pattern of seed dispersal by birds. For *Enchylaena tomentosa*, seed dispersal by birds may provide an adequate explanation for its distribution.

KEY WORDS: Chenopodiaceae, seed dispersal, plant distribution, birds, fleshy fruits.

Introduction

In the Australian arid zone, a variety of shrubs ("berry chenopods") and small trees (*Acacia, Exocarpus, Heterodendrum*) produce brightly-coloured fleshy fruits or arils that are consumed by birds (Davidson & Morton 1984; Forde 1986). Many of the shrubs (e.g. *Rhagodia spinescens, Enchylaena tomentosa* and *Chenopodium gaudichaudianum*) are found at higher frequencies underneath trees and large shrubs than in the open (e.g. Barker 1972[3]). Two hypotheses have been proposed to account for this. First, the clumped distribution reflects the pattern of dissemination by birds, the birds defaecating seeds while perched in trees (e.g. Osborn *et al.* 1935; Leigh & Mulham 1965; Forde 1986). Alternatively, or in addition, Barker (1972)[3] suggested that the clumping was due to more favourable growing conditions beneath tree canopies. To distinguish between these two hypotheses requires measuring the seed rain beneath and between tree canopies, and determining rates of germination and seedling establishment in the different microenvironments.

In this paper, we (1) document the distribution of several species of shrubs in relation to tree canopies on Middleback Station, 21 km north-west of Whyalla; and (2) report the use of a "seed trap" to measure the seed rain beneath trees due to birds and discuss the data so derived.

Materials and Methods

Study site

The study site was in the south-western corner of Overland Paddock, Middleback Station (32°57'S, 137°24'E) in an area of open woodland which is moderately grazed by sheep. Two tree species predominated: *Myoporum platycarpum* R.Br. which grows to 10 m and has a thin elevated canopy; and *Acacia papyrocarpa* Benth. which has a dense low spreading canopy. The two trees were infected by mistletoes: *M. platycarpum* by *Lysiana exocarpi* (Behr) Tiegh. and *A. papyrocarpa* by *Amyema quandang* (Lindl). Teigh. The understorey was dominated by the chenopods, *Maireana sedifolia* (F.Muell.) P. G. Wilson, *Atriplex vesicaria* Heward ex Benth., *Maireana pyramidata* (Benth.) P. G. Wilson and *Rhagodia ulicina* (Gand.) P. G. Wilson. Four species of small shrubs (*Rhagodia spinescens* var. *spinescens* F.Muell., *Chenopodium gaudichaudianum* (Moq.) P. G. Wilson, *Enchylaena tomentosa* R.Br., *Lycium australe* F.Muell.), the two

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[3] Barker, S. (1972) "Effects of Sheep Stocking on the Population Structure of Arid Shrublands in South Australia". Ph.D. thesis. University of Adelaide, Adelaide. Unpubl.

mistletoes and two small trees or large shrubs, *Exocarpus aphyllus* R.Br. and *Heterodendrum oleaefolium* Desf., produced fruits that were consumed by birds in the area (Reid 1984[4]; Forde 1986).

Distribution of shrubs

Distribution of shrubs in three zones: under the canopies of *M. platycarpum*, under the canopies of *A. papyrocarpa*, and in the spaces between the trees and large shrubs was measured. Interspaces were at least 2 m from the canopy of any tree or large shrub. Two hundred 0.5 m × 0.5 m quadrats were placed haphazardly in each zone, and the presence of a shrub species in each quadrat was scored if any part of its canopy occurred in the quadrat. The diameters of the canopies of 30 individuals of each shrub species in each zone was measured by measuring the width across the plant along two axes (north-south and east-west). Since the mean canopy diameter of a particular shrub species was the same under the two tree species as well as in interspaces, incidence in quadrats provides a measure of the relative density of a plant species in each of the three zones. However, the canopies of the different shrub species were not the same diameter (Table 1), so the relative densities of the different species cannot be determined from the quadrat frequencies.

Trapping for bird droppings

Twenty-two traps to collect bird droppings were deployed in March 1984. Traps were made by tying 1.2×1.5 m sheets of terylene voile (mesh 0.8×0.3 mm) to steel stakes to form a catching area of 1.0×1.5 m that stood 90 cm above the ground (e.g. see Sorensen 1981). This was the largest size of trap that could be conveniently erected under the canopies of the trees. A stone was placed in the centre of the catching area to prevent spillage of seeds by strong winds. Equal numbers of traps were placed beneath canopies of mature *M. platycarpum* and mature *A. papyrocarpa*. All of these trees were infected with variable amounts of mistletoes. Traps were inspected and emptied of seeds at two 4-monthly intervals. The seeds were identified using a reference collection of seeds compiled in the area. Many of the traps were damaged 4 to 8 months after deployment and observations ceased after 8 months.

Results

Distribution of shrub species in Overland Paddock

Nine species of shrubs were detected in the six hundred 0.5×0.5 m quadrats. Of these, five species occurred significantly more frequently under the canopies of either *Acacia papyrocarpa* or *Myoporum platycarpum* than in the interspaces between the trees and large shrubs (Table 1). Of these, three species produced fleshy fruits that were dispersed by birds (*Chenopodium gaudichaudianum*, *Enchylaena tomentosa* and *Rhagodia spinescens*), while the other two species (*C. desertorum* and

TABLE 1. *Frequency of occurrence of shrubs in 200 quadrats (0.5×0.5 m) in each of three zones in Overland Paddock, March 1984.*

Shrub species	Mean canopy[a] area (m²)	Frequency in 200 quadrats beneath *A. papyrocarpa*	beneath *M. platycarpum*	in interspace	X^2 value[b]
Atriplex vesicaria	0.40	38	74	44	14.3 ***
Chenopodium desertorum	—	12	10	2	6.0 *
C. gaudichaudianum[c]	0.17	51	16	0	60.9 ***
Enchylaena tomentosa[c]	0.11	32	34	7	18.6 ***
Lycium australe[c]	0.49	7	8	13	2.2 NS
Maireana pyramidata	—	11	11	11	0.0 NS
M. sedifolia	—	42	42	34	1.1 NS
Rhagodia spinescens[c]	—	41	22	0	40.1 ***
R. ulicina	—	23	32	18	4.1 NS

[a] Canopy areas calculated from diameters of 60 or 90 individuals depending on number of zones in which plant species occurred. Standard errors were less than 30% of the mean and there were no significant differences in the canopy area of a shrub species in different zones (ANOVAs, $P \geq 0.05$), so data for the different zones were pooled.

[b] The X^2 statistic (2 *d.f.*) tests the null hypothesis that shrub species were evenly distributed across the three zones:
* $P \leq 0.05$
** $P < 0.01$
*** $P < 0.001$
NS not significant

[c] Shrubs that produce fleshy fruits consumed by birds.

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[4] Reid, N. (1984) "The Role of Birds in the Reproduction of an Arid Zone Population of Grey Mistletoe *Amyema quandang* (Loranthaceae)." Ph.D. thesis. University of Adelaide, Adelaide. Unpubl.

Atriplex vesicaria) had wind or ant-dispersed seeds. *Enchylaena tomentosa* and *C. desertorum* were equally frequent under both canopies, but *A. vesicaria* was encountered most frequently under *M. platycarpum*, and *C. gaudichaudianum* and *R. spinescens* were encountered most frequently under *Acacia papyrocarpa*.

Four species of shrub showed no significant clumping under the canopies of trees (χ^2 tests, $p > 0.05$). Of these, the *Maireana* species and *R. ulicina* have wind or ant-dispersed seeds but *Lycium australe* produces fleshy fruits that are dispersed by birds and perhaps reptiles.

Seed rain detected by traps

Table 2 lists the quantity of seeds collected in the traps set under the canopies of *Acacia papyrocarpa* and *M. platycarpum* during two time periods. The numbers of seeds deposited per trap was highly variable, with variances often exceeding the means. There was no significant difference in the total numbers of seeds deposited under *A. papyrocarpa* and *M. platycarpum* (rank-sum tests, $p > 0.05$). More seeds were caught during the period July–November than between March–July (rank-sum test, $p < 0.002$). In general, the number and species of seeds being deposited during each period reflected the fruiting seasons of the plants. *Chenopodium gaudichaudianum*, *Enchylaena tomentosa* and *Exocarpus aphyllus* fruited mainly during winter and early spring, while *Heterodendrum oleaefolium* and *Lycium australe* fruited mainly in autumn. *Rhagodia spinescens* fruited mainly during summer, but like *Enchylaena tomentosa* and *Exocarpus aphyllus*, produced small quantities of fruit throughout most of the year.

Many of the traps also collected seeds of mistletoes. These data are not presented since mistletoe seeds must be deposited on the branches of host trees to be effectively disseminated. The seeds collected in the traps therefore represented ineffective dispersal.

Discussion

The purpose of this study was to measure the distribution of shrubs, particularly the fleshy-fruited chenopods, in relation to tree cover, and to determine the usefulness of traps in measuring seed rains. Prior to this study, statements that fleshy-fruited shrubs were clumped under trees were based largely on qualitative observations (e.g. Osborn *et al.* 1935; Leigh & Mulham 1965; Forde 1986). Our quadrat data show that three fleshy-fruited shrubs were found mainly under trees, and that the extent of this clumping varied from species to species. *Rhagodia spinescens* and *Chenopodium gaudichaudianum* were almost exclusively found under tree canopies, but more frequently under *Acacia papyrocarpa* than under *Myoporum platycarpum*. *Enchylaena tomentosa* was found with equal frequency under both tree species and occasionally in interspaces, while *Lycium australe* was equally abundant under trees and in interspaces (Table 1). However, clumping beneath trees was not restricted to bird-dispersed species. Among the shrubs dispersed by wind or ants, *Atriplex vesicaria* was more common beneath *M. platycarpum* than *Acacia papyrocarpa* or in interspaces, and *C. desertorum* was significantly more common under both trees than in the interspaces. Higher densities of shrubs under trees could occur because (1) more seeds are dispersed beneath trees and/or (2) germination rates and seedling establishment are

TABLE 2. *Numbers of seeds deposited by birds in traps set under* Myoporum platycarpum *and under* Acacia papyrocarpa *in Overland Paddock under two time periods in 1984.*

Species of shrub	Mean number of seeds per trap ± S.E.	
	March–July	July–November
Traps set under *M. platycarpum*	n = 11	n = 4
Chenopodium gaudichaudianum	0.3 ± 0.2	4.8 ± 3.3
Enchylaena tomentosa	2.3 ± 2.0	10.5 ± 3.5
Exocarpos aphyllus	5.7 ± 3.1	23.5 ± 10.9
Heterodendrum oleaefolium	3.2 ± 1.4	0.0 ± 0.0
Lycium australe	0.4 ± 0.2	0.0 ± 0.0
Rhagodia spinescens	1.1 ± 0.7	0.2 ± 0.3
Total	12.9 ± 7.2	39.0 ± 7.1
Traps set under *A. papyrocarpa*	n = 11	n = 8
Chenopodium gaudichaudianum	0.0 ± 0.0	0.4 ± 0.4
Enchylaena tomentosa	1.4 ± 0.7	5.8 ± 3.7
Exocarpus aphyllus	5.8 ± 3.8	28.4 ± 9.2
Heterodendrum oleaefolium	1.7 ± 0.8	0.6 ± 0.5
Lycium australe	0.2 ± 0.2	0.0 ± 0.0
Rhagodia spinescens	0.4 ± 0.4	1.1 ± 1.1
Total	9.5 ± 4.6	36.2 ± 14.2

higher under trees than in the open (e.g. Barker 1972[3]; Forde 1986). These two explanations are sequential and not mutually exclusive. Both are probably important in determining the distributions of various fleshy-fruited plants in Overland Paddock. The first thing to demonstrate, however, is whether birds disperse seeds mainly to sites under trees.

On Middleback Station, fleshy-fruited shrubs have their seeds dispersed largely by birds and most of the seeds appear to land under trees. Although our traps were not deployed to demonstrate that more seeds were deposited under trees than in the open, other observations enable such a conclusion. In Overland Paddock, two species of honeyeater are largely responsible for the dispersal of seeds by birds, the Spiny-cheeked (*Acanthagenys rufogularis*) and Singing (*Lichenostomus virescens*) Honeyeaters (Reid unpubl.). These honeyeaters mainly feed on the nectar and fruit of mistletoes, supplementing these foods with insects and fruits of other shrubs (Reid 1984[4]). More than 90% of their faeces are discharged while the birds are perched more than a metre above the ground in trees or tall shrubs (Reid unpubl.). Consequently bird-disseminated seeds should be concentrated under the canopies of trees.

The traps that we deployed under the trees were successful in collecting seeds, and the quantities collected (10–30 seeds/m^2/4 months; Table 2) are consistent with estimates of the numbers of seeds that should have been voided by birds. Assuming that there were 1.2 honeyeaters/ha, that these honeyeaters consumed 80–160 seeds from fleshy-fruited shrubs per day, that the birds largely disseminated these seeds under the canopies of trees and that the tree cover was 10%, then in 4 months approximately 10–20 seeds/m^2 should have been voided by birds under trees (Reid 1984[4], in prep.).

The numbers of seeds collected by individual traps were highly variable. Two potential sources of variation probably account for this: variation in the use of trees or parts of trees by birds, and variation in faecal composition. Certain trees or parts of trees may be used more extensively by birds because of their location, architecture or the amount of food associated with them. Trees centrally-located in a bird's territory or near the bird's nest may be used more frequently (e.g. Orians & Pearson 1979). The density of the foliage or height of a tree may provide birds with better protection from exposure or predators, or better vantage points for detecting predators or intruders, and so trees with these attributes may be used more frequently. The trees in the study area also differed in the numbers of mistletoes they supported (Reid 1984[4]) and probably also in the quantities of fleshy fruits provided by the shrubs beneath them. Birds should spend more time in trees where the food supply is greatest (e.g. Charnov 1976; Pyke *et al.* 1977). The second major source of variation concerns the faeces of the birds. A single faecal dropping may contain 0 to 20 seeds, and much of the variation between traps may be due to variations in the numbers of seeds in a faecal dropping rather than variations in the use of trees by birds. We counted the total number of seeds in the traps, not the number of faeces. Future studies may wish to control for these variations, or at least account for them by recording the architectural features, the locations, and associated food supplies of the trees under which the traps were placed. Use of several traps under the same tree also would allow within-tree variation in bird use to be measured.

The size and design of the traps seems appropriate for measuring seed rains under trees in the arid zone. Traps, however, would need to be set closer to the ground and under shrubs if seed rains were to be measured in the interspaces between trees, because the honeyeaters only defaecate while perched (Reid 1984[4]). The size of the traps (1.5 × 1.0 m) also seems appropriate since larger traps would have been too awkward to erect under trees and the size was such that there was a reasonable chance that a trap would collect at least some seeds. Traps failed to collect seeds on only six occasions out of 34 four-month exposures. Based on our experience, we would recommend clearing traps of their seeds every two months, and using a stronger mesh for the catching material. This would reduce the loss of faecal material due to the catching material deteriorating with time. We found that terylene voile deteriorated after about four months, particularly under *Myoporum platycarpum* where the traps were exposed to more sunlight.

Given that most of the seeds are dispersed to sites under trees we would expect bird-dispersed plants to be most abundant under trees in the arid zone. In general this is the case, but there are exceptions. *Lycium australe* was equally abundant under trees and in interspaces, and the low clonal tree, *Heterodendrum oleaefolium*, often occurs away from other trees. These species reproduce extensively by root suckers and are apparently long-lived relative to the trees (Purdie 1969[5]; D. E. Symon pers. comm.). Little is known about their seedling recruitment (cf. suckering), since seedlings are rarely seen: no seedlings of *H. oleaefolium* have

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[5] Purdie, R. (1969) "The Population Structure of Selected Arid Zone Tree Species". B.Sc.(Hons) thesis. Univ. of Adelaide. Unpubl.

been detected on Middleback Station over the last 20 years (Lange unpubl.). Seedlings of these species may only establish under trees, but once established, may produce suckers to exploit interspaces between trees where competitive interactions with the established trees presumably are reduced. The present distribution of these plants, then, may not reflect the sites where seedlings established, and the relatively high densities of these plants away from trees is not necessarily inconsistent with most of the seeds being deposited under trees. In addition, *Lycium australe* produces fruit close to the ground and lizards may therefore consume and disperse some *Lycium* seeds to interspaces.

The best evidence that factors other than seed dissemination by birds are also involved in the eventual pattern of distribution in these fleshy-fruited plants comes from comparing the distributions of the three berry chenopods, *Rhagodia spinescens*, *Chenopodium gaudichaudianum* and *Enchylaena tomentosa*. These three species are almost exclusively bird-dispersed, and similar quantities of seeds were deposited under *A. papyrocarpa* and *M. platycarpum* (Table 2). The density of *Enchylaena tomentosa* under the two tree species was similar, and so the pattern of seed dispersal by birds may provide an adequate explanation for its distribution. However, both *R. spinescens* and *C. gaudichaudianum* had higher densities under *A. papyrocarpa* than *M. platycarpum*. Factors besides dispersal by birds are needed to explain this. The most likely explanations involve the climatic or edaphic differences encountered beneath trees, coupled with differences in the regeneration niche of the shrubs. *Acacia papyrocarpa* and *M. platycarpum* differ in architecture (branching pattern etc.) and hence in the amount of shade they provide a germinating seed or seedling. The canopy of *A. papyrocarpa* is relatively dense and provides shade and a thick cover of litter. *Myoporum platycarpum* has a high thin canopy, so plants beneath it are subject to conditions of more severe water stress (Barker 1972[3]). Other factors such as increased nutrient cycling under *A. papyrocarpa* (Correll 1967[6]) or increased grazing pressure under *M. platycarpum* could also be involved. Similar sorts of factors would account for the fact that *Atriplex vesicaria* and possibly *Rhagodia ulicina* were more abundant under *M. platycarpum* than *A. papyrocarpa*. Careful field experiments will be required to determine the factors (edaphic, climatic, biotic) that are important for the germination and seedling establishment of each species. These experiments should involve transplanting seeds or seedlings between the canopies of different tree species as well as into the interspaces. Only after these experiments have been performed will we have the necessary evidence to state the relative contributions of bird dissemination of seeds and environmental factors in determining the distribution of fleshy-fruited shrubs in the arid zone.

Acknowledgments

We would like to thank Tim Croft and Christina Morris for assistance in the field, and Andrew, Lesley, Don and Penan Nicolson for their generous hospitality at Middleback Station. Hugh Ford and an anonymous reviewer provided helpful comments on an earlier draft. This work was based at the Middleback Field Centre which is supported by Broken Hill Propriety Co. and Mitsubishi Motors (Australia) Ltd.

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A PROPOSED REFERENCE SECTION FOR THE TORTACHILLA LIMESTONE

BY A. S. BEECROST, J. H. CANN† & C. STOCKSIEK‡*

Summary

Roadside outcrops of sedimentary rocks near Port Noarlunga, South Australia, are identified as Late Eocene stratigraphic units of the Noarlunga Embayment within St Vincent Basin. Fossil planktonic and benthic foraminifera from these rocks compare favourably with stratotype Tortachilla Limestone and the Tuketja Member of Blanche Point Formation. An exposure of highly fossiliferous, glauconitic calcarenite, bounded below by the South Maslin Sand Member of Maslin Sands, and above by the Tuketja Member of Blanche Point Formation, is proposed as a reference section for Tortachilla Limestone.

KEY WORDS: Eocene, foraminifera, Noarlunga Embayment, St Vincent Basin, Tortachilla Limestone.

A PROPOSED REFERENCE SECTION FOR THE TORTACHILLA LIMESTONE

by A. S. BEECROFT[*], J. H. CANN[†] & C. STOCKSIEK[‡]

Summary

BEECROFT, A. S., CANN, J. H. & STOCKSIEK, C. (1987) A proposed reference section for the Tortachilla Limestone. *Trans. R. Soc. S. Aust.* 111(1), 7-13, 29 May, 1987.

Roadside outcrops of sedimentary rocks near Port Noarlunga, South Australia, are identified as Late Eocene stratigraphic units of the Noarlunga Embayment within St Vincent Basin. Fossil planktonic and benthic foraminifera from these rocks compare favourably with stratotype Tortachilla Limestone and the Tuketja Member of Blanche Point Formation. An exposure of highly fossiliferous, glauconitic calcarenite, bounded below by the South Maslin Sand Member of Maslin Sands, and above by the Tuketja Member of Blanche Point Formation, is proposed as a reference section for Tortachilla Limestone.

KEY WORDS: Eocene, foraminifera, Noarlunga Embayment, St Vincent Basin, Tortachilla Limestone.

Introduction

The Tortachilla Limestone is a Late Eocene stratigraphic Member of St Vincent Basin (Reynolds 1953; Stuart 1970; Buonaiuto 1977; Cooper 1979; Beecroft 1980[1]; Jenkins *et al.* 1982). Within the Willunga Embayment, at the type locality, Maslin Bay, the Tortachilla Limestone has a maximum thickness of about two metres. It overlies the poorly fossiliferous South Maslin Sand Member of the Maslin Sands (Cooper 1979) and is in turn overlain by the younger Tuketja Member of the Blanche Point Formation (Jenkins *et al.* 1982). Buonaiuto (1977) confined the Tortachilla Limestone to the lower Polyzoal Limestone Member of Reynolds (1953) and this was followed by Cooper (1979), though not by Jenkins *et al.* (1982), whose nomenclature is used in this paper. Fig. 1 summarizes this stratigraphy.

About ten years ago the beach at Maslin Bay was proclaimed available for nude bathing and this factor has deterred some study groups from visiting the stratotype area. Also, an equivalent section at Whitton Bluff, Christies Beach, is no longer accessible for study due to coastal protection works. There is therefore a need for nomination of other outcrops as reference sections of the Tertiary units.

Outcrop descriptions

Daily (1952)[2] noted outcrops of Tertiary sediments of the Noarlunga Embayment in cliffs and road cuttings adjacent to the lower Onkaparinga River. More recently, additional road works have exposed these strata in greater detail (Stocksiek 1983[3]). An exposure on River Road (Fig. 2, Site 1) presents more than 100 metres of easily accessible and continuous outcrop. Part of this exposure is shown in Fig. 3.

From road level, yellow brown clays give way to coarse, limonitic, crossbedded sandstone, apparently non-fossiliferous. These sediments have a thickness of about 2.5 metres and are characteristic of the South Maslin Sand Member. Overlying Tortachilla Limestone, typically glauconitic green, sandy and richly fossiliferous, is 1 2 metres thick. Glauconitic marls of the Tuketja Member form the uppermost beds of the outcrop. These three outcropping units are essentially similar in lithological detail to descriptions of stratotype material given in Cooper (1979). Because of ease of access and clarity of stratigraphic boundaries, this exposure is here proposed as a reference section for the Tortachilla Limestone. Fossil foraminifera from the section are discussed later below.

In roadside outcrop west of the Reference Section (Fig. 2, Site 2) only 0.5 metre of South Maslin Sand Member appears above road level. Tortachilla Limestone is bleached and its upper boundary is indistinct. Tuketja Member constitutes most of the outcrop, though the higher, harder, more prominent beds may represent the Gull Rock Member of the

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[1] Beecroft, A. S. (1980) Foraminiferal biofacies of the Tortachilla Limestone and the Blanche Point Formation, Late Eocene, Willunga Sub-basin, South Australia. B.A.(Hons.) thesis, Univ. of Adelaide.

[2] Daily, B. (1952) Stratigraphy and geology of the Noarlunga basin. B.Sc.(Hons.) thesis, Univ. of Adelaide.

[3] Stocksiek, C. (1983) Some observations of the Tertiary strata outcropping adjacent to the Onkaparinga estuary, South Australia. Geology project report, S. Aust. Coll. Adv. Educ., Salisbury.

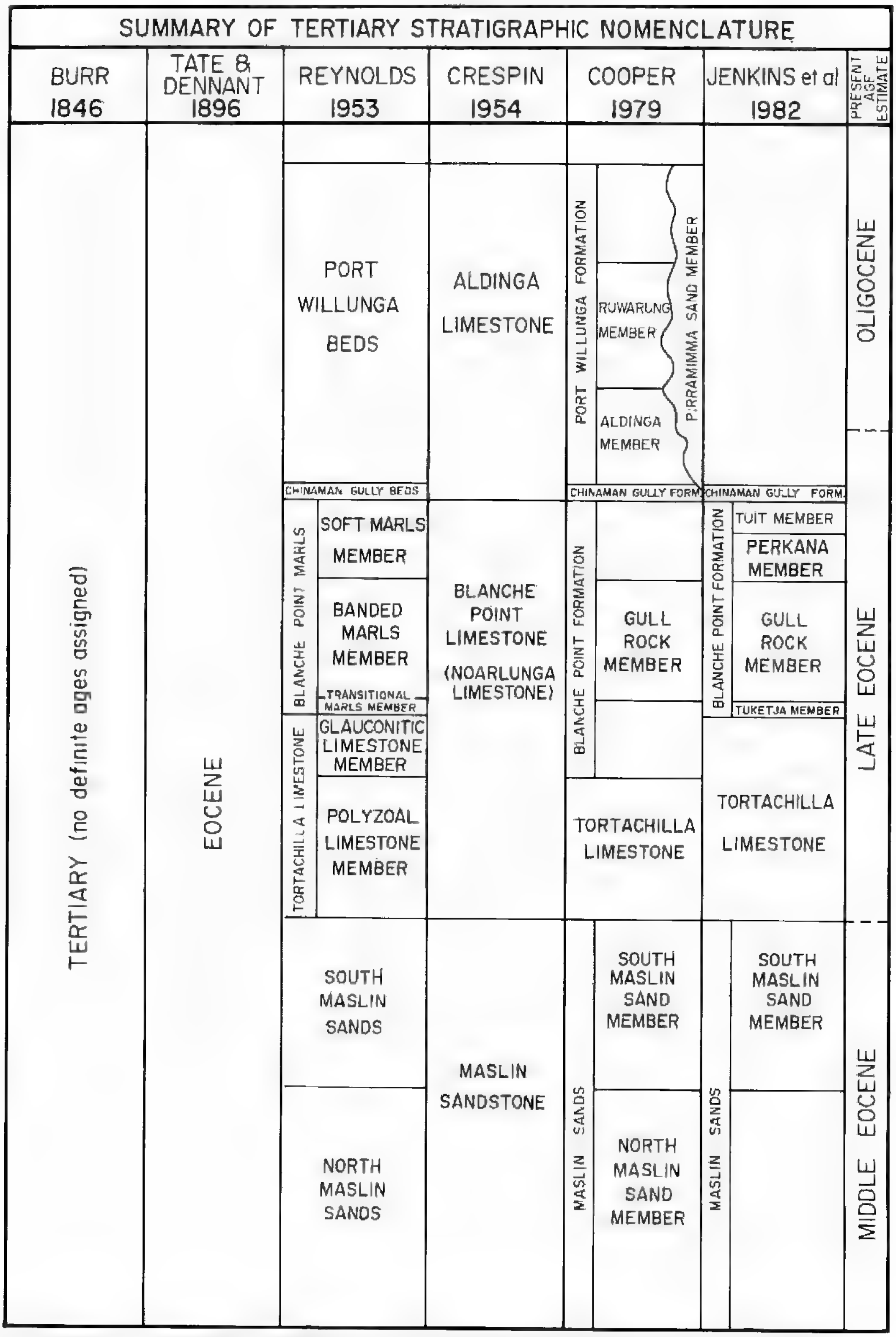

Fig. 1. Summary of stratigraphic nomenclature for St Vincent Basin, South Australia. No scale implied.
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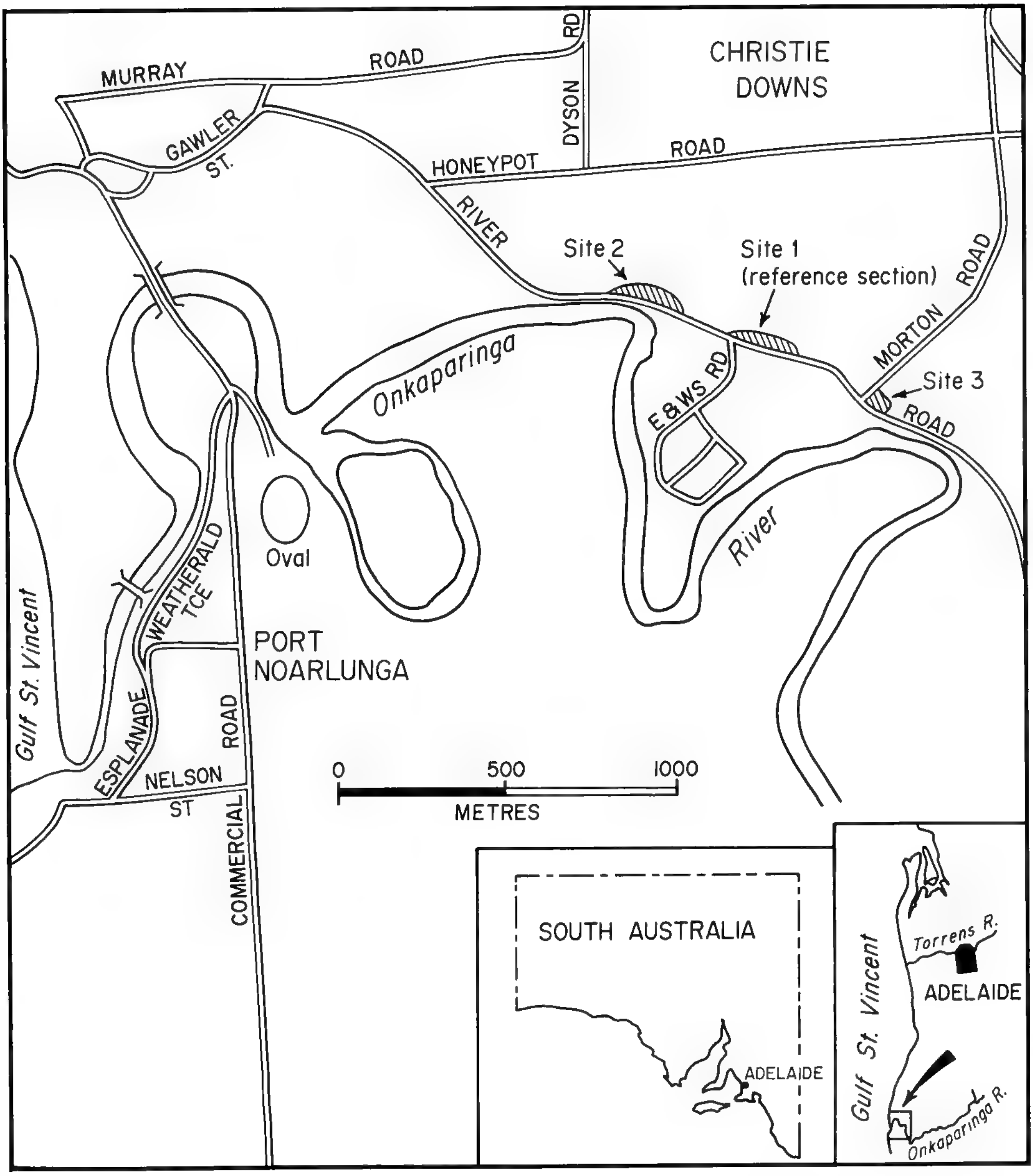

Fig. 2. Location map showing sites of outcrop of Tertiary sediments referred to in text.

the Blanche Point Formation. The sequence apparently dips gently westwards.

At the intersection of Morton and River Roads (Fig. 2, Site 3) Tortachilla Limestone outcrops prominently. It is conspicuously fossiliferous (Fig. 4) and overlain by both Tuketja and Gull Rock Members of the Blanche Point Formation.

Foraminifera

Microscopic examination of washed material from the identified Tortachilla Limestone at Site 1 revealed a rich micro-fauna dominated by benthic foraminifera, with occasional ostracods. Scanning electron photomicrographs of some species of the foraminifera are shown in Fig. 5. A similar

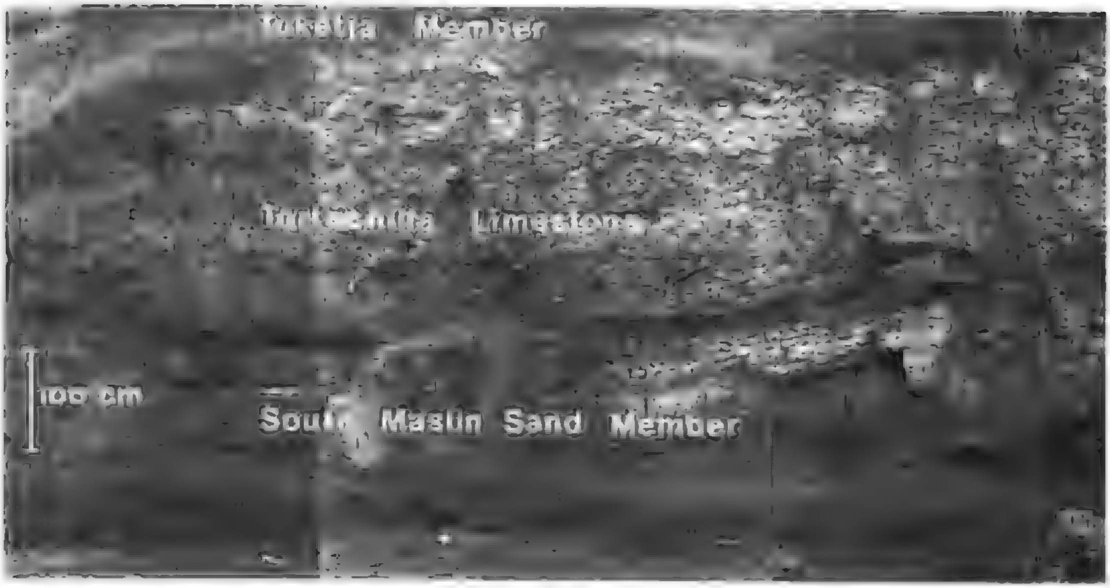

Fig. 3. Composite photography of part of the proposed reference section for the Tortachilla Limestone.

foraminiferal assemblage occurs at Maslin Bay in stratotype Tortachilla Limestone and has been referred to Zone P15 (Lindsay 1981,[4] and refs. therein).

Significant planktonic foraminifera present include: *Subbotina linaperta, S. angiporoides, Tenuitella aculeata, T. gemma, T. insolita, Turborotalia nana, T. centralis, T. cerroazulensis, Chiloguembelina cubensis, Pseudohastigerina micra* and *Globigerinatheka index*. The lower disjunct top to *Tenuitella aculeata* occurs within this unit, while *Turborotalia cerroazulensis* has only recently been found in the type section (Lindsay 1981) and is not known with any certainty to occur locally above the Tortachilla Limestone.

Among the benthic foraminifera, the presence of *Pseudopolymorphina carteri, Linderina glaessneri* and *Maslinella chapmani* is significant. *Pseudopolymorphina carteri* is restricted in occurrence to the Tortachilla Limestone and basal Blanche Point Formation (Tuketja Member) at Maslin Bay, while the presence of *Linderina glaessneri* at this level represents an extra-tropical excursion (Lindsay 1967, 1969; McGowran 1978). The presence of *Maslinella chapmani* appears to be temperature controlled, being found in the Tortachilla Limestone and Tuketja Member, and then not again until the basal part of the Aldinga Member of the Port Willunga Formation (P16) where *L. glaessneri* also reappears briefly.

The remainder of the assemblage are species which cover a wider stratigraphic range, but as an assemblage, the unit contains both planktonic and benthic elements which are consistent with stratotype Tortachilla Limestone.

The overlying unit contains rare, small, broken, but nonetheless unambiguous *Hantkenina primitiva*, which unequivocally confirms that this unit is the Tuketja Member of the Blanche Point Formation, and hence supports the identification of the Tortachilla Limestone unit. The Tuketja Member here does not contain *T. aculeata* nor *L. glaessneri*, consistent with the type section at Maslin Bay, although *P. carteri* and *M. chapmani* are present in reduced numbers.

Conclusions

The presence of key species, in particular *Tenuitella aculeata, Turborotalia cerroazulensis, T. centralis, Pseudopolymorphina carteri, Maslinella chapmani* and *Linderina glaessneri* enable this unit to be recognized stratigraphically as Tortachilla Limestone. Identification is further emphasised by the presence of *Hantkenina primitiva* in the overlying unit, which is thus confirmed as being the Tuketja Member of the Blanche Point Formation.

The foraminiferal fauna of the Tortachilla Limestone enables correlation with the equivalent level in the Browns Creek section of south-western Victoria and the Nanarup Limestone of the Bremer Basin, Western Australia (McGowran & Beecroft in prep.).

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[4] Lindsay, J. M. (1981) Tertiary stratigraphy and foraminifera, Adelaide, South Australia. M.Sc. thesis, Univ. of Adelaide.

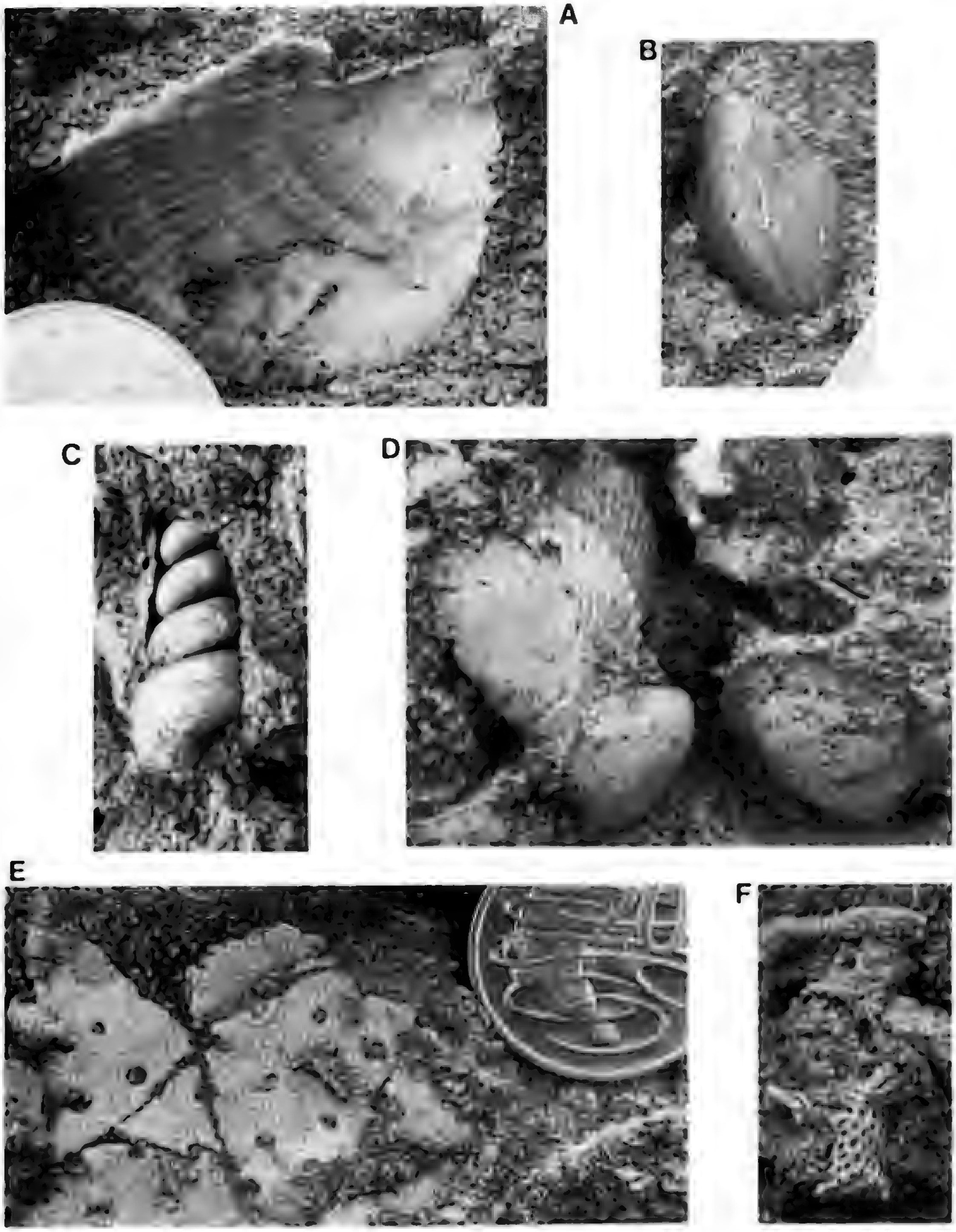
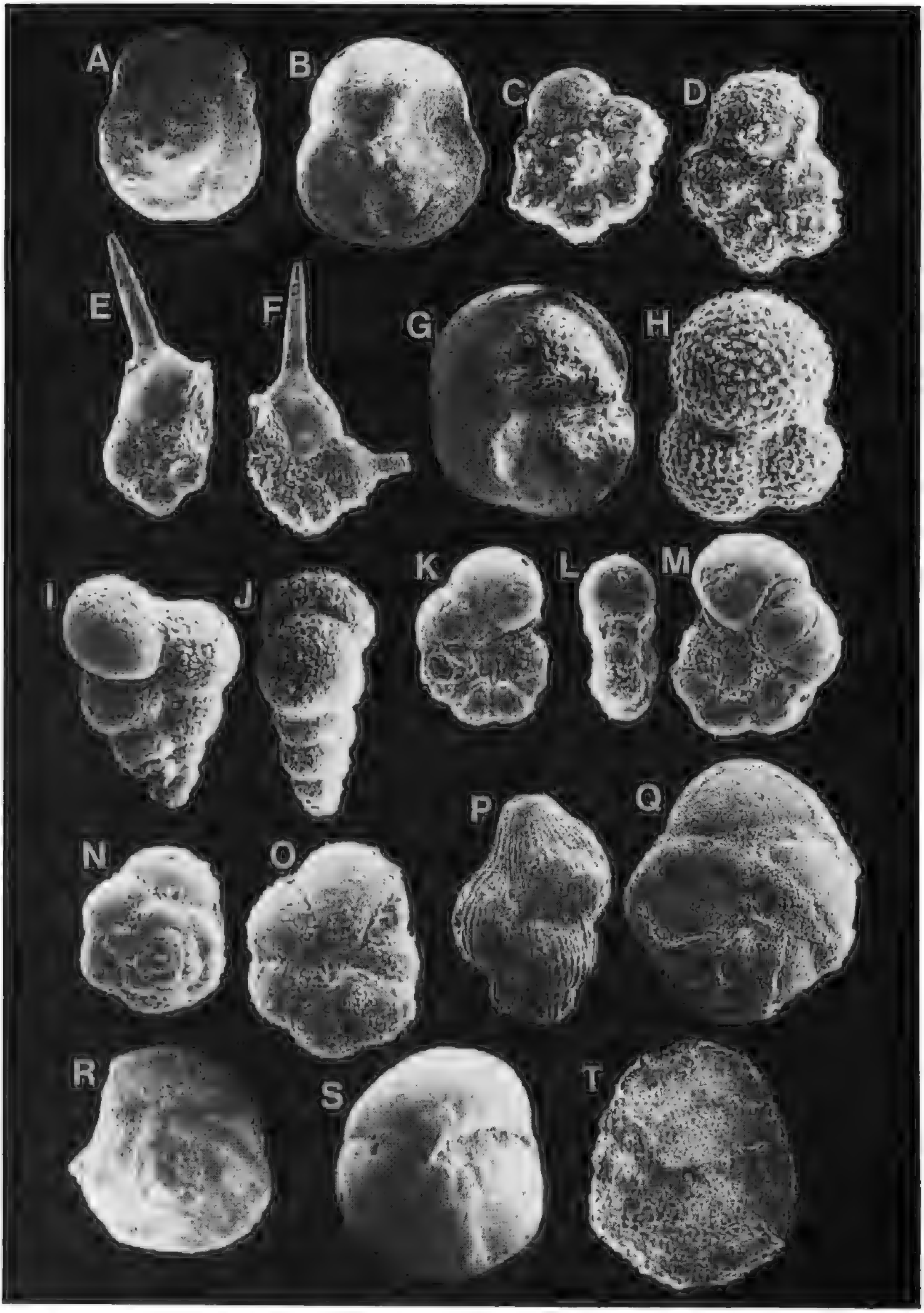


Fig. 4. Selected fossils, photographed at outcrop of the Tortachilla Limestone at site 3. A and D, bivalves; B, brachiopod; C, gastropod; E and F, bryozoa. all × 1.5 approx. (diameter of Aust. 20 cents coin is 28 mm).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Acknowledgments

Sharon Proferes drafted figures 1 and 2; Richard Barrett provided photographic assistance; Brent Bowman picked the *Hantkenina primitiva;* Chris Moore typed the final manuscript. We thank Dr Richard Jenkins and Mr Murray Lindsay for critically reading the manuscript.

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______ (1969) Cainozoic foraminifera and stratigraphy of the Adelaide Plains Sub-basin, South Australia. *Bull. Geol. Surv. S. Aust.* **42**.

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STUART, W. J. (1970) The Cainozoic stratigraphy of the eastern coastal area of Yorke Peninsula, South Australia. *Ibid.* **94**, 151-178.

Fig. 5. Selected foraminifera from the Tortachilla Limestone at the proposed reference section. A, B *Turborotalia cerroazulensis* (Cole) × 75; C, D *Tenuitella aculeata* (Jenkins) × 220; E, F *Hantkenina primitiva* Cushman and Jarvis × 120; G *Globigerinatheka index* (Finlay) × 145; H *Subbotina angiporoides* (Hornibrook) × 220; I, J *Chiloguembelina cubensis* (Palmer) × 220; K, L, M *Pseudohastigerina micra* (Cole) × 145; N, O *T. insolita* (Jenkins) × 220; P *Pseudopolymorphina carteri* Quilty × 27; Q *Stomatorbina concentrica* (Cushman and Bermudez) × 65; R, S *Eponides repandus* Fichell and Moll) × 45; T *Linderina glaessneri* Quilty × 27.

A COMPARATIVE ANALYSIS OF EOCENE/OLIGOCENE BOUNDARY OSTRACODA FROM SOUTHEASTERN AUSTRALIA AND INDIA WITH RESPECT TO THEIR USEFULNESS AS INDICATORS OF PETROLEUM POTENTIAL

BY K. G. MCKENZIE $ D. K. GUHA†*

Summary

Eocene/Oligocene boundary Ostracoda were analysed from selected wells in the Adelaide Plains Sub-Basin, South Australia and Cambay Basin, India. Source-rock characteristics of the sequences were determined - based mainly on ostracode parameters, with some additional information coming from their glauconite and gypsum content. Numerically similar ostracode counts were made for both sets of samples. The parameters studied were: carapace/valves ratio; adults/juveniles ratio; percentage of fragments; percentage of crushed and worn specimens; *Krithe* type; percentage of pyritised specimens.

Results (which concur with exploration results to date) indicate that the Eocene/Oligocene boundary zone sediments have little petroleum potential in South Australia, but high potential in India. This conclusion was largely reinforced when the South Australian borehole Ostracoda were analysed in more detail. Consistent results were also obtained when the same parameters were determined for Ostracoda in outcrop samples collected from Aldinga Bay, South Australia.

KEY WORDS: Ostracoda, petroleum indices, Eocene/Oligocene boundary, South Australia, India.

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McKenzie, K. G. & Guha, D. K. (1987) A comparative analysis of Eocene/Oligocene boundary Ostracoda from southeastern Australia and India with respect to their usefulness as indicators of petroleum potential. *Trans. R. Soc. S. Aust.* 111(1), 15-23, 29 May, 1987.

Eocene/Oligocene boundary Ostracoda were analysed from selected wells in the Adelaide Plains Sub-Basin, South Australia and Cambay Basin, India. Source-rock characteristics of the sequences were determined based mainly on ostracode parameters, with some additional information coming from their glauconite and gypsum content. Numerically similar ostracode counts were made for both sets of samples. The parameters studied were: carapace/valves ratio; adults/juveniles ratio; percentage of fragments; percentage of crushed and worn specimens; *Krithe* type; percentage of pyritised specimens.

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Introduction

During September-October 1983, one of us (D.K.G.) visited Australia under the aegis of the Australia-India Science and Technology Agreement to study the Tertiary ostracode microfaunas of southeastern Australia for comparison with ostracodes in Indian Tertiary sequences. The senior author (K.G.M.) acted as host for the visit and a co-operative project was initiated.

We soon decided on the Eocene/Oligocene boundary zone because it was well understood both in India and Australia and was known to be important for petroleum exploration in many parts of the world (Pomerol & Premoli-Silva 1986), including India (Guha & Pandey 1980), Australia (Douglas & Ferguson 1976) and China (Hou 1982). Our objective in the comparative study was to determine the respective petroleum potentials of selected Eocene/Oligocene sequences from Australia and India by using ostracode-based parameters developed by Pokorny (1965) and Oertli (1971) and tested recently by Guha (1983), plus some other ostracode (Peypouquet 1979) and sedimentary characteristics regarded by us as pertinent.

It seemed to us that the most pragmatic test of the relevance of the study parameters would be to determine them for wellsite samples. Nevertheless, examination of numerous outcrop samples, including several collected by us both on a brief field excursion during October 1983 to Aldinga Bay, South Australia, made it clear that outcrop material would also yield consistent results. Of the pioneering studies in this methodology that by Pokorny (1965) was based mainly on outcrop samples but included specimens from two boreholes, whereas Oertli (1971) worked exclusively with wellsite samples. In our study, Guha determined the selected parameters for nine samples from the Cambay Well, Cambay Basin, India, while McKenzie determined them for the South Australian Department of Mines and Energy (SADME) Light 1 Well, in the Adelaide Plains Sub-Basin, South Australia; and also for the outcrop samples.

Stratigraphic Summary and Material

South Australia

The Adelaide Plains Sub-Basin is part of the St Vincent Basin (Fig. 1, locality 1). It has been extensively drilled to develop the groundwater resources of the Adelaide region for which it contains two of the principal aquifers. Consequently, the subsurface stratigraphy is well understood (Lindsay 1969, 1985). The Palaeogene sediments include both marine and continental sands, marine limestones and marls. They indicate alternating shallow marine (inshore to outer shelf), transitional and fluvio-lacustrine Palaeogene palaeoenvironments (Lindsay 1969; Cooper 1985; Harris 1985).

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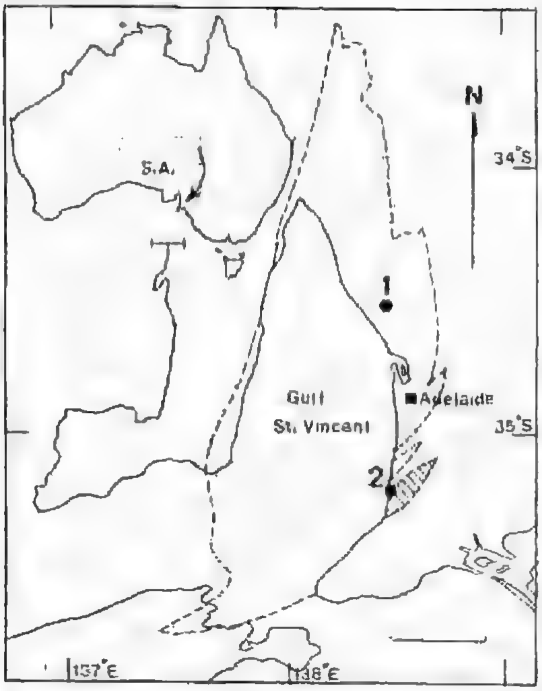

Fig. 1. Locality map of South Australia indicating the locations of: 1, the SADME Light No. 1 Well (about 138° 26'E. Long., 34° 26'S. Lat.); and 2, the Maslin Bay/Aldinga Bay coastal section of the Willunga Embayment (hachured) of the St Vincent Gulf Basin (dashed outline). Scale bar = 20 km. The general location is arrowed on the inset map of Australia.

The SADME Light 1 Well (reference bore 4, core 1 of Lindsay 1969), is particularly noteworthy because it contains, in a cored interval, the Eocene/Oligocene boundary as estimated by Lindsay (1969, 1985) near the base of dark grey, cherty calcareous siltstones forming the "siliceous unit" of Port Willunga Formation — the Ruwarung Member of Cooper (1977, 1979). Below this lie equivalents of the latest Eocene, basal Aldinga Member of Port Willunga Formation, comprising calcareous mudstone, greensand and siltstone; grey-brown speckled green, glauconitic, pyritic, carbonaceous, shelly; in part with very fine quartz sand. Beneath a regressive pebbly sand correlated with Chinaman Gully Formation (Lindsay 1985, Fig. 2), an abbreviated interval equivalent to basal Blanche Point Formation (Lindsay 1968[1]; 1969) rests on, and fills, fractures in probably Proterozoic quartzite (Cornish 1964[2]). Our material includes seven samples supplied by J. M Lindsay (SADME) from the Eocene/Oligocene boundary zone in this well, i.e. from basal Ruwarung Member and uppermost Aldinga Member of Port Willunga Formation.

Total depth of the SADME Light 1 Well was 171.9 m. The seven samples provided to us from core 1 came from the following depths: 139.7–139.8 m; 139.8–140.1 m; 141.1–141.2 m; 142.2–142.3 m; 142.3–142.4 m; 142.75–142.85 m; and 143.2–143.3 m. The Eocene/Oligocene boundary as determined by Lindsay (1969) lies between 141.2 and 142.2 m in this borehole.

Aspects of the regional stratigraphy were described in detail by Cooper (1979) in his study of the Willunga Embayment based on bores and the classic coastal section (Fig. 1, locality 2). Cooper (1979) concludes that the Willunga Embayment was a structurally controlled palaeobay for much of the Cainozoic. Sedimentation in this embayment of the eastern St Vincent Basin began in the Middle Eocene with fluvial sands and intermittent carbonaceous swampy sediments (North Maslin Sands). In the Adelaide Plains Sub-Basin, where SADME Light 1 is located, lignitic Clinton Formation sediments were deposited next, followed by the onset of marine transgression (South Maslin Sands) involving reworking of the earlier fluviatile sands as well as deposition of interdigitating marine and fluvio-lacustrine sandy sediments. Further transgression was marked by high energy bioclastic limestones rich in goethite pellets (Tortachilla Limestone) overlain by glauconitic, spicular and marly clays and silts (Blanche Point Formation) as the transgression attained its maximum level during the Late Eocene. Seasonal upwellings probably characterised this interval. There followed a brief regression (Chinaman Gully Formation) but then marine conditions returned (Port Willunga Formation). The sediments indicate inland to coastal lateral facies variations from non-marine and marginal sands to richly fossiliferous marine carbonates. Such facies persisted from latest Eocene throughout the Oligocene and into the Miocene (Lindsay 1967, 1969, 1985; Cooper 1979). Our material includes four outcrop samples from the Eocene/Oligocene boundary zone (Lindsay 1967; Lindsay & McGowran 1986) in the coastal section at Aldinga Bay (Fig. 1, locality 2).

India

The Cambay Basin (Fig. 2) has India's largest onshore oilfields and is ranked second after the

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[1] Lindsay, J. M. (1968) Palaeontology and stratigraphy. Appendix C, Vol. 1, *In* Northern Adelaide Plains groundwater study to May 1968. 2 vols. Dept of Mines and Energy Report 67/123 (unpubl.)

[2] Cornish, B. E. (1964) Light No. 1 Well completion report. Dept. of Mines report 59/113 (unpubl.).

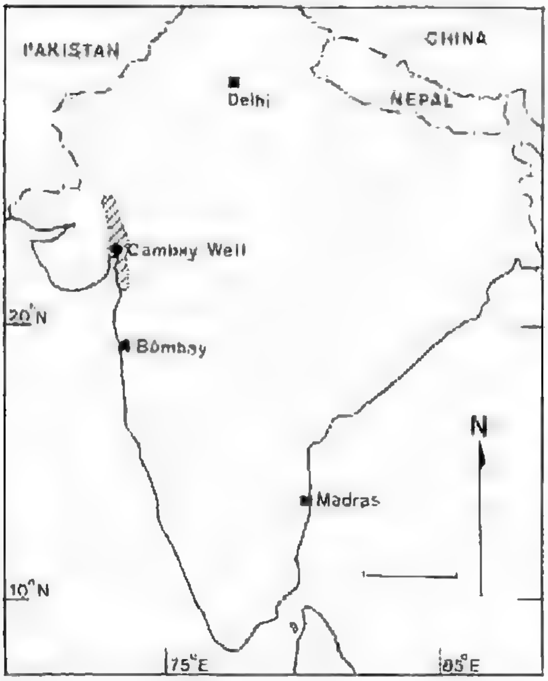

Fig. 2. Locality map of India indicating the Cambay Basin (hachured) and the location of the Cambay Well (72° 36'E Long., 22° 22'N. Lat.). Scale bar = 400 km.

Bombay offshore region in terms of reserves of hydrocarbons (Guha 1983). Not surprisingly, it has been studied in considerable detail and the Palaeogene sequence is confidently correlated and biozoned, based mainly on foraminifera. Palaeoecological analyses indicate alternating shallow marine (inner to outer shelf) and transitional depositional environments for the Basin during the Palaeogene (Guha & Singh 1980).

The Cambay Well is one of several that were drilled to about 2000–3000 m depth with the primary objective of determining the basinal lithostratigraphy. It bottomed in Late Cretaceous basalts of the Deccan Trap. The Eocene/Oligocene boundary in the Cambay area occurs in the Tarapur Shale (Late Eocene-Oligocene) which in this well overlies Cambay Shale (Early-Middle Eocene). The intervening Vaso Formation (Middle-Late Eocene) which is usually unfossiliferous was not identified in the Cambay Well (Guha 1 unpubl.).

The Tarapur Shale is variegated, grey-greenish to light brown, soft to fairly hard and poorly fissile. It is characterised by thick intercalations of quartzose, fine-medium but occasionally coarse-grained sandstone; and, in the Cambay area, by thin intercalations of limestone near its base. The underlying Cambay Shale is dark-coloured, bituminous, moderately hard to fissile, with occasional siltstone beds (Guha & Singh 1980). Guha examined six samples from the Tarapur Shale and three from the Cambay Shale.

Total depth of the Cambay Well was about 2500 m. The 9 samples available to us came from the following depths: 1520 m; 1530 m; 1535 m; 1545 m; 1550 m; 1555 m (Tarapur Shale); and 1570 m; 1585 m; 1605 m (Cambay Shale). The Eocene/Oligocene boundary lies at about 1540 m in this well.

There is considerable support for an Oligocene prospect from the offshore Cambay Basin. Guha & Pandey (1980) in a study based mainly on the Tarapur Offshore Well and incorporating microfaunal, palynological, lithologic and electric log analyses interpreted the interval above the disappearance of *Hantkenina* (Late Eocene foraminiferal datum) as beginning in deeper marine basinal facies and proceeding upwards (above an unconformity/disconformity) into two alternating regressive — estuarine and terrestrial — and transgressive — shallow marine — cycles before the appearance of a characteristic Lower Miocene assemblage. Except for the final (younger) shallow marine transgression there is good evidence for abundant organic matter in euxinic deeper facies and in shallow deltaic and paludal facies also characterised by rapid sedimentation and burial (Guha & Pandey 1980).

Methodology: Ostracode and Other Parameters

Carapaces/Valves ratio

Use of this ratio to yield palaeoecological information was pioneered by Pokorný (1965) in a wide-ranging paper which also dealt with the implications of changing sex ratios and variations in shell ornament. The changing sex ratio parameter has not yet been turned to account for petroleum exploration. On the other hand, many variations in shell ornament are now interpreted in terms of the rhopic factor (Peypouquet, *et al.* 1982) and can be used in suitable facies to suggest presence or absence of upwelling (McKenzie & Peypouquet 1984) which, in turn, is linked to the abundance of organic matter.

Oertli (1971) reviewed Pokorný's work and related the carapaces/valves ratio to potential for the formation of hydrocarbons. In summary, when the ratio is high, rapid sedimentation — which minimises disarticulation of carapaces into separate valves — is indicated; and with sufficiently rapid burial organic matter is not absorbed by mineral particles and so retains the potential for conversion into hydrocarbons.

Adults/Juveniles ratio

In any interpretation of a palaeoenvironment which is based on multispecies assemblages it is essential to separate the autochthonous from the allochthonous faunal elements. Ostracoda are one of the groups in which this separation is achieved rapidly because they molt frequently in progressing to adulthood and because juvenile shells, being also calcareous, are usually preserved. Reyment (1971) discusses in detail the preparation of a life table in order to understand the population dynamics of species. We note that juvenile mortality is always high in his examples based on autochthonous Ostracoda. Therefore, the adults/juveniles ratio should indicate a dominant percentage of juveniles in autochthonous fossil populations, but be heavily biassed towards either adults only or juveniles only for allochthonous taxa. Such biases are interpreted most reasonably as *post mortem* sorting effects. Of course, in some environments, e.g. shorelines, *post mortem* sorting is characteristic for all fossils, autochthonous as well as allochthonous. Thus, to be useful as a positive indicator of petroleum potential, a relatively low adults/juveniles ratio needs to be linked with a high carapaces/valves ratio. This is because the latter indicates rapid sedimentation, which tends to minimise sorting.

Percentage of fragments

This useful parameter is usually ignored by workers making up assemblages slides who tend to pick whole specimens. The percentage of fragments is simple to obtain: two or three counts of 100 specimens, inclusive of all fragmentary ones, being sufficient to estimate it reasonably for any washed sample. Obviously, care must be exercised to avoid damaging specimens during preparation of washings; and the parameter cannot be used conveniently with indurated sediments.

When there is a significant percentage of fragments, it implies a high energy environment. Low percentages indicate low energy environments or else rapid sedimenation.

Crushed or worn specimens

Commonsense suggests that, where autochthonous taxa are concerned, worn or abraded specimens are indicative of high energy environments and slow sedimenation. For allochthons, abrasion is another parameter by which their allochthonous provenance can be interpreted — in the case where autochthonous species are well preserved (not abraded). On the other hand, crushed specimens are associated typically with fine grained muddy and marly offshore sediments. When abundant they are interpreted as indicating considerable compaction pressure, as might be caused, for example, by rapid offshore sedimentation.

Krithe and Parakrithe

The podocopid ostracode genera *Krithe* and *Parakrithe* are used as palaeoecologic indices by Peypouquet (1977, 1979) and others to interpret the palaeohydrology of marine sediments, in particular palaeodepths but also dissolved oxygen (O_2) content, food supply (nutrient) and upwellings. Peypouquet's hypothesis is that the size of the vestibule in the non-calcified inner lamella in *Krithe* and *Parakrithe* is more or less inversely proportional to the dissolved O_2 content of the ambient seawater.

Peypouquet (1977) proposed a physiological explanation based on the known inverse relationship in crustaceans between external dissolved O_2 and organism haemoglobin (HB). In a current review, McKenzie (1986) considered the effects upon HB of several other environmental factors and found that those which were significant — pH, food supply and substrate ferrous iron — would all affect HB synthesis in the same direction as dissolved O_2. This result reinforces the hypothesis. Recently Aladin (1983, 1984) used microcryoscopical techniques to show biochemically that HB regulation in podocopid Ostracoda occurs probably via salt sequestration in the non-calcified membraneous part of the inner lamella. This is precisely the site which Peypouquet (1977, 1979) hypothesised would reflect HB response by *Krithe* and *Parakrithe* to dissolved O_2 variations. The hypothesis has been applied fruitfully in interpreting several palaeoenvironments ranging in age from Maastrichtian to Miocene (Donze *et al.* 1982; Peypouquet *et al.* 1982; McKenzie & Peypouquet 1984).

Pyrite and Gypsum

In oceanic sediments, sulphur is about equally divided between sulphate and sulphide species. The fractionation from sulphate to sulphide (pyritisation) is due to desulfobacterial sulphate reduction. The occurrence of pyritisation in a palaeoenvironment is readily interpreted by reference to its microfauna. For Ostracoda, pyritisation is indicated by a signifient percentage of brownish to blackish valves and carapaces. Occasional specimens glisten with pyrite which is the diagenetic oxidised state of the primary reduced ferrous sulphide that stains/permeates shells to produce the diagnostic coloration.

Gypsum is the predominant form of sulphate in marine sediments where it is a component in a global carbon/sulphur redox system that incorporates carbonates, sulphates, sulphides and organic carbon (Garrels & Lerman 1984). In weathered outcrops, its presence is signalled by clumps of relatively large and often fragile gypsum crystals; but in unweathered sediments it can occur as (presumably diagenetic) microspherulites. The latter were recorded, for example, in the Miocene Fyansford Formation, collected at Balcombe Bay, near Mornington, Victoria (McKenzie & Peypouquet 1984); gypsum crystals are common in weathered outcrops at the same locality.

When marine sedimentary sequences carry abundant sulphate/sulphide, their palaeoenvironment is interpreted as having been deoxygenated and strongly reducing in the presence of abundant decaying organic matter and interstitial plus seawater sulphate. This interpretation derives from their sulphide content. Even when diagenesis and weathering have led mainly to formation by oxidative processes of the sulphate gypsum, the stained shells of the microfauna are palimpsests of a depositional reducing palaeoenvironment. A reducing environment, characterised also by rapid sedimentation/burial, inhibits oxidation of organic matter hydrocarbons and, under appropriate depth of burial and temperature conditions, yields petroleum.

Glauconite

Glauconite is an easily recognisable green iron-bearing silicate which is associated with stable outer shelf environments, slow sedimentation, moderately anaerobic conditions on the bottom, and a large amount of decaying organic matter. Often, it occurs together with pyrite. Its significance in source rock interpretation stems from the association with slow, even negative, sedimentation because under such conditions organic matter becomes oxidised and is no longer available to generate hydrocarbons. Glauconite grains are readily transported and sorted commonly forming greensands. Such deposits, with the implication of bottom current action in addition to slow sedimentation, also are counter-indicators in petroleum source rock interpretation.

Results

Tables 1 and 2 provide results of determinations of several of the parameters discussed above for samples from the SADME Light 1 Well, Adelaide Plains Sub-basin, South Australia, and the Cambay Well, Cambay Basin, India, respectively. There were no significant occurrences of crushed or abraded specimens in the counts we made, and gypseous microspherulites were only searched for in the South Australian samples, in which they were uniformly rare.

The results indicate: that similar numbers of specimens were counted for both sets of samples; that the carapace/valves ratio is constantly higher in the Cambay Well as is pyritisation; that the percentage of fragments is much greater and that glauconite is only abundant in SADME Light 1; that the percentage of adults is similar in both sections — varying from 14.5–45% (mean 26.5%) in SADME Light 1, and from 15–44% (mean 33.4%) in the Cambay Well.

The last statistics suggest that we are dealing with assemblages which have approximately similar population dynamics and are predominantly autochthonous (both average about 70% juveniles). Thus, although the two wells are widely separated geographically, they may fairly be compared using ostracodes as indices for source rock characteristics.

The combination of high percentages of carapaces and pyritisation in the Cambay Well section especially in the lower Tarapur Shale and in the Cambay Shale (Table 2) suggests rapid sedimentation offshore combined with a reducing environment in the presence of abundant decaying organic matter. As organic matter decays it uses up available oxygen. This is confirmed by the results from the occasional valves of *Krithe* and *Parakrithe* in the Cambay Well assemblages. In the upper Tarapur Shale samples, above the Eocene/Oligocene boundary, the *Krithe* have small

TABLE 1. *Some parameters of Ostracoda in SADME Light 1 Well, Adelaide Plains Sub-basin, South Australia; recorded in percent except for 4 and 6.* a = abundant; c = common; 1 = carapaces; 2 = adults; 3 = fragments; 4 = glauconite; 5 = pyritisation; 6 = numbers of specimens (the figures in parentheses are the numbers of specimens excluding fragments). The Eocene/Oligocene boundary is indicated at the base of the Ruwarung Member, Port Willunga Formation (PWF).

	1	2	3	4	5	6
Ruwarung Member, PWF	4.6	34.1	45.1	a	12.0	217 (118)
Ruwarung Member, PWF	8.4	14.5	30.0	a	3.5	310 (217)
basal Ruwarung	9.6	22.9	37.3	a	1.5	271 (169)
top Aldina Member, PWF	3.6	26.2	55.7	a	4.0	305 (135)
top Aldinga Member; PWF	2.1	29.1	53.4	a	1.5	285 (133)
top Aldinga Member, PWF	7.0	23.4	39.8	a	1.0	244 (147)
top Aldinga Member, PWF	25.0	45.0	20.0	c	0.0	40 (32)

TABLE 2. *Some parameters of Ostracoda in the Cambay Well, Cambay Basin, India, recorded in percent except for 4 and 6.* r = rare; N.R. = not recorded. 1 = carapaces; 2 = adults; 3 = fragments; 4 = glauconite; 5 = pyritisation; 6 = numbers of specimens (including fragments). The Eocene/Oligocene boundary is indicated in the Tarapur Shale.

	1	2	3	4	5	6
Tarapur Shale	52	30	7	r	32	156
Tarapur Shale	49	36	13	r	37	178
Tarapur Shale	51	43	11	r	23	112
Tarapur Shale	72	37	12	r	68	124
Tarapur Shale	79	26	18	N.R.	65	196
Tarapur Shale	82	15	5	N.R.	71	276
Cambay Shale	100	41	42	N.R.	92	115
Cambay Shale	100	44	28	N.R.	87	132
Cambay Shale	100	29	37	N.R.	95	83

vestibules indicative of a well oxygenated milieu; in the lower Tarapur Shale samples the *Krithe* have very large vestibules which indicates an oxygen poor (or reducing) environment. Unfortunately, no *Krithe* or *Parakrithe* were identified in the three Cambay Shale samples.

On the other hand, in the SADME Light 1 Well section (Table 1) the percentage of carapaces is low in all samples (2.1–9.6%) except the oldest (25%) and the percentage of fragments is significantly high (30.0–55.7%) except in the oldest sample (20%). Further, glauconite is abundant in all samples (it is rare or not recorded in the Cambay Well) except the oldest sample, where it is common; and pyritisation is always rare except in the uppermost sample. These data suggest that marine sedimentation in the SADME Light 1 Well area during Eocene/Oligocene boundary time took place on a well oxygenated outer shelf characterised by slow sedimentation; and relatively constant bottom traction — which produced the large numbers of shell fragments. The occasional *Krithe* which occur in these assemblages confirm the well oxygenated milieu since they have small vestibules.

We conclude that, in terms of the ostracode and other parameters we have studied, the Eocene/Oligocene boundary zone sediments have good petroleum potential in India but little potential in South Australia. This conclusion is consistent with the drilling results. The Adelaide Plains Sub-basin has been extensively drilled as part of a thorough aquifer exploration programme without providing any satisfactory indications of petroleum hydrocarbons. In India, the Cambay Basin is second only to the Bombay Offshore Basin in hydrocarbon reserves and has India's largest onshore oilfields. The source rocks are located in offshore facies immediately below the Eocene/Oligocene boundary and extending downwards into the Middle-Early Eocene sediments.

Detailed Analysis — South Australia

Table 3 provides the results of a more detailed analysis of the SADME Light 1 Well samples. This analysis introduces another parameter, the number of ostracodes per gram of washings picked, as well as breaking down the assemblages into families and analysing these both compositionally and in terms of the parameters already studied for the assemblages as a whole. The prime objective is to enable a more precise palaeoecological interpretation.

All the washings were weighed and then picked for their ostracodes. In some cases, the entire fraction had to be picked to yield a satisfactory count (about 100–200 specimens) but in one instance (the stratigraphically lowest sample) even this method yielded only 40 specimens, including fragments. In most samples, however, Ostracoda were so abundant that only a fraction of the washings needed to be picked. This was the case especially with the two lowest samples from the Ruwarung Member of the Port Willunga Formation. The richest sample was the middle sample of this Ruwarung Member series and the poorest was the lowest Aldinga Member sample.

In terms of ostracode diversity, most of the samples seem very similar, having 19–20 species; but the two lowest (Aldinga Member) samples are less diverse carrying 15 and 11 species respectively. Since diversity can increase significantly with higher counts (Cronin 1984; Whatley & Downing 1983) these diversity results do not warrant more detailed comment.

TABLE 3. *Analysis of ostracode relative abundances in selected families for the SADME Light 1 Well (representing 93.7–99.2% of total ostracodes in the samples examined). Data recorded in percent.* Also recorded are the ostracodes/gm data. A-G = samples examined (as for Table 1), with A = uppermost Ruwarung Member sample to G = lowest Aldinga Member sample, respectively.

Ostracode Family	A	B	C	D	E	F	G
Bythocytheridae	1.8	0.0	4.1	9.5	10.2	0.6	5.0
Cytheruridae	14.8	9.7	7.0	13.1	11.9	9.0	12.5
Xestoleberididae	8.2	12.3	10.0	3.3	3.2	4.5	10.0
Trachyleberididae	46.1	31.9	55.4	43.9	51.9	58.6	45.0
Krithiidae	0.0	2.3	3.0	0.3	0.0	0.4	0.0
Pontocyprididae	8.3	23.9	9.2	11.5	10.5	6.2	30.0
Paracyprididae	0.0	1.3	8.5	0.0	0.0	0.0	0.0
Macrocyprididae	0.0	0.0	0.7	0.0	0.0	0.0	0.0
Bythocyprididae	0.5	2.6	0.0	0.0	0.0	0.0	0.0
Cytherellidae	17.1	9.7	1.1	17.4	10.9	19.7	5.0
% of total ostracodes	97.8	93.7	99.0	99.0	98.6	99.3	92.5
Other Parameters							
Ostracodes/gm (less fragments)	13.9	108.5	52.8	19.3	16.9	15.6	2.0
Ostracodes/gm (including fragments)	25.6	155	84.7	43.6	36.3	29.8	2.5

When the assemblages are broken down into their component families it seems clear that the two richest samples (Ruwarung Member) represent an offshore, even outer shelf environment. Both carry several specimens (7–8) of the genus *Krithe* which is diagnostic for outer shelf and deeper waters. Additionally, the middle Ruwarung Member sample (B, in Table 3) has the family Bythocyprididae (genus *Bythocypris*) which also is typical of deep water facies. This fauna occurs a little higher than the Eocene/Oligocene boundary as determined on foraminifera (Lindsay 1969) thus its palaeoecological interpretation is consistent stratigraphically with what we know of ostracode trends worldwide (Benson 1975) and with the data from Ostracoda of the Willunga Embayment (McKenzie, in Cooper 1979).

The dominant families are the Trachyleberididae, Cytheruridae Xestoleberididae, Pontocyprididae and Cytherellidae. Several other familiees are represented by so few specimens that they have not been included in Table 3, which lists only the 10 most abundant families — representing 93.7% to 99.2% of total ostracode assemblages. These poorly represented families include Loxoconchidae, Cytheridae (genus *Loxocythere*), Eucytheridae (genus *Rotundracythere*), Leptocytheridae, Schizocytheridae (genus *Paijenborchella*). Surprisingly, no specimens of Bairdiidae were identified although this family is virtually ubiquitous in marine facies. The absence of Bairdiidae seems to be a local variation because the family certainly occurs in coeval sediments from the Willunga Embayment (McKenzie 1979).

Clearly, the most abundant family is the Trachyleberididae (Table 3); although it is less abundant (31.9%) in the richest sample (B) than in the other samples (45–58.6%). On this ground, we decided to study trachyleberidid data for the parameters which we used in the preceding more general analysis (Table 4).

TABLE 4. *Some parameters of Trachyleberididae in the SADME Light 1 Well. Data recorded in percent except column 5 which gives actual numbers of specimens analysed.* 1 = carapaces; 2 = adults; 3 = fragments; 4 = pyritisation. Thus, for the Ruwarung Member, PWF there are: 2% carapaces, (98% valves); 30% adults (70% juveniles); 57% fragments; and a quarter of the specimens are pyritised.

	1	2	3	4	5
Ruwarung Member, PWF	2	30	57	25	100
Ruwarung Member, PWF	3	8	40	10	99
basal Ruwarung Member	10	30	40	5	150
top Aldinga Member, PWF	3	30	63	7	134
Aldinga Member, PWF	0	22	63.5	6	148
Aldinga Member, PWF	7	25	40	2.5	143
Aldinga Member, PWF	22	33	33	0	18

We infer, plausibly, that in the uppermost Ruwarung Member sample bottom conditions were reducing for at least part of the time. This suggests that elsewhere in the Eocene/Oligocene of South Australia the Early Oligocene might be a prospective petroliferous zone if the sediments are thicker and also contain high numbers of carapaces, fewer fragments and much less glauconite.

The Eocene/Oligocene boundary zone is already a drilling target off Gippsland, Victoria (Douglas & Ferguson 1976) but with respect to much thicker sections than occur in the St Vincent Basin. Unfortunately, our results from SADME Light 1 offer only slight encouragement for a more intensive exploration of this interval in South Australia

Comparison with Outcrops

During October 1983, we sampled the classic coastal Eocene/Oligocene sections at Maslin Bay and Aldinga Bay, South Australia. Table 5 provides a resume of the data on ostracode parameters and glauconite for samples from this collection.

Although the SADME Light 1 Well (Table 1) was much more closely sampled (over only 1.4 m in the basal Ruwarung Member and only 2.2 m in the upper Aldinga Member), the ostracode data from outcrops correspond rather well. In particular, the percentages of carapaces for the two lowest Aldinga Member samples of SADME Light 1 (located about 1.6–2.0 m below the basal Ruwarung Member sample) are similar in the two outcrop samples from the Aldinga Member (Table 5). Generally, the outcrop samples are less pyritised.

Conclusions

Ostracode parameters, reinforced with evidence from pyrite, gypsum and glauconite can be used to indicate petroleum source rock potential in the enclosing sediments.

1. A high percentage of carapaces indicates rapid burial.
2. Large percentages of adults and juveniles (with juveniles dominant) indicates a mostly autochthonous community.
3. A low percentage of fragments indicates low energy and minimal bottom currents/traction.
4. A high percentage of pyritisation of ostracode carapaces and valves indicates a reducing environment; as do diagenetic pyrite and gypsum in the enclosing sediments.

These several characteristics all indicate good petroleum source rock potential as our extended discussion has made clear.

TABLE 5. *Some parameters of Ostracoda, plus glauconite in outcrops of Aldinga Bay, South Australia, recorded in percent except for 5.* t = trace; 1 = carapaces; 2 = adults; 3 = fragments; 4 = glauconite; 5 = pyritisation; 6 = number of specimens (the figures in parentheses are the numbers of specimens excluding fragments). The Eocene/Oligocene boundary is indicated.

	1	2	3	4	5	6
3 m above base of Ruwarung Member	11.4	39.2	52.8	t	nil	237 (112)
30 cm below top of Aldinga Member	8.9	25.8	50.9	12.5	t	236 (116)
4 m above base of Aldinga Member	25.0	25.0	41.5	t	nil	164 (96)
2 m below top of Gull Rock Member	12.4	15.1	24.6	30	nil	225 (168)

In the exemplar series, ostracode parameters and high pyritisation all confirm the high petroleum source rock potential of the Eocene/Oligocene boundary zone in the Cambay Well, India. On the other hand, in the SADME Light 1 Well, South Australia, and in outcrop samples from South Australia the only positive correlations are with the dominantly autochthonous community characteristic (2, above). In other respects, the Australian samples of the Eocene/Oligocene boundary zone correlate negatively with indications of good petroleum source rock potential. Likewise, glauconite, which is counter-indicative of petroleum source rock potential, is generally common to abundant in the Australian exemplar samples but is not recorded or rare in the Cambay Well.

It is not surprising, therefore, that the Cambay Basin is India's major onshore oilfield in Eocene/Oligocene strata whereas South Australia is non-productive for this interval in the section concerned. Our present methodology appears to be as effective for the Eocene/Oligocene of India and Australia in the areas tested as similar but less detailed methods have proved previously in the Turonian-Coniacian of Bohemia (Pokorny 1965), the Neocomian-Aptian of southwestern France (Oertli 1971), the Maastrichtian-Palaeogene of Mozambique (Oertli 1971) and Bathonian-Tertiary of India (Guha 1983).

Finally, when these parameters are reassessed for samples in which the Ostracoda have been divided into their component families as done (K.G.M.) for the SADME Light 1 Well, the results allow an opportunity to achieve a consistent but more detailed palaeoecological interpretation than could result from the gross data alone.

Acknowledgments

D. K. Guha acknowledges with gratitude support from the Australia/India Science and Technology Agreement enabling his visit to Riverina-Murray Institute of Higher Education (R.M.H.I.E.) where the joint project was carried out. Both authors are grateful to Mr J. M. Linday and Dr B. J. Cooper, South Australian Department of Mines and Energy (SADME), and to Dr B. McGowran, Department of Geology and Geophysics, the University of Adelaide for guiding them through the classic Tertiary sections at Maslin Bay and Aldinga Bay, near Port Willunga, South Australia. Mr J. M. Lindsay is also thanked for loaning the samples from SADME Light 1 Well, and for his constructive comments on the paper. Professor J. P. Peypouquet, Université de Bordeaux, is thanked for a pertinent review. K. G. McKenzie acknowledges ARGS Grant No. E80 15287. D. K. Guha publishes with permission from the General Manager, Oil and Natural Gas Commission, India. Some Tables and the two Figures for this paper were exhibited at the 8th Australian Geological Congress, held at Flinders University, Bedford Park, South Australia, during February 1986. K. G. McKenzie acknowledges support from the R.M.I.H.E. Staff Development Programme enabling his attendance at the Congress. Mrs Jan Seaman and Ms Colleen Seberry typed the manuscript.

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THE CLASSIFICATION OF THE MITE FAMILIES TROMBELLIDAE AND JOHNSTONIANIDAE AND RELATED GROUPS, WITH THE DESCRIPTION OF A NEW LARVA (ACARINA: TROMBELLIDAE: *NOTHROTROMBIDIUM*) FROM NORTH AMERICA

*BY R. V. SOUTHCOTT***

Summary

Amongst the Trombidioidea an unnamed family group containing Trombellidae, Chyzeriidae and Audyanidae Fam. nov. is recognized; these families are defined and keys provided for the larvae of the families, subfamilies and genera. The Johnstonianidae is examined, and three new subfamilies, Tetrathrombiinae, Pteridopodinae and Ralphaudyninae are established, with *Ralphaudyna* Vercammen-Grandjean *et al.,* 1974 being transferred to the Johnstonianidae.

Ralphaudyna amamiensis Vercammen-Grandjean, Kumada, Newell, Robaux & Suzuki is recorded from a second Japanese location, as an ectoparasite on the gryllacridoid *Tachycines robustus* Ander (Orthoptera, Rhaphidophoridae). Further metric and descriptive data are given for this larval mite.

Nothrotrombidium treati sp. nov., larva (Acarina: Trombellidae) is described from a single specimen found dead on a noctuid moth *Spaelotis clandestina* (Harris) (Lepidoptera: Noctuidae) at Tyringham, Mass., U.S.A.

This is the first record of this genus in North America, previously recorded from Europe and South America, as well as Madeira, in the Atlantic Ocean, and Asia.

KEY WORDS: Taxonomy, *Nothrotrombidium, Ralphaudyna,* larva, North America, Japan, Acarina, Trombidioidea.

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Summary

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KEY WORDS: Taxonomy, *Nothrotrombidium, Ralphaudyna,* larva, North America, Japan, Acarina, Trombidioidea.

Introduction

The Johnstonianidae and the Trombellidae are accepted by some workers as the most primitive families of the Trombidioidea. In the case of the Johnstonianidae this opinion is based on the presence of a number of supposedly primitive morphological, behavioural and ecological characters (Newell 1957). Thus there are two pairs of sensilla on the scutum, crista or equivalent areas in most species, resembling the situation in the Erythraeoidea, but with loss or modification of the anterior pair in some genera. Other supposedly primitive characters are the simplicity of body setae, the presence of larger than usual numbers of sensory setae on various leg segments, and the general lack of reduction of leg segmentation, as well as the presence of various specialized setae on the gnathosoma. Some larvae are apparently predatory, while others are, as in the majority of the trombidioids, ectoparasitic upon arthropods. Newell (1957) has also stressed the "self-detaching" character of the larvae in response to stimuli, for example when the host with its larval ectoparasites is immersed in preserving fluids. There is also, among the adult as well as the larval johnstonianids, a sensitivity to heat and desiccation (Newell 1957, 1960).

The Trombellidae (which have only one pair of prodorsal sensilla) possess a number of similar characters: The adult leg segmentation is not reduced, and in the larvae the legs usually carry more sensory setae than other trombidioids. The larval coxae tend to be separated, and the urstigma may not be strongly associated with coxa I. The concept of the Trombellidae as primitive may be based more on a general resemblance to the Johnstonianidae than on more specific indications.

Variant views are expressed by other workers. Thus Feider (1959b) gave an illustration hypothesizing that the "Tanaupodidae" and "Calothrombiidae" are the two most primitive families of the Trombidioidea, originating from a common branch, while the next branch, at a slightly higher level, gave rise to the Johnstonianidae and "Notothrombiidae". On the other hand, Vercammen-Grandjean *et al.* (1973) considered that the families Trombiculidae and Leeuwenhoekiidae are more primitive than other "close families, such as the Johnstonianidae . . .".

Thus the phylogeny of these mites remains a matter of contention (an equivalent situation occurs in the Erythraeoidea — see Southcott 1961a).

Thor (1935) divided the family Trombidiidae Leach, 1815 (Trombidioidea of this paper) into 10 subfamilies, many of which have later been accorded family status. Among such were the Johnstonianinae and the Trombellinae, the latter

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defined as follows: Body elongate. Abdomen rectangular. Skin hard, firm ("hart"), rough/uneven ("höckerig"), hairs short, pointed. Crista lacking; the two sensory hairs sit close together in the middle of the thorax in two thick tubercles between the two sessile eye pairs. The fourth palpal segment with differing spines or hairs; fifth segment long.

Only the type genus *Trombella* Berlese, 1887, is included (translation R.V.S.). There was no reference to the larvae, as then unknown. The adult genus *Chyzeria* Canestrini, 1897 was omitted.

Feider (1958b) described the larva of the trombellid mite *Nothrotrombidium otiorum* (Berlese, 1902), stating that this was the first genus in the family for which there was correlation between larva and adult. However, two genera, *Chyzeria* (see Womersley 1939) and *Audyana* (see Womersley 1954a,b), had previously been correlated between the larva and the adult or deutonymph. These rearings allowed some attempts to define the characters of the larval Trombellidae (Vercammen-Grandjean *et al.* 1974; Southcott 1982). Following a correlation of an Australian *Trombella* larva with its deutonymph, the classification of the Trombellidae has been developed further (Southcott 1986a).

Nothrotrombidium was founded by Womersley (1954b), with type species *Trombella otiorum* Berlese, 1902 from Europe. In the genus he placed also *T. nothroides* Berlese, 1888 from South America, and *T. lundbladi* Willmann, 1939, from Madeira. A further species, *N. brevitarsum* André, 1960, has been described from Nha Trang, Indochina. All of these were adults.

In this paper a second larval species of *Nothrotrombidium, N. treati* sp. nov., is described from a noctuid moth in North America. This discovery prompts a further examination of the characters of the Trombellidae and related trombidioid mites.

TAXONOMIC DECISIONS AND ACCOUNTS

In the most recent reviews of the Trombellidae, Southcott (1982, 1986a) included the following genera: *Trombella, Chyzeria* Canestrini, 1897, *Womersleyia* Radford, 1946, *Nothotrombicula* Dumbleton, 1947, *Audyana* Womersley, 1954, *Nothrotrombidium* Womersley, 1954, *Durenia* Vercammen-Grandjean, 1955, *Parathrombella* André, 1958, *Neonothrothrombidium* Robaux, 1968, *Ralphaudyna* Vercammen-Grandjean *et al.*, 1974 and *Maiputrombella* Southcott, 1986. Of these *Trombella, Chyzeria, Durenia, Audyana* and *Nothrothrombidium* are known both as larvae and adults or deutonymphs; *Womersleyia, Nothotrombicula* and *Ralphaudyna* are known only as larvae, and *Parathrombella, Neonothrothrombidium* and *Maiputrombella* are known only as adults.

Southcott (1986a) excluded *Parachyzeria* Hirst, 1926, from the Trombellidae, and placed it in the Johnstonianidae.

Vercammen-Grandjean (1973) placed six subfamilies to the Trombellidae: Trombellinae, Tanaupodinae, Calothrombiinae, Spelaeothrombiinae, Notothrombiinae and Moyanellinae. He gave no reasons for these decisions, which may have stemmed largely from the difficulties of placing groups with which he was relatively unfamiliar. A well-marked crista is present in the adults of the Tanaupodinae, Calothrombiinae and Spelaeothrombiinae, so there appears no reason to associate them with the Trombellidae, Chyzeriidae and Audyanidae. In *Notothrombium* Štorkán, 1934 (the sole genus of the Notothrombiinae) and in *Moyanella* Boshell & Kerr, 1942 (the sole genus of the Moyanellinae) the crista of the adults is poorly defined or absent; both have two pairs of prodorsal sensilla (see Thor & Willmann 1947; Robaux 1967); thus it appears that their affinities lie more with the Johnstonianidae rather than the Trombellidae, and they are here considered as being part of the johnstonianid family group, possibly deserving family status. As the larva of neither of these two families is known, however, they will not be considered further here.

A difficulty in the classification of the Trombidioidea (and other Parasitengona) is caused by the extreme heteromorphy which exists between the larvae and the adults (or deutonymphs), causing dual generic and specific names for the hexapod and octopod instars, as well as difficulties in taxonomic placements, failing accurate correlations. One such instance is as follows.

Ralphaudyna Vercammen-Grandjean *et al.*, 1974 was placed by its authors in the tribe Chyzeriini of the Trombellinae (= Trombellidae of this paper). The genus was erected for a single specimen of *R. amamiensis* Vercammen-Grandjean *et al.*, 1974, obtained in "soil under an olden tree cave on the middle slope of Mt Yuwan-dake .... Amami-oshima Island", Japan, and hence from an unknown host, or potential host, arthropod. They laid stress upon the "presensillae" of the dorsal idiosomal scutum, and therefore considered it a link between "the two groups *Chyzeria* .... and *Parachyzeria*". However, the larva of *Parachyzeria* has not been described. The placing of *Ralphaudyna* in the Trombellinae was accepted by Southcott (1982, 1986a).

Further specimens of *Ralphaudyna amamiensis* have been found at a second locality in Japan, taken parasitic on a gryllacridoid (Orthoptera) (see p. 38).

Examination of these specimens shows that the "presensillae" or "prosensilla" are close to typical scutal trichobothria, placed more posteriorly on the scutum, although smaller. The only possibly important difference between the anterior and posterior trichobothria lies in the anterior ones having a somewhat thickened shaft for the whole of the sensillary seta. *Ralphaudyna* was placed in the Chyzeriini of the Trombellinae by its authors rather than in the Johnstonianidae principally on this character, and because it is "provided with a very wide nasus. Several nude genualae on each leg.".

As far as the presence of "prosensilla" is concerned, Newell (1958) used this term as "prosensillar setae" but without definition; in 1960 he defined a term "prosensillum" to apply to paired anteromedian scutal setae of Trombiculidae, Johnstonianidae and Trombidiidae. The presence of such setae, if one accepts Newell's concept, is not a definitive character for any particular member of the three families nominated. Newell in fact stated (1960) that the term "prosensillum" could be applied in many Trombiculidae to the unpaired anteromedian scutal seta.

A prominent, even wide, nasus had been described in various larvae of the Johnstonianidae, e.g. in *Diplothrombium* Berlese, 1910 by Newell (1957), Feider (1959a), in *Centrotrombidium* Kramer, 1896 by Newell (1957), and in other genera.

Accepting the term "genuala" as applying to any nude sensory seta on the leg genu (and excluding the vestigiogenualae) such setae are absent in *Chyzeria* and *Nothotrombicula*, but are present in *Trombella* and *Nothrotrombidium* (Vercammen-Grandjean 1972; Southcott 1982, 1986a) as well as in the johnstonianid genera *Lassenia* Newell, 1957, *Diplothrombium* and others (see Newell 1957).

None of the criteria advanced by Vercammen-Grandjean *et al.* (1974) for the exclusion of *Ralphaudyna* from the Johnstonianidae and its placement in the Trombellinae (Trombellidae) is sustained.

Thus, *Ralphaudyna* is removed from the Trombellidae, and placed in the Johnstonianidae, in Ralphaudyninae, subfam. nov.

Kranz (1978), following advice (*in litt.*) from Vercammen-Grandjean, has used the family term Chyzeriidae (as Chyzeridae), separating it by key characters from Trombellidae. Here I define the Chyzeriidae and a restricted family Trombellidae.

Seta and scutal terminology follows Southcott (1961a,b, 1963, 1986a,b).

Superfamily Trombidioidea Leach

Partial synonymy

Trombidides Leach 1815, pp. 387, 393.

Trombidiidae Michael 1884, pp. 4, 138 (ad p.); Thor & Willmann 1947, p. 187.

Trombidiinae Michael 1884, p. 50.

Trombidioidea Banks 1894, p. 209; Southcott 1957b, p. 173; 1982, p. 285; Vercammen-Grandjean 1973, p. 109; Welbourn 1983, p. 103; 1984, p. 135.

Trombidia Feider 1959b, p. 539; 1979, p. 420.

Definition: Prostigmatic mites of generally ovoid or elongate form in post-larval deutonymphal and adult (octopod) stages. With one or two pairs of dorsal propodosomal sensillary setae in all mobile stages; generally in association with a crista or shield in octopod stages, but crista and shield may be rudimentary, obsolete or absent. Larva generally rounded, hexapod, with one or more dorsal idiosomal shields, sensillary setae (one or two pairs) borne by anteromost shield. Gnathosoma well developed in all mobile stages, with mobile digits as hinged blades, not retractile, not styliform. Octopod states generally with genital acetabula (suckers). Coxae I and II, and III and IV, contiguous on each side in octopod stages, I and II generally contiguous in larvae, but may be separate in larvae. Larvae heteromorphic to octopod stages. Larva with urstigma and anus. Octopod stages predatory upon small arthropods. Larvae generally parasitic upon invertebrates and vertebrates. Mites never fully aquatic.

Type genus *Trombidium* Fabricius, 1775.

Remarks: The larvae of the Trombellidae and Johnstonianidae may have one or more of the following characters:

(1) coxae usually separated and urstigma usually separated from coxa I

(2) idiosomal setae usually arise from expanded basal plates

(3) usually many sensory setae on the femora and genua of the legs.

Two family groups may be distinguished among these larvae, as follows:

Dorsal shield well developed, with 6 or 8 setae, including one pair of sensillary setae, well developed, but never clavate or thickened. Coxae of legs separated; Urstigma attached to posterior margin of coxa I. Supracoxalae present or absent. Palpal tibial claws generally well-developed, bifurcate or trifurcate . . . . Trombellidae family group

Dorsal shield present, with eight setae, but may be only moderately sclerotized; a small separate anterior part may be present. Generally two pairs of scutal sensillary setae (one pair only, in one genus), of which one pair may be enlarged in central part, or even clavate. Anterior pair of sensillary setae and their alveoli may be rudimentary. Coxae I and II may be joined or separate on each side. Urstigma usually free of coxa — may project laterally between the coxae, or be attached to the anterior border

of a separate coxa II (*Tetrathrombium*). Supracoxalae present or absent. Palpal tibial claws generally small, bifurcate or with a single claw, or may be replaced by elongate setae, not claw-like.
.... Family Johnstonianidae (as yet considered a single family, with several subfamilies, as far as knowledge of the larvae is concerned).

As can be seen, there are many shared characters between the two groups. Nevertheless, at the family level there is rarely difficulty in placement.

Trombellidae family group

The Trombellidae family group here includes the Trombellidae, Chyzeriidae and Audyanidae, fam nov. These are separated as follows:

Key to the larvae of the Trombellidae family group

1. AM setae lacking. Dorsal propodosomal scutum with 6 setae. Leg segmental formula 7, 7, 7. Pedotarsal claws 3, 3, 3. Palpal tibial claw trifurcate. Lateral surface of cheliceral blade with many fine teeth. Supracoxalae present. Eyes 2 + 2 .... Chyzeriidae
   AM setae present. Dorsal propodosomal scutum with 8 setae. Leg segmental formula 6, 6, 6 or 7, 6, 6. Pedotarsal claws 1, 1, 1 or 1, 1, 2 or 2, 2, 2. Palpal tibial claw bifurcate. Lateral surface of cheliceral blade smooth, normal. Supracoxalae absent. Eyes 2 + 2 or absent 2
2. Leg segmental formula 6, 6, 6. Pedotarsal claws 1, 1, 1 or 1, 1, 2. None of scutal setae short and clavate. Coxalae and palpfemoralae normal, setulose. Eyes 2 + 2 .... Trombellidae
   Leg segmental formula 7, 6, 6. Pedotarsal claws 2, 2, 2. Some of scutal setae short and clavate, also coxala II and III, and palpfemorala. Eyes absent .... Audyanidae

Family Trombellidae

Partial synonymy

Trombellinae Thor 1935, p. 108; Womersley 1937, p. 75; 1954a, p. 117; 1954b, p. 121. Vercammen-Grandjean 1973, p. 109. Vercammen-Grandjean *et al.* 1974, p. 245.

Trombellidae Feider 1955, pp. 50, 67; 1979, pp. 421, 422. Southcott 1982, p. 289; 1986a, p. 145.

Thrombellinae (sic) André 1960, p. 315; Robaux 1968, p. 453. (all ad p.).

Thrombellidae Robaux 1973, p. 124.

Trombelloidea Feider 1979, pp. 421, 422 (ad p.) (nom. nud.).

Redefinition: Adult and deutonymph: Trombidioidea in which the propodosoma either lacks a crista or has only a rudimentary crista; one pair of sensillary setae (trichobothria). Eyes 2 + 2, sessile. Idiosoma may bear large plaques, which may be arranged in columns on upper surface of idiosoma. Idiosoma not attenuate or waisted.

Larva: Trombidioidea with one dorsal propodosomal scutum, which projects anteriorly to a narrowed extension or nasus. Dorsal scutum with eight setae, comprising 2 ALs, 2 PLs, 2 AMs, and 2 well separated sensillary setae, placed between ALs and PLs. Eyes 2 + 2. Leg segmental formula 6, 6, 6. Coxae separated. Pedocoxal formula 2, 1, 1 or 1, 1, 1. Pedotarsal claws 1, 1, 1 or 1, 1, 2. Supracoxalae absent.

Type genus *Trombella* Berlese, 1887.

Remarks: The Trombellidae, as restricted, includes all the genera listed earlier (above) for the family, except *Chyzeria*, *Nothotrombicula*, *Audyana* and *Ralphaudyna*. The larvae of remaining genera may be separated as in the following key:

Key to larvae of Trombellidae

1. Pedotarsal claws 1, 1, 1. Claws simple 2
   Pedotarsal claws 1, 1, 2 (in I and II the single claw is apically trifurcate) 3
2. Chelicerae compact, the combined chelobases about as long as wide. Scutal sensilla generally well behind the level of AL scutale .... *Trombella* Berlese
   Chelicerae elongate, the combined chelobases about twice as long as wide. Scutal sensilla only a little behind level of AL scutalae .... *Nothrotrombidium* Womersley
3. Nasus of scutum small, largely occupied by the bases of the AM scutalae, and with a deep constriction behind. Leg tibia III with a large solenoidala .... *Womersleyia* Radford
   Nasus of scutum large, triangular, its lateral borders continuous with anterolateral borders of scutum, with at most only minor constriction. Leg tibia III without a large solenoidala .... *Durenia* Vercammen-Grandjean.

Nothrotrombidium Womersley, 1954

Redefinition of larva: Trombellidae. Sensillary setae arise behind middle of scutum, a little behind level of AL scutalae. Coxal setal formula 1, 1, 1. Pedotarsal claws 1, 1, 1. Chelicerae bases long and slender; combined chelicerae bases about twice as long as wide. Palpi long and slender, palpal tibial claw small, with two minute terminal nearly apposed prongs.

Type species *N. otiorum* (Berl.) (adult).

Nothrotrombidium treati sp. nov.

FIGS 1 A–E; 2 A–C; 3

"Larva of undetermined genus", Treat (1975, p. 236).

Holotype (in American Museum of Natural History) mounted in Hoyer's medium, identification ACB760, somewhat damaged, found dead "under right forewing of *Spaelotis clandestina* [(Harris)] 68-39 ♂ [Lepidoptera: Noctuidae] "Tyringham, Mass[achusetts], U.S.A., 17 Sept. 1968. A. E. Treat ... (31: 29)", taken 10.10 p.m

TABLE 1. *Metric data of two species of larval* Nothrotrombidium.

	LN*	AW	PW	SB	ASB	PSB	L	W
N. treati sp. nov. Holotype	36	47	62	15	78	44	122	76
N. otiorum (Berl.) (from Feider, 1958b)							90–109	61

	AP	AM	AL	PL	AMB	SE	DS	MDS	PDS
N. treati	35	16	16	29	14	98	33–62	38–49	48–53

	TrochI	FeI	GeI	TiI	TaI†	TrochII	FeII
N. treati	50	100	55	93	151	50	100
N. otiorum	44	116	58	122	160	41	122

	GeII	TiII	TaII†	TrochIII	FeIII	GeIII
N. treati	52	83	125	64	118	62
N. otiorum	58	100	136	61	145	67

	TiIII	TaIII†	TiI/GeI	TiII/GeII	TiIII/GeIII
N. treati	145	146	1.69	1.60	2.34
N. otiorum	188	160	(2.10)	(1.72)	(2.81)

* LN = distance from anterior tip of scutum to level of the AM setae (see Southcott 1896b).
† Omitting claws and pedicle of the tarsi.

Description of holotype larva: Colour in life not available; the specimen was found dead by Dr A. E. Treat (see Treat 1975, p. 236), who advises (pers. comm. 1983) that the dead mite was orange.

Length of idiosoma (partially engorged) 390 μm, width 255 μm; total length of animal from tip of chelae bases to posterior pole of idiosoma 485 μm.

Dorsal scutum ovoid, narrower anteriorly, lateral and posterior margins somewhat flattened, but generally smoothly rounded.

Scutal scobalae as in definition; scutal sensilla behind middle of scutum, a little posterior to AL scutalae, somewhat separated from each other; scutalae tapering, short, with slight setules.

Metric data are as in Table 1.

Eyes 2 + 2, sessile, each lateral pair set on oval plate, separated from dorsal scutum, and placed between levels of AL and PL scutalae in specimen. Corneae oval, anterior 13 μm in longest diameter, posterior 15 μm.

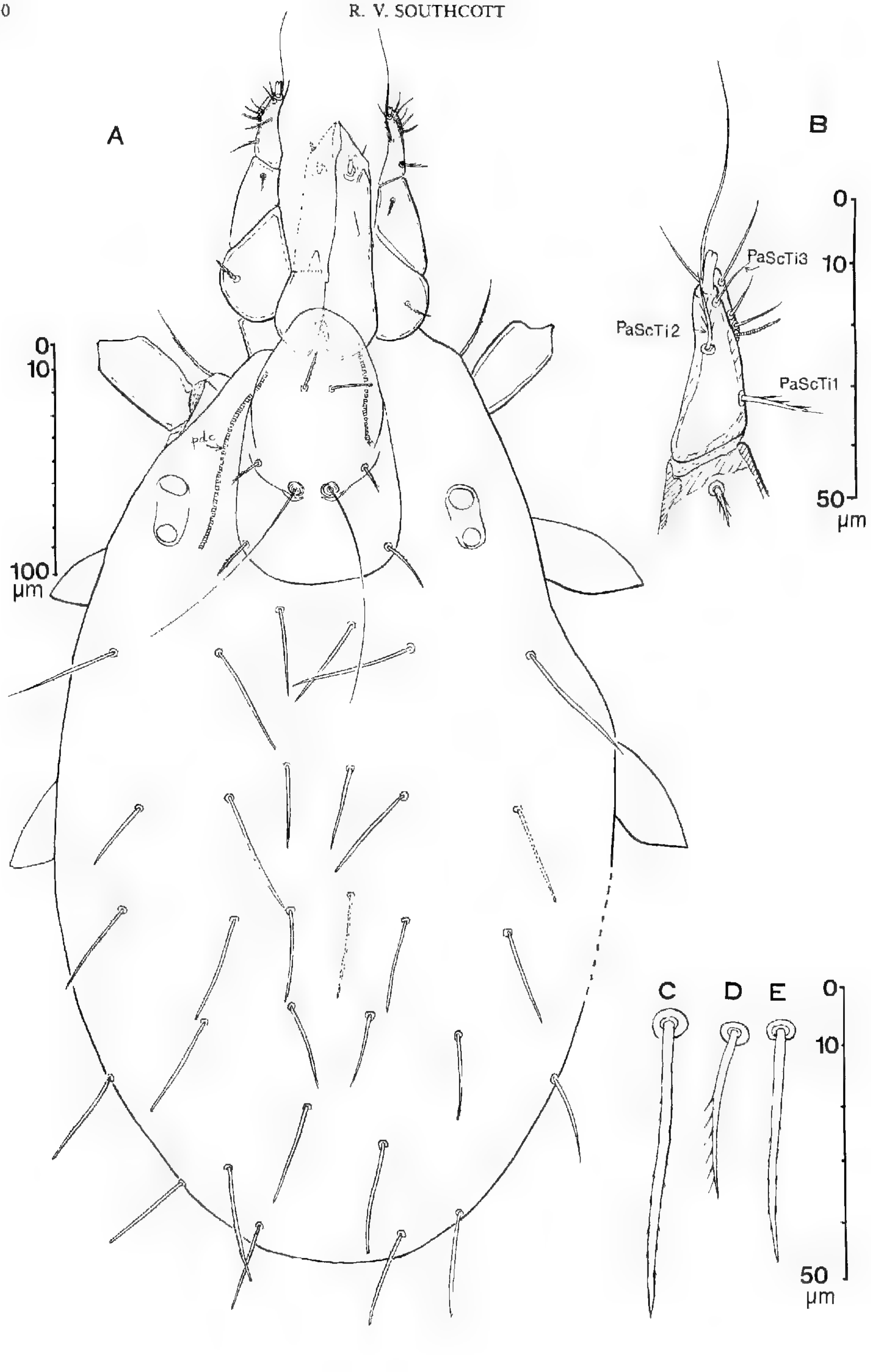
Dorsal idiosomal setae slender, tapering, slightly blunted at tip, with minute setules; arising from normal seta-bases (annuli); arranged 6, 6, 6, 6, 5, 2, total 31.

Venter of idiosoma with coxa I and II moderately separated on each side. Sternal area with a pair of scobalae, between coxae II, slender, tapering, pointed, with small setules, 31 μm long. Between coxae III a further pair, similar, 33 μm long, but with slightly more outstanding setules. Behind level of coxae III are 38 setae, slender, tapering, in irregular transverse rows, 15–49 μm long, lengthening posteriorad; the more anterior of these similar to the last-named pair, more posteriorad becoming smoother, similar to the posterior dorsal idiosomalae. Anus (uroporus) 35 μm long by 9 μm wide, with two slender valves and a crumpled lip.

Coxalae 1, 1, 1. Coxala I arises near AL angle of coxa, slender, tapering, pointed, with faint setules, 47 μm long. Coxala II arises anterior and lateral to central point of coxa, similar to I, 36 μm long. Coxala III arises anterior to centre of coxa, similar to I and II with adpressed setules, 32 μm long.

Leg segmental formula 6, 6, 6. Legs long and slender; femoral to tibial segments more or less cylindrical; tarsi elongate, spindle-shaped. Leg I 510 μm long, II 445 μm, III 595 μm (lengths include coxae and claws). Pedocoxal supracoxala absent. Tarsus I 151 μm long by 20 μm high where thickest, II 125 μm × 20 μm, III 146 μm × 18 μm (lengths exclude claw and pedicle). For other measurements, see Table 1. Tarsi bear small, falciform, simple, slender, single claws (in specimen broken in R leg II, missing in L leg II).

Chaetotaxy of legs: leg scobalae (normal setae) slender, tapering, pointed, with light setule formation. Setae of leg segments are indicated in Fig. 3. A number of specialized setae present on leg segments, in addition to scobalae, distal to trochanters. These include a number of spinalae (eupathidalae). These and other leg setae are identified in Fig. 3 as far as possible, but since, in the damaged specimen only three reasonably complete legs were available (L leg I, R legs II and III), it has not been possible always to identify them; in a number of cases only the setae bases remain. Vestigiogenualae present: VsGeI.85pd (7 μm long), VsGeII.84pd (6 μm). Vestigiotibiala: VsTiI.86d (7 μm). Solenotarsalae are present to I and II: SoTaI.10d


A
0
10
100
µm
pdc
B
0
10
50
µm
PaScTi3
PaScTi2
PaScTi1
C
D
E
0
10
50
µm

(37 µm), SoTaII.18d (22 µm); famulus is present to I and II: FaTaI.36d (4 µm), FaTaII.36d (4 µm). (Tarsal lengths measured to origin of pedicle; for explanation of coding symbols see Southcott 1961a,b, 1963).

Gnathosoma (damaged in specimen, part of one chela missing) small, elongate, combined chelae bases to origin of cheliceral digit (blades broken or missing) 84 µm long, × 47 µm across, elongate-pyriform. Galeala present, pointed, smooth, 11 µm long. Anterior hypostomala apparently absent. Palpal setal formula 0, 1, 1, 3, 8; palpal coxala ("capitular seta") apparently absent. Palpal supracoxala absent. Palpfemorala dorsal in position, short, pointed, with few setules, about 15 µm long (? broken). Palpgenuala similar, dorsal and distal, ca 10 µm long. Palpal tibialae and tarsalae as figured. Palpal tibial claw small, slender, with only a slight cleft and two minute ventrally directed prongs.

Remarks: The larva was found "on a ventral axillary membrane of the right wing" of the moth, which had been taken at light. However, the mite has only one dorsal scutum. The idiosoma contains a mass of fungal hyphae (Treat 1975). "The mite's legs were whitish . . . the mounted mite showed a clump of mold mycelia with fruiting bodies on one side of the idiosoma. This was white in the fresh, unmounted specimen" (Treat pers. comm. 1983). (The pallor of the legs is consistent with partial drying of the mite.)

The body of the mite contains fungal elements consisting of hyaline septate hyphae with numerous intercalary chlamydospores. No fruiting bodies are visible in the mounted specimen. Whether the fungal infection occurred before or after the death of the mite cannot be determined, but the latter is considered more likely. The fungus is placed in the Fungi Imperfecti (G. Kominski & D. Ellis pers. comm.).

Nothrotrombidium is the only trombellid larva in which the chelicerae are elongate; presumably this character has some adaptive value, if the finding of a *N. treati* larva on a lepidopteran indicates some advantage in burrowing through deep layers of scales.

Taxonomic position of N. treati

The two known species of *Nothrotrombidium* larvae may be separated as follows:

1a TiI/GeI > 2; about 29 ventral setae behind coxae III . . . . *N. otiorum* (Berl.)
1b TiI/GeI < 2; about 38 ventral setae behind coxae III . . . . *N. treati* sp. nov.

Remarks: There appears no doubt that *N. treati* is congeneric with the larva of *N. otiorum* as described by Feider (1958b). The urstigma is well shown, so that there is no doubt as to its trombidioid affinities, consistent with its general appearance. Coxa I is shown well separated from coxa II, which is in agreement with the structure of *Trombella* and *Chyzeria*.

A pair of setae on the idiosomal venter, anterior to coxae I is shown by Feider (1958b, Fig. 3), which may be an error of interpretation of some fold of integument. The figures of the gnathosoma (his Figs 3, 8) show a pair of hypostomalae (palpal coxalae, or tritorostrals *sensu* Newell 1957, p. 403) level with the medial angles of the femora, which I have not been able to identify in *N. treati*, presumably because I have only the single damaged specimen available. Feider (1958b) illustrates barbed dorsal and ventral palpal femoral setae, as well as a barbed dorsal palpal genual seta, although his text omits mention of the ventral femoral seta.

Family Chyzeriidae

Trombellidae, Trombellinae, Thrombellinae auctorum, s. sup. (ad p.).
Chyzeridae (sic) Krantz 1978, pp. 278, 304.

Definition: Trombidioidea in which the propodosoma of the adult and deutonymph either lacks a crista or has only a rudimentary crista, bearing a pair of sensillary setae. Eyes 2 + 2, sessile. Dorsum of idiosoma produced into a number of long processes. Idiosoma not elongate or waisted.

Larva with one dorsal scutum, with 6 setae: 2 ALs, 2 PLs and 2 sensillary setae, sensilla well separated, arising at about middle of scutum. Scutum with or without anteromedian nasus. Eyes 2 + 2, sessile. Leg segmental formula 7, 7, 7. Coxae separated. Coxal setal formula 2, 1, 1. Pedotarsal claws 3, 3, 3, the neolateral claws with widened tips. Dorsal and ventral idiosomal setae may have expanded seta bases. Supracoxalae present to gnathosoma and leg I. Lateral surface of cheliceral blades with many fine teeth. Parasitic on Orthoptera.

Type genus *Chyzeria* Canestrini, 1897.

Remarks: The two genera now included in the Chyzeriidae may be separated as in the following key:

Key to the genera of the Chyzeriidae

Dorsal scutum without nasus. Palpal tarsalae may be variously modified with setules, but not long and feather-like . . . . *Chyzeria* Canestrini

Fig. 1. *Nothrotrombidium treati* sp. nov., larva, Holotype. A Dorsal view, legs omitted beyond trochanters. pdc podocephalic canal. B Dorsal view of tip of right palp. C-E Idiosomal setae. C posterior dorsal idiosomala. D ventral idiosomal seta of first row behind coxae III. E posterior ventral idiosomala. (All figures to nearest scale.)

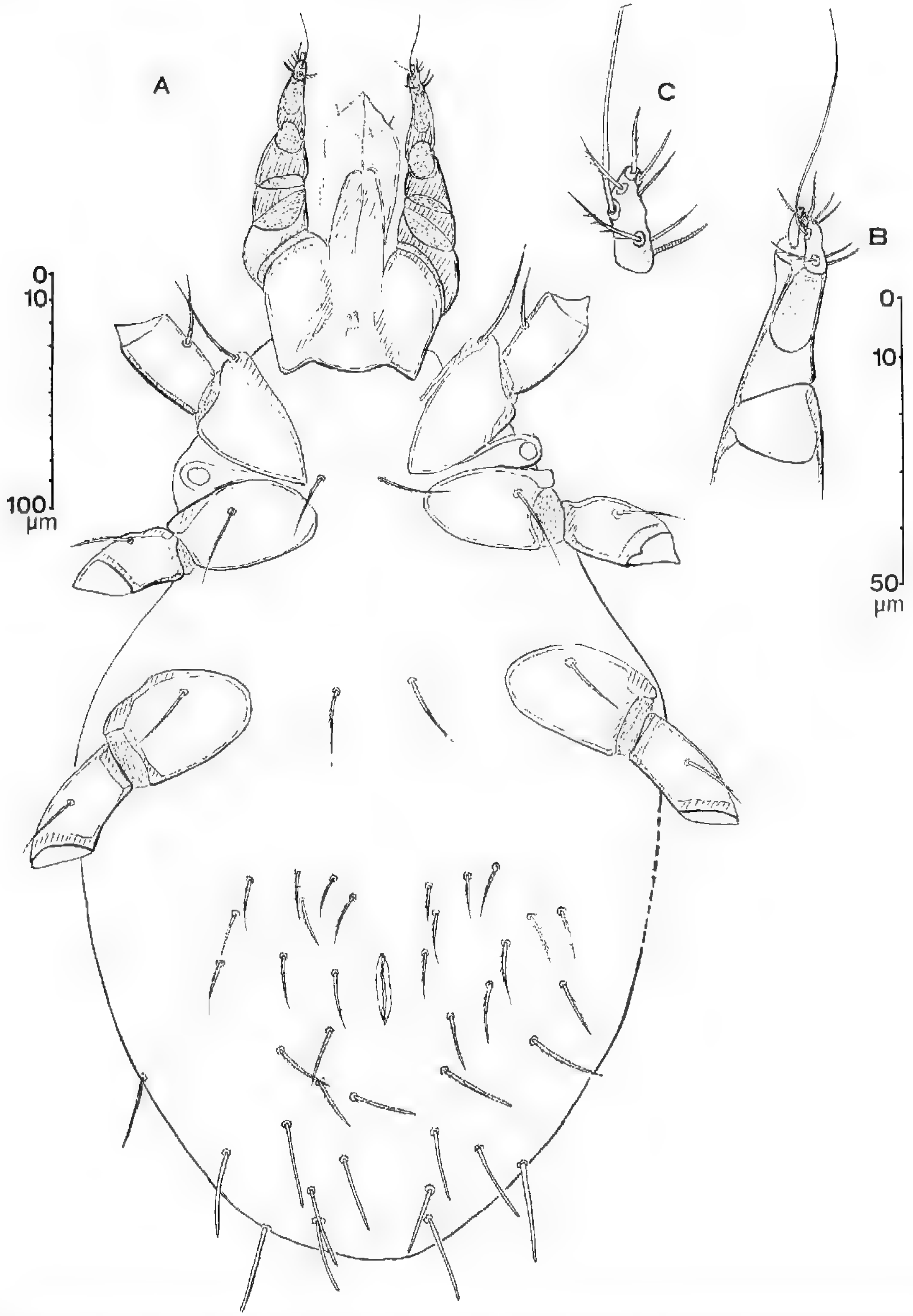
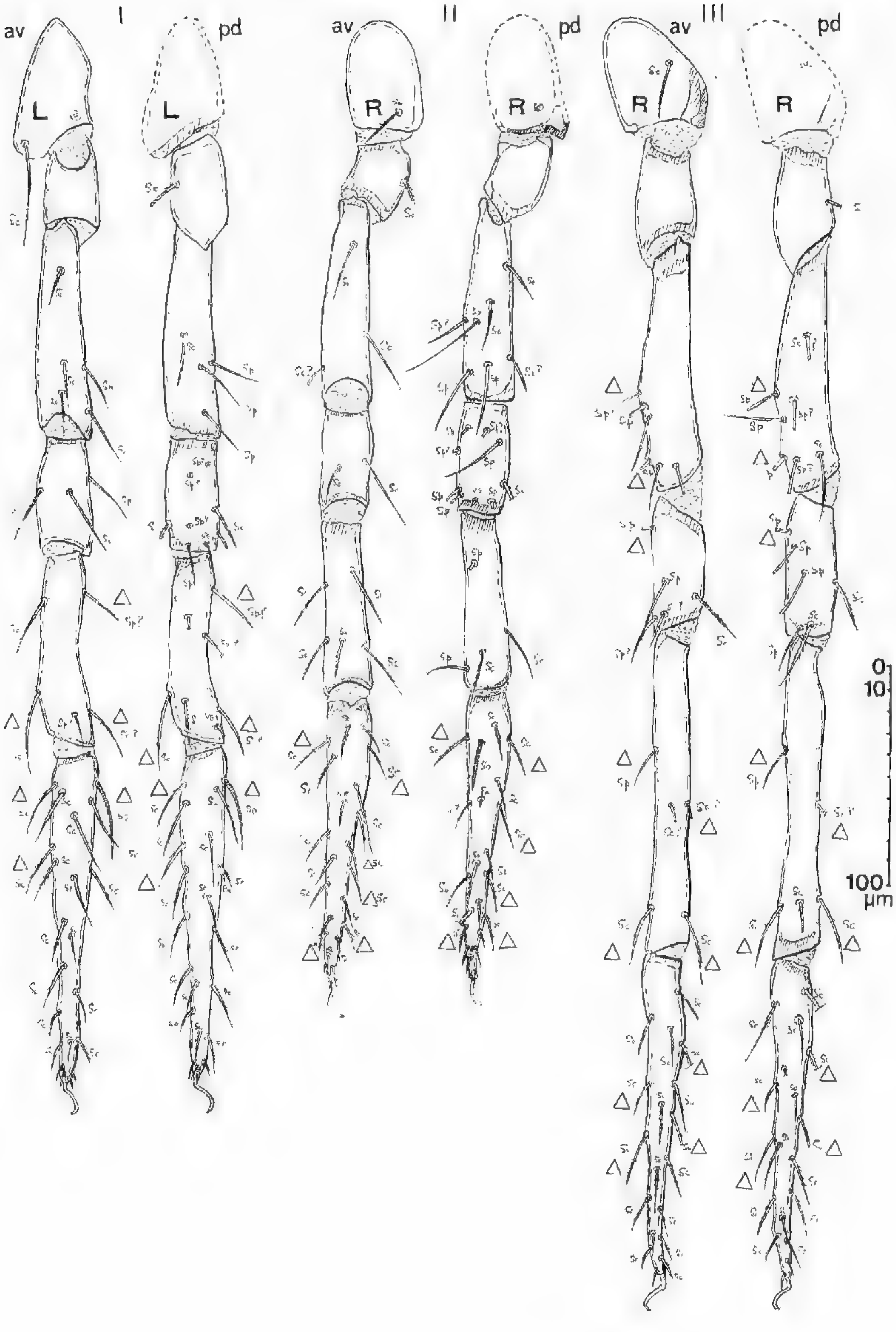


Fig. 2. *Nothrotrombidium treati* sp. nov., larva, Holotype. A Ventral view, legs omitted beyond trochanters, to scale on left. B Ventral view of right palp, to scale on right. C Further enlargement of tarsus of right palp, not to scale.

Fig. 3. *Nothrotrombidium treati* sp. nov., larva, Holotype. Legs I, II, III. Codes: L of left side, R of right side. av anteroventral. pd posterodorsal. Sc scobala (normal type seta), So solenoidala, Sp spinala (eupathidala), Vs vestigiala. Symbol Δ means that the seta is shown doubly, in both aspects for the leg. (All figures to same scale.)


I
II
III
av
pd
av
pd
av
pd
L
L
R
R
R
R
Sc
Sp
0
10
100
µm

Dorsal scutum with a prominent narrow nasus extending abruptly from anterior border. Some palpal tarsalae long and feather-like .... *Nothotrombicula* Dumbleton

Audyanidae fam. nov.

Definition: Trombidioidea in which the deutonymphs (adults are as yet unknown) lack a crista. Large dorsal propodosomal shield present, with anterior notch; two sensilla at posterior edge of shield, well separated. Idiosomal setae with annulus produced to form a high papilla bearing a small scobala at its tip, arranged in groups of 2–12 on small plates of the idiosoma. Similar setae on propodosomal shield and legs. Eyes absent. Palp with strong tibial claw, ctenidium present on palpal tibia as two dorsal spines. Palpal tarsus clavate, moderately enlarged. Genital valves each with single large, oval actabulum.

Larva with single prodorsal scutum, with 8 setae: 2 AMs, short, clavate, 2 similar ALs close to the sensilla, 2 normal PLs, sensilla present behind middle of scutum, sensillary setae pointed, somewhat thickened. Nasus lacking to scutum. Eyes absent. Leg segmental formula 7, 6, 6. Coxae separated. Coxal setal formula 2, 1, 1; coxalae II and III clavate, similar to AM and AL scutalae; palpal femorala similar. Tarsal claws 2, 2, 2. Supracoxalae absent.

Content: *Audyana* Womersley, 1954a.

Johnstonianidae family group

Family Johnstonianidae

Partial synonymy

Johnstonianinae Thor 1935, p. 108; Womersley 1937, p. 76; Thor & Willmann 1947, p. 221; Feider 1955a, p. 75.
Johnstonianidae Newell 1957, p. 396; 1960, p. 156; Feider 1959b, p. 540; 1979, p. 420 (also Johnstonianoidea), Vercammen-Grandjean 1972, p. 227; 1973, p. 110; Robaux 1973, p. 121; Vercammen-Grandjean *et al.* 1974, p. 245.

Definition: Adults: Small or middle-sized trombidioids with or without propodosomal dorsal crista. Propodosoma with one or two pairs of specialized or relatively unspecialized sensory setae, which may be set in trichobothrial pits or be less clearly defined. Eyes 2 + 2 or lacking; if present, on short peduncles. Skin comparatively smooth, without prominences or large sclerotized areas. Idiosomal setae simple, nude or, if setulose, not elaborately so; they commonly originate on small plates or raised papillae. Genital acetabula 3 + 3 or 2 + 2. Pedotarsal claws without empodium or empodium-like brush. Palp generally long and thin, with or without tibial claw, with few or no accessory spines. Paragenital sclerites present or absent. Predatory, may be associated with semiaquatic environments.

Larvae: Propodosomal dorsal scutum with two pairs of sensory setae and four normal setae, or with two pairs of setae, one pair sensory and the other pair normal; sensory setae may be rudimentary or fully developed in trichobothrial pits. Leg segmental formula 7, 7, 7 or 7, 7, 6 or 6, 6, 6. Coxal setal formula 2, 2, 3–4 or 2, 1, 2 or 2, 1, 1 or 1, 1, 1. Coxal setae setulose, not highly modified. Pedotarsal claws 3, 3, 3 or 2, 2, 2. Eyes 2 + 2, sessile, or absent. Supracoxalae present or absent.

Free-living predators or ectoparasitic on insects, at times semiaquatic.

Type genus *Johnstoniana* George, 1909.

Remarks: Thor (1935) defined the subfamily Johnstonianinae as (translation by author):

> "Body (abdomen) cylindrical, with pointed, simple hairs. Crista well developed, with two areolae in the middle (or one distal) and four (= two pairs) of sensory setae. Anterior to the thorax is an elongate triangular projection (nasus). Eyes on short peduncles (kurzgestielt). Palpi almost without, or with few, spines. Legs of middling length.
>
> Type: *Johnstoniana* C. F. George 1909 (syn. *Diplothrombium* Berlese, 1910 = *Rohaultia* Oudemans, 1911".

Other genera placed in this subfamily by Thor & Willmann (1947) were: *Centrotrombidium* Kramer, 1896, *Diplothrombium* Berlese, 1910 (they did not accept its synonymy with *Johnstoniana*), *Myrmicotrombium* Womersley, 1934, and *Hirstithrombium* Oudemans, 1947, the last-named with type species *Diplothrombium australiense* Hirst, 1928. They removed *Notothrombium* Štorkán, 1934 to a separate, new subfamily, Notothrombiinae.

Myrmicotrombium was shown by Southcott (1957a) to belong to the Erythraeidae.

All of the genera listed were based on the adults, except for *Rohaultia*, which was considered to be a larva of *Johnstoniana* (although this has been widely accepted, Cooreman (1949, p. 10) pointed out there was no certainty that *Rohaultia biungulum* Oudemans, 1911 was the larva of *Rhyncholophus errans* Johnston, and in fact *Rohaultia* was not established to be a larval synonym of *Johnstoniana* until Feider recorded and described the rearing of larvae of *Johnstoniana maxima* Feider, 1955 (Feider 1955a, 1958a)). Robaux (1970) described larvae of *J. errans* obtained by experimental rearing.

Further genera which have been placed in the Johnstonianidae are (see Vercammen-Grandjean 1973): *Polydiscia* Methlagl, 1928 (larva), *Parawenhoekia* Paoli, 1937 (larva), *Crossothrombium* Womersley, 1939 (adult), *Lassenia* Newell, 1957 (larva, deutonymph, adult), *Marcandreella* Feider, 1957 (adult, deutonymph), *Charadracarus* Newell, 1960 (adult, larva), *Pteridopus* Newell & Vercammen-Grandjean, 1964 (larva), *Paraplothrombium* Robaux, 1968 (adult). *Parachyzeria* Hirst, 1926 (adult) was placed in the Johnstonianidae by Southcott (1986a). Two further genera placed in the Johnstonianidae by Vercammen-Grandjean (1973) were *Nothotrombicula* and *Grossia* (= *Chyzeria*). Both of these genera have been placed here in the Chyzeriidae. *Parawenhoekia* is excluded, as of doubtful affinity (see Southcott 1961a).

There remains a total of nine genera in the Johnstonianidae, known as larvae, for which the following subfamily groupings are proposed: Johnstonianinae: *Johnstoniana* (= *Rohaultia*), *Diplothrombium*, *Centrotrombidium*; Tetrathrombiinae: *Tetrathrombium*; Lasseniinae: *Lassenia*; Polydisciinae: *Polydiscia*; Pteridopodinae: *Pteridopus*; Ralphaudyninae: *Ralphaudyna*; Charadracarinae: *Charadracarus*.

The following is a key to the subfamilies of the Johnstonianidae (larvae).

Key to the larvae in the subfamilies of Johnstonianidae

1. Tarsal claws 2, 2, 2. Anal sclerites absent. Supracoxalae absent to gnathosoma and leg I 2

   Tarsal claws 3, 3, 3. Anal sclerites present 3

2. Leg segmental formula 7, 7, 7 or 6, 6, 6. Posterior sensillary setae of prodorsal scutum without thickened central part to shaft, filiform (except in *Centrotrombidium* where the sensillary setae are terminally clavate). Sternal setae: usually a pair of setae between coxae III. Terminal seta of palpal tarsus not eupathidiform. Urstigma between coxae I and II not projecting away laterally from idiosoma. Coxal formula 2, 1, 1. Eyes 2 + 2. Tracheae absent. Anterior hypostomala absent .... Johnstonianinae Thor

   Leg segmental formula 7, 7, 6. Posterior sensillary setae of prodorsal scutum with thickened part in middle. Sternal setae numerous in area between coxae II and III. Urstigma in a chitinous extension projecting well lateral from idiosoma. Coxal formula 2, 1, 2. Eyes absent. Tracheae present. Anterior hypostomala absent. Terminal setae of palpal tarsus not eupathidiform ...... Charadracarinae Newell

3. Leg segmental formula 6, 6, 6. Coxal setal formula 2, 1, 2 or 2, 2, 3–4. Eyes 2 + 2. Anterior sensillary setae borne on a small sclerite which may be separated from the main body of prodorsal scutum. Sternal setae absent. A well-developed pore of a "lassenus" or "*Lassenia* organ" present upon a small separate sclerite anterior to coxa III. Supracoxalae present. .... Lasseniinae Newell

   Leg segmental formula 7, 7, 7. Eyes 2 + 2 4

4. Anterior scutal sensilla in anterior third of prodorsal scutum, posterior scutal sensilla in posterior third. Sternal setae absent. Coxal setal formula 2, 1, 1. .... Tetrathrombiinae subfam. nov.

   Anterior and posterior pairs of scutal sensilla both in anterior two-thirds of prodorsal scutum 5

5. Coxal setal formula 2, 1, 2. Sternal setae lacking. Neolateral claws of pedotarsi divided. Gnathosomal supracoxalae present .... Polydisciinae Vercammen-Grandjean

   Coxal setal formula 2, 1, 1. Two sternal setae present between coxae III. Neolateral claws of pedotarsi broadened but undivided. Supracoxalae present 6

6. Anterior sensilla of prodorsal scutum posterior to level of AL setae. Both pairs of scutal sensilla well developed. Scutum with small nasus. Coxalae normal, setulose. Tarsus III extremely elongate and carrying a dorsal row of long, feathered setae .... Pteridopodinae subfam. nov.

   Anterior sensilla of prodorsal scutum anterior to level of AL setae. Anterior sensilla and setae significantly smaller than posterior. Scutum with large nasus. Coxal setae tuberculate with a subterminal bristle. Tarsus III spindle-shaped, only moderately elongated, and not carrying a row of feathered setae .... Ralphaudyninae subfam. nov.

Remarks: All subfamilies are known from only one genus, except Johnstonianinae.

Subfamily Johnstonianinae Thor

Johnstonianinae auct. (ad p., v. sup.)

Definition (larvae): Prodorsal scutum with eight or four setae; if with eight then these are two pairs of each of sensillary setae and non-sensillary setae, if with four then with one pair of sensillary and one pair of nonsensillary setae. If with four setae then sensillary setae clavate; if with eight setae then sensillary setae filiform, and anterior pair may be reduced. Eyes 2 + 2, each lateral pair on a small ocular plate, which may be elevated into a tubercle; in *Centrotrombidium* posterior cornea may be obsolete or lacking. Usually two sternal setae between coxae III. Anal sclerites absent or weak; if the latter, they are non-setiferous. Coxalae 2, 1, 1; medial coxala I generally on a small pars medialis coxae, which is rarely separated from coxa. Urstigma between coxae I and II, not projecting away laterally from coxae. Pedotarsal claws 2, 2, 2. Galeala present, anterior hypostomala present, reduced or absent, posterior hypostomala present. Palpal tibial claw bifurcate. Terminal seta of palpal tarsus not eupathidiform. Tracheae absent. Supracoxalae absent.

Type genus *Johnstoniana* George, 1909.

Remarks: The following is a key to the genera of the larval Johnstonianinae:

Key to genera of larval Johnstonianinae

1. Scutum with four setae, posterior pair clavate sensillary setae. Vs absent all legs .... *Centrotrombidium* Kramer, 1896

   Scutum with eight setae (two pairs sensillary, two pairs non-sensillary; sensillary setae not clavate 2

2. Anterior pair of scutal sensillary setae at least one third as long as the posterior pair. VsGeI,II present, VsTiI, II, III absent. Anterior wall of palpal trochanter not fenestrated . . . . *Johnstoniana* George (*Rohaultia* Ouds.)
   Anterior pair of scutal sensillary setae reduced, at most one sixth as long as posterior pair. Vs absent all segments. Anterior wall of palpal trochanter may be fenestrated . . . . *Diplothrombium* Berlese, 1910.

The key above has been drawn up principally from descriptions of larvae allotted to those genera as follows: *Johnstoniana* from *J. latiscuta* Newell, 1957, *J. maxima* Feider, 1955 (described by Feider 1958a), *J. harghitensis* Feider, 1958c, *J. ventripilosa* Feider, 1958c, *J. errans* (described by Robaux 1970); *Diplothrombium monoense* and *D. cascadense* of Newell (1957), *D. moldavicum* Feider, 1959a, *D. newelli* Robaux, 1977; *Centrotrombidium* from *C. distans* of Newell (1957), *C. romaniense* of Vercammen-Grandjean & Feider, 1973, *C. dichotomocoxala* Vercammen-Grandjean & Cochrane, 1974.

Tetrathrombiinae subfam. nov.

Definition (larvae): Anterior pair of sensilla in anterior third of prodorsal scutum, posterior pair in posterior third. Sensilla well-developed, sensillary setae filiform. Eyes 2 + 2. Sternalae absent. Coxae separated. Urstigma attached to anterior border of coxa II. Leg segmental formula 7, 7, 7. Coxal setal formula 2, 1, 1. Pedotarsal claws 3, 3, 3 (lateral claws may be reduced). Galeala, anterior hypostomala and posterior hypostomala present. Palpal tibial claw bifid.

Type genus *Tetrathrombium* Feider, 1955.

Remarks: *Tetrathrombium* is known from two species, *T. zachvatkini* Feider, 1955b (type species) and *T. macronychus* Feider & Suciu, 1956, from Europe. *T. zachvatkini* was obtained as ectoparasitic upon a plecopteran, and *T. macronychus* from tipulid Diptera. The adults of the genus are unknown.

Lasseniinae Newell

Lasseniinae Newell 1957, p. 447; Vercammen-Grandjean 1973, p. 110.

Lassenidae (sic) Vercammen-Grandjean 1972, p. 236.

Definition (larvae): Anterior scutal sensillary setae borne on a small sclerite which may be separate from main body of scutum. Eyes 2 + 2. Sternal setae absent. Anal sclerites present, setiferous. Lassenus or "*Lassenia* organ" present (a small pore on a small separate sclerite anterior to coxa III). Leg segmental formula 6, 6, 6. Coxal setal formula 2, 1, 2 or 2, 2, 3–4. Coxalae setulose, unmodified. VsGeI, II present, VsTII present, VsTIII absent. Pedotarsal claws 3, 3, 3. Galeala, anterior hypostomala and posterior hypostomala present. Palpal tibial claw unidentate or bidentate. Supracoxalae present.

Type genus *Lassenia* Newell, 1957

Remarks: At present Lasseniinae should be restricted to one genus, *Lassenia*, known as larvae, deutonymphs and adults. Two species are known as larvae, both from North America. In neither case was there experimental correlation between larvae and octopod stages, and correlation was based purely on strong presumptive field evidence (Newell 1957). The larvae are parasitic on Diptera living in subaquatic environments.

Vercammen-Grandjean (1973) included in the "Lassenidae" *Lassenia*, *Polydiscia* Methlagl (known only as larva), and *Crossothrombium* Womersley, 1939 (known only as adult). The status of the last-named (which has 2 + 2 eyes, contrary to Womersley's description) will be considered in another paper. *Polydiscia* was made the type genus of Polydiscinae (sic) Vercammen-Grandjean by its author (1972); this subfamilial status will be retained here (see below).

Polydisciinae Vercammen-Grandjean

Polydiscinae (sic) Vercammen-Grandjean 1972, p. 236.

Definition (larvae): Dorsal propodosomal scutum well developed, with two pairs of trichobothrial setae and four non-sensillary setae. Anterior pair of sensillary setae originate anterior to AL setae, behind slight convexity of anterior border of scutum; no defined nasus present; scutum markedly waisted. Eyes 2 + 2. Sternal setae lacking. Anal sclerites present, setiferous. Coxa I and II contiguous on each side, with urstigma between them. Leg segmental formula 7, 7, 7. Coxal setal formula 2, 1, 2; coxalae setulose, unmodified. Pedotarsal claws 3, 3, 3; empodium thin, falciform; neolateral claws divided. Dorsal eupathidala + companala present to tarsus I and II. Palpal tibial claw greatly modified, reduced to seta without hook structure. Galeala present, anterior hypostomala present, posterior hypostomala absent. Gnathosomal supracoxalae present.

Type genus *Polydiscia* Methlagl, 1928

Remarks: Known only for the species *P. squamata* Methlagl, 1928.

Vercammen-Grandjean (1972) gave a careful redescription of *Polydiscia squamata* Methlagl, and

TABLE 2. *Pedal scobalar formula for three species of larval johnstonianid and one hydryphantid larval, mites.*

	Lassenia lasseni[1]			*Polydiscia squamata*[1]			*Piersigia limophila*[1]			*Charadracarus delitescens*[2]		
Leg	I	II	III	I	II	III	I	II	III	I	II	III
Fe	10	10	10	6	7	6	7	7	6	6	8	6
Ge	8	8	8	4	4	4	4	4	4	5	4	4
Ti	16	17	15	9	9	9	9	9	9	5	5	7
Ta	50	43	40	21	21	20	18	17	17	22	17	15
Sub-totals	84	78	73	40	41	39	38	37	36	38	34	32
Totals		235			120			111			104	

[1] From Vercammen-Grandjean (1972), re-arranged.
[2] Derived from the illustrations of Newell (1960).

founded Polydisciinae on the sole genus *Polydiscia* on the grounds of:

(1) limited size of palpotibial claw

(2) presence of subterminala (= dorsal eupathidala) and parasubterminala (= companala to dorsal eupathidala) on tarsus II

(3) "tabulation of leg setae is very much like that of certain water mites . . ." and commented "Those characters seem to imply a high ancestry to this genus, as does the peculiar shape and ornamentation of the scutum, which interestingly links the Lasseninae (sic) to the Hydryphantidae" (Vercammen-Grandjean 1972, p. 236).

In 1973 he listed (without discussion) *Polydiscia* in the Lasseniinae (possibly due to a publication delay).

However, the grounds advanced by Vercammen-Grandjean for the separation of the Polydisciinae are worthy of discussion, as they are relevant to subfamilial classification within the Johnstonianidae. Criterion (1) is true, but by itself does not appear to be a justification for subfamilial status. Criterion (2) also applies in e.g. *Lassenia lasseni* Newell (see Newell 1957) and *L. scutellata* Newell (see Newell 1957).

Criterion (3) is of more interest, and is an expression of an increasing tendency among specialists of the prostigmatic mites to use the numbers of normal setae (scobalae) on the leg segments in higher classifications. These numbers may be expressed in a "pedal scobalar formula", as has been done e.g. by Vercammen-Grandjean (1972), Robaux (1977). This formula, for four species of trombidiform mites, is shown in Table 2.

From Table 2 it can be seen that there is a decrease in pilosity through the four genera *Lassenia, Polydiscia, Piersigia* and *Charadracarus*. If reduction of the number of leg scobalae is considered to be derived then *Lassenia* is the most primitive of the four genera listed, and *Charadracarus* the most derived. These remarks apply only to absolute numbers of scobalae. In the case of the genua, however, *Polydiscia* has fewer setae than *Charadracarus*, at least for genu I.

On the other hand, if one considers the numbers of idiosomal scobalae, of the larvae, the relationship is reversed between *Lassenia* and *Charadracarus*. Thus *Charadracarus* larvae have a large number of setae in the intercoxal area between coxae II and II, while *Lassenia* larvae have none.

It would appear, therefore, that any conclusions about the phylogeny of the various johnstonianid subfamilies at least, based on the degree of pilosity of the larvae, should be treated with caution. Other characters must be introduced into such an analysis.

Pteridopodinae subfam. nov.

Pteridopiidae Feider, 1979, pp. 420, 421 (*nom. nud.*, proposed without definition or key).

Definition (larvae): Prodorsal scutum well-developed, with anterior nasus and eight setae: two pairs of well-developed sensilla, anterior pair originating behind level of AL scutalae. Sensillary setae setulose, not expanded, may be plumose. Eyes 2 + 2. Sternal setae: two, between coxae III. Anal sclerites present. Lassenus present. Coxae I and II contiguous or nearly so on each side, urstigma well developed. Leg segmental formula 7, 7, 7. Coxal setal formula 2, 1, 1; coxalae normal, setulose. VsGeI, II, VsTiI present; VsTiII absent. Tarsal claws 3, 3, 3; neolateral claws with distal widening. Tarsus III elongated, carrying dorsally a row of plumose setae; similar setae on tibia III. Cheliceral blades with many fine teeth and tubercles. Palpal trochanter not fenestrated; palpal tibial claw strongly bifid. Supracoxalae present.

Type genus *Pteridopus* Newell & Vercammen-Grandjean, 1964

Remarks: The Pteridopodinae at present contains only the genus *Pteridopus*, known for two species of larvae (adults are not known) from Africa: *P. auditor* Newell & Vercammen-Grandjean, 1964 (type species) and *P. pseudhannemania* Newell & Vercammen-Grandjean, 1964.

Ralphaudyninae subfam. nov.

Definition (larvae): Prodorsal scutum well-developed, with broad nasus; eight setae, four sensory. Anterior pair of sensilla anterior to level of AL scutalae, smaller than posterior pair. Sensillary setae not enlarged. Eyes 2 + 2. Sternal setae: two, between coxae III. Anal sclerites present, setiferous. Coxae I and II contiguous on each side, with the urstigma set laterally between them. Leg segmental formula 7, 7, 7. Coxal setal formula 2, 1, 1: all coxalae modified, tubercular, with subterminal bristle in only known species. Tarsus III only moderately elongated, does not carry a row of plumose setae along dorsum. Tarsal claws 3, 3, 3; all claws widened, but undivided. Galeala, anterior and posterior hypostomalae present. Palpal tibial claw bifid. Supracoxalae present.

Type genus *Ralphaudyna* Vercammen-Grandjean *et al.*, 1974.

Remarks: The Ralphaudyninae contains only the genus *Ralphaudyna*, known only for its type species.

Ralphaudyna Vercammen-Grandjean *et al.*, 1974

Definition: With the characters of the subfamily.

Ralphaudyna amamiensis Vercammen-Grandjean *et al.*, 1974

Remarks: Through the kindness of Mr W. C. Welbourn, Acarology Laboratory, State University of Ohio, I have examined three specimens which conform to this species. Collection details are as follows:

Japan, Shikoku, Ishizuchi National Park, Omogo Uly (sic), 700 m, 18–25.viii.1980, ex *Tachycines robustus* [Ander; Rhaphidophoridae, Gryllacridoidea] S. & J. Reck, codes WCW 81406-9, -2, -9; local identifications (RVS) ACB727A,B,C.

Significant morphological features have been discussed on p. 26, leading to the above taxonomic placement.

Metric data of scutum and legs of these three species are provided in Table 3.

The dorsal scutum is shown in Fig. 4C. The anterior sensilla have the typical "half-lidded" appearance of trombidioid scutal sensilla. The sternalae are between coxae III, long-conical with faint adpressed setules, 60 µm long. The palpal tibial claws are well-cleft; the tines are separated, and in the correct orientation can be seen to be angled about half-way along their length (Fig. 4A, B).

Remarks on biology: The finding of larvae of this species as ectoparasites on a gryllacridoid (cave cricket) is of considerable interest. Many of the larvae of the Johnstonianidae have been taken as ectoparasites upon water associated insects, e.g. upon tipulids, or even upon the aquatic pupae of water beetles of an unnamed family (Newell 1957).

There is a superficial resemblance between *Ralphaudyna* larvae and *Chyzeria* in the highly modified coxalae of at least some species of *Chyzeria* larvae (see Southcott 1982).

Charadracarinae Newell

Charadracarinae Newell 1960, p. 157; Vercammen-Grandjean 1973, p. 110.

Definition (larvae): Anterior propodosomal dorsal scutum well-developed, with a sharp nasus and slight evidence of a crista; with eight setae: two pairs of sensillary setae, two pairs non-sensillary. Anterior pair of sensillary setae little different from scutalae, without a well-developed typical alveolar pit. Posterior sensillary setae with expanded middle part, arising from approximately normal trichobothrial pits. Ocular sclerites and eyes absent. Sternal setae numerous on venter of idiosoma in area between coxae II and III. Anal sclerites absent. Coxae I and II contiguous on each side. Urstigma well-developed, in chitinous extension on lateral side of coxa I. Leg segmental formula 7, 7, 6. Coxalae 2, 1, 2: coxalae normal, tapering, setulose. Pedotarsal claws 2, 2, 2. Galeala present, anterior hypostomala absent, posterior hypostomala present. Anterior wall of palpal trochanter not fenestrated. Terminal setae of palpal tarsus not cupathidiform. Supracoxalae absent.

Type genus *Charadracarus* Newell, 1960.

Remarks: Charadracarinae includes only the genus *Charadracarus*, with two species in North America, *C. hurdi* Newell, 1960 and *C. delitescens* Newell, 1960, and two European species, *C. grandjeani* (André, 1930) and *C. aelleni* (Cooreman, 1954). The larva is known only for *C. delitescens;* correlation between the larva and adult for this species appears to have been based on strong evidence of association in the field, together with the morphological similarities of the adults and larva, without evidence of experimental rearing. There is no present evidence to dispute the proposed correlation; the larva is clearly a member of the Johnstonianidae on other grounds.

Acknowledgments

I am indebted to Dr Asher E. Treat, U.S.A., for sending the specimen of *Nothrotrombidium treati*, and for additional collecting information; and to Mr W. C. Welbourn, Acarology Laboratory, State University of Ohio, for the specimens of *Ralphaudyna amamiensis*. I thank Mrs Geraldine Kominski and Dr David Ellis, Mycologists, Adelaide Children's Hospital, for identification of the fungus associated with *N. treati*.

TABLE 3. *Metric data of three specimens of* Ralphaudyna amamiensis *larvae, in μm.*

Specimen	*LN*	*MA*	*AW*	*PW*	*SB*	*MS*	*ASB*	*PSB*	*L*	*W*	*AP*	*AM*	*AL*	*PL*
ACB727A	*46*	*36*	*58*	*124*	*23*	*43*	*89*	*45*	*134*	*159*	*53*	*43*	*55*	*72*
ACB727B	*45*	*33*	*57*	*116*	*22*	*43*	*88*	*42*	*130*	*149*	*53*	—	*56*	*67*
ACB727C	*46*	*38*	*67*	*133*	*22*	*40*	*86*	*46*	*132*	*159*	*55*	*46*	—	*69*
	AMB	SE	DS	MDS	PDS	BFeI	TFeI	GeI	TiI	TaI(L)	TaI(H)			
ACB727A	17	100	44–76	55	70	48	45	54	64	124	32			
ACB727B	18	—	38–75	38–64	64–75	49	42	48	62	116	34			
ACB727C	16	—	46 76	68	76	47	43	48	63	127	34			
	BFeII	TFeII	GeII	TiII	TaII(L)	TaII(H)	BFeIII	TFeIII	GeIII	TiIII	TaIII(L)	TaIII(H)		
ACB727A	49	49	43	53	115	29	55	54	42	62	144	27		
ACB727B	47	40	44	50	108	30	53	51	43	61	135	27		
ACB727C	45	46	45	54	115	31	51	53	46	62	147	25		

Note: In the above table I have used the terms customarily used for trombidiid larvae with two sensilla, e.g. I have used AMB instead of SBa, LN instead of ASBa, etc., which are appropriate for a scutum with two pairs of sensilla (see Southcott, 1961a, Fig. 8, p. 398), to make these data more readily comparable with the data of Vercammen-Grandjean *et al.* (1974).

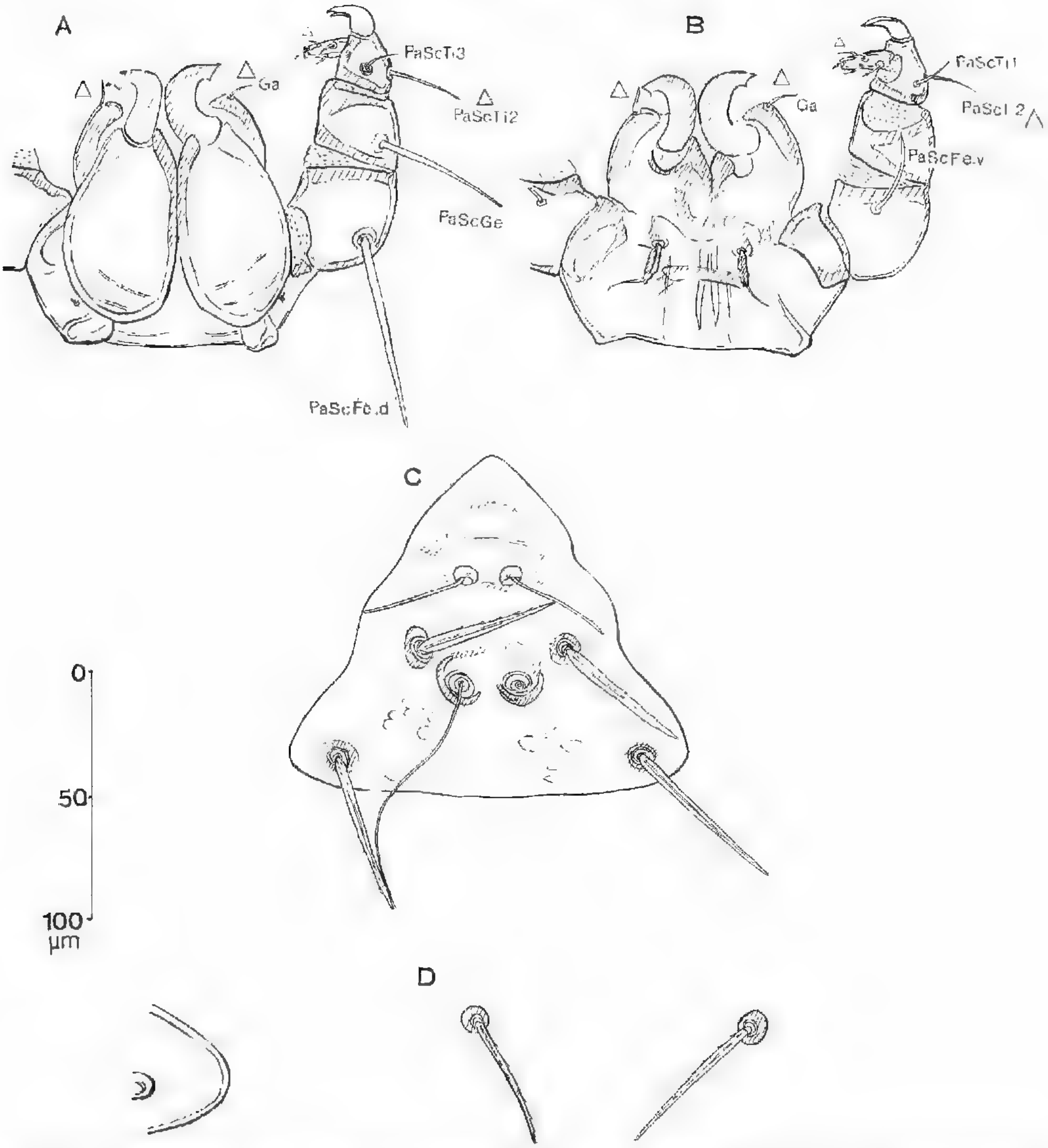


Fig. 4. *Ralphaudyna amamiensis* Vercammen-Grandean *et al.*, 1974, larva, specimen ACB727A, to standard notation. A Gnathosoma, dorsal. B Gnathosoma, ventral. C Dorsal scutum. D Part of coxa III and the two sternalae. (All to scale shown.)

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A NEW LARVAL MITE (ACARINA: TROMBIDIOIDEA) ECTOPARASITIC ON AN AUSTRALIAN CENTIPEDE, AND THE TROMBIDIIDAE RECLASSIFIED

*BY R. V. SOUTHCOTT**

Summary

Wondeclia centipedae gen. nov., sp. nov. is described, as an ectoparasite on the centipede *Rhysida nuda* (Newport) (family Scolopendridae) from north Queensland. It is the first larval trombidioid mite known as a centipede ectoparasite. The mite lacks eyes, and is unusual in the posterior displacement of the anteromedian scutal setae and their wide separation, the anterior displacement of the posterolateral scutal setae, the thickening of the anteromedian, anterolateral and sensillary scutal setae, and the excavation of the anterior scutum's anterior border.

A new subfamily, Wondecliinae, is erected for the genus, which is included with the Trombidiinae and Allothrombiinae in a restricted family Trombidiidae.

Metric characters for shield and leg characters customarily used in describing and specifying larval trombidioid mites are analysed by correlation methods. A moderate degree of positive correlation, above twice that of random expectation, is present throughout the sets of comparisons of the groups of variates utilized. There is no excess of negative correlations.

KEY WORDS: Taxonomy, *Wondeclia,* Wondecliinae, centipede, Queensland, Acarina, Trombidiidae, Trombidioidea, correlation.

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by R. V. SOUTHCOTT*

Summary

SOUTHCOTT, R. V. (1987) A new larval mite (Acarina: Trombidioidea) ectoparasitic on an Australian centipede, and the Trombidiidae reclassified. *Trans. R. Soc. S. Aust.* 111(1), 43-52, 29 May, 1987.

Wondecla centipedae gen. nov., sp. nov. is described, as an ectoparasite on the centipede *Rhysida nuda* (Newport) (family Scolopendridae) from north Queensland. It is the first larval trombidioid mite known as a centipede ectoparasite. The mite lacks eyes, and is unusual in the posterior displacement of the anteromedian scutal setae and their wide separation, the anterior displacement of the posterolateral scutal setae, the thickening of the anteromedian, anterolateral and sensillary scutal setae, and the excavation of the anterior scutum's anterior border.

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KEY WORDS: Taxonomy, *Wondecla*, Wondecliinae, centipede, Queensland, Acarina, Trombidiidae, Trombidioidea, correlation.

Introduction

Centipedes and millipedes are well known hosts for commensal or phoretic mites of a number of families (e.g. Berlese 1882, 1910a, b; Vitzthum 1941; Evans 1955; Domrow 1956; Rack 1979). André (1943) considered that some of these relationships verged on parasitism, a suggestion confirmed by Shiba's (1976) record of a larval trombidioid mite, *Milliotrombidium milliopodum* Shiba, ectoparasitic on millipedes in Malaya. However, larval trombidioid mites seem not to have been found on centipedes (see e.g. Oudemans 1912; Thor & Willmann 1947; Cloudsley-Thompson 1968).

A new genus and species of larval trombidioid mite ectoparasitic upon a north Queensland centipede is described below and its taxonomic position within the superfamily Trombidioidea discussed. It is placed in a new subfamily of a restricted family Trombidiidae, and some comments are made on its biology.

A key for the separation of the subfamilies of the Trombidiidae is presented.

Seta terminology follows Southcott (1961a, b, 1963, 1986a, 1987).

TAXONOMIC DECISIONS AND ACCOUNTS

Superfamily Trombidioidea Leach

Trombidides Leach, 1815 (restricted)
Trombidioidea Leach; Southcott, 1987.

Definition: As in Southcott (1987).

Family Trombidiidae Leach s. str.

Trombidides Leach, 1815 (restricted)
Trombidiidae Southcott 1986c.

Definition: As in Southcott (1986c).

Type genus *Trombidium* Fabricius, 1775.

Key to larvae of subfamilies of Trombidiinae

1. Anterior dorsal scutum more or less rounded anteriorly, without anteromedian excavation. AM setae of anterior dorsal scutum unmodified, arising towards anterior pole of scutum and in front of all other setae of scutum. Sensillary setae slender, tapering, not clavate. Eyes 2 + 2 2
   Anterior dorsal scutum with anteromedian excavation. AM setae displaced posteriorad nearly to mid-level of shield, short and clavate with long setules. AL setae the anteriormost setae of scutum, arising near AL angles. Sensillary setae clavate with strong setules, arising behind level of PL setae. Eyes absent . . . . Wondecliinae subfam. nov.
2. Urstigma oval* . . . . Trombidiinae
   Urstigma circular* . . . . Allothrombiinae

Remarks: With the discovery and formal description of *Wondecla centipedae* and its placement in the subfamily Wondecliinae, the subfamilies Trombidiinae and Allothrombiinae Thor, 1935 (see the discussion in Southcott 1986c), together with the Wondecliinae, should be placed in a restricted family Trombidiidae, as redefined

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*This distinction is tentative. See the discussion in Southcott (1986c).

(Southcott 1986c). That definition applies to all known adults and deutonymphs of the Trombidiinae and Allothrombiinae, but may need modification for the Wondecliinae, when the post-larval forms become known.

Subfamily **Wondecliinae** subfam. nov.

Definition of larvae: Eyes absent. Anterior dorsal scutum without nasus; with anteromedian excavation; AL scutal setae at anterolateral angle of scutum; AM setae well separated, displaced posteriorly nearly to level of middle of scutum; PL setae displaced anteriorly to level of middle of scutum. Sensillary setae widely separated, clavate, setulose. All coxal setae setulose. Tarsal claws 3, 3, 3.

Type genus *Wondeclia* gen. nov.

Genus **Wondeclia** gen. nov.

Definition of larva: Wondecliinae. Anterior prodorsal shield approximately square, posterior prodorsal scutum a transverse oblong. Scutal sensilla at about level of junction of third and fourth quarters of scutum. Posterior dorsal scutum with four normal, setulose setae. Tarsal claws falciform, simple. Gnathosoma with compact chelabases. Cheliceral blade with 2–4 barbed teeth. Galeala robust, sinuous, expanded near its base, unbranched. Palpal tibial claw bifid. Two large, setulose, posterior hypostomalae (tritorostral setae).

Type species *Wondeclia centipedae* sp. nov.

Wondeclia centipedae sp. nov.
FIGS 1–6

Description of larva (from Holotype SAM N19879, supplemented by other specimens). Yellow in life. Idiosoma ovoid (Fig. 1), somewhat flattened dorsoventrally; length (mounted) 710 μm, by 570 μm wide.

Anterior dorsal scutum widening a little posteriorad, with truncate anterolateral angles and rounded posterolateral angles (Fig. 3A); all sides somewhat concave, with anterior excavation the deepest, but owing to anterior edge being bent somewhat forward and down, apparent depth of anterior excavation may appear slight. Anteromedian scutal setae short, asymmetrical, with about four long, strong, pointed setules; these setae nearer to edges of scutum than to centre. Anterolateral scutal setae tapering, pointed, with long, strong, pointed setules. Posterolateral scutal setae similar, but more slender, near middle of lateral border, causing a slight convexity there. Sensillary setae most posterior setae of shield, long, with long, strong, pointed setules, orifices facing posterolaterally (Fig. 3A). Ridge of chitin runs from AL angle of shield to the annulus of AM seta. Shield porose.

Posterior dorsal scutum: porose; anterior border with a slight anterior projection, lateral borders convex, projecting anterolaterally, posterior border straight or sinuous; medial two setae anterior to posterior pair, and nearer to middle of scutum, posterior two setae nearer to lateral borders. All setae with outstanding setules.

For metric details of scuta and legs, see Table 1. (See Fig. 4 for interpretation of the setae of the scuta, and the conventions of seta and other codings.)

Dorsal idiosomal setae are pointed, with strong, barbed setules, and arranged in rows of 2 (between level of the two prodorsal shields), 4, 6, 10, 6, 2, 2; total 32 (Fig. 1). Ventral surface of idiosoma lacks setae between coxae I and II; a pair of setae between coxae III, slender, pointed, barbed, 37 μm long. Behind level of coxae III about 27 setae in irregular transverse rows, similar to preceding, becoming longer posteriorad, 20–42 μm long.

Legs short, moderately robust; lengths (including coxae and claws) I 260 μm, II 230 μm, III 240 μm.

All coxalae long, pointed, strongly setulose. Lateral coxala I 46 μm long, medial coxala I 37 μm, anterolateral coxala II 45μm, posterolateral coxala II 39μm, coxala III 27 μm. Urstigma large, prominent, approximately circular, external diameters 12 μm by 10 μm. Leg scobalae similar to coxalae; trochanteral scobalar formula 1, 1, 1, femoral 5–6, 4, 4, genual 4, 2, 2, tibial 6, 5, 5. Pedal supracoxalae absent.

Specialized setae of legs (except tarsi) as follows: SoGeI.20pd (16 μm), SoGeI.40d (17 μm), VsGeI.70d (4 μm), SoTiI.27pd (13μm), VsTiI.59d (4 μm), SoTiI.69pd (12 μm), SoGeII.24pd (29 μm), SoTiII.31pd (12 μm), SoTiII.67pd (10 μm), SoGeIII.46d (18 μm) (Figs 5–6).

Tarsus I and II each with a large central dorsal solenoidala. Specialized setae codings SoTaI.44d (14 μm), FaTaI.49d (3 μm), SoTaII.44d (18 μm), SoTaII.33pd (4 μm). Pretarsal formula 1, 0, 0. Tarsal claws normal, robust, subequal.

Gnathosoma robust, compact, each chela base from above irregularly ovoid, length 57 μm from tips of extruded chela digits to posterior pole of bases; combined chela bases 55 μm wide. Chela digits (blades) sharp-pointed, with 2–4 (usually 3) retrorse dorsolateral teeth, along edge. Galeala 15 μm long, tips pointing laterally. Posterior hypostomalae 26 μm long, somewhat bulbous towards base of shaft, shaft with several long, strong setules. Palpal setal formula 1, 0, 3, 6. Palpal femorala dorsal, spiniform, 5 μm long. Palpal tibialae and tarsalae as figured. Palpal tibial claw with tines robust, subequal but the dorsal the longer,

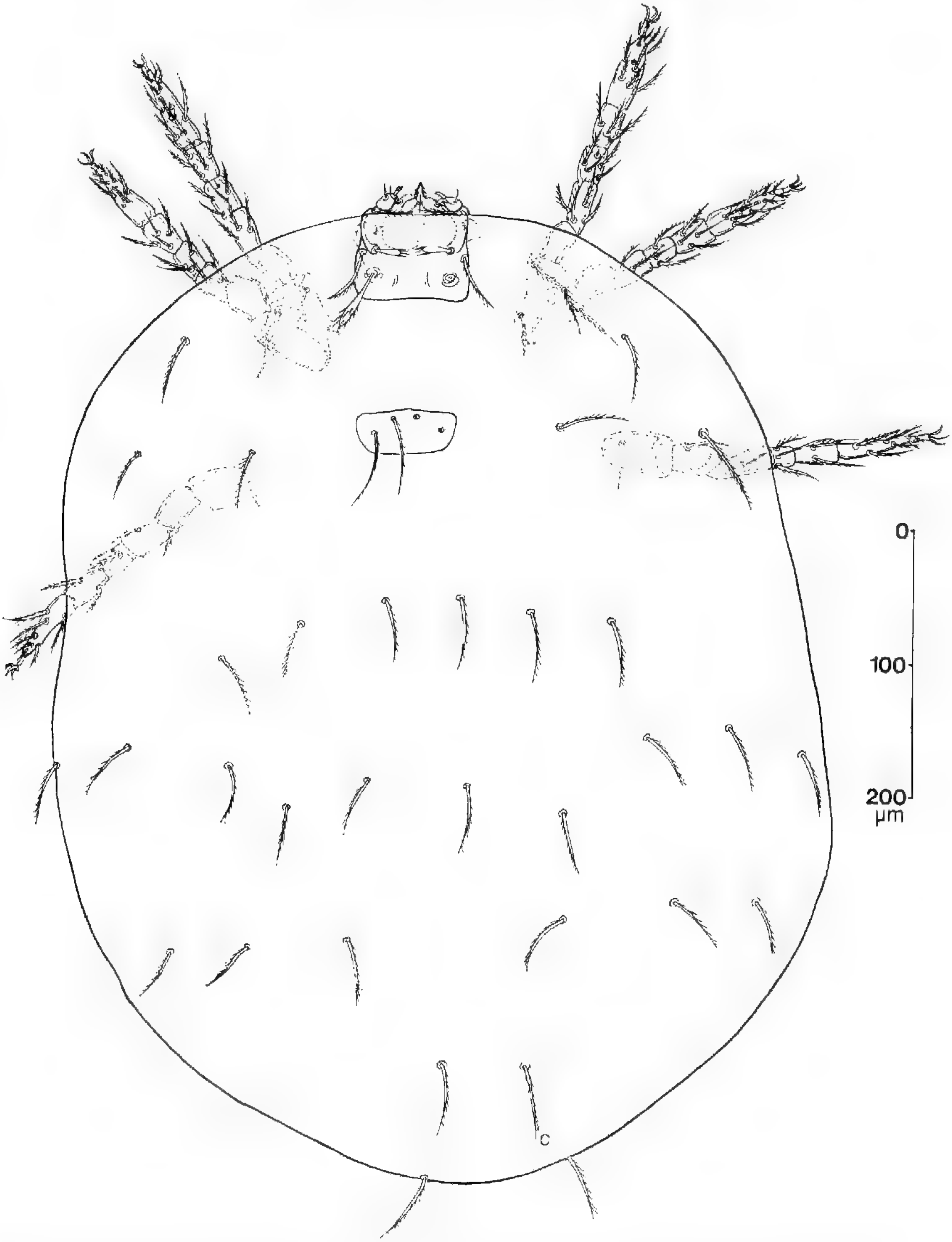

Fig. 1. *Wondeclia centipedae* gen. nov., sp. nov. Larva, holotype. Dorsal view, entire, shown partly in transparency (scutal sensillary seta from another specimen). To scale shown; seta "c" is figured in Fig. 3C.

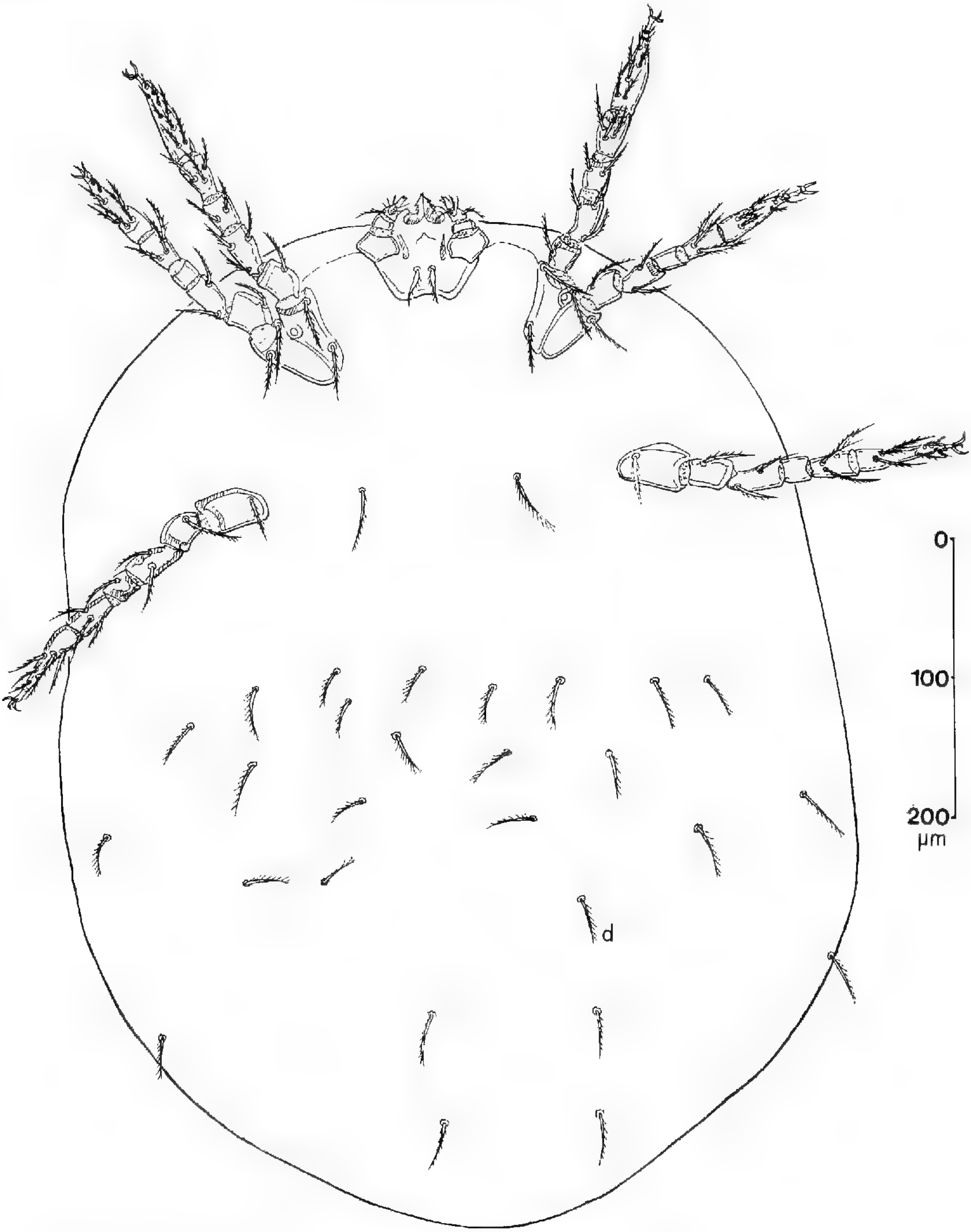

Fig. 2. *Wondeclia centipedae* gen nov., sp. nov. Larva, holotype. Ventral view, entire, to scale shown; seta "d" is shown in Fig. 3D.

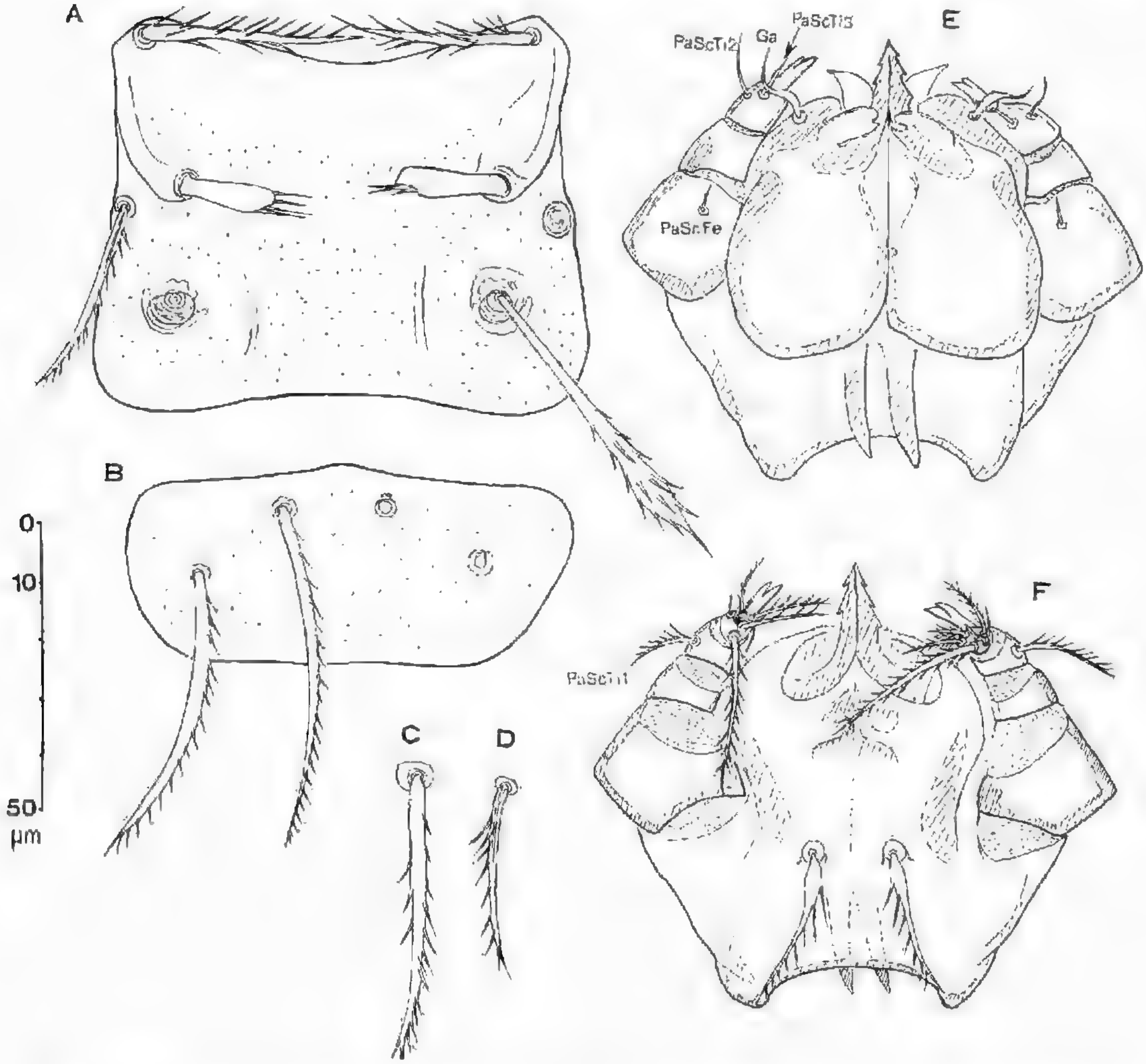

Fig. 3. *Wondeclia centipedae* gen. nov., sp. nov. Larva, holotype. A Anterior dorsal scutum (sensillary seta is from another specimen). B Posterior dorsal scutum. C Dorsal idiosomal seta ("c" in Fig. 1). D Ventral idiosomal seta ("d" in Fig. 2). E Gnathosoma, dorsal aspect. F Gnathosoma, ventral aspect. (All to scale shown.)

blunt-pointed; with a slight split. Palpal supracoxalae absent.

Metric data are provided in Table 1.

Material examined: Queensland: Wondecla, in eucalypt forest, 2.iii.1944, R. V. Southcott; 30 specimens, (South Australian Museum): SAM N19879 (Holotype, also with label ACB613A (RVS)); N198710–198738 (paratypes); ectoparasitic upon centipede SAM A391, *Rhysida nuda* (Newport) (kindly identified by Dr L. E. Koch, Western Australian Museum).

Correlations between shield and leg variates

In continuation of previous studies (Southcott 1966, 1986a, b, c) into the degree of correlation between shield and leg variates in prostigmatic mites; the data of 15 specimens of *W. centipedae* were examined by correlation analysis. The results are shown in Fig. 7.

Among a tabulation of 49 × 49 variates we may expect to find a number of significant correlations by chance alone; half of these should be positive and half negative. In Table 2 are shown the findings for the comparisons, at three levels of probability.

Fig. 7 and Table 2 show that there is a significant excess of positive correlations, and a deficit of negative correlations, from random expectations. There are no negative correlations at the 0.001 level of probability, and only two at the 0.01 level of

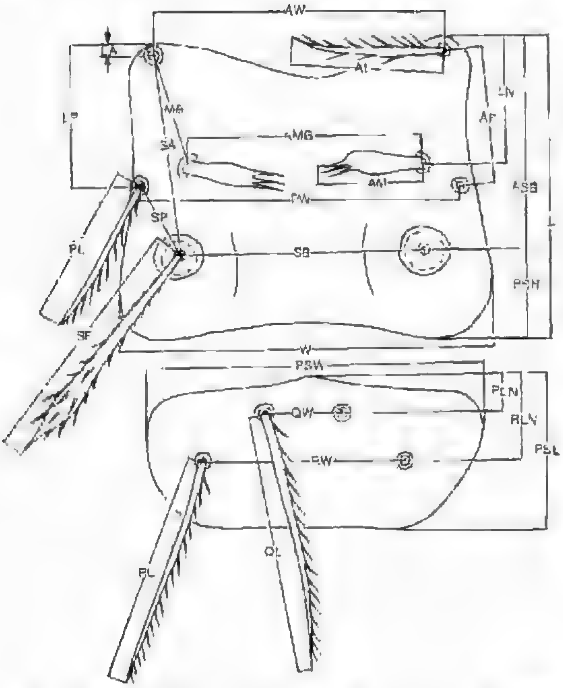

Fig. 4 *Wondeclia centipedae* gen. nov., sp. nov. Interpretation and coding of structures and dimensions of anterior and posterior dorsal scuta.

probability, neither of which relates to the same variate. The negative correlations observed can therefore be ignored.

The positive correlations appear to be scattered more or less evenly through Fig. 7. In Table 3 these significant positive correlations, over 6 groups of variates, are examined by a classification into comparisons between variate groups.

The 1176 correlation coefficients under study are not independent of each other, but approach independence as the sample size increases (see, e.g., Cameron & Eagleson 1985; also Southcott 1986b).

Table 3 shows that at the 0.05 level of probability there is an excess of positive correlations in each of the six groups examined — above twice in every one except that of group 4, of shield × leg variates. Table 3 shows also excesses in the numbers of positive correlations at levels of probability indicating greater significance. The overall degree of correlation appears comparable with that observed in some other trombidioid mites that have been studied for correlations by similar techniques (Southcott 1986b), lying between the levels observed for *Trombella cucumifera* Southcott and *T. rugosa* Southcott. However, as with the findings in *Trombella*, the degree of correlation found is not sufficiently great to inspire confidence in the use of a restricted set of variates for species identifications.

TABLE 1. *Metric data for larvae of* Wondeclia centipedae, *in μm (except proportions).*

Variate	Holotype	n	range	mean	s.d.
LN	30	15	24–31	27.53	1.9223
MA	27	15	22–27	24.67	1.3452
AW	67	15	57–67	62.40	2.5857
PW	73	15	69–76	72.07	2.1536
SB	55	15	49–55	52.67	1.7593
ASB	49	15	40–49	46.80	2.3664
PSH	19	15	16–20	18.00	1.000
L	68	15	58–68	64.87	2.6690
W	83	15	78–86	82.80	2.4260
AP	32	15	28–35	31.73	1.7915
AM	27	15	22–29	26.33	1.7182
AL	40	14	32–41	36.29	2.7296
PL	42	15	40–50	44.20	2.4260
AMB	54	15	47–55	50.13	2.1668
SE	—	3	51–58	54.67	3.5119
LA	3	15	3–5	3.80	0.6761
LP	32	15	8–37	33.27	7.1461
SA	46	15	38–46	43.53	2.2949
SP	18	15	13–18	15.33	1.3452
PLN	7	15	5–8	6.93	0.8837
PSL	35	15	31–35	33.93	1.2799
PSW	74	15	69–81	75.33	3.2878
QW	17	15	16–20	18.13	1.4573
QL	58	15	48–59	54.00	2.9761
RLN	18	15	15–19	17.07	1.2228
RW	46	15	45–56	49.33	3.4157
RL	55	15	49–58	55.13	2.2949
DS (shortest)	39	15	31–44	39.13	3.2704
DS (longest)	55	15	49–56	52.40	2.0976
MDS	55	15	49–56	52.40	2.0976
PDS	51	15	43–51	47.13	2.4456
FeI	40	15	34–40	38.60	1.6818
GeI	29	15	27–29	28.00	0.8452
TiI	34	15	30–36	32.13	1.6847
TaI(L)	62	15	55–63	60.47	2.1336
TaI(H)	17	15	15–20	16.40	1.1212
FeII	35	15	28–36	32.87	2.3563
GeII	25	15	23–26	24.47	0.8338
TiII	31	15	28–31	29.13	1.1255
TaII(L)	54	15	50–55	52.13	1.7265
TaII(H)	15	15	15–16	15.20	0.4140
FeIII	40	15	36–41	37.73	1.5796
GeIII	26	15	22–26	23.60	1.0556
TiIII	35	15	29–35	31.27	1.6242
TaIII(L)	59	15	53–62	58.13	2.2949
TaIII(H)	15	15	13–15	14.27	0.7988
TiI/GeI	1.17	15	1.03–1.33	1.15	0.0774
TiII/GeII	1.24	15	1.08–1.24	1.19	0.0488
TiIII/GeIII	1.35	15	1.21–1.45	1.32	0.0701

TABLE 2. *Correlations in variates for larvae of* Wondeclia centipedae *sp. nov.*

P	+ve correlations		ve correlations	
	Observed	Expected*	Observed	Expected*
0.001	7	1	0	1
0.01	34	6	2	6
0.05	113	29	10	29

*Rounded to whole numbers.

Remarks on the biology of *Wondeclia centipedae*

Since the centipede host was killed on capture, few observations on the biology of its mites could

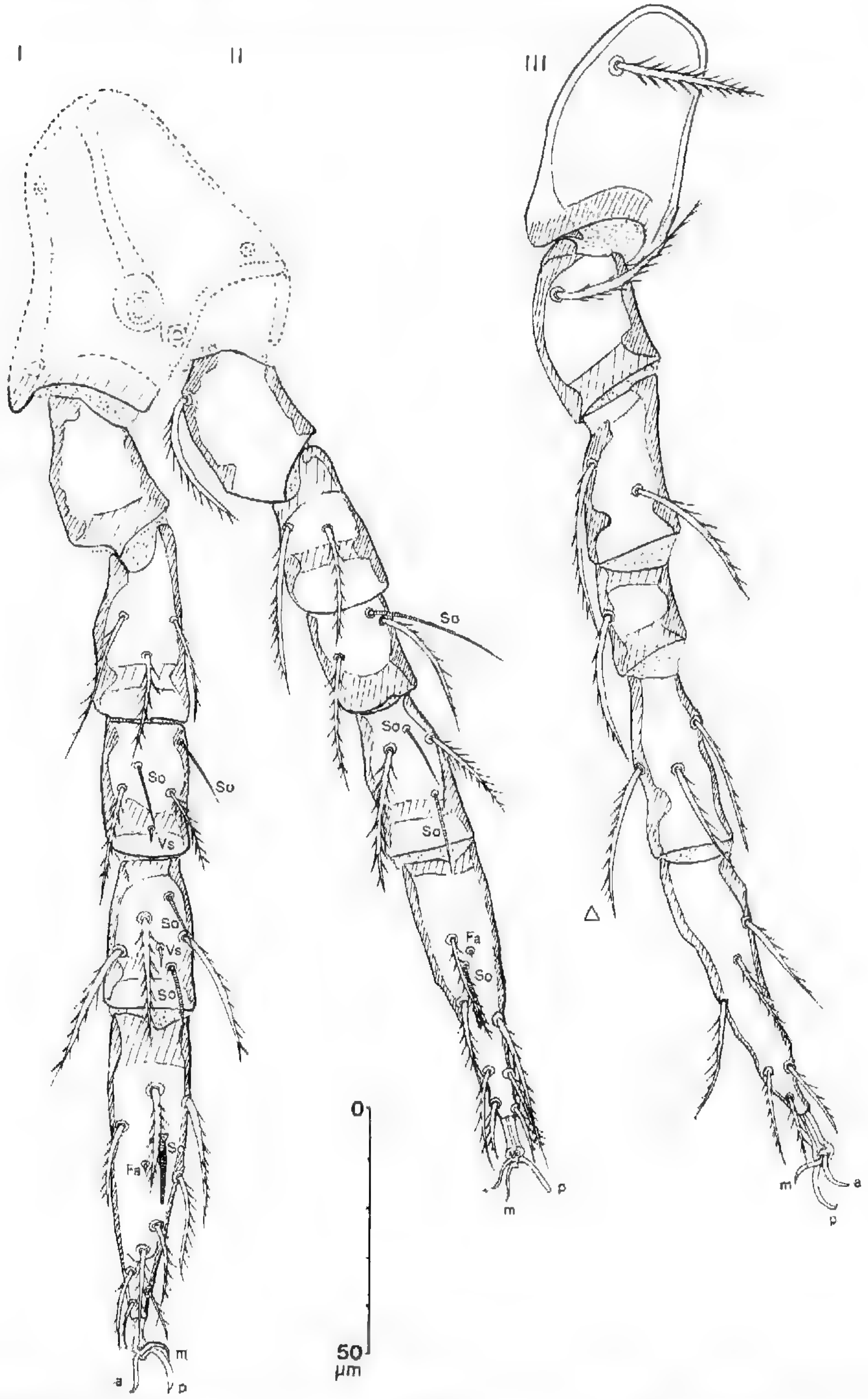

Fig. 5 *Wondeclia centipedae* gen. nov., sp. nov. Larva, holotype. Legs I, II and III, to scale shown, to standard notation. Dorsal aspect of legs I and II, and anterodorsal aspect of leg III.

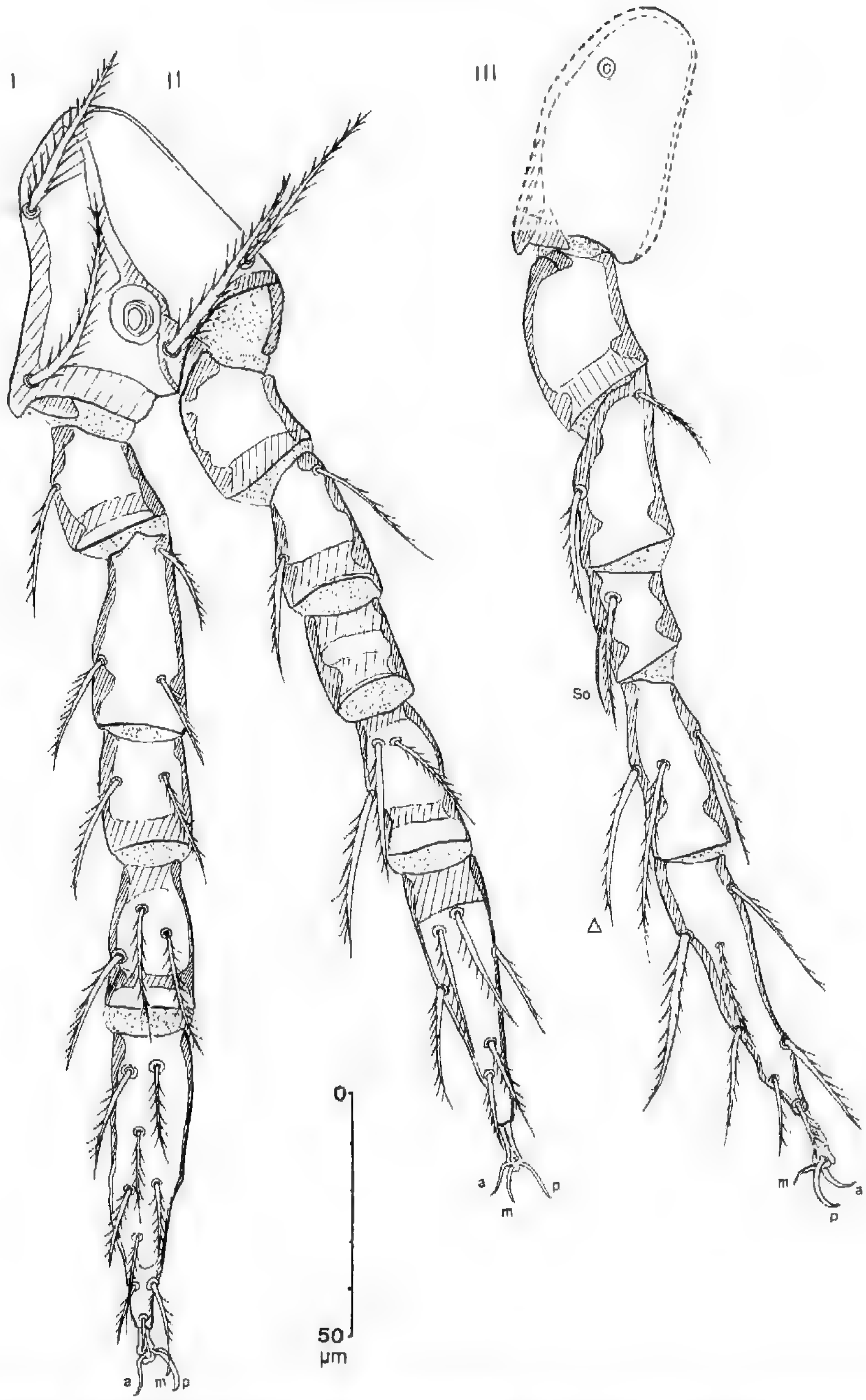

Fig. 6 *Wondeclia centipedae* gen. nov., sp. nov. Larva, holotype. Legs I, II and III, to scale shown, to standard notation. Ventral aspect of legs I and II, and posteroventral aspect of leg III.

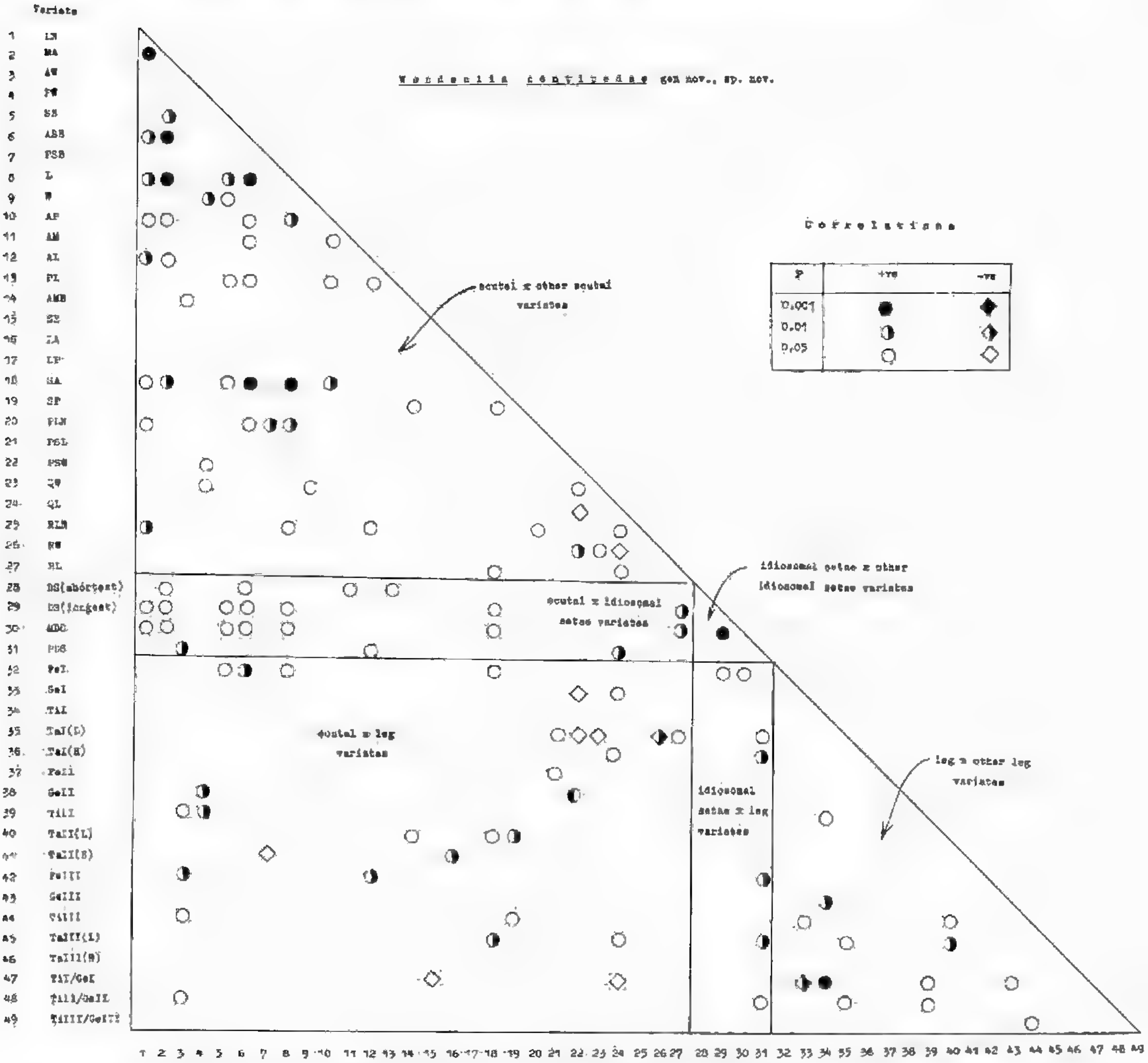

Fig. 7. Correlation matrix of data of *Wondeclia centipedae* gen. nov., sp. nov., for 49 × 49 variates (see text).

be made. The dead centipede and its mites were placed in a tube. Two days later some of the mites were still alive on the host. No particular sites of attachment on the centipede were observed.

The mouthparts of the mites are well-developed for piercing, in fact the cheliceral digits are longer, more pointed, and with more developed barbs than in most trombidioid larvae. Presumably the intersegmental membranes of the centipede would offer least resistance to puncture.

The absence of eyes in a larval trombidioid is unusual, and is consistent with a hypothesis that this larva is well-adapted to a life of parasitism upon a nocturnal and soil- and litter-inhabiting host. The flattened idiosoma of the mites may be compared, for example, with that of the trombiculid mite genus *Babiangia*, an ectoparasite upon smooth-skinned skinks (Southcott 1954). Possibly such flattening is an adaptation to a mode of life in a restricted space on a flexible, soil-inhabiting host, and might reduce the risk of being wiped off as the centipede moves through soil and litter.

Acknowledgments

I thank Mr L. G. Veitch, Principal Research Scientist, CSIRO Division of Mathematics and Statistics, for aid and advice in statistical analysis

TABLE 3. *Classification of positive correlations between variates in larvae of* Wondeelia centipedae, *for observed and expected values.*

Variate groups compared	Number of comparisons available	Observed numbers			Expected numbers
				P	
		0.001	0.01	0.05	0.05
1. Shield × other shield variates	351	6	19	48	8.78
2. Shield × idiosomal setae variates	108	0	4	21	2.7
3. Idiosomal setae × other idiosomal setae variates	6	1	1	1	0.15
4. Shield × leg variates	486	0	9	24	12.15
5. Idiosomal setae × leg variates	72	0	3	7	1.8
6. Leg × other leg variates	153	1	2	11	3.83
Totals	1176	8	38	114	29.4

and the Australian Biological Resources Study for support.

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NEW FRESHWATER DIATOM TAXA FROM TROPICAL NORTHERN AUSTRALIA

by DAVID P. THOMAS*

Summary

THOMAS, D. P. (1987) New freshwater diatom taxa from tropical northern Australia. *Trans. R. Soc. S. Aust.* **111(1)**, 53-58, 29 May, 1987.

Two new taxa were discovered during a study of freshwater diatoms from the Alligator Rivers region of the Northern Territory. *Achnanthes pseudohungarica* sp. nov. is differentiated from *A. hungarica* by the presence of the horseshoe-shaped area on the raphe valve instead of the rapheless valve. *Eunotia didyma* var. *maxima* f. *tumida* f. nov. varies from the nominate variety by having a consistently smaller length to breadth ratio.

Both taxa appear to have a limited distribution within the Alligator Rivers region with the *Achnanthes* having been found also in the East Finnis River further to the west.

KEY WORDS: *Achnanthes*; *A. pseudohungarica* sp. nov.; *Eunotia*; *E. didyma* var. *maxima* f. *tumida* f. nov.; tropical Australia; freshwater; Bacillariophyta.

Introduction

The two taxa described herein were found during a general survey of the freshwater diatoms of tropical Australia between 1979 and 1981. More than 160 taxa from 32 genera of diatoms were identified from the survey (Thomas 1983).

The climate of this region exhibits a typical tropical alternation between periods of extreme drought and periods of monsoonal rain. These lead to rivers varying from a series of disconnected pools during the "dry" to components of sheets of water, often several metres deep, which cover thousands of square kilometres of Australia's north coast during the "wet". Such extreme environmental variation provides a wide range of growth environments for algae and a greater regional algal diversity compared to the more temperate areas of Australia.

Methods

Field samples were preserved as soon as possible in 10% formalin (usually within an hour). Subsamples were then cleared using 50% nitric acid at 60°C for 12 hours (Crawford 1971). The material was then rinsed of acid by repeated dilutions in distilled water before being transferred to absolute ethanol for storage.

Samples were prepared for light microscopy by evaporating off the ethanol from a suspension of cells placed on a coverglass at 90°C on a hotplate. The coverglass was then mounted on a slide using CAEDEX (MERCK), a synthetic Canada Balsam. The slides were examined and specimens photographed with the aid of a Zeiss PM2 photomicroscope.

For scanning electron microscopy, coverglasses with the dried suspension were mounted onto SEM stubs and sputter coated with gold before being viewed with the aid of a Philips 505 SEM.

Terminology follows that of Anonymous (1975), von Stosch (1975) and Ross *et al.* (1979).

Systematics

Achnanthes pseudohungarica sp. nov.

FIGS 1-5

Valvae lanceolatae, 14-45 μm longae, 5-13 μm latae. Striae 21-25 in 10 μm, ad centrum parallelae, versus polos leviter radiantes. Areovalva: area axialis circa 1 μm lata, recta, inter polos secus lineam mediam formata, saepe crista angusta longitudinali secus lineam mediam. Raphovalva: area axialis recta, ad polos circa 1 μm latos, versus centrum inflata area 4 μm lata et 7 μm longa formans. Area centralis rhombea, sed area hippocrepica in late uno. Raphe recta, in lineam mediam areae axialis formata, spatio 2 μm longo ad nodulum centralem.

Description: Valves lanceolate, length 14-45 μm and width 5-13 μm. Striae 21-25 in 10 μm, varying from parallel at centre to slightly radiate towards the poles.

Rapheless valve: Axial area approximately 1 μm wide, straight, formed between poles along the centre line, often with a narrow longitudinal ridge formed externally along the centre line of the area.

Raphe valve: Axial area straight, varying from approximately 1 μm wide at the poles and inflating into a central area 4 μm wide and 7 μm long. The central area is rhomboid but with a horseshoe-shaped area on one side. The raphe is straight,

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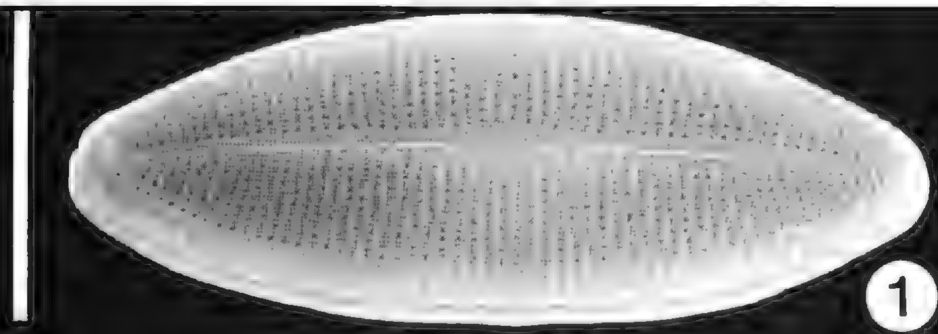

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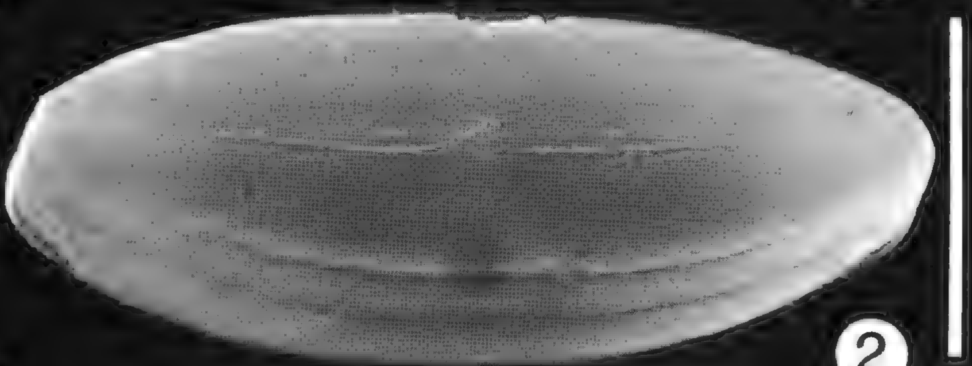

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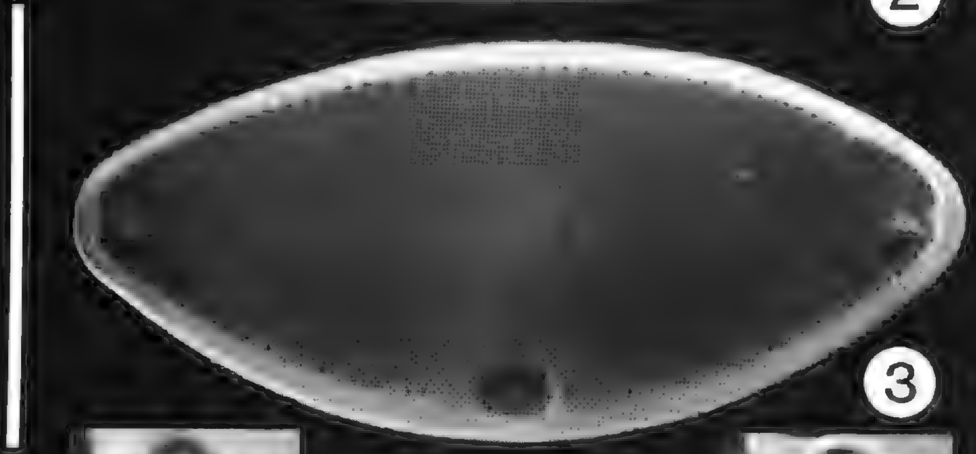

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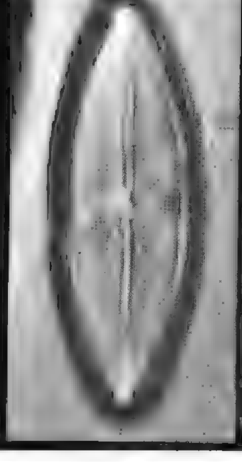

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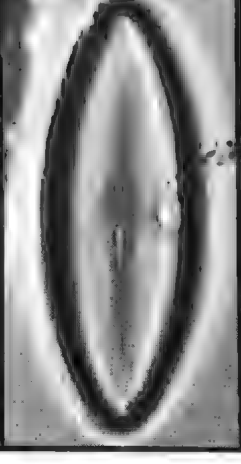

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formed in the central line of the axial area and with a 2 μm gap at the central nodule.

Holotype: D930 (D. P. Thomas' collection, Tasmanian Herbarium—HO 101052), collected by *K. Bishop* on 28.ix.1979 at Magela Falls, N.T. (12°47′12″S, 133°06′07″E) in slightly acid, freshwater splashpool at the base of Falls.

Distribution: Also found in Bowerbird, Gulungul and Nankeen water holes from the Magela Creek and from Rum Jungle on the East Finnis River, Northern Territory (see Thomas 1983).

With the aid of the scanning electron microscope (Fig. 2) it is evident that the cingulum is composed of the valvocopulae alone and that these are open and apparently unstructured.

Eunotia didyma var. ***maxima*** f. ***tumida*** f. nov.
FIGS 6–8

Valvae formam maximam *similes, sed abbreviatae et plus inflatae, polis obtusioribus (50° vs 42°) et ratione longitudinis versus latitudinem reducta (2.4 vs 3.7). Valvae 76–110 μm longae et 38–44 μm latae.*

Description: Valves similar to *E. didyma* var. *maxima* Hustedt 1913 (Fig. 6) but shorter and more inflated with less acute poles (50° *vs* 42°) and a reduced length to breadth ratio (*ca.* 2.4 *vs* 3.7). Valves range from 76–110 μm long and 38–44 μm wide.

Holotype: D868 (D. P. Thomas' collection, Tasmanian Herbarium—HO 101051) collected by *D. Thomas* on 19.viii.1979 at Jim Jim Falls, N.T. (13°16′34″S, 132°50′12″E) in slightly acid, freshwater splashpool at the base of Falls.

Distribution: Has not been observed outside the type locality.

Scanning electron microscopy (Fig. 8) shows that the valve is ornamented with irregularly arranged, brief, broad based spines. The cingulum is composed of a valvocopula and up to three pleurae with all elements open. The valvocopula has fine vertical striae (ca. 30 in 10 μm) while the pleurae appear to be unstructured.

Discussion

Achnanthes pseudohungarica is similar to *A. hungarica* (Grunow 1863) Grunow *in* Cleve & Grunow (1880) except that the horseshoe-shaped area is formed on the raphe valve of *A. pseudohungarica* and on the rapheless valve of *A. hungarica.* This is the same feature which was used to differentiate *A. pseudolanceolata* Manguin (1962) (*non* Hustedt 1952) and *A. lanceolata* (Brébisson *in* Kützing 1849) Grunow *in* Cleve & Grunow (1880). In addition, *A. hungarica* has a lower strial density (16–22 in 10 μm *vs* 22–25 in 10 μm) and *A. pseudohungarica* does not have a narrow stauros on either valve.

The absence of *A. hungarica* from this region combined with the wide distribution of *A. pseudohungarica* make in unlikely that this is just a mutant variant of the latter and can be considered a stable species. On the other hand, the very narrow distribution of *Eunotia didyma* var. *maxima* f. *tumida* and the presence of its nominate variety in the same and adjacent water holes makes me very reluctant to raise it to a higher status than that of forma.

Acknowledgments

Grateful thanks are extended to Dr Peter Tyler and the members of the Botany Department, University of Tasmania who participated in the field studies upon which this paper is based and made odd collections in out of the way places. The same can be said of Mr Keith Bishop from the N.S.W. State Fisheries who collected the type sample of *A. pseudohungarica.* The Latin diagnoses were provided by Dr Tony Orchard, Director of the Tasmanian Herbarium and the manuscript was critically read by Dr Tyler. This work was supported by a grant from the Office of the Supervising Scientist East Alligator Rivers Region and the use of their facilities at Jabiru.

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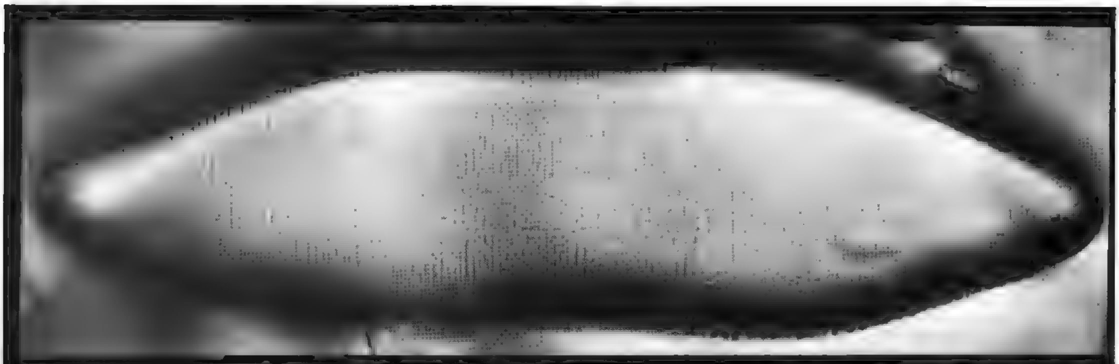
Figs 1-5. *Achnanthes pseudohungarica* sp. nov. 1. SEM of external surface of the rapheless valve. 2. SEM of external surface of the raphe valve showing lack of external opening of the horseshoe shaped area and the valvocopula. 3. SEM of internal surface of the raphe valve showing the internal opening of the horseshoe shaped area. 4. LM of the rapheless valve (Holotype slide HO 101052). 5. LM of raphe valve (Holotype slide HO 101052). All scales 10 μm.



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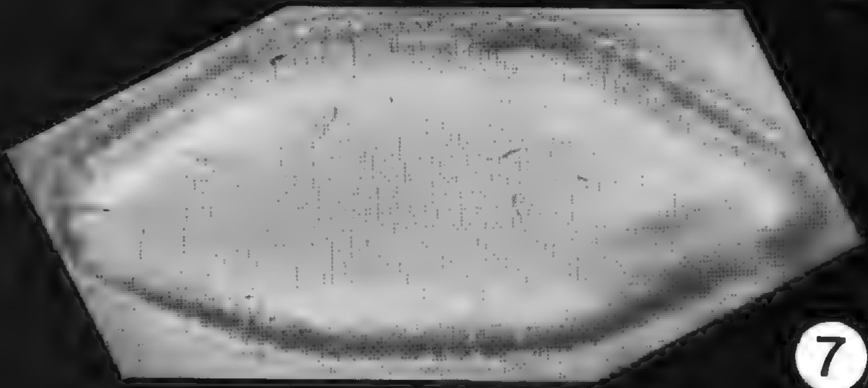

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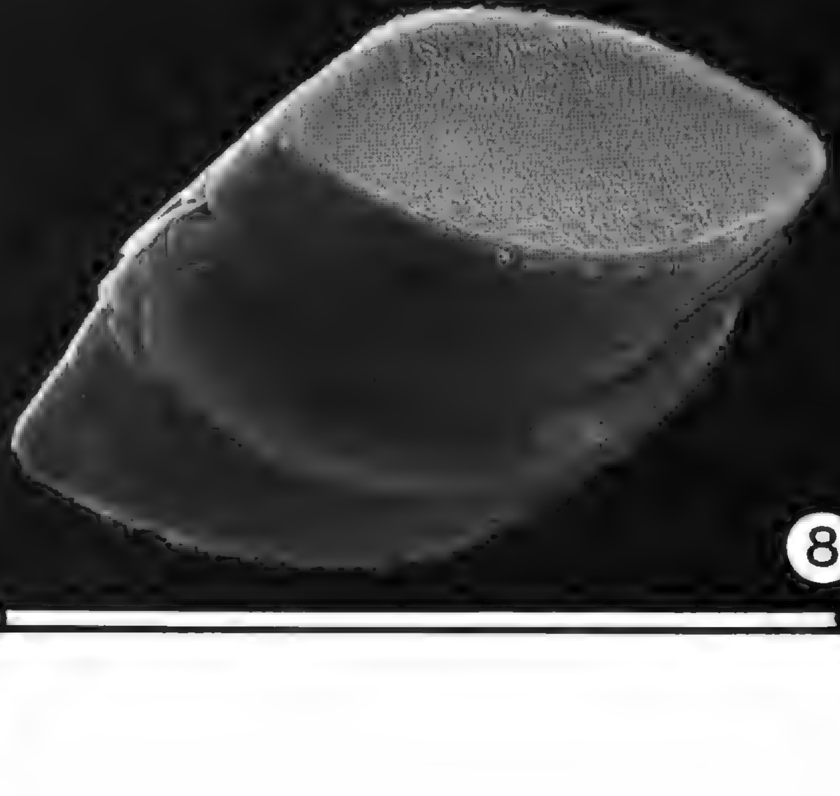

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Zweite Folge. *Verhandlungen der kais.-königl. zool.-bot. Gesell. Wien* **13**, 137-162, Plates 13-14.

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Figs 6–8, 6. LM of *Eunotia didyma* var. *maxima* from sample no. 868. *Eunotia didyma* var. *maxima* f. *tumida* f. nov. 7. LM of valve (Holotype slide HO 101051), 8. Oblique SEM of dividing frustule showing raphe, girdle structure and marginal spines. Scale 100 μm.

FEEDING AND GROWTH OF GOLDEN PERCH LARVAE AND FRY (MACQUARIA AMBZGUA RICHARDSON)

*BY P. T. ARUMUGAM & M. C. GEDDES**

Summary

Golden perch larvae were stocked into an earthen pond and grew exponentially from a mean standard length 4.5 mm (dry weight 0.16 mg) to a mean of 31 mm (165 mg) in 46 days from 12 November until 28 December, 1984. The growth coefficients were 0.04 mm mm^{-1} day^{-1} for length and 0.15 mg mg^{-1} day^{-1} for weight. The mouth gape was related to length. At first feed the type and size of prey was restricted by poor swimming and pursuit abilities and small mouth gape. Larvae and fry greater than 10 mm standard length were able to pursue a wide range of zooplankters but feeding was limited by mouth gape. The daily food consumption of larvae and fry increased from 33 to 5600 µg dry weight per day. Because of the relatively small size of golden perch larvae at first feed, survival is dependent upon a high density of appropriate sized zooplankters.

KEY WORDS: Fish, larvae, fry, *Macquaria arnbigua*, feeding, growth, mouth gape.

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KEY WORDS: Fish, larvae, fry, *Macquaria ambigua*, feeding, growth, mouth gape.

Introduction

The golden perch (*Macquaria ambigua* Richardson) belongs to the Percichthyidae, a group of fishes which includes both freshwater and marine representatives. *M. ambigua* occurs throughout the Murray-Darling system except at higher altitudes, in the Lake Eyre and Bulloo-Bancannia drainage systems and the Dawson-Fitzroy River system in eastern Queensland (Lake 1971; MacDonald 1978; Llewellyn & MacDonald 1980; Merrick & Schmida 1984). These references cite the occurrence of *M. ambigua* in coastal streams in northern New South Wales, but there are no self-maintaining populations in these drainages (Rowland pers. comm.).

Little is known about the biology and ecology of golden perch larvae and fry in the natural environment. An upstream spawning migration is initiated by water level rises at the onset of major floods (Reynolds 1983). The semi-buoyant eggs are probably carried downstream by the flood waters with the larvae hatching and drifting in the water, before entering shallow floodplain areas and "billabongs", which probably act as nursery grounds (cf. Lake 1967a; Rowland 1983; Rowland pers. comm.). These floodplain areas receive nutrients and allochthonous materials that promote increases in plankton and other organisms essential for survival of the larvae and fry (cf. Shiel 1980; Maher 1984; Briggs *et al.* 1985). In many areas dams and weirs have blocked spawning migrations, lowered water temperatures by discharging colder water from the deeper water layers of dams and reduced flooding which is necessary to induce spawning and provide suitable conditions for the pelagic eggs and space and planktonic food for the young fish (Lake 1971; Reynolds 1976; Cadwallader 1978; Pollard *et al.* 1980; A.R.I.E.R. 1983).

Much of the available information on golden perch larvae and fry comes from research into spawning and larval rearing carried out at the Inland Fisheries Research Station (I.F.R.S.), Narrandera (Lake 1967a, b; Rowland 1983, 1986a, b; Rowland *et al.* 1983). Golden perch are induced to spawn using human chorionic gonadotrophin and the larvae are reared in earthen ponds from first feed until they are about 25 to 30 mm standard length, usually a period of 25 to 35 days. Lake (1967b) observed that the stomach contents of larvae at first feed consisted of cladocerans, copepods and phytoplankton.

The present study was conducted at the I.F.R.S. The main objectives of this study were to describe the growth characteristics of the golden perch larvae in rearing ponds, to investigate the behaviour and ecology of the larvae and fry in relation to feeding, and to measure daily food consumption of the different size larvae and fry. The description of growth involved the determination of length-weight relationships and the estimation of the growth rate of golden perch in a rearing pond. Particular emphasis was placed on the relationship between length and mouth gape, as mouth gape determines the size of prey that can be taken (Shirota 1970). This information, in conjunction with that on feeding behaviour and daily food consumption will provide useful guidelines to the conditions required for survival and growth in golden perch larvae.

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Methods and Materials

Growth Characteristics

Larvae and fry were caught from a rearing pond at I.F.R.S. over a period of 46 days from 12 November–28 December, 1984. They were killed with an overdose of soda water, standard and total lengths were measured, wet weights were determined and then they were dried in an oven for 24 hours at 60°C, and dry weights measured. To establish the power relationships between weight and length, linear regressions were performed on the log transformed data of both lengths and weights (Bagenal & Tesch 1978). For the total length-standard length and dry weight-wet weight relationships, regressions were performed on untransformed data. The growth rates of the larvae and fry in the pond were analysed by establishing standard length-time and dry weight-time relationships. An exponential model gave the best fit and so both standard length and dry weight measurements were log transformed. Mouth gape and standard length were measured for about 450 specimens collected during 1983 and 1984 and preserved with formalin. The mouth gape was measured as the external distance between the two corners of the mouth when shut. The regression of mouth gape and standard length was performed without transformation.

Behaviour

Observations on feeding and territoriality were made on fry from first feed to about 30 mm standard length either alone in 250 ml capacity beakers or in groups of 10–15 in 70 l aquaria. The larvae were fed with brine shrimp (*Artemia*), using the nauplii for the smaller larvae and adults for the larger larvae and fry. Zooplankters and chironomid larvae were occasionally fed to the larvae and fry. Cover was provided in the form of a 30–40 mm length of opaque, plastic tubing with 2.5 mm internal diameter for the smaller larvae and a 60–70 mm length of tube with internal diameter of 3.0 mm for the larger fry (25–30 mm). One cover was provided for the fry held singly and the number of covers was about two-thirds the number of fry for the group study. The study was carried out at 20–24°C under daylight conditions.

Daily food consumption

The daily food consumption of a fish, estimated as the number of food items supplied over 24 hours minus the number of items remaining (cf. Gophen 1980), was estimated for size classes of 4.5 (= first feed), 10, 20 and 30 mm standard length. Freshly hatched brine shrimp nauplii (length: 400–600 μm) were used as food except for the 30 mm fry where *Daphnia carinata* (length: 1600–2320 μm) were used because of the enormous number of brine shrimp nauplii that would have been required. The feeding regime involved small numbers of food items being fed to the larvae and fry at a time, the next feed being given when only a few food items remained. Three to six feeds were required over the 24-hour period. For the feeding trials, five different individuals of a particular size were placed simultaneously in separate beakers which received circulating filtered pond water at 20–22°C. The fry were not starved prior to commencement of feeding trials and a tube was provided as a refuge for the fry. The daily food consumption was expressed as number of items and as μg dry weight consumed per day. Dry weights of brine shrimp nauplii and *Daphnia* were obtained from weighing a known number of oven-dried specimens at 60°C and obtaining the weight per individual brine shrimp nauplius (2.55 μg) or *Daphnia* (20 μg).

Results

Larvae at first feed were 4.4–4.6 mm standard length (mean 4.5 mm) (total length = 4.5–4.7 mm; mean 4.6 mm) with a dry weight of 0.14–0.18 mg (mean 0.16 mg) (wet weight = 0.47–0.58 mg; mean 0.52 mg). Their mouth gape at first feed was 0.5 mm. After 46 days in the rearing pond, they reached 30–31.6 mm (mean 30.6 mm) standard length with a dry weight of 154–195 mg (mean 165 mg) (wet weight = 667–743 mg; mean 691 mg). The regression equations describing length-weight relationships, the relationship between length and mouth gape and the growth rate of fry and their correlation coefficients are given in Table 1. The correlation coefficients of all pairs of relationships are highly significant. In the length-weight relationships, regression coefficients (= slopes) ranged from 3.29–3.72 and for this range growth is considered allometric (cf. Bagenal & Tesch 1978). The standard length of the fry was directly proportional to the total length and dry weight was linearly related to wet weight. The exponential growth in both standard length and dry weight are shown in Fig. 1. The growth coefficients for standard length and dry weight were 0.04 mm/mm day and 0.15 mg/mg day respectively (Table 1). The mouth gape of the fry was directly proportional to their standard length with a slope of 0.13 (Fig. 2).

The larvae at first feed swam freely in the water column. They exhibited an innate feeding behaviour of darting forward and gulping even when no food particles were present. After two to three days of feeding, larvae could follow and capture brine shrimp nauplii. Efficiency in capturing *Moina* was lower. When the golden perch were 10 mm and

TABLE 1. *Regression equations, intercepts (a), slopes (b) and correlation coefficients (r) for weight-length, standard length-total length, wet weight-dry weight, mouth gape-standard length, dry weight-time and length-time relationships in golden perch.* (N = number of data pairs; CL = 95% Confidence Interval; $P>0.01$; DW = dry weight (mg); WW = wet weight (mg); SL = standard length (mm); TL = total length (mm); MG = mouth gape (mm); T = time (days); e = exponential).

Y	X	N	Equation	a	b (+/– 95% CL)	r
DW	SL	29	$Y = a X^b$	7.5×10^{-4}	3.61 (0.10)	0.997***
DW	TL	29	$Y = a X^b$	1.1×10^{-3}	3.29 (0.08)	0.998***
WW	SL	29	$Y = a X^b$	2.9×10^{-3}	3.72 (0.18)	0.993***
WW	TL	29	$Y = a X^b$	3.8×10^{-3}	3.39 (0.13)	0.995***
WW	DW	29	$Y = a + b X$	7.98	4.09 (0.14)	0.996***
SL	TL	29	$Y = a + b X$	0.78	0.79 (0.01)	0.999***
MG	SL	415	$Y = a + b X$	0.23	0.13 (0.10)	0.984***
DW	T	9	$Y = a e^{bx}$	0.22	0.15 (0.10)	0.991***
SL	T	9	$Y = a e^{bx}$	4.81	0.04 (0.0046)	0.992***

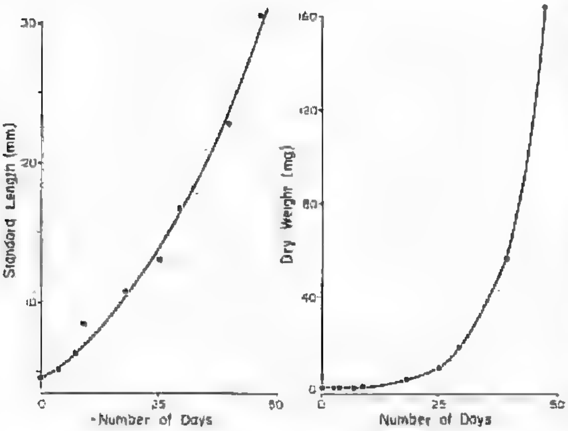

Fig. 1. The growth in length and weight of golden perch larvae and fry from release into the pond on 12 November until harvest on 28 December 1984. The points represent mean values from 3 to 5 fish on each sample date.

greater, they preferred cover when kept alone or in groups and exhibited territoriality. They stayed inside their tube, with part of their head up to the eye level protruding, coming out to feed or to chase other larvae or fry away. When disturbed, they would temporarily retreat inside the tube. When a larger tube was provided, two to three fry sometimes shared it. In group experiments those fry that did not have cover stayed in the water column or at the bottom of the container away from "defined" territories. When food supply was low, the fry in covers were healthier and had more convex bellies than fry without cover, and with continued low food availability mortalities occurred first in fry without cover. Larvae and fry of 10 mm and greater could pursue cladocerans and copepods with ease but the size of prey engulfed was limited by their mouth gape. They attacked very large *Daphnia* but released them as they were too big to swallow. Individuals could slowly engulf a chironomid larva width-wise until the whole larva was swallowed.

The larvae at first feed, ate 7–21 brine shrimp nauplii per day (mean 13), 10 mm larvae ate 240–251 nauplii (mean 247), while 20 mm fry ate 790–1631 nauplii per day (mean 1110). The 30 mm fry ate 141–423 *Daphnia* per day (mean 280). The daily food consumption of larvae and fry ranged from 33–5600 μg dry weight per day and was directly proportional to the standard length of the fish (r 0.899), ($p<0.05\%$) (Fig. 3). There was a large individual variation in daily food consumption as indicated by the spread of the points on the graph.

Discussion

Size at first feed is a critical feature of the biology of larval fish but there is only limited information on the size at first feed of Australian freshwater fish (Table 2). It is clear that golden perch, along with two other large Australian freshwater fish that lay

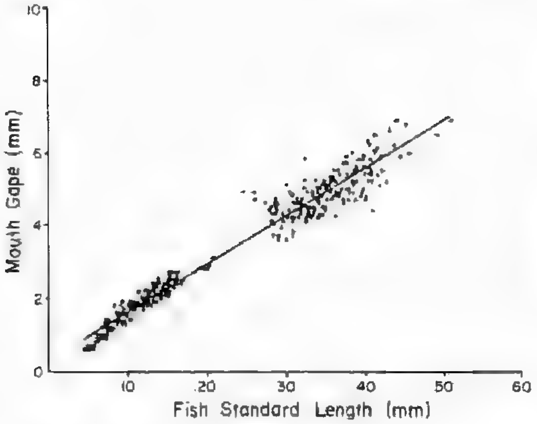

Fig. 2. The relationship between standard length and mouth gape for golden perch larvae and fry from first feed to 50 mm standard length.

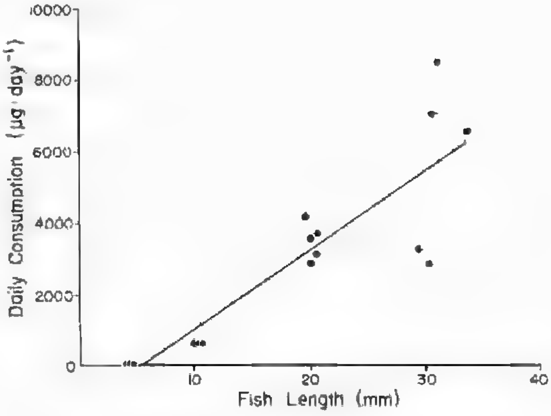

Fig. 3. The daily food consumption (μg dry wt. day^{-1}) of golden perch larvae and fry held in the laboratory and fed brine shrimp nauplii or *Daphnia*.

small pelagic eggs, silver perch (*Bidyanus bidyanus*) and silver barramundi (*Lates calcarifer*), possess larvae that are particularly small at the time of first feed. By comparison the larvae of fish such as Murray cod (*Maccullochella peeli*) and freshwater catfish (*Tandanus tandanus*) that lay demersal eggs are up to three times longer than *M. ambigua* larvae, while those of buccal incubating saratoga (*Scleropages leichardti*) and fork tailed catfish (*Arius graeffei*) are up to seven times longer than golden perch larvae at first feed. The small size of the golden perch larvae presents problems for feeding and survival similar to those faced by the larvae of marine fishes during the "critical period" of larval mortality (May 1974). Another percicthyid that breeds in fresh water, the North American striped bass *Morone saxatilis*, has larvae that are only 3.1 mm at hatching and 6–7 mm at the time of first feed and face survival and feeding problems similar to those of golden perch (Doroshov 1970).

The allometric growth form of the fry indicates that golden perch change their body form as they grow. This is consistent with the observation that golden perch fry acquire adult features very early in their development from when the fry are about 11 mm total length (Llewellyn & MacDonald 1980).

TABLE 2. *Total length (TL in mm), size of mouth gape (MG in mm) at first feed and initial food items of the larvae of some Australian fishes.*

Species	TL	MG	Food items	References
Macquaria ambigua	5.5	—	small copepods/cladocerans (<500 microns), algae.	Lake (1967b), Rowland (1986a)
	4.7–4.9	0.5	mainly small *Moina/Daphnia*	This study
Maccullochella peeli	12	—	chironomid larvae, *Daphnia*, copepods	Lake (1967b)
Bidyanus bidyanus	5.5	—	mainly filamentous algae/ phytoplankton	Lake (1967b)
	4.6–5.4	0.4	mainly filamentous algae/rotifers	Arumugam (unpubl.)
Tandanus tandanus	13	—	plankton	Lake (1967b)
Arius graeffei	50–59	—	microcrustaceans, insect larvae, filamentous algae	Rimmer (1985)
Scleropages leichardti	35	—	—	Lake (1971)
Lates calcarifer	3.5–4.5	—	—	Moore (1982)
	—	—	rotifers/algae	M. Mackinnon (pers. comm.)
Cyprinus carpio	6.4	0.55	—	B. Pierce (pers. comm.)
	—	—	small cladocerans/copepods	
Perca fluviatilis	7	—	—	Lake (1967b)
	—	—	algae, ciliates rotifers, cyclopoid nauplii	Guma'a (1978b)

Data from I.F.R.S. shows that metamorphosis from the larva to the fry stage is completed when fish are about 15–18 mm, 20–29 days after spawning (Rowland pers. comm.).

The growth curves for both length and weight of the golden perch in the present study were best described by an exponential relationship with time. The exponential curve also fitted both length-time and weight-time regressions for the first growth stanza of a wild population of *Perca fluviatilis* fry (Guma'a 1978b) but other workers have found that while growth by weight might be exponential, length increases linearly. Thus Swanson & Ward (1985) found that the best fit for total length-time regression curve for walleye (*Stizostedion vitreum vitreum*) was achieved with untransformed data and A.R.I.E.R. (1983) assumed linear length-time relationships for common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*) and redfin. However in these studies, the sampling intervals were so far apart, especially in the earlier larval phase, that any possible exponential relationship during the early growth phase would have been obscured. The exponential rate of growth of golden perch larvae and fry (0.15 mg mg^{-1} day^{-1}) can be compared to the growth rate of fish fry and juveniles, expressed as % increase in weight per day, reviewed by Brett (1979). Growth rates varied from less than 1% to as high as 23% for small (5 mm) *Cyprinodon macularis*. Most figures for various fish under good conditions were between 1 and 5%. The value of 15% for golden perch in the present study represents relatively a high rate of exponential growth. This is not surprising as the golden perch were very small and were in a pond that was fertilized and managed to promote maximum survival and growth.

The mouth gape of the larvae at first feed is important because it determines the size of food items that can be taken during this critical period. Shirota (1970) showed that mouth size of marine fish larvae at first feed ranged from 200 to 1000 μm and that the range of prey was related to mouth size. In many fish, the size of prey eaten has been shown to change with growth and the associated increase in mouth gape (Shelbourne 1962; Einsele 1965; Shirota 1970; Wong & Ward 1972; Siefert 1972; Guma'a 1978a; Townsend 1983). Therefore comparisons between the mouth gapes of different length golden perch larvae and fry and the array of common zooplankters in the rearing ponds will indicate the food items that can be taken by different sized fish (Fig. 4). The larvae at first feed are smaller than large *Daphnia carinata* and chironomid larvae. Their mouth gapes are similar to or larger than the smallest *Daphnia*, small *Moina*, copepodites, cyclopoids, copepod nauplii

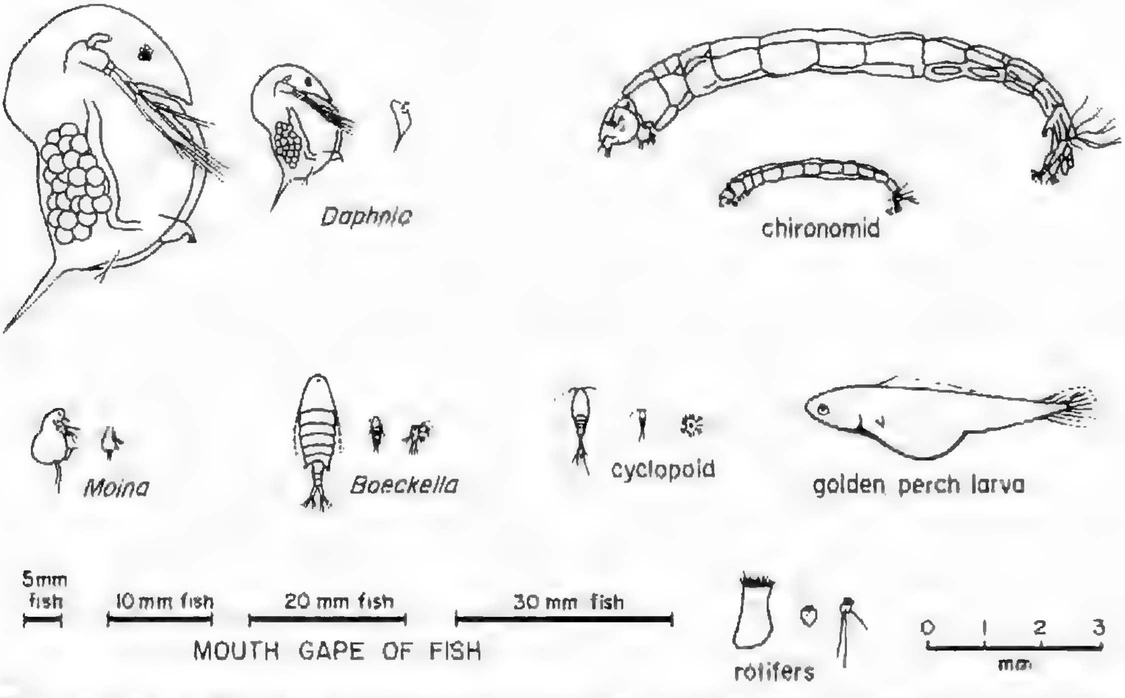

Fig. 4. Relative sizes of the development stages of some common zooplankters and insect larvae in the fry rearing pond, golden perch larva at first feed, and the mouth gapes of golden perch larvae and fry of different standard lengths.

and rotifers, making them all potential prey. The potential prey size increases as the fry grow. At 30 mm standard lengh, the mouth gape of golden perch is similar to or larger than the largest *Daphnia* available in the plankton.

The observations on feeding behaviour suggest that golden perch larvae at first feed would have a relatively poor capture efficiency. For striped bass at first feed the estimated strike efficiency on *Artemia* nauplii was only about 2% (Miller 1977 in Setzler *et al.* 1980). More mobile zooplankters would be less prone to being captured. Cladocerans are more sluggish and more conspicuous than other zooplankters such as copepods and would be more prone to being eaten by the larvae (Zaret 1980). The feeding efficiency of the golden perch larvae improved very rapidly and after 2 to 3 days they were able to follow slow-moving brine shrimp nauplii and capture them with ease. At 10 mm, they were agile and fast enough to attack any cladocerans, copepods, or chironomid larvae. Being a faster swimmer with good escape responses (Zaret 1972) would not be an effective strategy for a prey at this stage. The speed and agility of the fry meant that once they visually sighted their prey, capture was inevitable. In fact, zooplankton that are faster swimmers and cover a greater distance (e.g. copepods) may become more prone to being predated because the probability of encountering the fish would be greater (Townsend 1983).

Although there was a high correlation between daily food consumption and standard length of the fry, variability of daily food consumption for the larger fry was high. Fry used in feeding trials were individuals recently caught from the pond and so different growth histories and different levels of satiation may have contributed to high variability (Elliott & Persson 1978). Also, the larger fry were easily disturbed and this may have affected feeding. Considering that the food intake increased as a linear function of size and that growth of golden perch in the pond was exponential with time, the daily food consumption would also increase exponentially with time. Thus the intensity of predation by the fry on the zooplankton populations would increase slowly at first but at later stages it would increase rapidly and might produce a sudden impact on the zooplankton community.

The information on feeding behaviour, growth and the mouth gape, highlight the difficulties faced by golden perch larvae and fry. Survival and growth requires an environment with a high density of appropriate sized food so that larvae with limited feeding ability and mouth gape can predate successfully. Mouth gape increases only slowly during the first weeks and so the range of zooplankters available to the fry will be limited for some time and high densities of small (<1 mm) zooplankters will be necessary for high survival and growth rates. These requirements are met at the I.F.R.S. where ponds are flooded just prior to the release of fish fry and the early stages of zooplankton succession are dominated by rotifers, small cladocerans (especially *Moina*) and copepod nauplii (Arumugam & Geddes 1986). In the wild, the same conditions may be provided in recently inundated floodplain areas where zooplankton communities are in early successional stages. If so, then the possession of pelagic eggs and the timing of breeding to coincide with rising water levels may allow golden perch larvae to be dispersed over recently inundated floodplains where they find conditions that are suitable for their development. The availability of cover for the fry in these areas may also affect the growth and survival.

Acknowledgments

We thank the Department of Agriculture, New South Wales, for permission to carry out the study at the Inland Fisheries Research Station, Narrandera. Thanks to the I.F.R.S. staff, especially Stuart Rowland, Steve Thurstan and John Dirou for their help and advice. We also thank Stuart Rowland for critically reading the manuscript. The work was made possible by the provision of a Post Graduate Fellowship by IDP to one of us (P.T.A.) and support from FIRTA. Thanks to David Culver for assistance in the field, Ruth Evans for artwork and Sandra Lawson and Heather Kimber for word processing several drafts of the manuscript.

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TRANSACTIONS OF THE

ROYAL SOCIETY OF SOUTH AUSTRALIA

INCORPORATED

VOL. 111, PART 2

PESTICIDE CONCENTRATIONS IN SOME SOUTH AUSTRALIAN BIRDS AND OTHER FAUNA

BY P. R. BIRKS & A. M. OLSEN†*

Summary

Data are provided for concentrations of the pesticides DDT plus metabolites, HCB, lindane, aldrin and dieldrin present in tissues of 20 native and two exotic bird species, one freshwater crustacean, one amphibian, two reptiles (lizards) and two exotic mammals from Saddleworth-Riverton survey, 1972; 18 native and two exotic bird species from miscellaneous areas, 1968-74; eggs of 23 native and two exotic bird species from miscellaneous areas 1971; and 26 foxes from miscellaneous areas, 1973.

KEY WORDS: Organochlorine pesticides, Aves, Reptilia Amphibia, Crustacea, exotic Mammalia, South Australia.

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Introduction

There is a paucity of published data on pesticide contamination in Australian fauna. In Victoria, 24 widely separated areas, each covering about 9300 ha, were surveyed for determination of concentrations of pesticides in 63 bird species, 10 mammal species, 15 fish species and eggs of 14 different birds (Butcher 1967; Australian Academy of Science 1972). In the Northern Territory Best (1973) surveyed the organochlorine pesticide residues in the fatty tissues of 12 mammal, four bird, ten reptile and six fish species from undeveloped and developed areas in arid and tropical zones.

The Australian Academy of Science (1972) reported ranges in concentrations of DDT plus metabolites in the Namoi cotton growing region for waters of creeks and rivers and their sediments, algae, crustaceans, fish, birds and turtles together with the range in concentrations of 29 fat samples from ten species of birds of the Bathurst area.

Olsen & Settle (1979) when reporting on the pesticide contamination in various tissues of water rats in the Murrumbidgee Irrigation Area, N.S.W. 1970–72 indicated that "little is known of the pesticide contamination of Australian fauna".

The South Australian Pesticides Advisory Committee was concerned about the lack of data on the concentrations of pesticide residues in fauna and the implications of this for research planning. As a consequence, in mid 1971, programmes to obtain these much needed baseline data were commenced. The Department of Fisheries and Fauna Conservation arranged for eggs of a number of bird species to be collected in the spring of 1971 while officers of the Department of Agriculture undertook the collection of representative fauna in a selected area in January 1972.

Broad surveys to determine concentrations of pesticides in native and exotic avi-fauna and some other terrestial fauna from selected areas in South Australia were undertaken between 1971 and 1973. Determinations of pesticide residues in birds suspected of pesticide poisoning were carried out between 1968 and 1974.

History of Pesticide use —
Saddleworth-Riverton area

pp'DDT

This area was selected because of the relatively high DDT usage for control of pea weevil (*Bruchus pisorum*) and native budworm (*Heliothis punctiger*) in field pea crops. As it is usual to have a 7–8 year crop rotation and the average annual area sown to peas is about 3%, it follows that about 20% of the total area of over 5000 ha would have received direct applications of about 1.5 kg/ha of pp'DDT in the 8-year period prior to 1971. The area has an annual rainfall of about 500 mm.

In October 1971, 150 hectares of field peas were treated with pp'DDT; 40 ha were sprayed with 0.7 kg/ha pp'DDT in early October and a second spraying, at the same concentration was given later in the month whilst the 109 ha paddock of peas was sprayed once with 1.05 ka/ha pp'DDT. Thus a total of approx. 170 kg of pp'DDT was applied over 150 ha three months before the fauna sampling study was commenced in late January 1972. Lucerne growing in the area was not sprayed.

Lindane

The only report of the use of lindane in the Saddleworth-Riverton area was as lindane-

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TABLE 1. *Fauna Pesticide Concentrations — Saddleworth-Riverton Area, January-February 1972§*

Common name	Scientific name	Saddleworth Distance-Direction	Habitat	Tissue	Pesticide (mg/kg wet weight)							
					HCB	LINDANE	ALDRIN	DIELDRIN	pp' DDT	DDD	DDE	DDT plus metabolites
White-faced heron	*Ardea novaehollandiae*	3 km NNE	p	l	0.09	0.06	*	*	*	*	46.7	46.7
Australian kestrel	*Falco cenchroides*	5 km ENE	p	l	0.03	*	*	*	*	*	3.94	3.94
Feral pigeon	*Columba livia*†	0.5 km NNE	p	l	0.01	0.03	*	*	0.13	0.66	1.68	2.47
Crested pigeon	*Ocyphaps lophotes*	5 km ESE	r.v.	l	0.008	*	*	1.2	*	*	0.34	0.34
Galah	*Cacatua roseicapella*	3 km NNE	p	l	0.01	0.02	*	*	*	*	6.0	6.0
Galah	*Cacatua roseicapella*	12 km NNE	r.v.	s	0.05	0.03	*	*	0.4	*	4.3	4.7
Cockatiel	*Nymphicus hollandicus*	3 km NNE	p	b	0.01	*	0.53	0.29	*	*	0.33	0.33
Cockatiel	*Nymphicus hollandicus*	3 km NNE	p	b	0.03	0.03	*	0.05	0.4	0.2	0.9	1.5
Cockatiel	*Nymphicus hollandicus*	3 km NNE	p	b	0.04	0.07	*	0.5	0.5	0.16	0.5	1.16
Red rumped parrot	*Psephotus haematonotus*	3 km NNE	p	b	0.03	0.10	0.71	0.29	0.18	*	0.23	0.41
Red rumped parrot	*Psephotus haematonotus*	2 km NNE	p	b	0.05	0.11	*	*	0.43	*	3.55	3.98
Red rumped parrot	*Psephotus haematonotus*	3 km NNE	p	b	0.13	0.31	*	1.3	3.0	0.8	5.8	9.6
Red rumped parrot	*Psephotus haematonotus*	3 km NNE	p	b	0.01	0.03	*	0.36	0.22	0.11	0.34	0.67
Red rumped parrot	*Psephotus haematonotus*	5 km NNE	r.v.	b	0.02	0.10	*	0.2	0.2	*	0.4	0.6
Red rumped parrot	*Psephotus haematonotus*	7 km NNE	r.v.	b	0.02	*	*	0.13	0.08	*	0.38	0.46
Laughing kookaburra	*Dacelo novaeguineae*	5 km ESE	u.l.	s	0.11	*	*	*	0.35	0.13	7.2	7.68
Willie wagtail	*Rhipidura leucophrys*	3 km NNE	p	b	0.02	0.10	*	*	1.8	0.4	14.2	16.4
Willie wagtail	*Rhipidura leucophrys*	3 km NE	p	b	0.03	*	*	*	0.8	0.3	60.8	61.9
Hooded robin	*Melanodryas cucullata*	4 km ESE	u.l.	b	0.05	*	*	*	1.2	0.5	14.5	16.2
Brown treecreeper	*Climacteris picumnus*	6 km ENE	p	b	0.05	0.12	*	1.5	0.8	0.4	8.2	9.4
Brown treecreeper	*Climacteris picumnus*	6 km NE	r.v.	b	0.111	*	*	*	2.0	0.7	16.1	18.8
Striated pardalote	*Pardalotus striatus*	3 km NNE	p	b	0.01	0.02	*	*	10.3	1.1	27.6	39.6
Striated pardalote	*Pardalotus striatus*	5 km SE	u.l.	b	0.05	0.27	*	*	2.2	0.6	12.4	15.2
Striated pardalote	*Pardalotus striatus*	5 km ESE	u.l.	b	0.028	0.16	*	1.1	0.5	1.0	6.5	8.0
White-plumed honey-eater	*Lichenostomus penicillata*	5 km NE	r.v.	b	0.09	0.14	*	1.1	0.2	0.3	5.0	5.5
White-plumed honey-eater	*Lichenostomus penicillata*	3 km E	r.v.	b	0.05	0.30	*	*	0.3	0.3	12.6	13.2
Brown-headed honey-eater	*Melithreptus brevirostris*	3 km E	r.v.	b	0.04	0.20	*	1.3	0.5	0.3	7.3	8.1
Noisy miner	*Manorina melanocephala*	3 km NNE	p	b	0.10	0.05	1.56	*	*	*	16.3	16.3
Noisy miner	*Manorina melanocephala*	2 km E	r.v.	b	0.05	*	*	*	0.3	0.4	13.8	14.5
Noisy miner	*Manorina melanocephala*	3 km NNE	r.v.	b	0.06	0.06	*	*	0.2	*	33.0	33.2
House sparrow	*Passer domesticus*†	3 km NE	p	b	0.02	0.05	*	*	9.0	3.3	270	282.3
Magpie-lark	*Grallina cyanoleuca*	0.5 km NE	p	l	0.09	*	*	*	8.7	28.1	112	148.8
White-winged chough	*Corcorax melanorhamphos*	3 km E	r.v.	l	0.15	*	*	1.0	0.2	0.4	1.3	1.9
White-winged chough	*Corcorax melanorhamphos*	3 km E	r.v.	l	0.14	*	*	1.5	0.2	0.5	1.4	2.1
White-browed wood-swallow	*Artamus superciliosus*	5 km NE	r.v.	b	0.07	*	*	*	*	*	8.0	8.0
Black-faced wood-swallow	*Artamus cinereus*	6 km NE	r.v.	b	0.13	*	*	*	2.2	0.4	41.2	43.8
Australian magpie	*Gymnorhina tibicen*	3 km NNE	p	l	0.03	*	*	*	1.0	0.8	94.0	95.8
Australian magpie	*Gymnorhina tibicen*	0.5 km E	p	s	0.36	0.20	*	*	9.5	0.5	15.3	25.3
Little raven	*Corvus mellori*	3 km NNE	r.v.	s	0.24	0.11	*	*	8.4	0.8	29.8	39.0

TABLE 1. *Fauna Pesticide Concentrations — Saddleworth-Riverton Area, January-February 1972§*

Common name	Scientific name	Saddleworth Distance-Direction	Habitat	Tissue	Pesticide (mg/kg wet weight)							
					HCB	LINDANE	ALDRIN	DIELDRIN	pp' DDT	DDD	DDE	DDT plus metabolites
Yabbie	*Cherax destructor*	3 km NE	d	m	0.004	*	*	*	*	*	0.4	0.4
Marbled frog (juv)	*Limnodynastes tasmaniensis*	3 km NE	d	b	*	*	*	*	*	*	0.5	0.5
Marbled frog (adult)	*Limnodynastes tasmaniensis*	3 km NE	d	b	0.007	*	*	0.4	*	*	0.1	0.1
Dragon lizard	*Amphibolurus barbatus*	3 km E	r.v.	s	*	*	*	*	*	*	*	*
Skink	*Morethia boulengeri (?)*	5 km NE	r.v.	b	*	*	*	*	*	*	0.1	0.1
Hare	*Lepus capensis*	6 km NE	r.v.	k	*	*	*	*	*	*	0.2	0.2
Fox (juv)	*Vulpes vulpes*	5 km NE	r.v.	k	*	*	*	*	*	*	*	*

* Not detected. † Exotic species. § After Lim, Y. P. Unpublished Report 1972, Dept. of Agriculture, Adelaide.

Tissue
l – liver
s – stomach fat
b – body fat
m – muscle
k – kidney fat

Habitat
p – cleared land
r.v. – roadside vegetation
u.l. – uncleared land
d – dam

superphosphate for the control of redlegged earthmite (*Halotydeus destructor*) and for pests of germinating cereals in May to July 1971.

Dieldrin

The use of this organochlorine compound for pasture or crop spraying was discontinued in the Saddleworth-Riverton area in 1967.

HCB

The only use of HCB was as a seed dressing and its use and availability ceased in 1972.

Methods

All bird and mammal specimens in the Saddleworth-Riverton area were taken by shooting with 0.410 gauge shotgun or 0.22 calibre rifle whereas the lizards, frogs and yabbies were taken alive. All specimens showed normal behaviour at the time of collection.

All dead specimens were placed individually in polythene bags approved by the Chemistry Division, Department of Services and Supply. The specimens were labelled and packed in ice for delivery to Department of Fisheries and Fauna Conservation for identification checks before being sent for analysis by gas liquid chromatography in the Chemistry Division. Limits of detection were HCB 0.007 mg/kg, lindane 0.01 mg/kg, dieldrin 0.01 mg/kg, DDE 0.01 mg/kg, DDD 0.05 mg/kg, pp'DDT 0.07 mg/kg.

Some bird specimens were badly damaged by shot and for that reason only the available parts of the bodies were used in the analysis. The wings and feathers of all birds were removed before extraction.

Some data on pesticides residues in a few native birds from miscellaneous areas taken incidentally in the course of other studies as well as results of analyses of birds forwarded for examination by interested people suspecting that the birds may have died from pesticide poisoning were obtained.

A limited sampling of birds' eggs for pp'DDT plus metabolites was undertaken in the spring of 1971. Single eggs from clutches of two or more eggs were collected from a wide range of habitats extending from Lyndhurst in the north of the State to Lucindale in the south-east by H. J. Morton of Jervois. No shell thickness measurements were made.

During 1973 the Animal Health Branch, Department of Agriculture, carried out a survey of the intestinal parasites of foxes, the animals being taken from widely scattered districts throughout the State. The Pesticides Committee requested that samples of fat adhering to the kidney be taken for pesticide analysis.

Results

Saddleworth-Riverton area

Table 1 shows individual pesticide concentrations in the fauna examined from the Saddleworth-Riverton area.

The metabolite DDE was present in all birds while the parent pp'DDT was present at low concentrations or absent.

The rearrangement of the data in descending order of DDT plus metabolites (Table 2) indicates that pesticide concentrations were extremely variable, the highest and lowest were in grain feeding species. However, the high concentration in the house sparrow (a grain feeder) and the lower levels in the laughing kookaburra and the Australian kestrel (meat-eaters) demonstrate the need for more data before a relationship can be postulated between residues and diet.

In most cases, those species which are known from data of the Australian Bird Banding Scheme to show least movement from banding sites, were those which had the higher concentrations of pesticides in their tissues.

Miscellaneous areas

The analyses of 35 birds representing 21 species from miscellaneous areas (Table 3) showed that 14 birds had concentrations above 1 mg/kg DDT plus metabolites, two birds had above 0.5 but less than 1.0 mg/kg and 19 birds had less than 0.5 mg/kg in various body tissues.

The two highest concentrations were in birds forwarded by concerned people who considered that the birds may have died from pesticide poisoning. A grey butcherbird (281 mg/kg), which came from a farm on Eyre Peninsula, is believed to have died from eating field mice from a grain store which had been dusted with pp'DDT for rodent control during the 1970 mouse plague. Even then the use of pp'DDT as a rodenticide was not officially approved or recommended. Likewise the sacred kingfisher from Rendelsham (South-East) with a concentration of 75.6 mg/kg DDT plus metabolites, was suspected by the finder, of poisoning from pesticides.

The next highest concentrations were in an Australian pelican (9.41 mg/kg); a little penguin (5.2 mg/kg); a stubble quail (4.2 mg/kg); another two little penguins (4.0 and 3.8 mg/kg respectively) and a darter (3.78 mg/kg) all of which were collected opportunistically. Four young little penguins came ashore with oil soaked bodies; they were starving. Because of the scarcity of their body fat, oil from the preening gland was used in the analyses.

It is doubtful whether the presence of pp'DDT was responsible for the deaths of birds from home

TABLE 2. *Descending order of concentrations of DDT plus metabolites in birds — Saddleworth-Riverton area 1972*

Species	Prime-Food*			Concentration (mg/kg — wet weight)		
	Invertebrates	Small Animals	Seeds Fruits	Max	Other	Fat Tissue
House sparrow			+	282.3		body
Magpie-lark	+		+	148.8		liver
Australian magpie	+	+	+	95.8		liver,
					25.3	stomach
Willie wagtail	+			61.9	16.2	body(2)
White-faced heron	+	+		46.7		liver
Blackfaced wood-swallow	+	body		43.8		
Striated pardalote	+		+?	39.0	15.2, 8.0	body(3)
Little raven	+	+	+	39.0		stomach
Noisy miner	+		+?	33.2	16.3, 14.5	body(3)
Brown treecreeper	+			18.8	9.4	body(2)
Hooded robin	+			16.2		body
White-plumed honeyeater	+			13.2	5.5	body(2)
Red-rumped parrot			+	9.6	3.98, 0.67, 0.6, 0.46, 0.41	body(6)
Brown-headed honeyeater	+			8.1		body
White-browed swallow	+			8.0		body
Laughing kookaburra	+	+		7.68		stomach
Galah			+	6.0		liver
Galah					4.7	stomach
Australian kestrel	+	+		3.94		liver
Feral pigeon			+	2.47		liver
White-winged chough	+		+	2.1	1.9	liver(2)
Cockatiel			+	1.5	1.16, 0.33	body(3)
Crested pigeon			+	0.34		liver

(after Lim 1972 see Table 1)

* Invertebrates = insects, crustaceans, and some molluscs. Small animals = fish, frogs, lizards and young birds. Seeds and fruits = includes bulbs and such like underground plant storage tissues. (0) Number of birds examined.

gardens in various areas of the State (Table 3) when apparently healthy birds of the same species with much higher concentrations of the pesticide were surviving without showing any stress symptoms (Table 2). In post-mortem examinations of the cormorants and the pelican by veterinarians, death was ascribed to respiratory infections.

Twenty-six eggs of 23 species (21 native species) were examined and no evidence of pp'DDT or metabolites was found in eggs from eight species. Another eight species had a range of concentrations from 0.01 to 0.10 mg/kg DDT plus metabolites, whereas seven species had eggs with concentrations between 0.12 and 0.50 mg/kg. Eggs of three species had concentrations above 0.5 mg/kg, namely a butcherbird (1.34 mg/kg), a brown thornbill (0.69 mg/kg) and a superb fairy-wren (0.62 mg/kg). All three species came from near cleared cultivated areas.

Three species had eggs taken from separate nests at different times. In the black-faced cuckoo-shrike from two widely separated areas, the Beltana egg sample from the earlier brood had no pesticides present whereas the Finnis sample of November had a concentration of 0.50 mg/kg DDT plus metabolites. Two eggs from different broods of the superb fairy-wren had a five-fold difference in concentration (0.12 to 0.62 mg/kg) of the pesticide. On the other hand the concentrations of DDT plus metabolites in broods of the two rainbow bee-eaters, taken six weeks apart at Tailem Bend were virtually identical (0.03 and 0.02 mg/kg respectively). Most birds, whose broods were sampled, are predominantly insect and arthropod eaters and only a few cockatoos supplement their diet with seeds while two species, the common bronzewing and little quail have seeds as their prime food.

In the bird broods sampled (Table 4) those eggs with the nil or lowest concentrations of pesticides came from nests in the lower rainfall areas. Those birds with the higher concentration of DDT plus metabolites were from higher rainfall areas and hence more closely settled districts where cropping practices were more intensive.

In only two of the 26 foxes was the sex recorded and no observations were given on the estimated

TABLE 3. *Pesticide concentrations in birds — miscellaneous areas.*

Common name	Scientific name	Date Collected	Area	Habitat	Tissue Examined	Pesticide (mg/kg wet weight)						
						HCB	LINDANE	DIELDRIN	pp'DDT	DDD	DDE	DDT plus metabolites
Little penguin (adult)	*Eudyptula minor*	20.x.71	Penguin Island (SE)	burrow	b	*	*	*	0.2	*	1.2	1.4
					l	*	*	*	*	*	*	*
					pr.g.	*	*	*	0.1	*	0.5	0.6
Little penguin (juv.)	*Eudyptula minor*	19.x.71	Robe	beach	pr.g.	*	*	*	0.4	*	3.6	4.0
Little penguin (juv.)	*Eudyptula minor*	19.x.71	Robe	(oil soaked)	pr.g.	*	*	*	0.3	*	4.9	5.2
Little penguin (juv.)	*Eudyptula minor*	19.x.71	Robe	(oil soaked)	pr.g.	*	*	*	0.3	*	3.5	3.8
Little penguin (juv.)	*Eudyptula minor*	19.x.71	Robe	(oil soaked)	pr.g.	*	*	*	0.2	*	0.8	1.0
Stubble quail	*Coturnix novaezelandiae*	24.i.72	4 km E. Moonta	pasture stubble	b	*	*		*	*	1.43	1.43
Stubble quail	*Coturnix novaezelandiae*	24.i.72	4 km E. Moonta	pasture stubble	b	*			*	*	4.2	4.2
Stubble quail	*Coturnix novaezelandiae*	24.i.72	4 km E. Moonta	pasture stubble	b	0.01			*	*	1.47	1.47
Crested pigeon (juv.)	*Ocyphaps lophotes*	Oct. 1971	Adelaide	park-lands†	b				*	*	0.02	0.02
Great cormorant	*Phalacrocorax carbo*	22.ii.70	Moorook	river swamp†	br				0.07	0.09	0.10	0.26
					l				0.02	0.02	0.02	0.06
					b				0.03	0.04	0.17	0.24
Great cormorant	*Phalacrocorax carbo*	22.ii.70	Moorook	river swamp†	b				0.09	0.12	0.18	0.39
					l				0.04	0.05	0.05	0.14
					b				0.04	0.05	0.07	0.16
Great cormorant	*Phalacrocorax carbo*	3.viii.70	near Moorook	river swamp‡	l	*		*				0.18
Great cormorant	*Phalacrocorax carbo*	3.viii.70	near Moorook	river swamp‡	l	*	*	*				0.06
Great cormorant	*Phalacrocorax carbo*	3.viii.70	near Moorook	river swamp‡	l	*	*	*				0.08
Darter	*Anhinga melanogaster*	13.xi.69	near Barmera	river swamp†	b	0.021	* 0.02	0.53	0.14	0.08	3.56	3.78
Australian pelican	*Pelecanus conspicillatus*	20.ii.70	Lake Bonney	lake area‡	b	*	*	*	0.24	3.96	5.21	9.41
Gannet	*Sula serrator*	19.v.71	Robe	beach‡	l	*		*	0.1		1.3	1.4
Straw-necked ibis (juv.)	*Threskiornis spinicollis*	28.iii.69	Bool Lagoon	marsh‡	d.o.	*	* *	*			*	*
Musk duck	*Biziura lobata*	28.iii.69	Bool Lagoon	marsh‡	br	*		*			*	*
Musk duck	*Biziura lobata*	28.iii.69	Bool Lagoon	marsh‡	br	*		*			*	*
Horsfield's bronze-cuckoo	*Chrysococcyx basalis*	28.vi.68	Loxton	country garden‡	br d.o.			*	*		*	*
Sacred kingfisher	*Halcyon sancta*	20.xi.71	Rendelsham	home garden†	b	0.03	0.1		1.3	1.9	72.4	75.6
Welcome swallow	*Hirundo neoxena*	16.x.60	Naracoorte	home garden‡	b			1.6				0.8
Willie wagtail	*Rhipidura leucophrys*	11.iii.70	Adelaide Hills	bush-land	b	*	*		0.01		0.31	0.32
Silvereye	*Zosterops lateralis*	July 1974	Campbelltown	home garden†	b	0.005	0.016	0.04	0.13	0.02	2.20	2.35

TABLE 3. *Pesticide concentrations in birds — miscellaneous areas.*

Common name	Scientific name	Date Collected	Area	Habitat	Tissue Examined	Pesticide (mg/kg wet weight)						
						HCB	LINDANE	DIELDRIN	pp'DDT	DDD	DDE	DDT plus metabolites
Red wattlebird	*Anthochaera carunculata*	24.ix.68	Toorak Gardens	home garden‡	br	*	*	*	*		0.20	0.20
Red wattlebird	*Anthochaera carunculata*	24.ix.68	Toorak Gardens	home garden‡	d.o.	*	*	*	*		0.23	0.23
Red wattlebird	*Anthochaera carunculata*	24.ix.68	Toorak Gardens	home garden‡	d.o.	*	*	*	*		*	*
White-browed babbler	*Pomatostomus superciliosus*	28.vi.68	Berri	country garden‡ (died in spasm)	br d.o.			* *	* *		0.30 0.10	0.30 0.10
Australian magpie	*Gymnorhina tibicen*	Oct. 1968	Adelaide Hills	home garden‡	b	"Endrin" 1.8		2.0	*			*
Apostle bird	*Struthidea cinerea*	28.vi.68	Berri	country garden‡	br d.o.			*	*	*	0.3	0.3
Grey butcherbird	*Cracticus torquatus*	3.viii.70	Eyre Peninsula	farm-yard‡	l				43.0	156.0	82.0	281.0
House sparrow	*Passer domesticus*†	July 1974	Campbelltown	home garden‡	b	0.003		0.01	0.012	0.016	60.42	0.448
Common starling	*Sturnus vulgaris*†	July 1974	Campbelltown	home garden‡	d.o.	0.004	0.005	0.025	0.011	0.006	0.59	0.607
Common starling	*Sturnus vulgaris*†	July 1974	Campbelltown		d.o.	0.006	0.004	0.024	<0.010	0.012	0.39	0.402

* Not detected
† Exotic species
‡ Found dead or dying
b = body fat
l - liver
pr.g. — preening gland
br brain
d.o. - digestive organs

TABLE 4. *Descending order of concentrations of DDT plus metabolites in eggs — miscellaneous areas.*

Common name	Scientific name	Date collected	Area	Concentration (mg/kg wet weight)				Approx. average annual rainfall (mm)
				pp'DDT	DDD	DDE	DDT plus metabolites	
Grey butcherbird	*Cracticus torquatus*	8.xi.71	Swede Flat	*	*	1.34	1.34	530
Brown thornbill	*Acanthiza pusilla*	7.x. 71	Lucindale	0.09	0.04	0.56	0.69	620
Superb fairy-wren	*Malurus cyaneus*	7.x. 71	Lucindale	0.06	0.05	0.51	0.62	620
Black-faced cuckoo-shrike	*Coracina novaehollandiae*	5.xi.71	Finnis	*	*	0.50	0.50	450
Eastern yellow robin	*Eopsaltria australis*	7.x. 71	Lucindale	0.04	0.03	0.22	0.29	620
Grey fantail	*Rhipidura fuliginosa*	7.x. 71	Lucindale	*	*	0.18	0.18	620
Blackbird	*Turdus merula*†	16.x. 71	Jervois	*	*	0.17	0.17	360
Superb fairy-wren	*Malurus cyaneus*	14.xi.71	Salt Creek	*	*	0.12	0.12	490
Silvereye	*Zosterops lateralis*	12.xi.71	Bakers Range	*	*	0.12	0.12	610
Noisy miner	*Manorina melanocephala*	10.xi.71	Swede Flat	*	*	0.12	0.12	530
White-throated treecreeper	*Climacteris leucophaea*	16.x. 71	Willunga	*	*	0.08	0.08	650
Purple swamphen	*Porphyrio porphyrio*	24.x. 71	Lucindale	*	*	0.06	0.06	620
Diamond firetail	*Emblema guttata*	27.x. 71	Tailem Bend	*	*	0.06	0.06	385
Striated grasswren	*Amytornis striatus*	7.xi.71	Murray Bridge	*	*	0.05	0.05	344
Grey shrike-thrush	*Colluricincla harmonica*	11.xi.71	Bakers Range	*	*	0.04	0.04	610
Rainbow bee-eater	*Merops ornatus*	9.x. 71	Tailem Bend	*	*	0.03	0.03	380
Rainbow bee-eater	*Merops ornatus*	28.xi.71	Tailem Bend	*	*	0.02	0.02	380
European goldfinch	*Carduelis carduelis*†	10.x. 71	Jervois	*	*	0.01	0.01	360
Little quail	*Turnix velox*	18.x. 71	Lyndhurst	*	*	*	*	175
Common bronzewing	*Phaps chalcoptera*	28.xi.71	Tailem Bend	*	*	*	*	385
Yellow-tailed black-cockatoo	*Calyptorhynchus funereus*	27.xi.71	Spring Hill	*	*	*	*	580
Black-faced cuckoo-shrike	*Coracina novaehollandiae*	12.x. 71	Beltana	*	*	*	*	209
Little grassbird	*Megalurus gramineus*	19.x. 71	Orroroo	*	*	*	*	341
Masked woodswallow	*Artamus personatus*	13.x. 71	Edeowie	*	*	*	*	300
Red-browed firetail	*Emblema temporalis*	20.xi.71	Nangkita	*	*	*	*	750
Chirruping wedgebill	*Psophodes cristatus*	13.x. 71	Lyndhurst	*	*	*	*	174

* Not detected † Exotic species

ages of the foxes i.e. juvenile or adult. The foxes were taken in the course of a tapeworm survey and it is presumed they were mostly older animals and not pups.

HCB

All 26 samples of fox kidney fat showed traces of HCB. Thirteen foxes showed the presence of dieldrin in the kidney fat. The highest concentration of 0.67 mg/kg was present in a fox from Mannum district, the next highest was 0.27 mg/kg in a fox from the Port Lincoln area (Table 5). The remaining 11 foxes had concentrations ranging from 0.02 to 0.16 mg/kg dieldrin. Six only of the 26 foxes examined showed the presence of pp'DDT or metabolites, the highest concentration of 1.34 mg/kg was in the same fox from Mannum which registered the highest concentration of dieldrin.

Discussion

The amounts of pp'DDT used in the Saddleworth-Riverton area were believed to be the highest used anywhere in South Australia at that time and survey results from that area were considered likely to show the highest residues from DDT in this State. The annual application of about 1.5 kg/ha of pp'DDT to about three percent of the area is not high compared with application rates of four to six times heavier on greater areas of cotton and tobacco planted elsewhere in Australia (Australian Academy of Science 1972).

The data on pesticide residues in Australian fauna is limited to small numbers of some of the more common species present in different areas. Comparison of residues is difficult because of different tissues analysed.

Of the 38 native and four exotic bird species from South Australia, only 12 native and one exotic species were common to the 63 species previously surveyed in Victoria (Australian Academy of Science 1972). Table 6 shows these in descending order of maximum concentrations of DDT plus metabolites found in any tissues.

The highest concentration, 160 mg/kg was in the body fat of an Australian kestrel and was also the highest level recorded in six other raptor species from Victoria. Best (1973) reported up to 12.15 mg/kg wet weight in bulked samples of body fat of fork tailed (black) kites, raptors from the N.T. The recording of 3.94 mg/kg in the Australian

TABLE 5. *Concentrations of pesticides in fat of foxes — miscellaneous areas — 1973.*

Date received	Town or district	Pesticide (mg/kg wet weight)					DDT plus
		HCB	DIELDRIN	pp'DDT	DDE	DDD	metabolites
8-i-73	Port Lincoln	0.006	0.06	*	*	*	*
13-i-73	Port Lincoln	0.007	0.06	*	*	*	*
13-i-73	Port Lincoln	0.007	0.06	*	*	*	*
25-i-73	Port Lincoln	0.05	0.14	*	0.08	*	0.08
19-ii-73	Port Lincoln	0.001	0.27	*	0.02	*	0.02
25-v-73	Port Lincoln	0.02	*	0.11	0.26	*	0.37
28-v-73	Port Lincoln	0.18	*	*	*	*	*
6-vi-73	Port Lincoln	0.21	*	*	0.18	*	0.18
16-vi-73	Murray Bridge	0.31	0.05	*	*	*	*
16-vi-73	Murray Bridge	0.006	*	*	*	*	*
16-vi-73	Mount Gambier	0.002	*	*	*	*	*
25-vi-73	Port Lincoln	0.008	0.08	*	*	*	*
25-vi-73	Mount Gambier	0.005	*	*	*	*	*
25-vi-73	Mount Gambier	0.002	*	*	*	*	*
27-vi-73	Murraytown	0.008	*	*	*	*	*
27-vi-73	Murraytown	0.015	0.04	*	*	*	*
27-vi-73	Murraytown	0.014	0.02	*	*	*	*
2-vii-73	Port Lincoln	0.003	0.16	*	*	*	*
4-vii-73	Port Lincoln	0.004	*	*	*	*	*
18-vii-73	Mannum	0.028	0.06	*	*	*	*
18-vii-73	Mannum	0.091	0.67	0.50	0.75	0.09	1.34
26-vii-73	Port Lincoln	0.004	*	*	*	*	*
26-vii-73	Port Lincoln	0.004	*	*	*	*	*
26-vii-73	Port Lincoln	0.02	*	*	0.05	*	0.05
8-viii-73	Jamestown	0.007	0.10	*	*	*	*
8-viii-73	Hallet	0.009	*	*	*	*	*

* Not detected

TABLE 6. *Descending order of concentrations of DDT plus metabolites in 13 bird species common to South Australia and Victoria.*

Species	Maximum pesticide concentration mg/kg wet weight	
	South Australia	Victoria
Australian kestrel	3.94	160.0
Magpie lark	148.8	0.20
Australian magpie	95.8	26.0
White faced heron	46.7	78.0
Little raven	39.0	0.36
Laughing kookaburra	7.68	20.0
Fairy penguin	5.2	14.0
Stubble quail	4.2	0.67
White-winged chough	2.1	0.09
Great (large black) cormorant	0.39	1.8
Welcome swallow	0.80	1.2
Red wattle bird	0.20	0.81
Starling	0.60	0.07

kestrel is the only measurement from a raptor species in S.A.

Although many waterbird species were examined for pesticides in Victoria, only the white-faced heron, the great (large black) cormorant and the fairy penguin were also examined in the South Australian studies and they had lower concentrations than their respective Victorian specimens.

In the Namoi cotton growing area of N.S.W., which had received the highest rates of application of pp'DDT in Australia (Australian Academy of Science 1972), seven cormorants had an average of 4.6 mg/kg (basis unspecified) in the body fat. Two great cormorants from Moorook, S.A., had 0.24 and 0.39 mg/kg wet weight in body fat whereas a Victorian great (large black) cormorant had 1.8 mg/kg wet weight in body fat.

Two quail from the Namoi area had an average of 0.45 mg/kg (basis unspecified) in body fat, three stubble quail from Moonta, S.A., had 1.43, 1.47 and 4.2 mg/kg wet weight in body fat and four stubble quail in Victoria had 0.67 and 0.14 mg/kg wet weight in fat.

Two galahs from Saddleworth-Riverton area had DDT residue concentrations of 4.7 and 6.0 mg/kg (stomach and liver fat respectively) whereas lower concentrations (0.22 to 3.69 mg/kg wet weight), were recorded in bulked samples of galahs from developed arid areas near Alice Springs and still lower concentrations (nil to 0.17 mg/kg) in bulked samples from undeveloped arid areas in the N.T. (Best 1973).

Freshwater crayfish from river and creek sources in the Namoi area had DDT residue concentrations ranging from 0.17 to 6.5 mg/kg, dry weight, and higher values between 13.8 and 54.7 mg/kg, averaging 29.9 mg/kg dry weight from specimens collected in irrigation drains (Australian Academy of Science 1972). A yabbie from a dam in the Saddleworth-Riverton area had a lower concentration of 0.4 mg/kg wet weight.

In the South Australian results, pesticide levels were generally higher in those bird species which feed on other animals, including insects, than in bird species which utilise food of vegetable origin, i.e. seeds, fruits, bulbs and other underground storage organs.

The lower proportion of pp'DDT than DDE present in the tissues is indicative of pesticides having been applied some time ago rather than of recent application. There was no apparent effect on the general well-being of the birds examined in the Saddleworth-Riverton survey although some, e.g. the sparrow, carried high concentrations of pesticide, particularly DDE. Davis (1967, 1974) drew attention to the wide variations in susceptibility of different bird species to specific pesticides and considered that lethal levels for a species may vary with conditions such as stress. From the high concentrations of pp'DDT plus metabolites in the butcher bird and its known contact with pp'DDT, it is presumed that this chemical caused its death. With the sacred kingfisher from Rendelsham, the cause of death is uncertain because there was no known association with pesticide application and it had lower concentrations of pesticides than three other apparently unaffected bird species with high pesticide concentrations in the Saddleworth-Riverton survey (Table 1).

In the species, other than birds, examined, concentrations of DDT plus metabolites were low. In foxes the low concentrations and absence (21 out of 27) was interesting particularly in view of the omnivorous diet of this species. Two foxes in the Northern Territory also had low concentrations of DDT residues (0.03 mg/kg) (Best 1973).

The DDT plus metabolites concentrations in eggs of 23 South Australian bird species were relatively low. Eggs of seven species were free of pesticides, 13 species had concentrations of 0.5 mg/kg wet weight or less and the eggs of three species contained 1.34 mg/kg (grey butcherbird), 0.69 mg/kg (brown thornbill) and 0.62 mg/kg (superb fairy wren) (Table 4).

In the Victorian survey, eggs from nests of 14 different bird species, nine of which were water birds, contained DDT plus metabolites. Four of the species contained concentrations higher than values found in eggs of the 23 South Australian species. The eggs of a stilt had a concentration of 12 mg/kg wet weight, a whistling eagle 3.2 mg/kg, a little pied cormorant 2.5 mg/kg and a starling 1.70 mg/kg.

Because of wide differences in food preferences and feeding habits of birds from Victoria and those from S.A. there is no basis for comment except to record the concentrations of DDT plus metabolites found in the eggs of birds in these two surveys.

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ECHINOCEPHA LUS OVERSTREETI DEARDORFF & KO, 1983 (NEMATODA:GNATHOSTOMATOIDEA) FROM ELASMOBRANCHS AND MOLLUSCS IN SOUTH AUSTRALIA

BY IAN BEVERIDGE

Summary

Specimens of *Echinocephalus overstreeti* were found in the following elasmobranch and chaemeriform fishes from South Australia: *Heterodontus portusjacksoni* (Meyer, 1793), *Parascyllium ferrugineum* McCulloch, 1911, *Orectolobus maculatus* (Bonnaterre, 1788), *Myliobatis australis* Macleay, 1881, *Aptychotrema vincentiana* (Haacke, 1885), *Trygonorhina guanerius* Whitley, 1932, *Raja whitleyi* Iredale, 1938, *Urolophus mucosus* Whitley, 1939, *Dasyatis brevicaudatus* (Hutton, 1875), *D. thetidis* (Waite, 1899), *Hypnos rnonopterygium* (Shaw & Nodder, 1795) and *Callorhynchus milii* Bory de St Vincent, 1823. Gravid nematodes were found only in *H. portusjacksoni*. A redescription of the nematode is given and its differentiation from congeners discussed. Nematodes undergoing the final moult in elasmobranchs permitted the identification of the scallops *Pecten albus* Tate, 1887 and *Chlarnys bijrons* (Lamark, 1819) as possible intermediate hosts.

KEY WORDS: Nematoda, Gnathostomatoidea, *Echinocephalus,* morphology, life history.

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BEVERIDGE, I. (1987) *Echinocephalus overstreeti* Deardorff & Ko, 1983 (Nematoda: Gnathostomatoidea) from elasmobranchs and molluscs in South Australia. *Trans. R. Soc. S. Aust.* **111**(2), 79-92, 29 May, 1987.

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KEY WORDS: Nematoda, Gnathostomatoidea, *Echinocephalus*, morphology, life history.

Introduction

Adults of the nematode genus *Echinocephalus* Molin, 1858 occur in the stomach and spiral valve of sharks and rays in various regions of the world. Larval stages occur commonly in the gonads or adductor muscles of molluscs as well as in the mesenteries of teleosts. In Australian waters, adult *Echinocephalus* have been found in the Port Jackson shark, *Heterodontus portusjacksoni* (Meyer 1793) (syn. *H. philippi*) and the stingaree, *Urolophus testaceus* (Mueller & Henley 1841) (Johnston & Mawson 1943, 1945a). Johnston & Mawson (1943) assigned the material they examined to *E. spinosissimus* (Linstow 1905), a species described originally from *Myliobatis aquila* (Linnaeus 1758) from the Gulf of Manaar, Sri Lanka. However, *E. spinosissimus* has usually been regarded as a synonym of *E. uncinatus* Molin, 1858 (see Milleman 1963). Johnston & Mawson (1943) noted however that their specimens were much larger than any previously described, while Milleman (1963) pointed to differences in cephalic anatomy and the caudal papillae of the male tail, suggesting that the Australian specimens might represent a distinct species. Notwithstanding this suggestion, Milleman (1963) tentatively included Johnston and Mawson's specimens under *E. uncinatus*.

Larval stages of *Echinocephalus* in the Australian region have been found in the molluscs *Amusium balloti* Bernardi, 1861, *Katylesia scalarina* (Lamarck, 1818) and *Polinices conicus* (Lamarck, 1822) (Johnston & Mawson 1945a; Lester *et al.* 1980) as well as in the mesenteries of the teleosts *Chrysophrys auratus* (Schneider, 1801) (Syn. *Pagrosomus auratus*), *Platycephalus arenarius* Ramsay & Ogilby, 1885, *P. bassensis* Cuvier, 1829, *P. fuscus* Cuvier & Valenciennes, 1829, *P. laevigatus* Cuvier, 1829, *Pseudolabrus psittaculus* (Richardson, 1840) and *Sillaginodes punctatus* (Cuvier, 1829) (Johnston & Mawson 1945a, b; Hooper 1983). Larval echinocephalids have also been found in the stomachs of turtles, *Caretta caretta* (Linnaeus, 1758) (Lester *et al.* 1980), and dolphins, *Delphinus delphius* Linnaeus, 1758 (Johnston & Mawson 1941). Generally, specific identifications of larvae have not been made except for those identified as *E. uncinatus* by Johnston & Mawson (1945a, b) based on the earlier designation by Baylis & Lane (1920) of a larval specimen as the type of Molin's species *uncinatus*. Baylis & Lane's (1920) action is now considered invalid (Milleman 1963; Beveridge 1985) but in the intervening period many larval forms have been incorrectly identified as *E. uncinatus* (see Beveridge 1985).

The taxonomic status of both larval and adult forms of *Echinocephalus* from Australian hosts is therefore in doubt. Examination of new collections has shown that they belong neither to *E. uncinatus* nor to *E. spinosissimus*, but to *E. overstreeti* Deardorff & Ko, 1983 originally described from the ray *Taeniura melanospilos* Bleeker, 1853 from the Marqueses Islands (Deardorff & Ko 1983) although they differ from the original description in some

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respects. A detailed description of both adult and larval specimens from Australia is therefore given below, together with some observations on life history.

Materials and Methods

Elasmobranchs were collected on commercial fishing vessels in St Vincent and Spencer Gulfs, Encounter Bay, off Beachport and off the south coast of Kangaroo Island, S.A. Additional specimens were obtained at Goolwa, S.A., using handlines. The sex and total length of each fish were recorded and the gastrointestinal tract was removed and opened. Nematodes were preserved either by washing them in sea-water and fixing them immediately in Berland's fluid or alternatively, opened spiral valves and stomachs were flooded with boiling water to straighten any helminths, and formalin was added to preserve the specimens. Nematodes were cleared in lactophenol and the total length measured while cleared. Drawings were made using a drawing tube attached to an Olympus BH microscope. Measurements were made either directly with an ocular micrometer or from calibrated drawings. In the descriptions, measurements are given in millimetres as the range for five specimens followed by the mean in parentheses.

Scallops, *Chlamys (Equichlamys) bifrons* (Lamarck, 1819) and *Pecten albus* Tate, 1887 (probably a synonym of *P. meridionalis* Tate, 1887), were collected from Northaven and Edithburgh. The total length from hinge to free side, was recorded and they were then examined fresh or were frozen prior to examination for nematodes. Live larvae were fixed in Berland's fluid and cleared in lactophenol. Larvae from frozen scallops were fixed in 10% formol saline. Sixteen abalone, *Haliotis laevigata* Donovan, 1808 from Edithburgh were also examined.

Larval and adult nematodes were prepared for scanning electron microscopy (SEM) by dehydrating in ethanol, air drying and coating with gold and carbon. Specimens were viewed with a JEOLSE microscope.

All nematodes collected have been deposited in the Australian Helminthological Collection (AHC) housed in the South Australian Museum.

Existing collections of *Echinocephalus* in AHC were also examined as well as the paratypes of *E. overstreeti* from the United States National Museum Helminth Collection (77384).

Adult female nematodes from one shark were maintained in sea-water at room temperature for the collection of eggs. Egg development and hatching was observed. Larvae were fixed in formol saline or in lactophenol.

Results

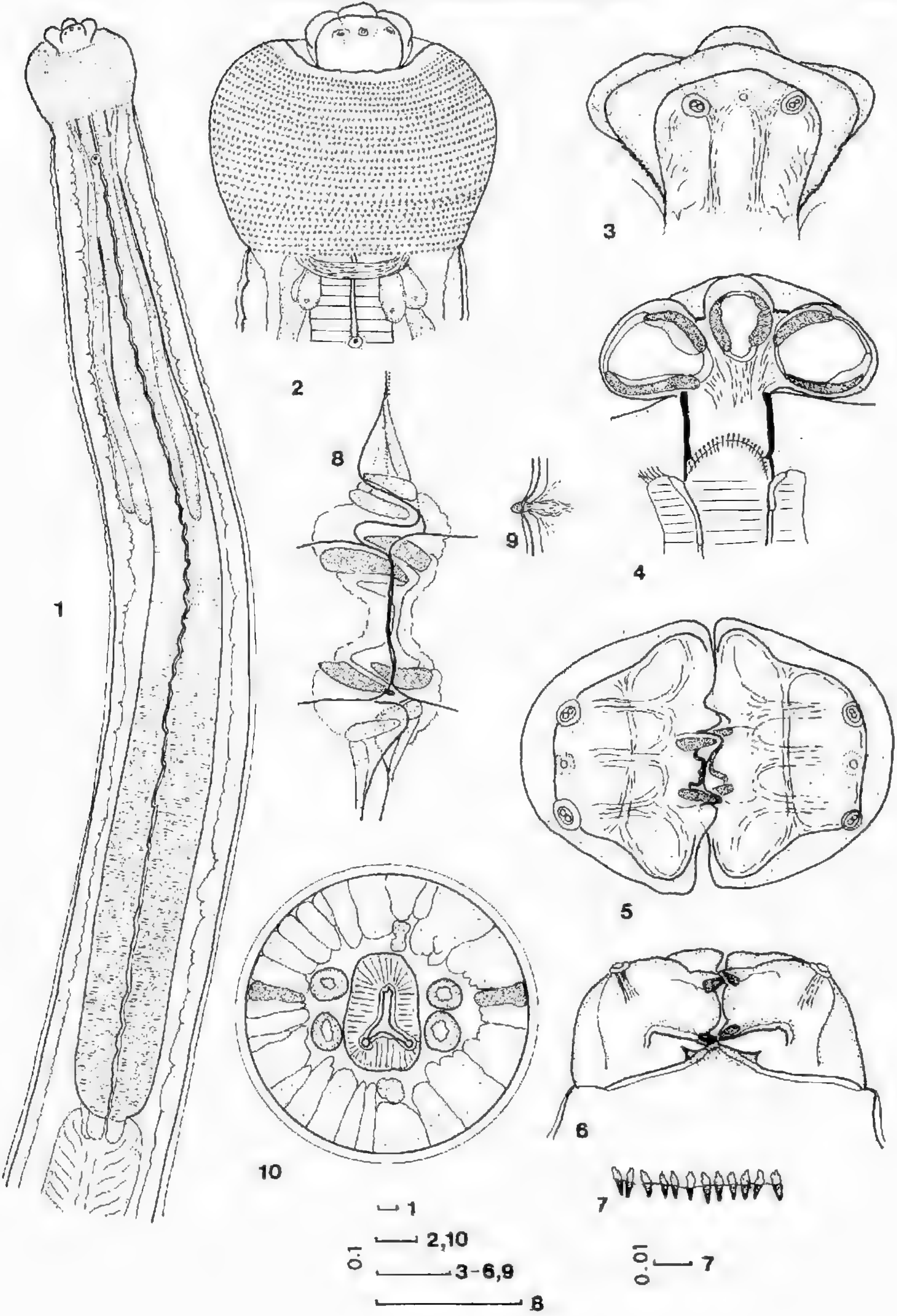
Echinocephalus overstreeti Deardorff & Ko, 1983

FIGS 1–38

Adults: Large stout nematodes; body unarmed, maximum width in mid-body region; cuticle with fine, regularly-spaced annular striations 0.002–0.003 apart; female straight; tail of male coiled in loose spiral. Mouth opening dorso-ventrally elongate with 2 elongate lateral pseudolabia; lateral part of pseudolabium bulbous, with median amphid and double cephalic papilla on either side; medial extremity of pseudolabium wider than lateral extremity, trilobed, each lobe with 2 cuticular thickenings along external edges; thickenings of median lobes interlock to give appearance of pairs of "teeth" in apical view; median lobes may be partially or fully introverted such that one lobe or both is not visible in apical view; projections or "teeth" of sub-dorsal and sub-ventral lobes of pseudolabia only clearly visible in median views, sometimes visible in oblique or apical views giving appearance of additional interlocking "teeth"; postero-dorsal and postero-ventral part of base of each pseudolabium with distinct cuticular serrations; small triangular interlabia present dorsally and ventrally, with 2 additional small triangular projections on either side of apex. Cephalic bulb prominent, armed with numerous rows of small uncinate spines; anterior rows incomplete, restricted to dorsal and ventral areas of bulb; rows of mid-bulb region frequently non-continuous; rows of spines non-overlapping; buccal capsule weakly developed; oesophagus divided into anterior muscular and posterior glandular sections; nerve ring in anterior oesophageal region, immediately posterior to cephalic bulb; 4 cervical sacs extend from cephalic bulb almost to junction of muscular and glandular oesophagus. Tail conical, with blunt tip; tail tip without ornamentation.

Male: Total length 55–60 (56); maximum width 1.0–1.2 (1.1); cephalic bulb 0.51–0.56 (0.54) long by 0.76–0.82 (0.78) wide; bulb with 30–40 (34) rows of spines; spines 0.010 long; oesophagus 5.9–8.5 (7.2) long; anterior muscular region 3.0–5.4 (4.7) long;

Figs 1–10 *Echinocephalus overstreeti*. 1. Oesophageal region, lateral view; 2. Cephalic extremity, lateral view; 3. Pseudolabium, lateral view; 4. Pseudolabium internal surface; 5. Pseudolabia, apical view; 6. Pseudolabia, dorsal view; 7. Spines of cephalic bulb; 8. Details of interlocking teeth of pseudolabia, apical view; 9. Deirid, median view; 10. Transverse section through oesophageal region showing four cervical sacs. Scale lines in mm.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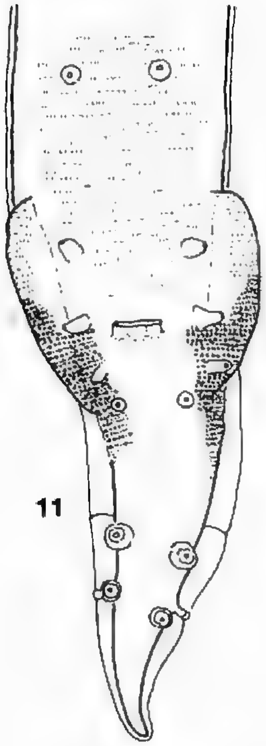

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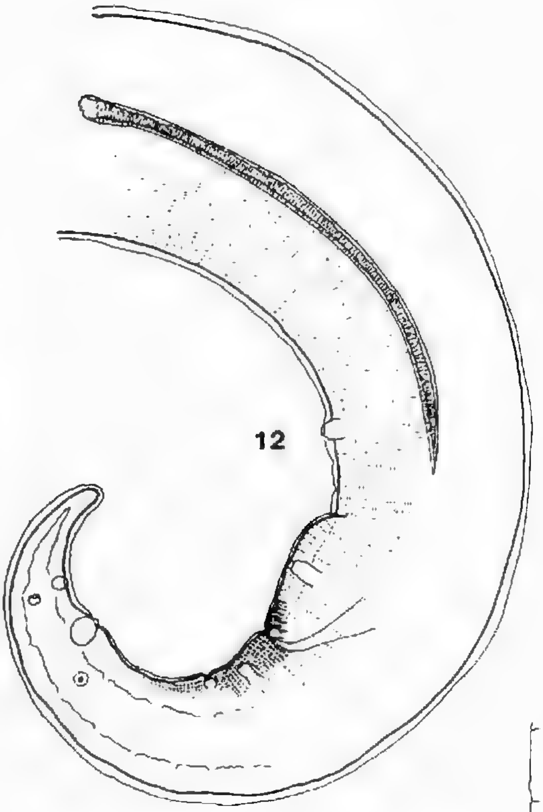

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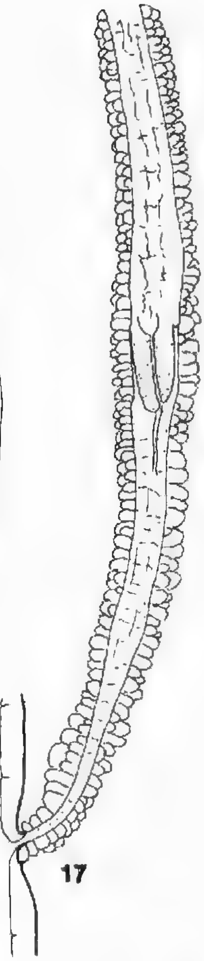

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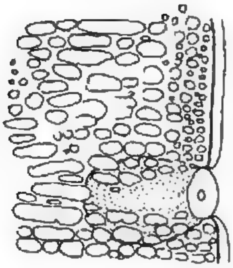

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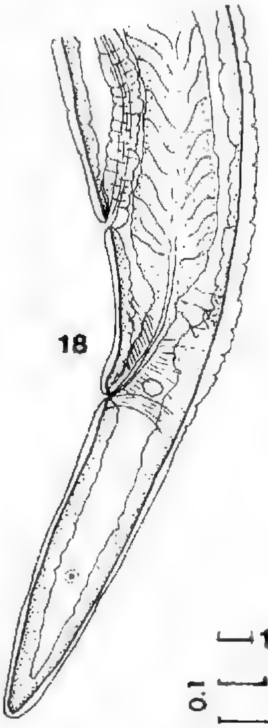

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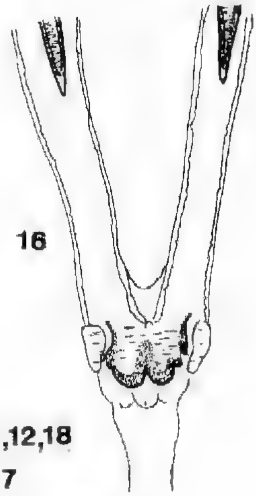

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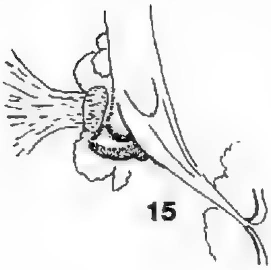

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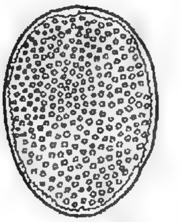

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posterior glandular region 2.5–3.2 (2.9) long; nerve ring 0.85–0.95 (0.91) from anterior end; deirids 1.1–1.3 (1.2) from anterior end; cervical sacs extend 2.6–3.2 (2.9) posterior to cephalic bulb. Tail 1.0–1.6 (1.3) long; spicules sub-equal 1.70–1.94 (1.82), ratio of left : right spicule lengths 0.98–1.03; distal extremity of spicule slender, tapering to sharp point; gubernaculum present, poorly sclerotised, clearly visible in young specimens only, punctate, 0.07–0.09 (0.08) long; W shaped in ventral view. Prominent caudal alae present on male tail, extending 1.6–2.6 (2.0) from posterior end; prominent rugose area extending along lateral areas of alae from between papillae 2 (numbered antero-posteriorly) and 3 to between papillae 5 and 6, most prominent in region of papilla 5; composed of prominent bosses arranged in irregular rows, giving cobblestone appearance. 7 pairs of caudal papillae; 3 pairs pre-anal; anterior pair distant from remainder; pairs 2 and 3 on lateral alae; pair 2 largest; 4 pairs of post-anal papillae; pair 5 slightly medial to remainder; pairs 6 and 7 widely separated from pair 5; pair 6 larger than pair 7, phasmids at level of pairs 7. Annulations on ventral surface of male tail; extend from a little anterior to papillae to between rugose areas. Annulations 0.007–0.010 (0.009) apart; meet normal striations in region of lateral lines.

Immature males: Total length 20–31 (27); maximum width 0.53–0.68 (0.60); cephalic bulb 0.39–0.42 (0.40) long by 0.56–0.64 (0.60) wide; bulb with 30–35 (32) rows of spines; spines 0.010 long; oesophagus 4.2–5.5 (4.7) long; anterior muscular region 2.8–3.5 (3.0) long; posterior glandular region 1.2–2.0 (1.6) long; nerve ring 0.55–0.74 (0.64) from anterior end; deirids 0.77–0.90 (0.84) from anterior end; caudal alae extending 1.1–1.5 (1.4) from posterior end.

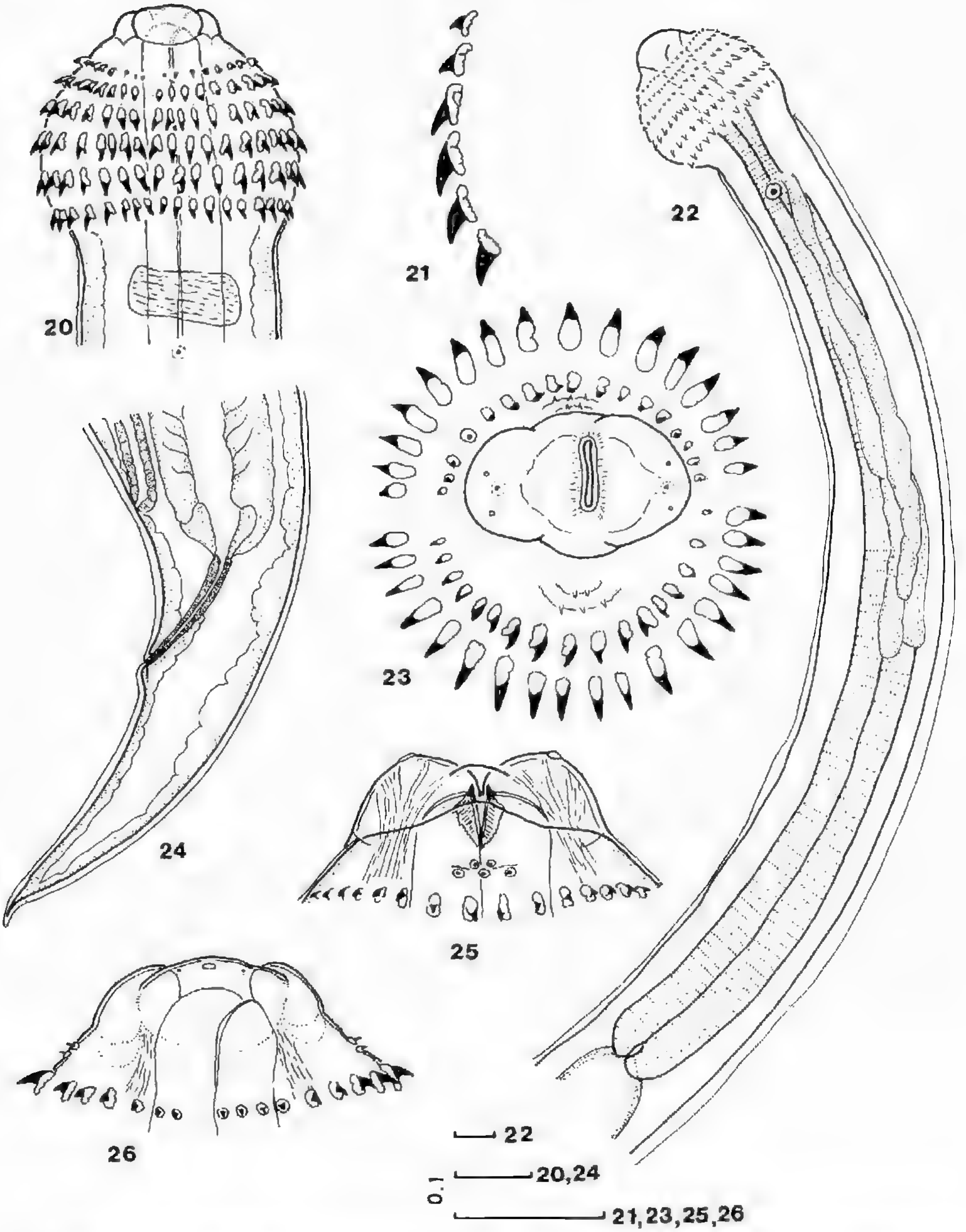
Female: Total length 58–63 (59); maximum width 1.3–1.6 (1.5); cephalic bulb 0.48–0.66 (0.55) long by 0.80–0.90 (0.84) wide; bulb with 29–35 (33) rows of spines; spines 0.008–0.010 (0.009) long; oesophagus 8.0–8.9 (8.5) long; anterior muscular region 5.0–6.0 (5.5) long; posterior glandular region 2.4–3.3 (3.0) long; nerve ring 0.70–0.85 (0.77) from anterior end; deirids 0.88–1.20 (0.96) from anterior end; cervical sacs extend 2.1–3.8 (3.1) posterior to cephalic bulb; tail 1.4–1.7 (1.6) long, conical, blunt; vulva 1.8–2.6 (2.3) from posterior end; vagina (sphincter to vulva) 0.9–1.2 (1.0) long; length from sphincter to division of uterus approximately 6.0; uterus didelphic, prodelphic; eggs oval 0.050–0.055 (0.053) × 0.036–0.040 (0.038), operculate, with irregularly pitted shell.

Immature females: Total length 28–31 (29); maximum width 0.58–0.86 (0.66); cephalic bulb 0.34–0.45 (0.39) long by 0.56–0.72 (0.64) wide; bulb with 30–35 (33) rows of spines 0.010 long; oesophagus 4.2–6.5 (5.1) long; anterior muscular region 2.8–4.8 (3.6); posterior glandular region 1.4–2.7 (1.7); nerve ring 0.67–0.72 (0.70) from anterior end; deirids 0.79–1.02 (0.89) from anterior end; cervical sacs extend 1.9–2.9 (2.3) posterior to cephalic bulb. Tail 0.95–1.06 (0.98) long; vulva 1.35–1.61 (1.48) from posterior end; vagina (sphincter to vulva) 0.51–0.60 (0.56); eggs absent.

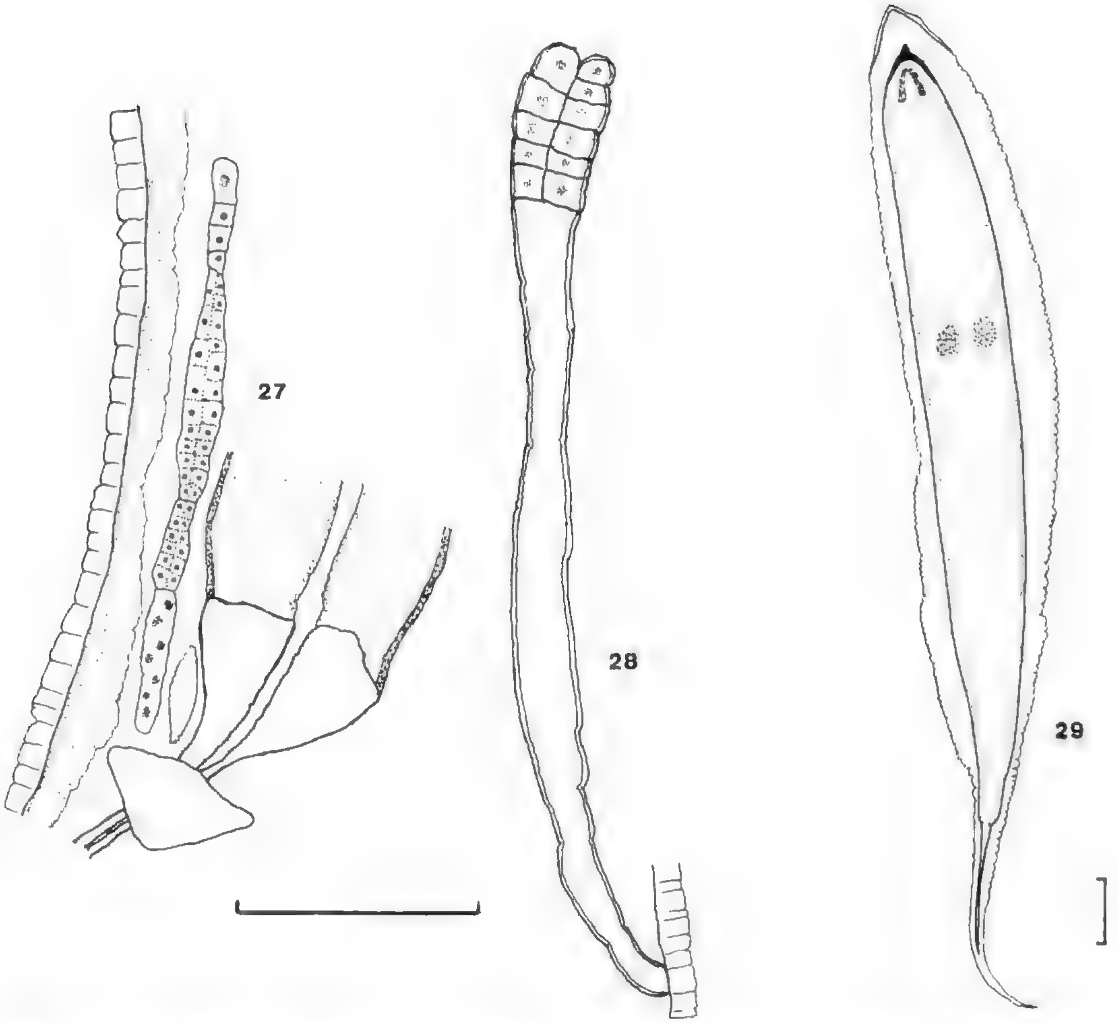
Fourth-stage larvae: (measurements of specimens from *Chlamys bifrons*. Small nematodes, coiled ventrally; 12.9–14.3 (13.7) long, maximum width 0.28–0.35 (0.31); body covered with fine annular striations; mouth opening dorso-ventrally elongate, surrounded by 2 lateral pseudolabia; pseudolabia without accessory lobes, bearing amphids and pairs of barely discernible cephalic papillae; cephalic bulb prominent, 0.25–0.40 (0.33) long by 0.30–0.36 (0.33) wide; 5 tiny spine-like structures, arranged in rows of 2 and 3 on dorsal and ventral aspects of mouth opening. Cephalic bulb armed with 6 rows of subulate hooks arranged in semi-circles, with unarmed spaces laterally; hooks generally increase in size medially, but some median hooks smaller than submedians; number of hooks in dorsal and ventral sectors of rows not always identical; hook numbers as follows: row 1, 14–18 (16.9); row 2, 16–20 (17.4); row 3, 16–22 (18.8); row 4, 16–19 (18.3); row 5, 16–19 (18.2); hooks in row 6 could not be counted accurately. Length of median hooks increases from row 1 to row 4; median hooks of rows 4–6 of similar size; hook lengths: row 1, 0.020–0.025 (0.023); row 2, 0.025–0.035 (0.031); row 3, 0.030–0.035 (0.034); row 4, 0.035–0.040 (0.038); row 5, 0.035–0.045 (0.039); row 6, 0.035–0.040 (0.038; oesophagus 2.2–4.4 (3.3) long; tail conical, 0.25–0.36 (0.30) long. Genital primordia visible in some specimens. Male primordium divided into 3 regions; posterior region terminating near rectum, contains approximately 8 cells; mid-region short, with 6 pairs of cells; anterior region elongate, cells arranged in pairs in posterior two-thirds, singly in anterior third. Female primordium elongate, subdivided at anterior end into two short lobes, each with 5 cells.

Eggs: Eggs held in sea-water at room temperature began to hatch after 10 days. Larvae emerging from

Figs 11–19. *Echinocephalus overstreeti.* 11. Male tail, ventral view; 12. Male tail and spicule, lateral view; 13. Detail of rugose area in vicinity of left fourth caudal papilla of male; 14. Spicule tip, lateral view; 15. Gubernaculum, lateral view; 16. Gubernaculum, spicule sheaths and spicule tips, ventral view; 17. Terminal region of female genitalia, lateral view; 18. Female tail, lateral view; 19. Egg. Scale lines in mm.



Figs 20–26. Larva of *Echinocephalus overstreeti* from scallops, *Chlamys bifrons*. 20. Cephalic extremity, lateral view; 21. Median row of hooks, lateral view; 22. Oesophageal region, lateral view; 23. Mouth opening and pseudolabia, apical view; 24. Tail of female, lateral view; 25. Pseudolabia, dorsal view; 26. Pseudolabia, lateral view. Scale lines in mm.



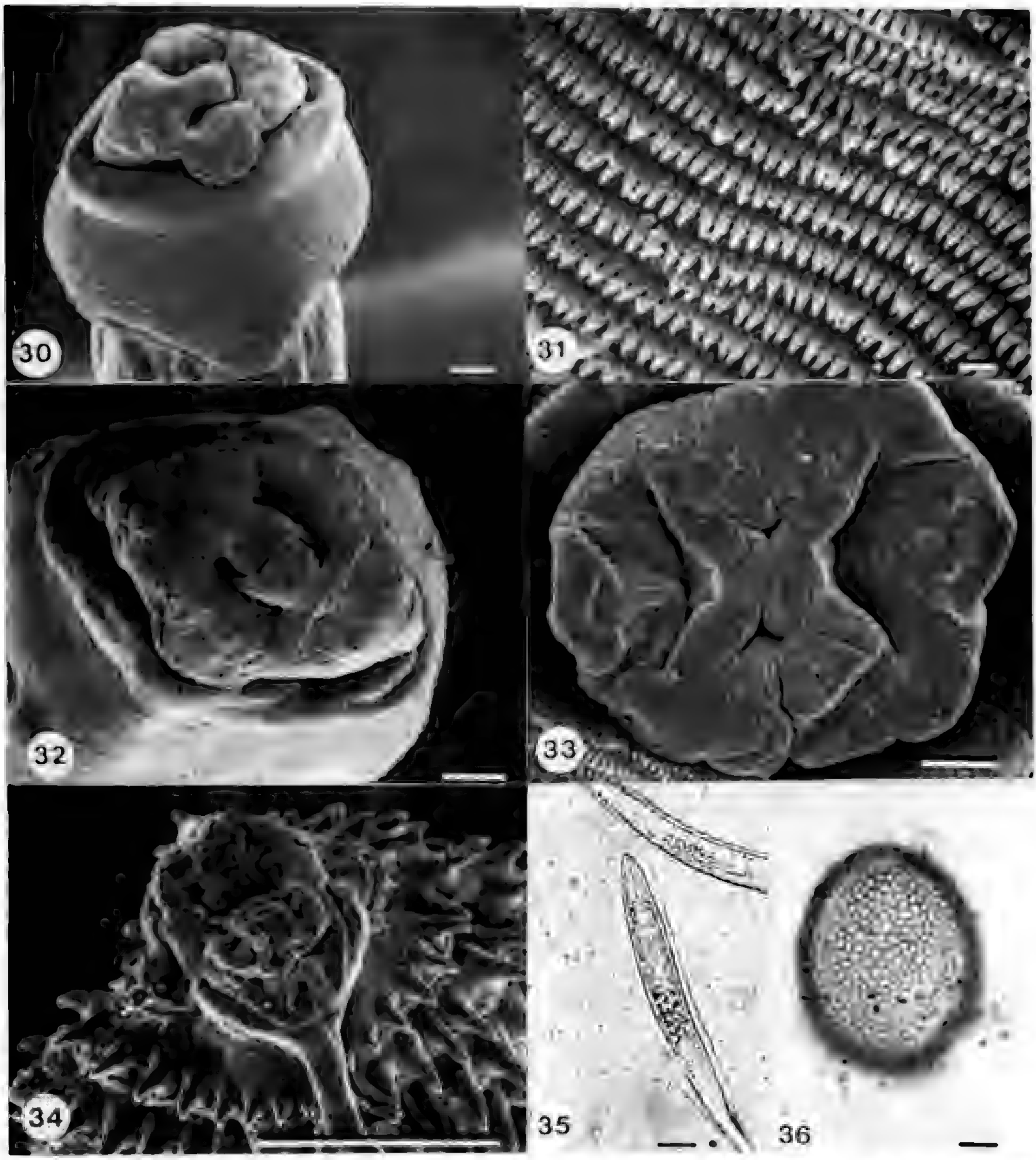
Figs 27–29. Larval stages of *Echinocephalus uncinatus*. 27. Male genital primordium in larval stages from scallop; 28. Female genital primordium in larval stage from scallop; 29. Ensheathed larva newly emerged from egg. Scale lines 0.1 mm.

eggs were ensheathed, with a conspicuous thickening at the anterior end of the sheath. Few internal features of the larvae were discernible except for an apical thickening and paired granular regions in the mid-region of the nematode body, even when stained with methylene blue. The tail of the larva was long and slender with a recurved tip. Motile larvae quickly became attached, by the tail, to debris in the sea-water. Length of larvae 0.108–0.122 (0.114), maximum width 0.009–0.010 (0.009).

Fourth-stage larvae in elasmobranchs: Larvae identical to those occurring in scallops were found in the stomachs of rays and sharks. In addition, several specimens were found undergoing the final moult. The external cuticle of the cephalic bulb bore six rows of hooks identical with those occurring on larvae in scallops; underneath the external cuticle were the numerous rows of small spines found on the cephalic bulb of the adult, indicating that the larvae in scallops and the adults in elasmobranchs belong to the same species. No further moults were observed in elasmobranchs.

Spicule lengths: Observations indicated that the spicules of immature nematodes were shorter than those of adults. Data (Fig. 39) indicate a linear relationship between worm length and spicule length of the form $y = 0.46 + 0.24\,x$ ($r^2 = 0.922$).

Larval stages in scallops: Larval stages were found in *C. bifrons* and *P. albus* from Northaven in Gulf



Figs 30-36. Micrographs of adult and larval *Echinocephalus overstreeti*. 30. Cephalic end of adult with single interlabium exerted; 31. Cephalic spines of adult showing discontinuities in rows; 32. Cephalic end of adult with both interlabia visible; 33. Cephalic end of adult with both interlabia inverted; 34. Cephalic end of larval stage from scallop, showing detail of interlabia and groups of spine-like structures anterior to major rows of hooks; 35. Larval *E. overstreeti* newly emerged from egg; 36. Egg shell showing mammillate surface. Scale lines: figs 30, 32, 33, 34, 0.1 mm; figs 31, 35, 36, 0.01 mm.

St Vincent and in *C. bifrons* from Edithburgh (Table 1). A higher prevalence of *E. overstreeti* was found in *P. albus* as well as a higher intensity of infection.

The prevalence of infection was significantly lower, using a χ^2 test, in *C. bifrons* less than 65 mm in total length compared with larger class sizes. Other differences in prevalence between class

Figs 37-38. Adult male and larva of *Echinocephalus overstreeti*. 37. Male tail, ventral view with papillae numbered; phasmid indicated by arrow; 38. Cephalic end of larva from scallop, *Chlamys bifrons*. Scale lines 0.1 mm.

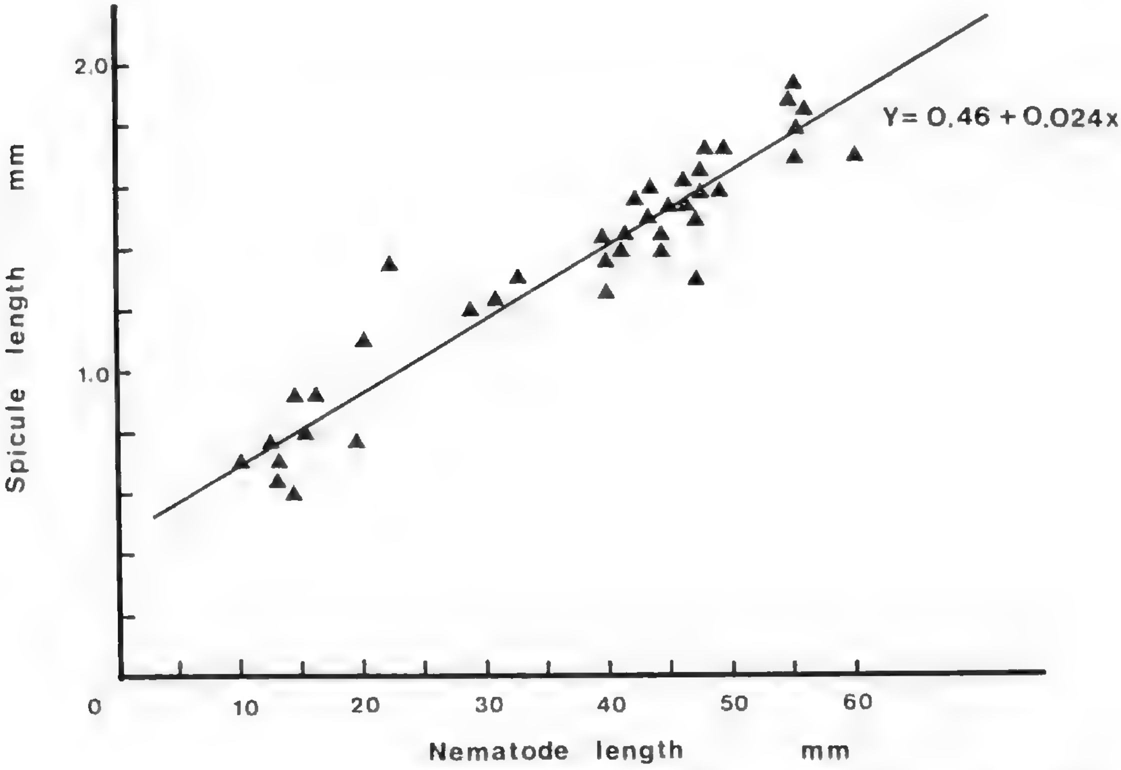


Fig. 39. Relationship between spicule length and total body length of 40 specimens of *Echinocephalus overstreeti* from *Heterodontus portusjacksoni*.

TABLE 1. *Occurrence of larvae of* Echinocephalus overstreeti *in scallops,* Pecten albus *and* Chlamys bifrons.

Host species	Locality	No. examined	Prevalence (%)	Intensity of infection Range (mean)
Chlamys bifrons	Northaven	136	61.8	1– 7 (2.0)
	Edithburgh	34	41.2	1– 4 (2.5)
Pecten albus	Northaven	20	80.0	1–14 (4.4)

sizes were not significant statistically. Intensity of infection (Table 2) declined slightly, but not significantly, with increasing size.

The occurrence of different intensities of infection fitted an exponential curve of the form $y=113.6_e - 0.566\,x$(Fig. 40).

No nematode larvae were found in abalone (*Haliotis laevigata*).

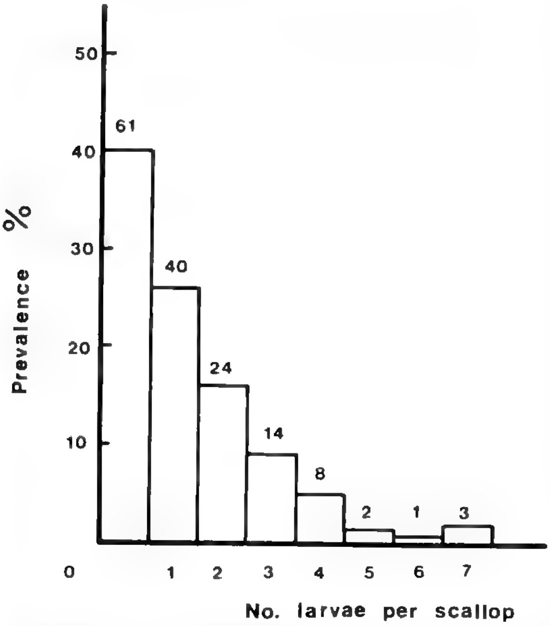


Fig. 40. Intensity of infection in 153 scallops, *Chlamys bifrons,* from St Vincents Gulf, with the larva of *Echinocephalus overstreeti.* Numbers of scallops in each class is indicated above the histogram. The relationship between prevalence and larvae per scallop is $y=113.6_e^{-0.566x}$.

Definitive hosts: E. overstreeti, including some gravid females, was found commonly in *H. portusjacksoni* (Table 3). There was no association between host length, used as an indicator of age, and either prevalence or intensity of infection (Table 3). Infections were also found in several species of ray and in the chaemeriform *C. milii,* but in none of these hosts were gravid females seen. The largest nematodes found in a ray were in *Myliobatis australis* in which females reached 45 mm in length; none was gravid. No *E. overstreeti* were found in 11 *Furgaleus ventralis* (Whitley, 1943), 11 *Notorhynchus cepedianus* (Péron, 1807), 40 *Mustelus antarcticus* (Guenther, 1870), 6 *Galeorhinus australis* (Macleay, 1881), 9 *Pristiophorus cirratus* (Latham, 1794), 15 *Centrophorus moluccensis* Bleeker, 1860, 41 *Squalus megalops* (Macleay, 1881), 17 *Carcharhinus brachyurus* (Guenther, 1870), 30 *Orectolobus tentaculatus* (Peters, 1864), 14 *Narcine tasmaniensis* Richardson, 1840, 47 *Raja cerva* Whitley, 1939, 20 *Urolophus expansus* McCulloch, 1916, 8 *U. cruciatus* (Lacèpede, 1804) and 7 *Squatina australis* Regan, 1906 examined. Histograms of nematode lengths (Fig. 41) indicate that those from rays were predominantly immature nematodes and that a greater proportion of the nematodes recovered from rays were larvae.

Echinocephalus *from other regions of Australia:* Two collections of *Echinocephalus* from Queensland were available for examination. The first, consisting of 15 males, 25 nongravid females and 2 larvae of *E. overstreeti* was collected from *Dasyatis fluviorum* Ogilby, 1928 at Caloundra (AHC 1077).

A second collection consisting of 5 females and 2 males, taken from *Aetobatus narinari* (Euphrasen

TABLE 2. *Prevalence and intensity of infection of* Echinocephalus overstreeti *larvae in scallops,* Chlamys bifrons *of different length classes.*

Scallop length class (mm)	No. examined	Prevalence of infection (%)	Intensity of infection (no. larvae per infected scallop)
<60	20	40	2.88
61–65	23	48	2.18
66–70	31	71	2.18
71–75	52	65	2.03
>76	27	63	1.94

TABLE 3. *Prevalence and intensity of infection of adult* Echinocephalus overstreeti *in* Heterodontus portusjacksoni.

	Size class (cm)	No. sharks	Prevalence (%)	Intensity of infection range (mean)
Males	30–40	13	100	8–52 (22)
	41–50	9	100	2–61 (19)
	51–60	5	80	3–13 (7)
	61+	3	77	12–16 (14)
		Total 30		
Females	30–40	10	100	8–35 (19)
	41–50	9	89	3–47 (19)
	51–60	5	100	8–30 (13)
	61+	5	40	13–63 (38)
		Total 29		

TABLE 4. *Occurrence of* Echinocephalus overstreeti *in elasmobranch and chaemeriform fishes from South Australian gulf and adjacent waters.*

Host species	No. Examined	Prevalence (%)	Intensity of infection Range (mean)	Adult (A) or larval (L) stages
Heterodontus portusjacksoni	59	89.8	3–63 (13.9)	AL
Parascyllium ferrugineum	6	66.7	1–13 (8.3)	L
Orectolobus maculatus	7	14.3	2	L
Dasyatis brevicaudatus	17	35.3	1–32 (8.3)	L
Dasyatis thetidis	4	75.0	1–10 (2.7)	L
Raja whitleyi	10	40.0	1–24 (3.1)	AL
Urolophus mucosus	10	20.0	1–4 (2.5)	AL
Trygonorhina guanerius	47	12.7	1–20 (7.7)	AL
Aptychotrema vincentiana	35	2.9	1	L
Myliobatis australis	26	30.8	1–16 (3.6)	AL
Hypnos monopterygium	6	16.7	1	L
Callorhynchus milii	21	42.8	1–4 (2.0)	L

1790) from Moreton Bay (AHC 1080), was identified as *E. sinensis* Ko, 1975.

Discussion

The adult nematodes described above most closely resemble *E. overstreeti*. They are distinguished from all congeners except *E. pseudouncinatus* Milleman, 1951 by the arrangement of the papillae on the tail of the male, with the terminal three pairs widely separated from the remaining papillae. In addition, the specimens differ from *E. diazi* Troncy, 1969, *E. multidentatus* Balyis & Lane, 1920, *E. southwelli* Baylis & Lane, 1920, *E. pseudouncinatus* and *E. sinensis* Ko, 1975 in having more than 29 rows of spines on the cephalic bulb, from *E. spinosissimus* (Linstow, 1905) and *E. daileyi* Deardoff, Brooks & Thorson, 1981 in possessing a well developed rugose area on the ventral surface of the tail of the male and from *E. uncinatus* in the form of the rugose area, which in the latter species is ornamented with regular rows of fine bosses (Beveridge 1985) rather than the irregularly shaped bosses illustrated in Fig. 13. *E. mobulae* Kalyankar, 1971 is considered a *species inquirenda* following Ko (1975) and Soota (1983), as is *E. oligocanthus* Anya, 1977 which is based solely on a larval form. These two species have not been considered further. The Australian specimens conform to the description of *E. overstreeti* in all details except for measurements. Males from the type series of *E. overstreeti* measured 21–30 mm with spicules 0.6–1.4 mm long (Deardoff & Ko 1983), compared with Australian specimens measuring 55–60 mm and spicules 1.70–1.94 mm. However, as indicated in Fig. 39, considerable growth occurs during the final stages of development and the spicules as well as the body increase markedly in length, the relationship between the two being linear. The ratio of spicule length: body length for the Australian material is similar to that of *E. overstreeti*. Specimens of *E. overstreeti* from Australian rays were generally smaller than those from sharks, and since the type series of *E. overstreeti* was taken from a ray,

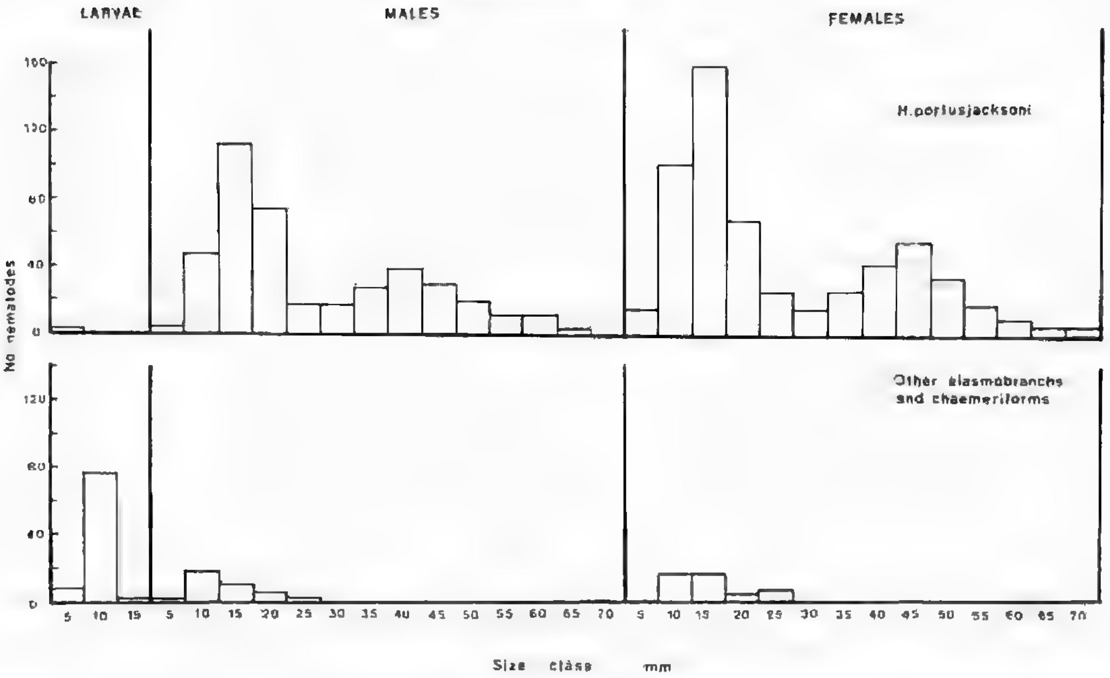


Fig. 41. Size distribution of larval and adult *Echinocephalus overstreeti* arranged in 5 mm size classes. Numerals on abscissa indicate lower limit of size class. Nematodes from *Heterodontus portusjacksoni* are compared with those from other species of shark, from rays and from chaemeriforms, grouped together.

Taeniura melanospilos, the size differences noted may be host induced. The Australian material was compared with paratypes of *E. overstreeti* before being assigned to this species.

Redescription of the cephalic anatomy of Australian specimens confirms that the arrangement of the pseudolabia and teeth is identical with congeners and contradicts Milleman's (1963) suggestion that the pseudolabia and teeth of Australian *Echinocephalus* are unique. These differences plus the large size of the specimens was the basis of Milleman's suggestion that Johnston & Mawson's (1943) specimens represented a new species. Although a correct conclusion, Milleman's (1963) reasons for reaching it were not.

Two features of the morphology of the adult, the arrangement of the pseudolabia and the gubernaculum, warrant comment. Examination of several specimens of *E. overstreeti* by SEM revealed that cephalic morphology is extremely plastic, a feature not noted previously in the genus. The median lobes of the pseudolabia may both be exerted and interlock (Fig. 32), one may be concealed below the other (Fig. 30), or both may be completely introverted such that the trilobed nature of the interlabia is concealed (Fig. 33). Congeners have been described exclusively with both pseudolabia exerted.

The gubernaculum was only clearly visible in immature males, as a weakly sclerotised structure at the junction of the spicule sheaths. In adult males, the highly developed surrounding musculature makes it more difficult to detect. A gubernaculum is present in all species which have been described or re-examined in recent years (Troncy 1969; Ko 1975; Deardorff *et al.* 1981; Deardorff & Ko 1983; Beveridge 1985), and may well be present in all members of the genus. Attempts to sub-divide the genus based on the presence or absence of a gubernaculum (Deardorff *et al.* 1981) may thus be premature until all species have been re-examined carefully.

The larvae of *Echinocephalus* from scallops are also attributed to *E. overstreeti* based on the evidence of moulting nematodes which clearly demonstrated the features of the fourth stage externally and those of the adult internally. Milleman (1963) considered the stage of *E. pseudouncinatus* in abalone to be the second stage, and Ko (1975) described the larval stages of *E. sinensis* in oysters as second and third stages. By contrast, the nematodes in scallops are considered to be fourth stage larvae. Not only are adult features present in larvae entering the final moult, but well developed genital primordia are present in larvae from the scallops. Gonad development normally occurs during the latter part of the fourth stage in nematodes. Although the nematodes in scallops undergo considerable growth in *H. portusjacksoni*, no evidence of moulting was seen in nematodes greater than 15 mm in length when the six rows of hooks on the cephalic bulb are replaced by the 30 rows present in the adult.

Only the larvae of *E. pseudouncinatus* and *E. sinensis* have been described in detail, and both are remarkably similar to that of *E. overstreeti*. Hook numbers and sizes may allow the species to be separated, but more detailed morphological data are needed before this can be done. No larval *Echinocephalus* were found in the abalone examined, though abalone are the normal intermediate host of *E. Pseudouncinatus* (Milleman 1951). *E. overstreeti* is the only species that has been found in South Australia, and on this provisional basis, earlier records of *Echinocephalus* sp. or *E. uncinatus* from this region can probably be attributed to *E. overstreeti*. Records from other parts of Australia (Johnston & Mawson 1945a, b; Lester *et al.* 1980; Hooper 1983) cannot be assigned to any species with certainty at present, pending investigations of the geographic distribution of *E. overstreeti*, but the original description of the nematode from the Marquesas Islands suggests that it is widely distributed. The naming of larval forms as *E. uncinatus* by Johnston & Mawson (1945a, b) is due to the fact that at the time of their work, the name *uncinatus* had been applied, incorrectly by Baylis & Lane (1920), to a larval nematode from *Dasyatis centroura* (Mitchill, 1815) (syn. *Trygon brucco*) from the Adriatic sea (Milleman 1963; Beveridge 1985) and their specimens closely resembled larval *uncinatus*. *E. uncinatus* is known only from the Adriatic and Black seas (Beveridge 1985).

Ko (1975) described the larva of *E. sinensis* as having seven rows of spines. *E. overstreeti* is considered to have six major rows, and the groups of five spine-like projections dorsally and ventrally, posterior to each pseudolabium, described as the "first" row by Ko (1975) are not considered to constitute a row of spines. Their structure is quite different to spines of the major rows, but their function is not known.

Data presented above suggest that *H. portusjacksoni* is the principal definitive host of *E. overstreeti* in South Australian gulf waters. This shark feeds predominantly on molluscs, echinoderms and crustaceans (McLaughlin & O'Gower 1971), and gravid female nematodes were commonly encountered in it. There appeared to be a slight reduction in prevalence in larger sharks of both sexes, although the number of sharks examined in each size class was small. *H. portusjacksoni* are approx. 23 cm at birth, and grow at 5.1–7.4 cm per year. (McLaughlin & O'Gower 1971). Thus most of the small sharks examined were probably at least two years of age, and the relatively large numbers of nematodes in some sharks of this length is therefore not surprising. Because of the paucity of data on growth in *H. portusjacksoni* (McLaughlin & O'Gower 1971), the relationships between host age and infections with *E. overstreeti* has not been analysed in detail. Scallops are heavily infected with *E. overstreeti*, but no other species of molluscs other than abalone were examined, and scallops may not be the only possible intermediate hosts.

Rays and other species of shark which feed on shellfish may also ingest larvae of *E. overstreeti*. The high percentage of larvae present and the lack of mature nematodes in hosts other than *H. portusjacksoni* suggests that they may not be entirely suitable hosts for the development of the nematode. The largest nematodes found in a ray were in a specimen of *Myliobatis australis*, but the females were not gravid. Examination of a wider variety of elasmobranchs may reveal that *E. overstreeti* develops to maturity in some species, since the type specimens from the ray *Taeniura melanospilos* were gravid (Deardorff & Ko 1983). The same species of ray occurs in northern Australian waters but none were examined in this study.

E. sinensis is reported here for the first time from Australia, in the ray *Aetobatus narinari*. The nematode was formerly known only from Hong Kong, from the same definitive host species (given as *A. flagellum*, now a synonym of *A. narinari*). The usual intermediate hosts are oysters, *Crassostrea gigas* (Thunberg, 1793) (Ko 1975).

Acknowledgments

Thanks are due to Mesdames E. Moore and J. Clarke and Messrs M. O'Callaghan and R. Martin for expert assistance in the laboratory and for collecting sharks and rays, to Mr B. Robertson for the collection and examination of many of the elasmobranchs and to Dr J. R. Lichtenfels for the loan of specimens. Mr K. Smith took the scanning electron micrographs and Dr T. Deardorff kindly confirmed the identity of the species.

The descriptive work was carried out in the Laboratoire des Vers, Muséum national d'Histoire naturelle, Paris. Prof. A. G. Chabaud is thanked for providing laboratory assistance and financial support. Mr J. Glover is thanked for his advice on host numenclature and Dr D. M. Spratt for comments on a draft of the manuscript.

Collection of the majority of the elasmobranchs was supported financially by the Australian Biological Resources Survey.

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FOSSIL BROOD CELLS OF STENOTRITID BEES (HYMENOPTERA: APOIDEA) FROMTHE PLEISTOCENE OF SOUTH AUSTRALIA

*BY TERRY F. HOUSTON**

Summary

Calcareous fossils from the west coast of Eyre Peninsula, South Australia, previously recognized correctly as petrified brood cells of burrowing bees and denoted by the ichnospecies names *Celliforma bedfordi* and *C. septata* by Zeuner & Manning (1976), are assigned to the bee family Stenotritidae. Notes are provided on a fossil site and samples from it are described, figured and discussed.

KEY WORDS: fossils, brood cells, stenotritid bees, Pleistocene, South Australia.

FOSSIL BROOD CELLS OF STENOTRITID BEES (HYMENOPTERA: APOIDEA) FROM THE PLEISTOCENE OF SOUTH AUSTRALIA

by TERRY F. HOUSTON*

Summary

HOUSTON, T. F. (1987) Fossil brood cells of stenotritid bees (Hymenoptera: Apoidea) from the Pleistocene of South Australia. *Trans. R. Soc. S. Aust.* 111(2), 93-97, 29 May, 1987.

Calcareous fossils from the west coast of Eyre Peninsula, South Australia, previously recognized correctly as petrified brood cells of burrowing bees and denoted by the ichnospecies names *Celliforma bedfordi* and *C. septata* by Zeuner & Manning (1976), are assigned to the bee family Stenotritidae. Notes are provided on a fossil site and samples from it are described, figured and discussed.

KEY WORDS: fossils, brood cells, stenotritid bees, Pleistocene, South Australia.

Introduction

The fossils forming the subject of this paper were first described by Zeuner & Manning (1976) who recognized them as the petrified brood cells of burrowing bees but could not identify them further. Instead, they referred them to the ichnogenus *Celliforma* recognizing two ichnospecies *C. bedfordi* and *C. septata*. Zeuner and Manning's specimens were collected from "coastal travertine and consolidated dune-rock" of Pleistocene or Sub-Recent age at Venus Bay on the west coast of Eyre Peninsula, South Australia, and are lodged in the British Museum of Natural History. Their description of the fossils contains some confusing errors and these are dealt with later.

Additional specimens of the fossils from the west coast of South Australia were located in the South Australian Museum (registered numbers SAM P24877-82). They were collected by A. Crooks from "5 ml [miles] east of Rocky Point". Guided by directions from this collector, I was able to locate a bed of the fossils in coastal cliffs 0.5 km west of Scott Point (32°01'S, 132°23'E) and about 6 km west of Fowlers Bay. I observed the form and distribution of the fossils and obtained samples for the Western Australian Museum (registered nos. WAM 86.723-86.730) on 7 January 1985.

Recent studies of stenotritid bee nests (Houston 1984; Houston & Thorp 1984) have revealed several features which distinguish stenotritid brood cells from those of other bees. These same features characterise the fossils known as *Celliforma septata* and *C. bedfordi* and are the basis of my contention that the fossils are a legacy of the nesting activities of stenotritid bees.

Observations

Description of fossil site

The geological terminology employed here follows Flint (1986).[1]

The bed of fossils found near Scott Point is located in an embayment of the coastal cliffs and forms a band about 20 cm high and approximately 30 m long in the cliff face (Fig. 1). The fossil band rests on a hard calcrete shelf that rises gently at each side and beneath this are three other calcrete shelves separated by soft aeolian calcarenite. The fossil band appears to be situated in the lowest horizon of a fossil colluvial soil about 1 m high. Three horizons are evident: (1) an upper zone of brown silt about 30–40 cm high (presumably the original surface); (2) a middle zone of calcrete breccia; and (3) a lower zone of pale yellow clayey calcareous aeolianite in which the fossils are embedded. Above this fossil soil is deep white aeolianite capped by calcrete and on this are recent aeolian dunes (suffering deflation).

The fossil brood cells are very numerous and occur densely packed, some being welded together or to the calcrete basement. All are horizontal or subhorizontal.

Searches nearby located only a small number of other brood cells welded to a lower calcrete shelf.

Description of fossils

Loose fossils from the Scott Point site (Fig. 2) measure 40–70 mm in length and 17–20 mm in diameter. Usually they are slightly curved, rounded at one end and truncated or concave at the other. Within the rounded end of each is a somewhat ovoidal chamber (either empty or soil-filled) measuring 13 mm in maximum diameter and, when plugged, 28 mm in maximum length. When not plugged, the chamber is continuous with a cylindrical burrow which extends to the truncate

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[1] Flint, R. B. (1986) Explanatory Notes, Nuyts 1:250 000 Map Sheet area. South Australian Department of Mines and Energy report 86/7 (unpublished).

Fig. 1. Fossil site west of Scott Point (background). Fossilliferous horizon in upper Bridgewater Formation is arrowed.

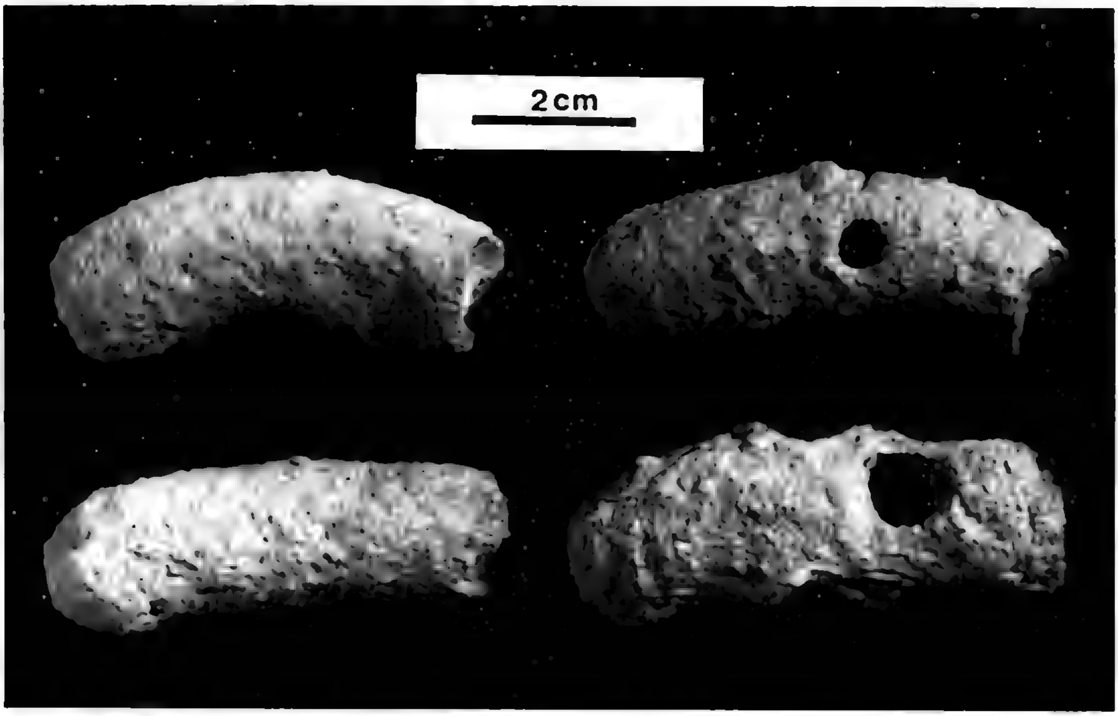
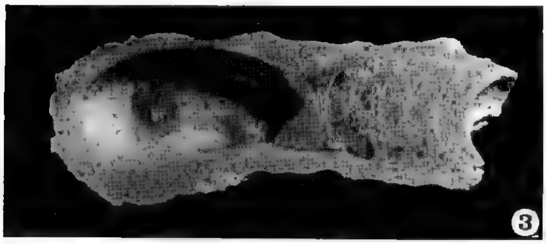
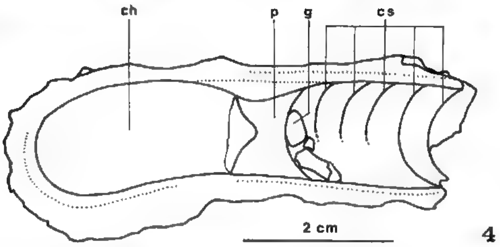


Fig. 2. Loose fossils from upper Bridgewater Formation west of Scott Point. Holes in the specimens on the right were probably made by emergence of a parasite (upper) and a bee occupant (lower). (WAM 86.723-86.726).

end. The cemented wall of the chamber varies from 2–7 mm in thickness and while variably rough externally it is quite smooth internally (Figs 2, 3).

Many of the fossils are sealed with a complex closure. In the neck of each chamber is a plug about 10 mm long, the inner face of which usually exhibits an inverted conical spiral pattern and the outer face being smoothly concave. Between this and the truncate end may be 4–8 thin concave cemented partitions, 3–4 mm apart. The spaces between them are solidly filled with fine soil and gravel particles up to 5 mm across.





Figs 3 and 4. Sagittal section of an intact fossil (WAM 86.727) from west of Scott Point (3) and interpretation of its structure (4). Legend: ch, cell chamber; cs, concave septa (1st–3rd appear to have been disturbed in lower parts); g, gravel particles; p, cell plug.

Other fossils lack the plugs and partitions and are uniformly filled with soil and gravel. Many specimens with intact closures had a lateral hole 9–10 mm in diameter about 30 mm from the rounded end while a few had smaller holes in a similar position (Fig. 2).

Amongst the S. Aust. Museum specimens are some that are embedded in a solid calcrete rock matrix (e.g. P24879 and P24882) and which are evidently older than those described above. Nevertheless, they clearly show the series of concave partitions in the chamber access burrows and their internal dimensions match those of free fossils (Fig. 5).

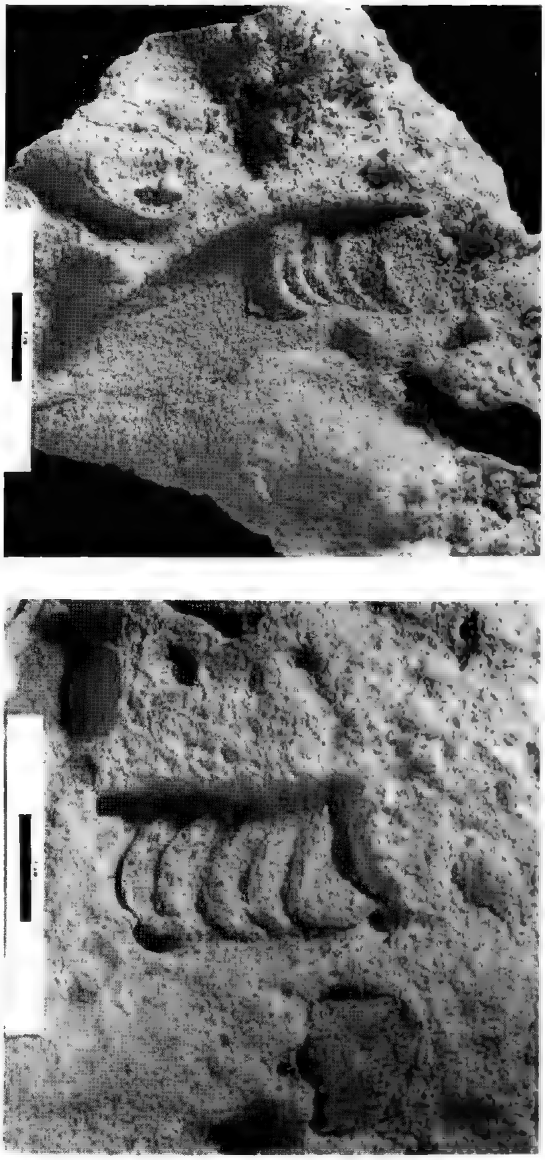


Fig. 5. Trace fossils embedded in solid calcrete from lower Bridgewater Formation, 8 km west of Rocky Point. (SAM P24879, P24882). Scale lines, 1 cm.

Discussion

An uncritical observer could easily confuse the fossils described here with other more common kinds of fossils derived from the pupal cases of Coleoptera, in particular the large weevils, *Leptopius* spp. These were described and figured by Lea (1925) and are distinguishable by their more ovoidal form (both externally and internally), the absence of a chamber closure, and usually by their larger diameter.

That the fossils described here are the petrified brood cells of a stenotritid bee can scarcely be doubted in view of their close resemblances to the brood cells of extant species. Diagnostic features of stenotritid cells (Houston & Thorp 1984) which are observable in the fossils are: (1) built-in walls of cell chamber continuous with those of access burrow; (2) cell plug with concave spiral pattern on inner face, outer face smooth and concave; (3) access burrow sealed with one or more concave cemented partitions; (4) gravel particles included in soil-filling between plug and partitions; and (5) cells more or less horizontally oriented.

Only two genera of Stenotritidae, *Stenotritus* and *Ctenocolletes*, are recognized and our present knowledge of stenotritid nest architecture provides no means of distinguishing the brood cells of these two taxa. However, adults of *Ctenocolletes* are larger on average than those of *Stenotritus* and, since the internal dimensions of the fossil cells marginally exceed those of the largest known *Ctenocolletes* cells (*C. nicholsoni* (Cockerell); unpublished personal observations), it seems more probable that they are derived from the constructions of a *Ctenocolletes* species. Were that species to be extant, it would most probably be *C. fulvescens* Houston, the only stenotritid known to inhabit the country fringing the Great Australian Bight. Unfortunately, nests of this species are unknown. One of the extraordinary features of the fossils is the high number of concave septa occurring in the cell closures (up to eight of them). Three is the maximum number observed in the closures of extant Stenotritidae (Houston & Thorp 1984).

Although Zeuner & Manning (1976) recognize two ichnospecies of fossil cells from Venus Bay, there is no reason to suppose that more than one bee species was involved in their making. *Celliforma bedfordi* was distinguished by the cell plug having a concave spiral pattern on its inner face (absent in *C. septata*). The spiral pattern would be typical of cells which remained undisturbed after closure (presumably when occupants had died). The closure of cells from which adults had emerged would be modified or destroyed as the occupants burrowed out.

Retallack (1984) likened *C. bedfordi* and *C. septata* to the earthen brood cells of living *Melitoma* and *Ptilothrix* bees (Anthophoridae) but the resemblances are few and are far surpassed by those of stenotritid brood cells.

The stenotritid fossils occur in rocks forming part of the Bridgewater Formation which was laid down during the middle Pleistocene (Flint 1986).[1] Fossils occurring in the lower part of this formation (those embedded in solid calcrete) are of uncertain age but possibly as old as 700 000 years while those from the upper part (the separable or only slightly fused fossils) may be up to 100 000 years old (R. B. Flint, personal communication).

I consider the fossil bed in the upper Bridgewater Formation near Scott Point to represent a perennial nesting site where hundreds of female bees over numerous generations had nested gregariously (but individually) in colluvial soil filling a limestone swale. Stenotritids burrow into level ground and construct brood cells at the lower ends of the shafts. They cement the earthen walls of the cells and the access burrows with some secretion so that they are quite durable constructions which may remain for years. There must be a tendency for lime to be deposited in the walls of the cells at a greater rate than in the surrounding soil. Thus they become calcified first as separate entities, then gradually fused to one another, then finally encased in a solid calcrete matrix.

Because of the high frequency of unperforated closures amongst the specimens examined it must be supposed that either there was a high mortality rate amongst immatures or that emerging adults bypassed the closures. Evidence for the latter possibility occurred in the many specimens with a large lateral hole in near proximity to the cell plug (Fig. 2). However, such lateral emergence is so far unknown amongst extant Stenotritidae and is atypical of bees generally, emergence usually occurring via the old access burrows and involving demolition of the closures.

Comment

The following corrections are made to Zeuner & Manning (1976).

Page 205: Under "Remarks" for *C. bedfordi*, the second sentence should be restructured to make it clear that the whole fossils are "some 6-7 cm long by 2 cm in diameter", not the septate cross walls.

Registration number for paratype of *C. septata* should be In. 31433 (not 34133).

Caption for Plate 1, Fig. 9, should read Paratype (not Holotype).

Plate 1 figure numbers should be altered as follows: 6 to 9, 7 to 6, and 9 to 7.

Caption for Plate 2, Fig. 1, should read Holotype (not Paratype).

Acknowledgments

Preparation of this paper was facilitated by the generous assistance of a number of people. In particular I wish to thank the following: Messrs Alistair Crooks and Richard Flint (Department of Mines and Energy, South Australia) and the Director-General of their department for information on fossil sites in South Australia and access to an unpublished report; Mr Tony Gayski (Geology Department, University of Western Australia) for preparing sections of the fossils; Dr Ken McNamara (Department of Palaeontology, Western Australian Museum) for providing copies of some relevant literature; and Mr Neville Pledge (Department of Palaeontology, South Australian Museum) for providing access to specimens and data in his department. Dr McNamara and Mr Pledge also read a draft of this paper and made useful suggestions for its improvement, as did two referees, Dr B. Webby and Professor A. Seilacher.

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ANOPLOZETES, A NEW GENUS OF ZETOMOTRICHIDAE (ACARIDA:CRYPTOSTIGMATA) FROM SOUTH AUSTRALIA

BY DAVID C. LEE & GEORGE A. PAJAK*

Summary

Anoplozetes jamiesoni gen. nov., sp. nov. is described from arid tussock grassland in the Victoria Desert, northern South Australia. The Zetomotrichinae are considered and a key provided to separate the seven genera. This is the first record of Zetomotrichidae from Australasia.

KEY WORDS: Acarida, Zetomotrichinae, new family record, Anoplozetes jamiesoni, new genus, new species, South Australia.

ANOPLOZETES, A NEW GENUS OF ZETOMOTRICHIDAE (ACARIDA: CRYPTOSTIGMATA) FROM SOUTH AUSTRALIA

by David C. Lee & George A. Pajak*

Summary

Lee, D. C. & Pajak, G. A. (1987) *Anoplozetes*, a new genus of Zetomotrichidae (Acarida: Cryptostigmata) from South Australia. *Trans. R. Soc. S. Aust.* **111**(2), 99-103, 29 May, 1987.

Anoplozetes jamiesoni gen. nov., sp. nov. is described from arid tussock grassland in the Victoria Desert, northern South Australia. The Zetomotrichinae are considered and a key provided to separate the seven genera. This is the first record of Zetomotrichidae from Australasia.

Key Words: Acarida, Zetomotrichinae, new family record, *Anoplozetes jamiesoni*, new genus, new species, South Australia.

Introduction

This publication is part of an ongoing study (Lee 1981; 1982; 1985; in press) of sarcoptiform mites of South Australian soils, sampled from nine florally diverse sites. The new species described here was collected only at the arid grassland site. It is established as the type of a new genus and requires modification of the subfamily diagnosis. The Zetomotrichidae include two subfamilies of which the Rohriinae Balogh & Balogh, 1984 from Brazil are not considered. The briefness of the description of the single species of Rohriinae makes it uncertain as to whether or not some of the diagnostic character states of the Zetomotrichinae should apply to the whole family.

Materials and Methods

The notation and methods of measurements follow Lee (1981) with modifications made by Lee (in press). Measurements are in microns (μm). The trochantera are illustrated (Fig. 3), although normal, to emphasize their similarity to both those of the short-legged *Constrictobates* (Lee in press) and the saltatory *Zetomotrichus*. The mites examined are deposited in the South Australian Museum.

ZETOMOTRICHINAE Grandjean

Zetomotrichidae Grandjean, 1954: 16.

Diagnosis: Comalida. Planofissurae. Poronotae. Oripodoidea. Zetomotrichidae. Notal foramina absent, but numerous scattered refractile micropores. Soma spindle-shaped; dorsosejugal furrow mainly absent, row of sigilla across line it would occupy. Rostral margin of proteronotum denticulate. Lamella (seta *z*1 to *z*2) absent. Pteromorphs absent but conspicuous tooth-shaped process bearing seta (*Z*1) on hysteronotal shoulder (both directed forward) and deep limbus around lateral and posterior hysteronotal margin. Hysteronotum with 10 pairs (3*J*, 5*Z*, 2*S*) of setae. External malae narrow, not ventrally obscuring oral setae. Legs long, leg IV longest (femur-tarsus longer than half somal length), both tibia and tarsus IV subequal in length to femur IV, femur I and II with long stalk, tarsi I, II, III narrow proximally (subequal to distal diameter), pretarsi pedunculate with three claws.

Distribution: Previously known from two main areas: around the Mediterranean, Caspian seas and in India, and from the Andes in Peru and southward. Particular species recorded from caves, tussock grass or as saxicolous, but also known from woodland and forest litter.

Remarks: The Zetomotrichidae are unique in the Oripodoidea (=Oribatuloidea: Balogh & Balogh, 1984, see Lee in press), and unusual in the Poronotae, in lacking foramina. Although the refractile notal micropores may serve the same function, they do not appear to be homologous. Despite the absence of this diagnostic character state, the only nymphs described (Covarrubias 1969) belong to the "Excentrosclerosae" (=Oripodoidea, see Lee in press).

Balogh & Balogh (1984) record only three genera in the Zetomotrichinae and incorrectly date the authority of the name as "1934". Besides the new genus established in this paper, there are six genera recorded here in chronological order of establishment date, with references to fuller descriptions for two genera, as well as number of species and distribution:

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Zetomotrichus Grandjean, 1934: One species; Algeria (Pm), ? Caucasus (Ps), Pakistan (Oi).

Mikizetes Hammer, 1958 (Covarrubias, 1969 includes only description of immatures for the family): Two species; Argentina, Peru and Chile (NTc).

Ghilarovus Krivolutsky, 1966 (Subias & Pérez-Inigo, 1977): Three species; Spain (Pm), Uzbekistan and Turkmenia in Central Asia (Ps near Pm).

Pallidacarus Krivolutsky, 1975: One species; Turkmenia in Central Asia (Ps near Pm).

Oglasacarus Bernini, 1978: One species; Montecristo Island (Pm).

Keralotrichus Mahunka, 1985: One species; South India (Oc).

KEY TO ZETOMOTRICHINAE GENERA
(Adults)

1. Notal setae Z1 & *j2* similar to Z2. Pores *hf2*, *hf5* slit-like, enlarged, twice length of seta Z2. No pyriform organ in area of pore *hf3*, no humeral organ or subapical process present. Coxisternal setae *I2* & *III2* more than twice length of *I1* & *III1*. Genital shields bearing four setal pairs (*4JZg*), two pairs of paranal setae (2*Sa*) .... *Anoplozetes*

   Notal setae Z1 & *j2* at least twice as long and stout as Z2, Z1 usually not setose. Pores *hf2*, *hf5*, if similarly slit-like, subequal in length to or shorter than seta Z2. Humeral organ or subapical process present, pyriform organ may be present in area of pore *hf2*. Coxisternal setae *I2* & *III2* subequal in length to or shorter than *I1* & *III1*. Genital shields with three to five setal pairs, two or three pairs of paranal setae, but never *4JZg*, 2*Sa* 2

2. Hysteronotal pores *hf3*, *hf6* slit-like, subequal in length to seta Z2. Coxisternal setae *I2* & *III2* subequal in length to *I1* & *III1*. Rostral margin denticulate, teeth shape similar, larger towards centre 3

   Hysteronotal pore *hf6* slit-like, *hf3* inconspicuous or absent, pyriform organ in similar location. Coxisternal setae *I2* & *III2* less than half length of enlarged *I1* & *III1*. Rostral margin with convex apex bordered by large teeth 6

3. Genital and paranal setal formula *4JZg*, 3*Sa* 4

   Genital and paranal setal formula *5JZg*, 2*Sa* 5

4. Humeral process present, no humeral organ. Soma yellow brown, integument without linear sculpturing. Rostral teeth larger towards centre ..... *Ghilarovus*

   Humeral process absent (humeral organ not known). Soma pale yellow, integument covered in parallel linear sculpturing. Rostral teeth subequal in size *Pallidacarus*

5. Humeral organ without associated larger sacculate structure .... *Mikizetes*

   Humeral organ with associated larger sacculate structure .... *Oglasacarus*

6. Genital setal formula *3JZg*. Hysteronotal seta Z1 subequal in length to c1. Inner hysteronotal region framed by conspicuous line (adaxial to setae, Z1, Z2, Z4, S5, Z5, J6) .... *Keralotrichus*

   Genital setal formula *4JZg*. Hysteronotal seta Z1 shorter than c1. No conspicuous line framing part of hysteronotum .... *Zetomotrichus*

The short descriptions of *Pallidacarus* and *Keralotrichus* were a drawback in constructing the key. *Pallidacarus* is assumed to be similar to *Ghilarovus*, but it would be useful to know whether or not it has a humeral organ. *Keralotrichus* can be delineated from *Zetomotrichus*, but there is a suggestion in an illustration (Mahunka 1985: Fig. 42) that it may have acetabulum IV similarly dorsal to acetabulum III, and it is, therefore, assumed here that it has character states as for *Zetomotrichus* which are associated with jumping, such as the enlarged dorsal setae on tarsus IV. The homologies of the pyriform organ, humeral organ and associated sclerite or sacculate structure need to be clearly established. The phylogenetic model held in this study is that *Anoplozetes* is primitive and *Keralotrichus* and *Zetomotrichus* are the latest derived sister group. The remaining genera apparently form an intermediate group, amongst which the similarity between the South American *Mikizetes* and the others, which are all Palaearctic genera, suggests that this group is, or has been, widespread. The loss of setae is not valuable as an indicator of derivation, different losses on the venter not being correlated, and setal losses are only occasional in the leg chaetotaxy (*Ghilarovus*, only four setae on femur II; *Zetomotrichus*, only two setae on tibia I).

Anoplozetes gen. nov.

Type species: *Anoplozetes jamiesoni* sp. nov.

Diagnosis: Zetomotrichinae. Notal setae Z1 and *j2* fine, setose, similar to Z2. Hysteronotal pores *hf3* and *hf6* slit-like, enlarged, twice length of seta Z2. Pyriform organ in area of pore *hf3* absent. Humeral organ and subapical humeral process absent. Coxisternal setae *I2* and *III2* at least twice length of *I1* and *III1*. Genital shields bearing four setal pairs (*4JZg*). Two pairs (2*Sa*) of paranal setae. Tarsus IV without enlarged dorsal setae.

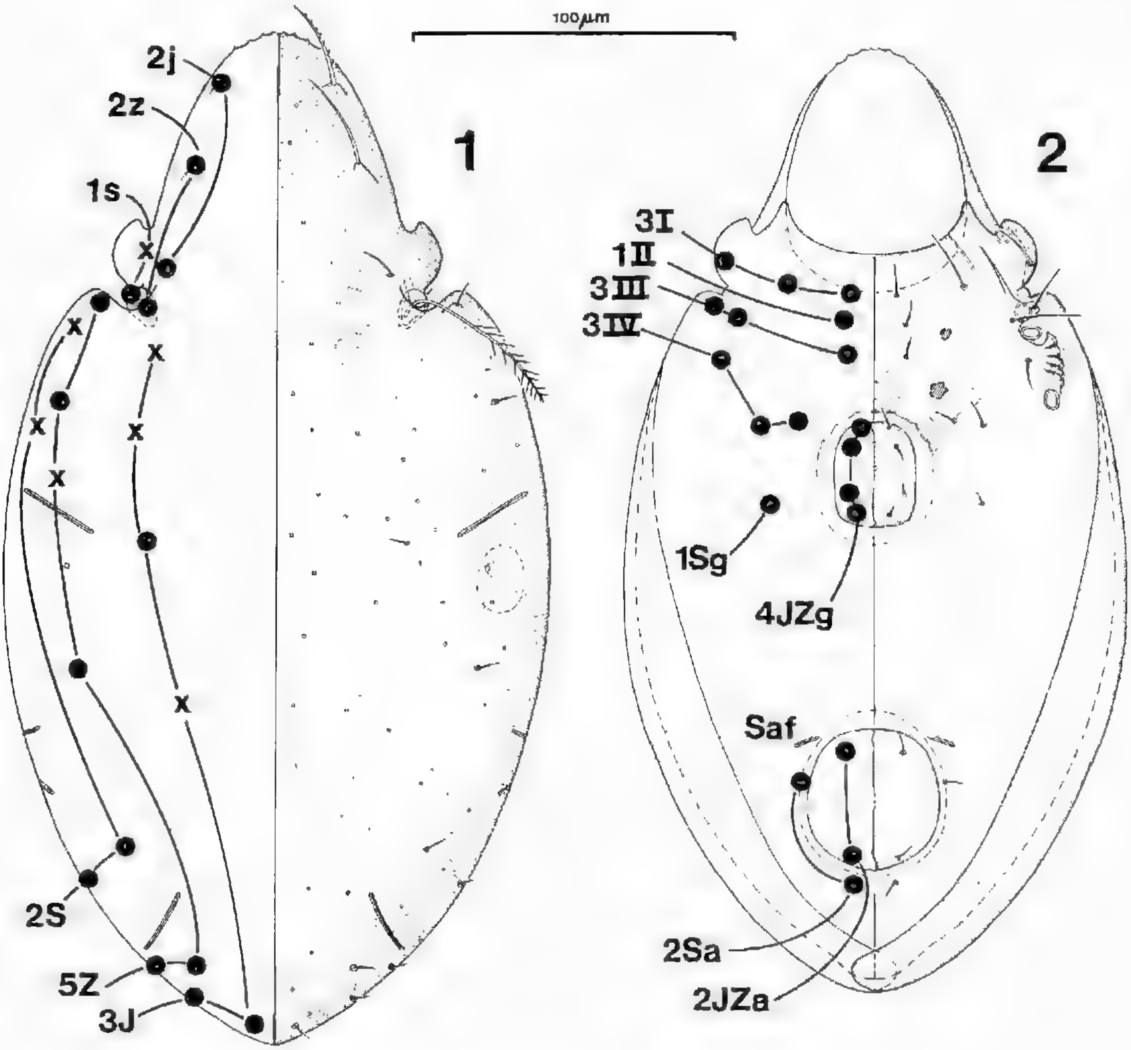
Remarks: Two character states previously diagnostic of Zetomotrichinae are not represented. These are the enlarged setae Z1 and *j2* and the presence of either humeral organ or subapical process. Also, the derived states of the type-genus (and possibly *Keralotrichus*) associated with jumping, such as the presence of enlarged dorsal setae on tarsus IV and the positioning of acetabulum IV dorsal to acetabulum III, are absent. On the other hand, although the lack of these states has been regarded (Covarrubias 1969; Bernini 1978) as indicating a lack of adaptation of leg IV for jumping, it is possible that the unusual length of leg IV may be related to some ability to jump. *Anoplozetes*, lacking the derived character states of the hysteronotal shoulder and leg IV, is considered to be the most primitive genus in Zetomotrichinae.

Anoplozetes jamiesoni sp. nov.

FIGS 1–3

Female: General appearance shiny yellow-brown, cerotegument inconspicuous, most somal setae fine and short. Integument generally smooth, irregularly placed refractile micropores on notum, few fine striations around proteronotal seta *j*2 and reticulations on coxisternum. Idiosomal length 323 (4, 298–344). Appendage lengths (femur–tarsus, for 333) — I 173, II 150, III 149, IV 202; tibial height — I 23, II 16, III 13, IV 16.

Prosternum with deep mentotectum, crossed laterally by longitudinal ridge. Custodium extending forward from pedotectum II, no discidium nor circumpedal ridge present. Five refractile ridges running vertically up into pleural region from between acetabulae III/IV. Coxisternal setae in 10 pairs (3*III*, 1*II*, 3*III*, 3*IV*), lateral setae longer, seta



Figs 1–2: *Anoplozetes jamiesoni* sp. nov. Fig. 1, notum of soma. Fig. 2, sternum of soma.

I2 and *III2* more than twice length of *I1* and *III1*.

Proteronotal rostral margin weakly denticulate, laterally extending backward behind level of seta *j1* (not illustrated because pointing ventrally). Without lamella between setae *z1* and *z2*, although short apodeme anterior to *z2* and weak ridge behind *z1*. Proteronotal setae in five pairs: *j1*, *z1* long and stout, *j1* with conspicuous unilateral row of cilia, *z2* long with conspicuous bilateral rows of cilia, *j2* and *s2* fine and short, with *s2* positioned ventrad to bothridium (around *z2*).

Opisthosternal shield margin (Fig. 2, broken line) extending unusually far behind anal shields and marginally overlapped by hysteronotal limbus. Chaetotaxy: 4*JZg*, 1*Sg*, 2*JZa*, 2*Sa*. On genital shield, anterior setae longer than posterior setae. Slit-like pore *Saf* almost transverse.

Hysteronotal margin with forwardly directed triangulate shoulders, elsewhere ventrally directed limbus overlapping margin of opisthosternal shield and with two posterior hyaline lobes, one overlapping the other (note Fig. 2 has no representation of hysteronotal margin with unsclerotized cuticle between it and opisthosternal shield). Chaetotaxy: 3*J*, 5*Z*, 2*S*. Two pairs of slit-like pores, *hf3* and *hf6*, over three times length of nearby setae, *hf4* and *hf5* subequal in length to such setae (not completely visible from above, see Fig. 1). Many refractile micropores scattered over surface.

Legs long, order of decreasing length IV, I, II, III, leg IV (femur–tarsus) longer than half somal length. Femora I and II with long stalk, short ventral flange bearing ventral seta on femur II. Femora III and IV with short stalk, caput large, rectangular, anteroposteriorly flattened with shallow

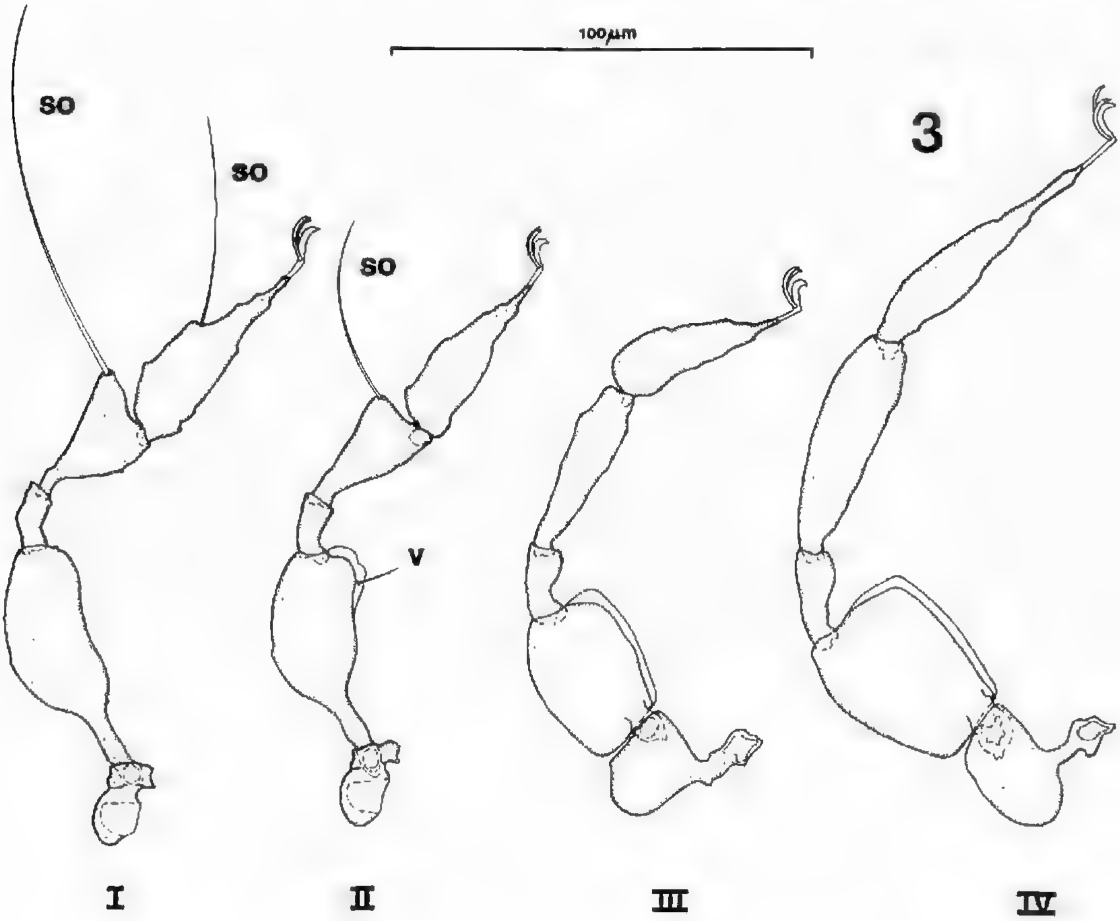


Fig. 3. *Anoplozetes jamiesoni* sp. nov., posterior aspect of right legs, showing only flagelliform solenidia and one ventral seta.

ventral flange. Tarsi long (1–1.5× length of tibia), anterior three tarsi gradually tapering proximally to less than quarter of breadth. One long flagelliform solenidium on tibia I, II and tarsus I, other solenidia setiform or bacilliform and shorter (not illustrated, Fig. 3). Solenidiotaxy: I(1,2,2,), II(1,1,2), III(1,1,0), IV(0,1,0).

Length of finely wrinkled ovipositor tube, 129 (soma 333), including three lobes (23). Ovipositor bearing 16 setae, subequal in size to each other, all longer than coxisternal seta *l2*, proximal setae (*pg*) with tips reaching bases of distal setae (*dg*). Only one female with a single large oval egg (141×102), surface smooth. Boli may be granular, including amorphous fragments, non-septate hyaline tube fragments (?hyphae), regular minute rods (?bacilli) or spheres (?spores), and sometimes larger fungal (Deuteromycotina, ?*Alternaria*) conidia (one bolus with 26 dark brown septate conidia, 18–26 long). *Male:* As female except for measurements and spermapositor. Idiosomal length 289 (14, 258–314). Spermapositor very short, length less than greatest breadth (24), anterior–posterior axis of included bilobed sclerite 22. Spermapositor bearing 14 setae, short, subequal to each other, length about twice diameter of setal base.
Material examined: Holotype female (N1986244), three paratype females (N1986245–N1986247), 14 paratype males (N1986248–N1986261), bases of love grass (*Eragrostis eriopoda*) tussocks, near Emu (28°41'S, 132°08'E), 11.x.1974, D. C. Lee.
Distribution: Australia (Aa). South Australia, Great Victoria Desert, tussock grassland, 4 females, 14 males, in 5 of 8×25 cm^2 samples.
Remarks: This species, being the type of a monotypic genus, has diagnostic character states as for *Anoplozetes*. There is an unusually high proportion of males possibly reflecting an adaptation to the environment or that the material collected does not represent a normal population.

The species is named after Dr B. J. M. Jamieson, Queensland University, for his encouragement during the earlier stages of this project on soil mites.

Acknowledgments

We wish to thank the Australian Biological Resources Study for a grant to one of us (D.L.) funding the salary of the other (G.P.) and Ms Jenni Thurmer for the notation and presentation of the figures.

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THE SUBORDER CHORIPLACINA STAROBOGATOV & SIRENKO, 1975 WITH A REDESCRIPTION OF *CHORZPLAX GRAYZ* (H. ADAMS & ANGAS, 1864) (MOLLUSRA:POLYPLACOPHORA)

*BY K. L. GOWLETT-HOLMES**

Summary

The suborder Choriplacina Starobogatov & Sirenko, 1975 is reevaluated and redefined as a suborder of the order Neoloricata. The sole living member of this suborder, *Choriplax grayi,* is redescribed and its habitat discussed. The family Afossochitonidae is reviewed and placed in synonymy with the Acanthochitonidae. *Afossochiton* is placed in the Acanthochitonidae. *Lirachiton* is placed in synonymy with the subgenus *Bassethullia* of *Notoplax* in the Acanthochitonidae. Glyptochitonidae is recognised and contains the genus *Glyptochiton.*

KEY WORDS: Chiton, Polyplacophora, Choriplacina, Choriplacidae, *Choriplax grayi,* Afossochitonidae, Acanthochitonidae, Glyptochitonidae.

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Key Words: Chiton, Polyplacophora, Choriplacina, Choriplacidae, *Choriplax grayi*, Afossochitonidae, Acanthochitonidae, Glyptochitonidae.

Introduction

The suborder Choriplacina was erected by Starobogatov & Sirenko (1975) to accommodate the two monogeneric families, Glyptochitonidae (Carboniferous) and Choriplacidae (Recent). However, both families were regarded as synonyms of Afossochitonidae by Van Belle (1975, 1981, 1983), Ferreira (1981) and Kaas & Van Belle (1985), who placed them in the suborder Lepidopleurina, based on characters of the shell (the animal of the Choriplacidae being then unknown).

Starobogatov & Sirenko (1975) placed *Choriplax grayi* in the Choriplacina because of its reduced tegmentum, but Van Belle (1975, 1983) and Ferreira (1981) placed this species in the Afossochitonidae (Lepidopleurina) because of its unslit insertion plates, regarding the reduced tegmentum as of generic value only.

The recent discovery of several complete specimens of *C. grayi* has provided the opportunity to fully redescribe this species and reexamine its systematic position. Consquently it is necessary to reevaluate the suborder Choriplacina Starobogatov & Sirenko, 1975, based on the characters of *Choriplax grayi* (H. Adams & Angas, 1864), the only known extant species.

The following abbreviations are used: AM, Australian Museum, Sydney; BMNH, British Museum (Natural History), London; NMV, Museum of Victoria, Melbourne; SAM, South Australian Museum, Adelaide. Colour descriptions follow Kornerup & Wanscher (1978).

Systematics

Class Polyplacophora Blainville, 1816

Order Neoloricata Bergenhayn, 1955

Suborder Choriplacina Starobogatov & Sirenko, 1975

Diagnosis: Small to large chitons with large unslit insertion plates in all valves; tegmentum much reduced; gills holobranchial.

Composition: This suborder contains the two monogeneric families Choriplacidae and Glyptochitonidae.

Family Choriplacidae Ashby, 1928

Diagnosis: Small to medium chitons with the characteristics of the suborder.

Composition: This family contains only the monotypic genus *Choriplax*, endemic to southern Australia.

Genus *Choriplax* Pilsbry, 1894

Microplax H. Adams & Angas, 1864, p. 194 (*Microplax grayi* H. Adams & Angas, 1864, original designation) not *Microplax* Fieber, 1861 (Hemiptera).

Choriplax Pilsbry, 1894, p. 139 (*Microplax grayi* H. Adams & Angas, 1864, original designation).

Diagnosis: Small to medium chitons; tegmentum sculpture granular; articulamentum very large, sutural laminae well developed, sinus obsolete; girdle large and fleshy; gills holobranchial, abanal.

Composition: This genus contains the single species *Choriplax grayi*.

Choriplax grayi (H. Adams & Angas, 1864)

FIGS 1–2

Microplax grayi H. Adams & Angas, 1864, p. 194; Angas, 1865, p. 58, pl. 2, fig. 16; Angas, 1867, p. 224; Pilsbry, 1892, p. 21, pl. 6, figs. 9–11.

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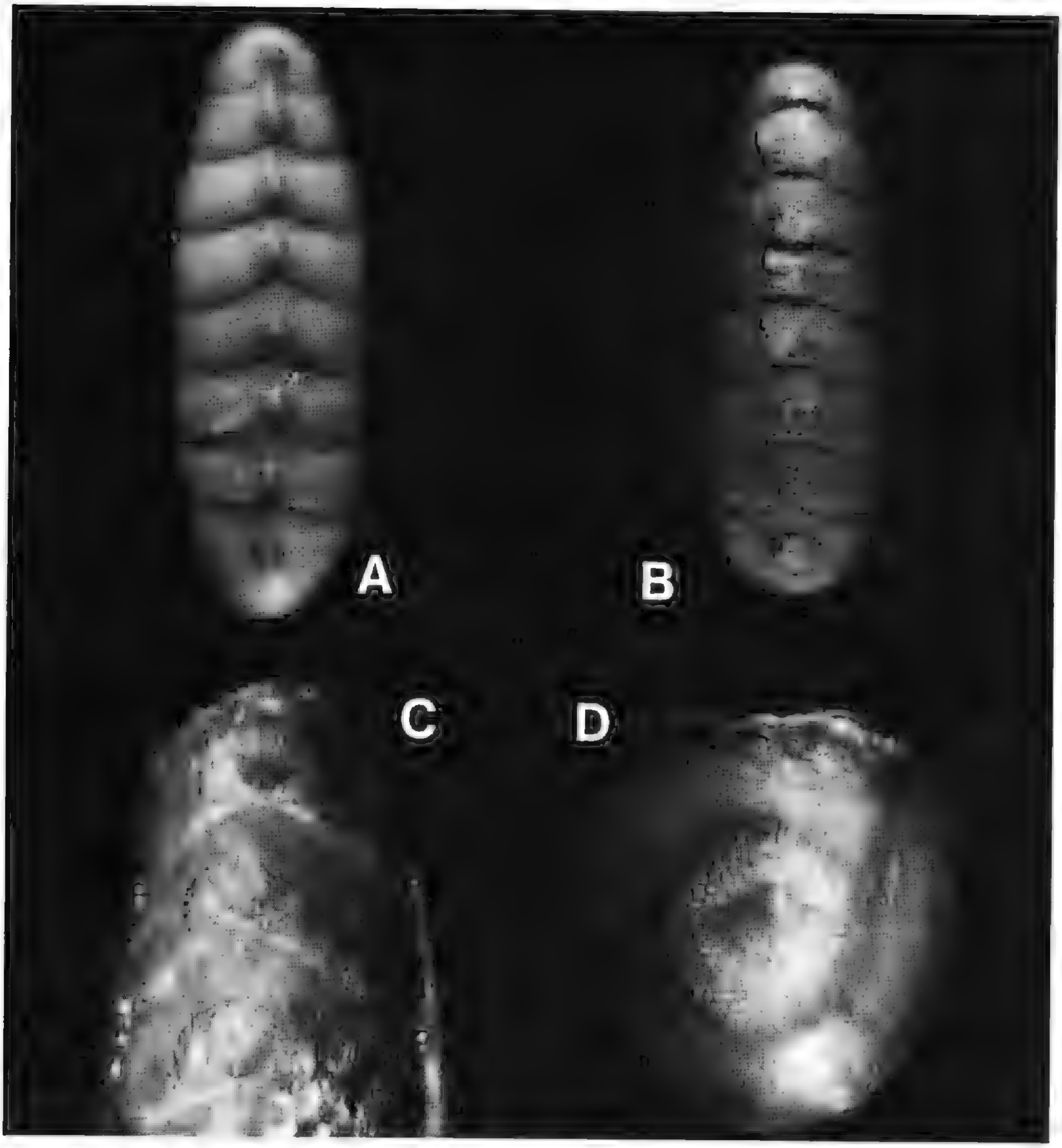

Fig. 1 *Choriplax grayi*. A. dry adult specimen, ×3.2 (SAM D17443); B. dry juvenile specimen, ×7 (SAM D16543); C. median valves, ×15 (BMNH 1877.11.7.2); D. posterior valve, ×20 (BMNH 1877.11.7.2).

Choriplax grayi (H. Adams & Angas, 1864); Pilsbry, 1894, p. 139; Ashby, 1924b, p. 383; Kaas & Van Belle, 1980, p. 56; Kaas & Van Belle, 1985, p. 204, fig. 95, map 16; Zeidler & Gowlett, 1986, p. 105.

Lepidopleurus (*Choriplax*) *grayi* (H. Adams & Angas, 1864); Ashby, 1918, p. 83.

Choriplax grayi pattisoni Ashby, 1921, p. 137, pl. 9, figs. 1a-c; Iredale & Hull, 1925, p. 100, pl. 11, fig. 28; Iredale & Hull, 1927, p. 90, pl. 10, fig. 28; Kaas & Van Belle, 1980, p. 56, 96; Zeidler & Gowlett, 1986, p. 105.

Choriplax grayi grayi (H. Adams & Angas, 1864); Iredale & Hull, 1925, p. 99, pl. 11, figs. 24-27; Iredale & Hull, 1927, p. 89, pl. 10, figs. 24-27.

Choriplax pattisoni Ashby, 1921; Ashby, 1924a, p. 331; Ashby, 1924b, p. 383; Cotton & Weeding, 1939; p. 188; Cotton & Godfrey, 1940; p. 540; Cotton, 1964, p. 85, fig. 542, fig. 96.

Material examined

Types: Holotype (BMNH 1877.11.7.2) dredged from Watsons Bay, Port Jackson, New South Wales, collected by G. F. Angas (anterior valve missing, presumed lost). *Choriplax grayi pattisoni*: Holotype (SAM D15019) from Cape Banks, South Australia, collected by G. Pattison, 1918.

Other material: Tasmania: SAM D16542 (1) Fluted Cape, Bruny Island, S. A. Shepherd, 11.ii.1972. South Australia: SAM D17443 (1) Racecourse Bay, Port MacDonnell, T. & M. Young, 1968; SAM D16543 (2) Cape Northumberland, S. A. Shepherd, 19.vii.1974. Western Australia: NMV F51767 (2) Carnac Island, Perth, N. Coleman, 1971; AM C151131 (1) Carnac Island, Fremantle, N. Coleman, 18.xii.1971.

Species description: Small to medium chiton to 30 mm. Semicarinated; tegmentum discrete, very small; more or less posteriorly positioned on valves. Tegmentum colour variable: greyish-red to greyish-orange to light brown. Articulamentum white with pastel red under tegmentum and along posterior edge of valves. Girdle very large, fleshy (Fig. 2A); in dried specimens shrinking to thin horny covering (Figs 1A, 1B). Girdle colour in living animal matches tegmentum (Shepherd pers. comm.), dried or alcohol preserved specimens greyish-yellow to khaki.

Anterior valve tegmentum almost circular, with slight beak; sculptured with longitudinal, granular ridges posterior to beak, central area with radiating granular riblets over 1/3 of area, granules becoming coarser, then irregularly pustulose over remaining area. Median valves (Fig. 1C) tegmentum heart shaped, with distinct beak; sculptured like anterior valve. Posterior valve (Fig. 1D) tegmentum tear-drop shaped; antemucronal area with longitudinal, granular ridges; mucro granulose, in anterior 1/3 of valve; postmucronal area like anterior valve anterior to beak.

Girdle covers valves completely with transparent layer over tegmentum; subsurface with granular appearance; with sparse, 20–30 μm long, smooth, conical, calcareous spicules, wider at the base in a chitinous cup (according to Kaas & Van Belle 1985).

Gills (Fig. 2B) numerous, holobranchial, abanal, 23 to 28 medium to large ctenidia on each side.

Radula (Figs. 2C, 2D) with small weak central teeth, heads weak and asymmetrical; first lateral teeth broadly rounded, slightly narrower basally; major lateral teeth with wide tricuspidate heads, cusps sharp, of equal length.

Habitat: On the prostrate red alga *Sonderopelta coriacea* Womersley & Sinkora, 1981; occasionally on sponge on brown algae or on stones.

Range: Port Jackson, N.S.W. to Perth, W.A.; and south eastern Tas.

Remarks: This species was known for many years from the two type specimens (Kaas & Van Belle 1985), which had never been compared together. Ashby (1921) distinguished his new subspecies *Choriplax grayi pattisoni* from the nominate subspecies by its greater width and its proportionately smaller tegmentum. He elevated his subspecies to specific rank (Ashby 1924a) after examining the holotype of *C. grayi* in the British Museum, but did not actually compare the two holotypes. Kaas & Van Belle (1985) synonymised the two taxa, which is in agreement with my findings.

Kaas & Van Belle (1985), who have not examined the holotype of *C. grayi pattisoni*, state that the proportionately smaller tegmentum of this specimen is an artifact of Carpenter's (in Pilsbry 1892) erroneous measurements of the holotype of *C. grayi*. However, they appear to misunderstand the proportions involved, as they state that the tegmentum of the holotype of *C. grayi pattisoni* is nearly 14% larger than that of the holotype of *C. grayi*, but ignore the fact that the former specimen is 50% larger than the latter, so that the ratio of tegmentum to total size is in fact smaller. The holotype of *C. grayi* (BMNH 1877.11.7.2) is a juvenile shell with a proportionately larger tegmentum than the holotype of *C. grayi pattisoni* (SAM D15019), which is an adult specimen. After examining the series of specimens available, it is apparent that the tegmentum is produced at an early stage of growth and then does not increase in size. The articulamentum continues to increase in size, so that the tegmentum in an adult shell (Fig. 1A) is proportionately much smaller than in a juvenile (Fig. 1B), and is more central on the valves.

The habitat of this species has been in doubt for many years. The first specimen found (BMNH 1877.11.7.2) was collected on a stone (Angas 1867), but of the other eight specimens known, two were found washed ashore with kelp (SAM D15019, D17443), one was found on sponge on brown algae by a diver (AM C151131) and five were found on red algae by divers (SAM D16542–3; NMV F51767). The last five specimens were all pink in colour, matching the host plant, when collected. The host plant was identified for three specimens (SAM D16542–3) as the red alga *Sonderopelta coriacea*. The identity of the host plant of two of the W.A. specimens (NMV F51767) is unknown, and could not be determined from the preserved sample. Previously, *C. grayi* had been recorded as epiphytic on kelp (Ashby 1921; Cotton & Godfrey 1940), in particular on *Macrocystis porifera* (Cotton 1964). This arose because the holotype of *C. grayi pattisoni* was found washed ashore with this kelp, and because the colour of the

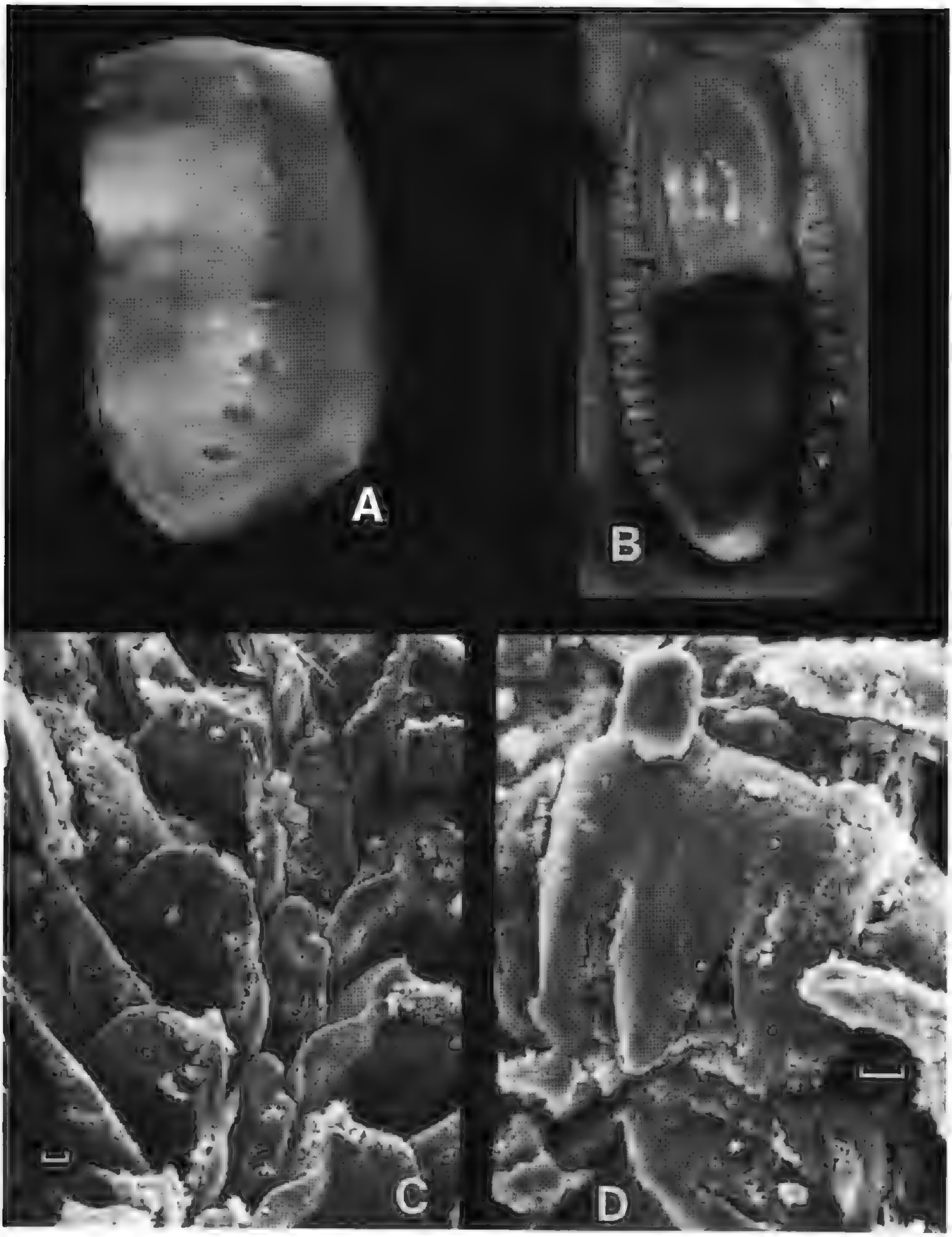

Fig. 2. *Choriplax grayi* (SAM D16542). A. dorsal view of spirit specimen, ×3.5; B. gills, ×4.8; C. radula, scale bar = 10 μm; D. major lateral tooth cusp, scale bar = 10 μm.

dried girdle was very similar to that of the kelp, the above authors assumed this to be the host plant.

The records from Tas. and W.A. are notable range extensions for the species, and new records for the faunas of those states.

Discussion

The family Afossochitonidae Ashby, 1925 was defined by Van Belle (1975, 1981, 1983), Ferreira (1981) and Kaas & Van Belle (1985) as containing the genera *Afossochiton* Ashby, 1925 (Miocene, Pliocene), *Lirachiton* Ashby & Cotton, 1939 (Pliocene), *Choriplax* (Recent) and *Glyptochiton* De Koninck, 1883 (Carboniferous). The distinguishing feature of the family as defined by these authors is the presence of unslit insertion plates in all valves.

The type specimens and any other material in SAM collections of all species of *Afossochiton* and *Lirachiton* were examined to determine the position of these species and their relationship to *Choriplax grayi*. All of these specimens are incomplete, and many are in a poor state of preservation.

The members of the genus *Afossochiton* have tegmental form and sculpture identical with the genus *Acanthochitona* (Acanthochitonidae: Acanthochitonina), but are distinguished by raised ridges on the well developed insertion plates where grooves and slits would be on the latter genus. *Afossochiton* is defined as lacking insertion plate slits, but the worn and incomplete nature of the insertion plates makes it impossible to confirm the presence or absence of slits. I regard *Afossochiton* as a genus within the family Acanthochitonidae, and Afossochitonidae as a synonym of this family. More complete specimens of *Afossochiton* with well preserved insertion plates are required to verify the position of this genus.

The single species in *Lirachiton*, *L. inexpectus* (Ashby & Cotton 1939) appears to be very closely related to the extant species *Notoplax* (*Bassethullia*) *matthewsi* (Bednall & Pilsbry, 1894) (Acanthochitonidae), a relationship also recognised by Cotton & Godfrey (1940) and Cotton & Weeding (1941). *Lirachiton* is defined as lacking insertion plate slits, but I believe the slits are not visible on the available specimens due to the extremely worn and incomplete state of their insertion plates. As *L. inexpectus* has the same combination of pustulose sculpture and grooves as the members of the subgenus *Bassethullia*, I regard *Lirachiton* as a junior synonym of this subgenus.

In *Choriplax grayi*, the structure of the valves and girdle, and the position of the gills, demonstrate that it is a unique extant species with characters differing from all existing suborders recognized by Kaas & Van Belle (1980, 1985) and Van Belle (1981, 1983). The large number of holobranchial and abanal gills preclude its inclusion in the suborder Lepidopleurina, characterised by few posterior gills only (Smith 1960; George & George 1979), and the combination of characters — large, unslit insertion plates, reduced tegmentum, holobranchial gills — preclude its assignment to any of the recognized suborders within the order Neoloricata. Recognition of the family Choriplacidae Ashby, 1928 and the suborder Choriplacina Starobogatov & Sirenko, 1975 is therefore justified.

Starobogatov & Sirenko (1975) and Sirenko & Starobogatov (1977) regard the Choriplacina as a suborder of the Lepidopleurida in the subclass Neoloricata. Their classification includes many orders and suborders, the majority of which are poorly defined. In view of the poor definition and ambiguity of many of the taxa of these authors, I prefer to follow the higher classification of Van Belle (1983), which is well defined and consistent within the characters used.

Choriplacina is here regarded as a fourth suborder of the order Neoloricata, because its combination of characters place it within this order but distinguish it from the three suborders recognized by Van Belle (1983). I believe that the gills and girdle, as well as the insertion plates, are important characters in the higher systematics of the Polyplacophora. If the gills and girdle are ignored as distinguishing characters in the higher systematics of chitons, as proposed by Van Belle (1983) and Kaas & Van Belle (1985), then the remaining characteristics of the valves do not appear to be sufficient to justify the division of the orders of the Polyplacophora into suborders.

Regarding Glyptochiton, no specimens were available for study, however, based on descriptions and illustrations of the genus and species (Kirkby & Young 1867; De Koninck 1883; Van Belle 1983), it would seem to be sufficiently distinctive to warrant recognition of the family Glyptochitonidae Starobogatov & Sirenko, 1975. This family appears to be related to the Choriplacidae, because of its large, unslit insertion plates and much reduced tegmentum. A detailed examination of *Glyptochiton* is required to determine its true place.

Acknowledgments

I am grateful to Mr and Mrs T. Young who collected the third known specimen of *Choriplax grayi*, which precipitated this investigation. I wish to thank Ms S. Morris (BMNH), Mr I. Lock (AM) and Ms S. Boyd (NMV) for the loan of specimens from their respective institutions. Mr W. Zeidler, Mr S. A. Parker and Dr W. F. Ponder kindly reviewed earlier versions of the manuscript. Dr P. Kaas and an anyonymous referee are thanked for

critical comments. The photographs were taken by Mrs J. Forrest, Ms A. Renfrey (SEM of radula) and Mr N. Holmes (BMNH 1877.11.7.2).

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A NEW SPECIES OF *ACANTHOCHITONA* (MOLLUSCA: POLYPLACOPHORA:ACANTHOCHITONIDAE), FROM SOUTH AUSTRALIA

*BY K. L. GOWLETT-HOLMES & W. ZEIDLER**

Summary

A new species, *Acanthochitona saundersi* sp. nov., is described from Nuyts Archipelago, Spencer Gulf and Yorke Peninsula, South Australia. The new species most closely resembles *A. bednalli* but is distinguished from it by a narrower, deeply grooved jugum and by the spicule arrangement of the sutural tufts. The new species was located on rocks embedded in sand pockets amongst reef by divers.

KEY WORDS: Chiton, Polyplacophora, Acanthochitonidae, South Australia, *Acanthochitona,* new species.

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by K. L. Gowlett-Holmes & W. Zeidler*

Summary

Gowlett-Holmes, K. L. & Zeidler, W. (1987) A new species of *Acanthochitona* (Mollusca: Polyplacophora: Acanthochitonidae), from South Australia. *Trans. R. Soc. S. Aust.* **111**(2), 111-114, 29 May, 1987.

A new species, *Acanthochitona saundersi* sp. nov., is described from Nuyts Archipelago, Spencer Gulf and Yorke Peninsula, South Australia. The new species most closely resembles *A. bednalli* but is distinguished from it by a narrower, deeply grooved jugum and by the spicule arrangement of the sutural tufts. The new species was located on rocks embedded in sand pockets amongst reef by divers.

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Introduction

The chiton fauna of South Australia is relatively well known due to the past work of E. Ashby, W. G. Torr and others (Zeidler & Gowlett 1986). The last species description from South Australia was that of Weeding (1940). During studies on the Acanthochitonidae, one of us (KLG-H) located what was thought to be an aberrant form of *Acanthochitona bednalli* (Pilsbry, 1894) Later discovery of four more specimens with the same characters and from similar habitats has led us to recognise the form as undescribed. Here we describe this new species.

Materials and methods

The material reported here is desposited in the South Australian Museum, Adelaide (SAM) and was collected by "Hookah" diving. All wet material is preserved in 2% formaldehyde/propylene glycol solution. Measurements of specimens are linear when the specimen is laid flat rather than along the curved surface. The radula was removed from one of the paratypes (SAM D16698) for examination after the method of Ponder & Yoo (1976). As the holotype has not been disarticulated, diagnostic features of the articulamentum and radula are described from the above paratype. Colour descriptions follow Kornerup & Wanscher (1978).

Acanthochitona saundersi sp. nov.

FIGS 1, 2

Holotype: SAM D16699, dry, complete specimen 11.95 × 5.15 mm, collected on edge of granite slope, under sand in 8 m depth, in cove off NW point of East Franklin Island, Nuyts Archipelago, S. Aust. by K. L. Gowlett, 20.vii.1983.

Paratypes: SAM D16698, one specimen, disarticulated, in spirit 10.9 × 6.15 mm, collected on granite ledge, under sand at 6 m depth, on inside of reef off SW side of East Franklin Island, Nuyts Archipelago, S. Aust. by K. L. Gowlett, 18.vii.1983; SAM D17441, two dry complete specimens 12.8 × 6.8 mm and 8.05 × 5.4 mm respectively, collected on smooth rock, under sand at 12 m depth, on Far West Bottom, Tiparra Reef, Spencer Gulf, S. Aust. by K. L. Gowlett, 13.v.1982. SAM D17475, one complete specimen, in spirit 11.85 × 6.9 mm, collected on granite fragment in sand pocket on reef at 7 m depth, off Point Gilbert, Port Moorowie, Waterloo Bay, Yorke Peninsula, S. Aust. by N. J. C. Holmes, 29.iii.1986.

Diagnosis: Small chiton to 15 mm. Carinated. Tegmentum white to cream speckled with brownish yellow; jugum about 1/6 width of specimen with few nodulose ribs with deep narrow interspaces; beak of 4th valve with dark brown spot; pustules "U" shaped. Articulamentum white, slit formula 5/1/3. Girdle with alternating bands of white and brownish yellow; spiculose with prominent sutural tufts of various sized white spicules.

Description of Holotype: Anterior valve with five weak ribs, sculptured with distinct, random, "U" shaped pustules, smaller, but not coalescing near apex.

Median valves beaked, jugum narrow, 1/6 to 1/3 width of tegmentum, with longitudinal nodulose ribs containing deep, narrow interspaces, pustulose posteriorly. Lateropleural areas with longitudinal rows of distinct, elongated, triangular pustules near jugum; pustules becoming random and "U" shaped toward edges. Third median valve with distinct dark brown spot on beak.

Posterior valve tegmentum slightly longer than wide; jugum pustulose; antemucronal area with radially arranged, distinct, triangular to "U" shaped pustules; mucro dark brown, granulose, central;

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* South Australian Museum, North Terrace, Adelaide, S. Aust. 5000.

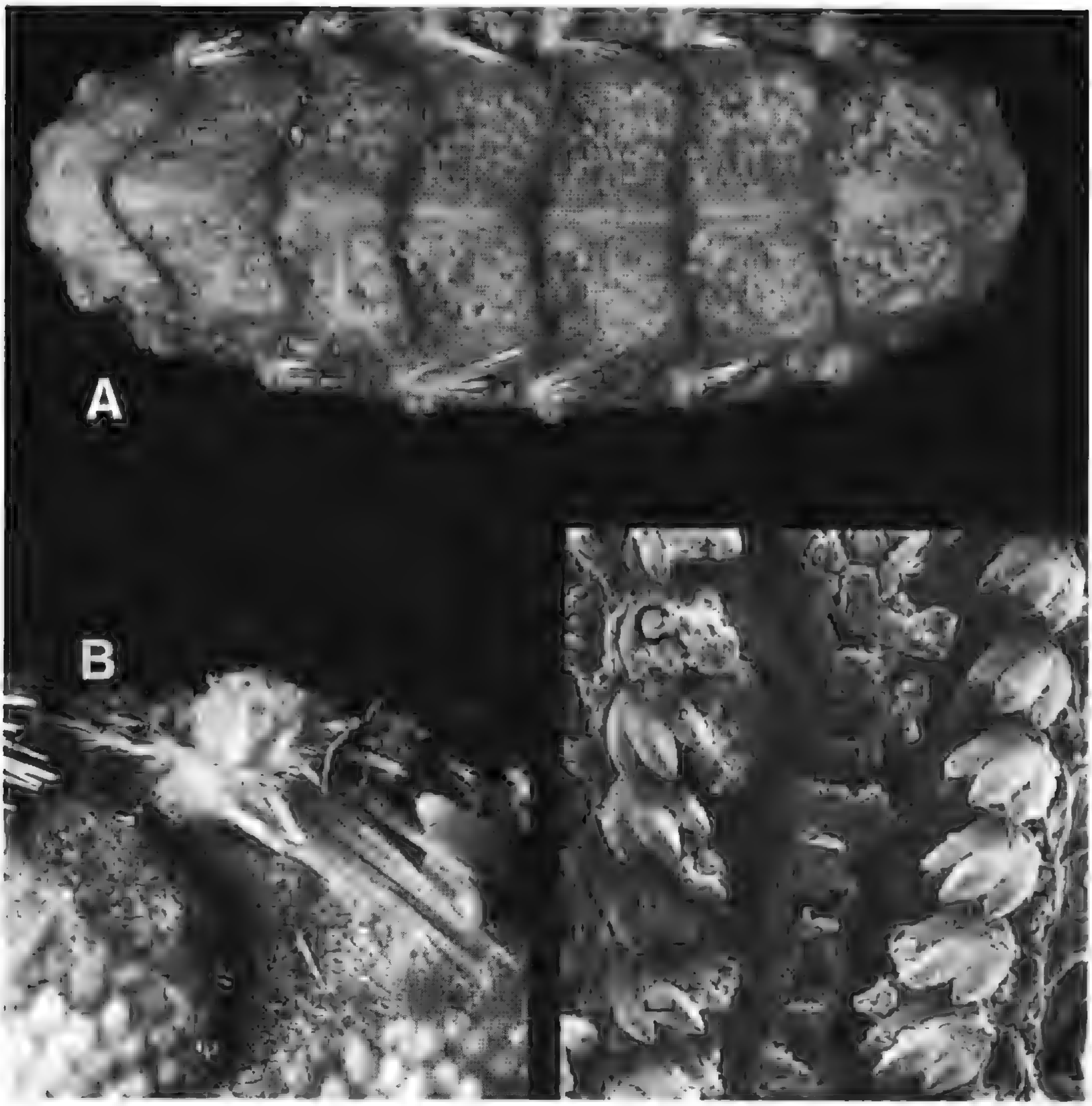

Fig. 1 *Acanthochitona saundersi* sp. nov. A. holotype, × 10.5 (SAM D16699); B. girdle and sutural tuft, paratype, × 25 (SAM D17441); C. radula, paratype, scale bar = 20 μm (SAM D16698).

postmucronal area slightly concave but not steep, with distinct, random, "U" shaped pustules.

Girdle with numerous coloured, blunt-tipped spicules (75–100 μm long, 5 μm wide), and sparse, long, clear, sharp-tipped spicules 4–5 times longer, more numerous toward outer edge. Some spicules in girdle encroachment at valve sutures and toward outer edge are clear, blunt-tipped, 3–5 times thicker and 2–4 times longer than coloured spicules. Sutural tufts (Fig. 1A, 1B) prominent, with many clear, tapering, sharp-tipped spicules (100–350 μm long, 20–30 μm wide at base) with a few to 2 mm long, 600 μm wide at base.

Gills merobranchial, adanal, with 11 ctenidia on right side and 10 ctenidia on left side.

Etymology: Named for Mr Frank L. Saunders (1887–1982) who, as an amateur collector, contributed significantly to the study of the chiton fauna of southern Australia and was directly responsible for one of us (KLG-H) developing an interest in chitons.

Additional Characters from Paratype: Articulamentum white; anterior valve slits 5, short, 1/6–1/5 width of articulamentum, in short grooves 1/4–2/3 width of articulamentum (Fig. 2A); median valve slit 1, short, 1/5–1/3 width of articulamentum, in shallow groove to edge of tegmentum (Fig. 2B); posterior valve slits 3, 1/3-1/2 width of articulamentum, in grooves to edge of tegmentum, articulamentum edge between teeth pectinate (Fig. 2C, 2E).

Radula (Fig. 1C) with small, rectangular, concave, central teeth, slightly narrower apically, heads weak; first lateral teeth narrow, elongate, folded around base of central teeth; major lateral teeth elongate, narrower basally, with wider tricuspidate heads, central cusp slightly longer.

Variation: Apart from slight colour variations, the four paratypes are like the holotype and vary only in the number of gills, with 12-14 ctenidia on right side and 11-13 ctenidia on left side.

Range: Central to western South Australia.

Habitat: Singly on rock embedded in fine to medium sands, in sand pockets on reefs in areas usually exposed to moderate swell.

Comparison with other species: *A. saundersi* was compared with other species of *Acanthochitona* in the collections of SAM, the Australian Museum, Sydney (AM), the Museum of Victoria, Melbourne (NMV), the Western Australian Museum, Perth (WAM) and the Tasmanian Museum and Art Gallery, Hobart (TM). It most closely resembles *A. bednalli* (Pilsbry, 1894) and superficially resembles *A. granostriata* (Pilsbry, 1894). Both *A. saundersi* and *A. bednalli* are easily distinguished from other southern Australian species, including *A. granostriata*, by the jugum which is ribbed in these two species but is smooth or pustulose in the other

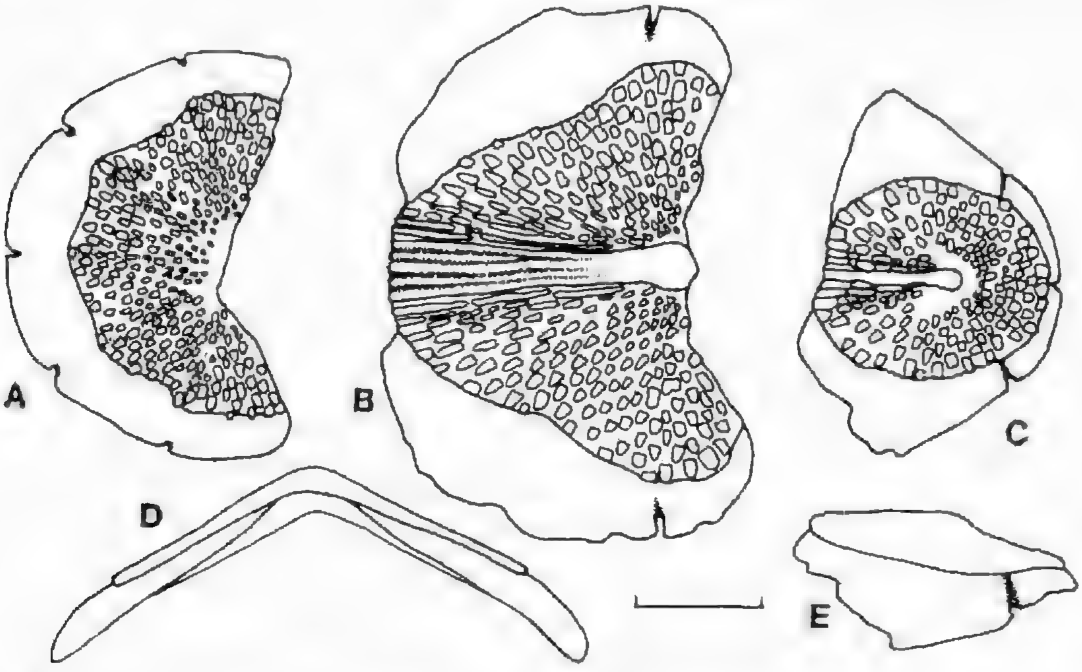

Fig. 2. *Acanthochitona saundersi* sp. nov. paratype (SAM D16698). A. anterior valve; B. median valve; C. posterior valve; D. median valve (anterior profile); E. posterior valve (side profile); scale bar = 1 mm.

TABLE 1. *Distinguishing characters of* Acanthochitona bednalli *and* A. saundersi *sp. nov.*

Character	*A. bednalli*	*A. saundersi*
Jugum	width approx. 1/3 width of specimen (dry); with many ribs with wide interspaces	width approx. 1/6 width of specimen (dry); with few nodulose ribs with deep narrow interspaces
Pustules on valves	elongate, drop or oval-shaped	"U" shaped
Sutural tufts	with very numerous, thin, sharp-tipped spicules, all of similar length	with fewer, slightly thicker spicules of various sizes
Colour	white and dark brown; beak of 4th valve without spot	white and brownish yellow; beak of 4th valve with dark brown spot
Habitat	intertidal, under rocks in silty areas	sub-littoral, on rock under sand, in sand pockets amongst reef

species. We consider *A. johnstoni* (Ashby, 1923) (holotype, SAM D12185) to be a synonym of *A. bednalli*, (Zeidler & Gowlett 1986). *A. saundersi* is best distinguished from *A. bednalli* by the characters given in Table 1, but is otherwise very similar.

Remarks: The kind of habitat occupied by *A. saundersi* and its relatively small size probably accounts for it not having been collected previously. It is probably rare as only five specimens have been collected despite extensive collection of chitons by SAM divers or associates for the past decade. None were found in the collections of other Australian museums.

Acknowledgments

We thank Ms M. A. Garback, Academy of Natural Sciences of Philadelphia, U.S.A., for the loan of the syntypes of *A. bednalli* (ANSP 64955) and *A. granostriata* (ANSP 64847) and the following curators and collection managers for providing data and specimens from collections held by their respective institutions: Mr I. Lock (AM), Ms S. Boyd (NMV), Dr F. E. Wells (WAM) and Ms E. Turner (TM). The photographs were taken by Mrs J. Forrest and Ms A. Renfrey (SEM). Mr Nigel Holmes is thanked for his many collecting efforts resulting in the discovery of the fifth specimen of *A. saundersi*.

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REIDENTIFICATION OF CTENOTUS SCHOMBURGKII (PETERS, 1864) (LACERTILIA: SCINCIDAE)

Summary

BRIEF COMMUNICATION

REIDENTIFICATION OF *CTENOTUS SCHOMBURGKII* (PETERS, 1864) (LACERTILIA: SCINCIDAE)

Lygosoma schomburgkii Peters[1] was described in 1864 from a collection of reptiles made by Richard Schomburgk of Buchsfeld, South Australia (= Loos, 4.5 km W of Gawler[2]). Peters neither indicated the number of specimens on which he based the species, nor whether all of the collection was from the vicinity of Buchsfeld. However, with the exception of *Moloch horridus* ("ein einziges verstümmeltes Exemplar"), a single specimen of *Litoria adelaidensis*[3] and *Ctenotus schomburgkii* (auctorum), all of the 42 species of reptiles and amphibians recorded in the paper (on modern synonymies) have been subsequently recorded within 50 km of Buchsfeld (our data: T. D. Schwaner, *pers. comm.*).

After devoting "a month to the examination of the specimens in the Berlin Museum", at which Peters was based, Boulenger[4] placed *L. schomburgkii* in the synonymy of *L. lesueurii*, diagnosed in the generic key as having 24–32 midbody scales, feebly keeled subdigital lamellae, four supraoculars and prefrontals in contact. However, *C. schomburgkii* as currently recognised has mucronate subdigital lamellae and prefrontals usually not in contact[5,6].

Storr[5] examined four specimens identified as types of *Lygosoma schomburgkii* in the collection of the Zoologisches Museum, Universität Humboldt, Berlin (ZMB). Two species were represented and ZMB 4713a (SVL 45 mm) was designated lectotype[5] (not Storr[6] as listed by Cogger *et al.*[7]). One of the paralectotypes (ZMB 4713b) is conspecific with the lectotype, while the others (ZMB 4713c–d) were subsequently[6] (as ZMB 4719c–d) included in the paratype series of *Ctenotus uber orientalis* Storr[6]. These latter two specimens were re-registered ZMB 41236–37.

Subsequent collections of reptiles from about the type locality by us, and examination of South Australian Museum specimen records, have revealed only *C. uber orientalis* (AM R59944, Thompsons Beach; R115921, 6.3 km S Mongalata; R115926, "Tracy", 4.8 km N Mongalata; R115979, Middle Beach; R115989, R115991, nr "Glenview", Barossa Range; SAM R11202, 1.6 km N Tea Tree Gully; R15034a–b, Pt Prime; R15141, Sturt Ck, Adelaide Hills; R15617, Golden Grove; R16543, Morialta Conservation Park; R16867, Belair Recreation Park) and *C. robustus* Storr (AM R111491–92, 4.5 km SSE Gawler; R115878–79, Burra Creek Gorge; SAM R1703, Bute; R2093, Fifth Ck, Montacute; R8144, Hummock Mt; R9983–86, R9992, R9994–95, Waterfall Gully, R10006, foot of Mt Osmond; R11208, Eden Hills, nr Sturt Ck; R11209, 1.6 km N Tea Tree Gully; R14192a–b, Aroona Rd, Reynella; R27413–14, 4 km W Palmer) from the Adelaide Plains and Mt Lofty Ranges. The latter is presumably Peters'[1] "12. *Lygosoma australe* Gray sp. = *L. Lesueurii* D.B." There have been no subsequent records of *C. schomburgkii* (*sensu* Storr and subsequent authors) from the Adelaide Plains, the nearest record being from Bungunnia Station (33°50'S 139°50'E; South Australian Museum R15045), over 120 km from Buchsfeld, in the Murray Mallee.

A translation of the type description of *Lygosoma schomburgkii* reads:

> "Stands between *L. labillardieri* and *australe*. Head and tail brown, back black, with four white or green stripes, of which the two middle ones are the thinnest and are almost twice as far apart from the outer stripes as from each other; on either side of the body is a line, which is twice as far from the outer back stripes as they are from the middle back stripes which lie next to them; between each outer and inner back stripe is a line of white spots; between the side stripes and the outer back stripes are three to four rows of small white spots, and below the side stripes a few largish speckles, which often blend in with the greenish-white belly."

In the nomenclature of subsequent workers on *Ctenotus*, *Lygosoma schomburgkii* has a pair of paravertebral stripes (Peters' "middle back stripes"), a single laterodorsal line of white spots between the paravertebral and dorsolateral stripes ("outer back stripes") and three to four lines of small spots in the upper lateral zone between dorsolateral and midlateral stripes ("side stripes") on a black dorsal ground. Our interpretation is supported by the stated degree of separation between stripes.

South Australian populations of *Ctenotus schomburgkii* (auctorum) are of the eastern colour type of Storr[5] (Fig. 1A), and have an irregular orange laterodorsal stripe between an orange paravertebral and a white dorsolateral stripe (i.e., six light dorsal stripes), and a single row of large orange squarish to oblong blotches between the dorsolateral and midlateral stripes. Eastern populations do not have a single laterodorsal row of white spots (this being replaced by an orange stripe), and no population of this species has three to four series of small spots between the dorsolateral and midlateral stripes. Specimens ZMB 4713a–b (Fig. 2A) are representative of this species. Both have the prefrontals separated.

In contrast, the populations of *C. uber orientalis* from about Buchsfeld (Fig. 1B), including ZMB 41236–37, agree in all respects with the description of *Lygosoma schomburgkii* Peters, although the white midlateral stripe may be absent in some individuals and the dorsal ground is more brown than black in some (but not all) specimens from coastal situations. A white midlateral stripe is present in ZMB 41236–37 (Fig. 2B).

As Peters did not designate types in his description, and as the four specimens formerly included in ZMB 4713 were untagged, and probably registered after the publication of the description (R. Günther *pers. comm.*), we consider that the type status of the two syntypes ZMB 4713a–b is open to question, and as these specimens do not agree with the type description or Boulenger's[4] subsequent definition, and are representative of a species not known from near the type locality, we reject their type status. If ZMB 4713a is not a syntype, Storr's[5] designation of this specimen as lectotype is invalid.

The Zoologisches Museum collection contains frogs purportedly collected by Schomburgk from Adelaide[3] additional to those listed by Peters[1], suggesting that Schomburgk sent material from South Australia to Peters subsequent to 1864 and supporting the possibility that

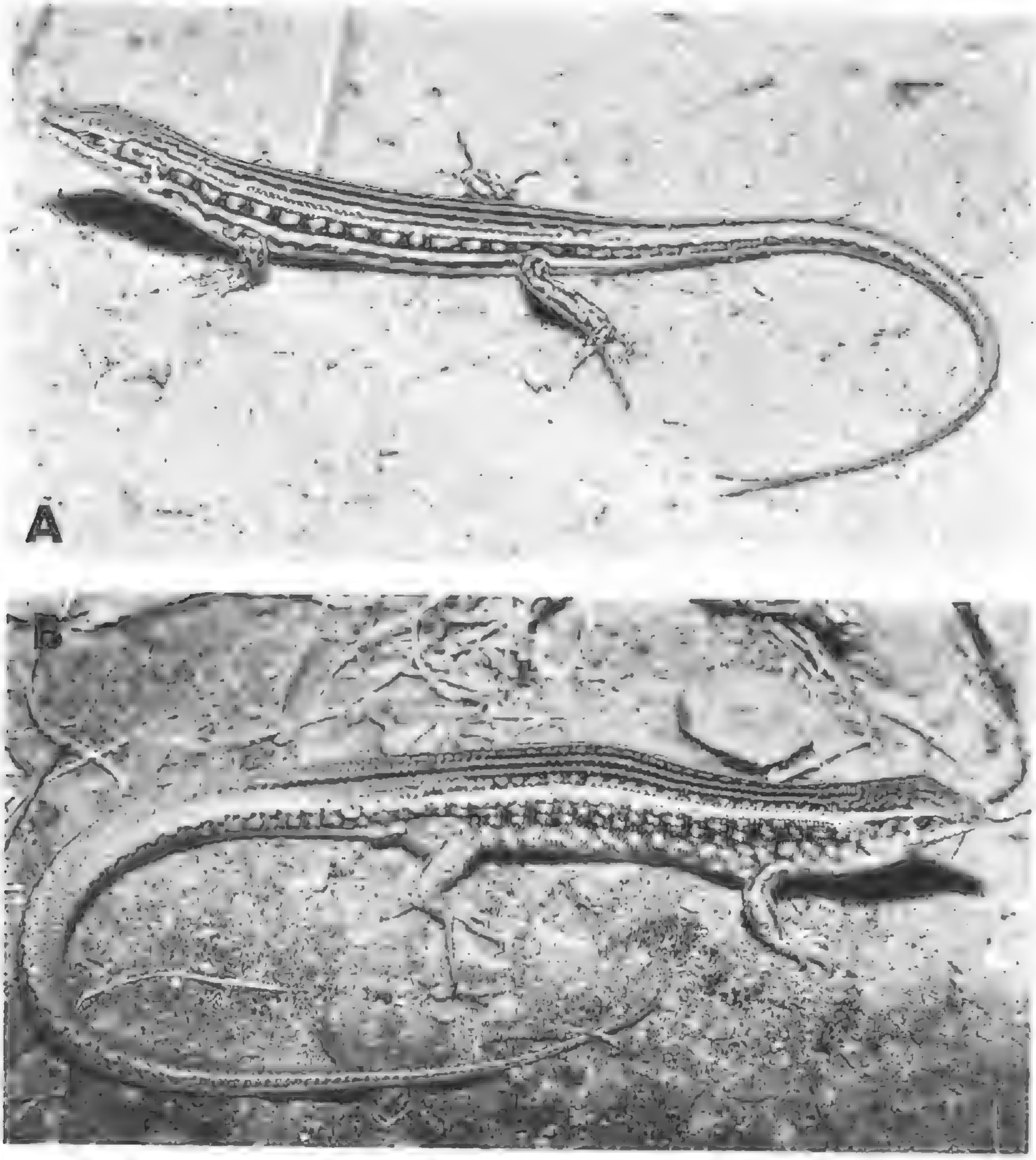

Fig. 1. A, *Ctenotus schomburgkii* auctorum (Australian Museum R114482; Lake Mungo National Park, NSW); B, *Ctenotus uber orientalis* (Australian Museum R115926; 4.8 km N "Mongalata" HS, SA).

ZMB 4713a-b were sent to Peters after the description of *L. schomburgkii*.

We consider that ZMB 41236-37 are syntypes of *L. schomburgkii* Peters, and we designate ZMB 41236 as lectotype.

This reassignment of the name *Lygosoma schomburgkii* necessitates four nomenclatural changes. *C. uber orientalis* Storr[6] becomes a synonym of *C. schomburgkii* (Peters), while *C. uber uber* Storr[5] and *C. uber johnstonei* Storr[8] become *C. schomburgkii uber* and *C. schomburgkii johnstonei* respectively. The only available name for *C. schomburgkii* (auctorum) is *Lygosoma fischeri* Boulenger[4,5,7], a *nomen novum* for *Hinulia muelleri* Fischer[9], at that time a junior secondary homonym of *Scincus muelleri* Schlegel[7,10]. Although the types of *H. muelleri* cannot be found[7], the description and figures[9] clearly apply to the western colour type of *C. schomburgkii* (auctorum).

H. G. Cogger kindly allowed access to unpublished notes and reproduction of photographs of the types

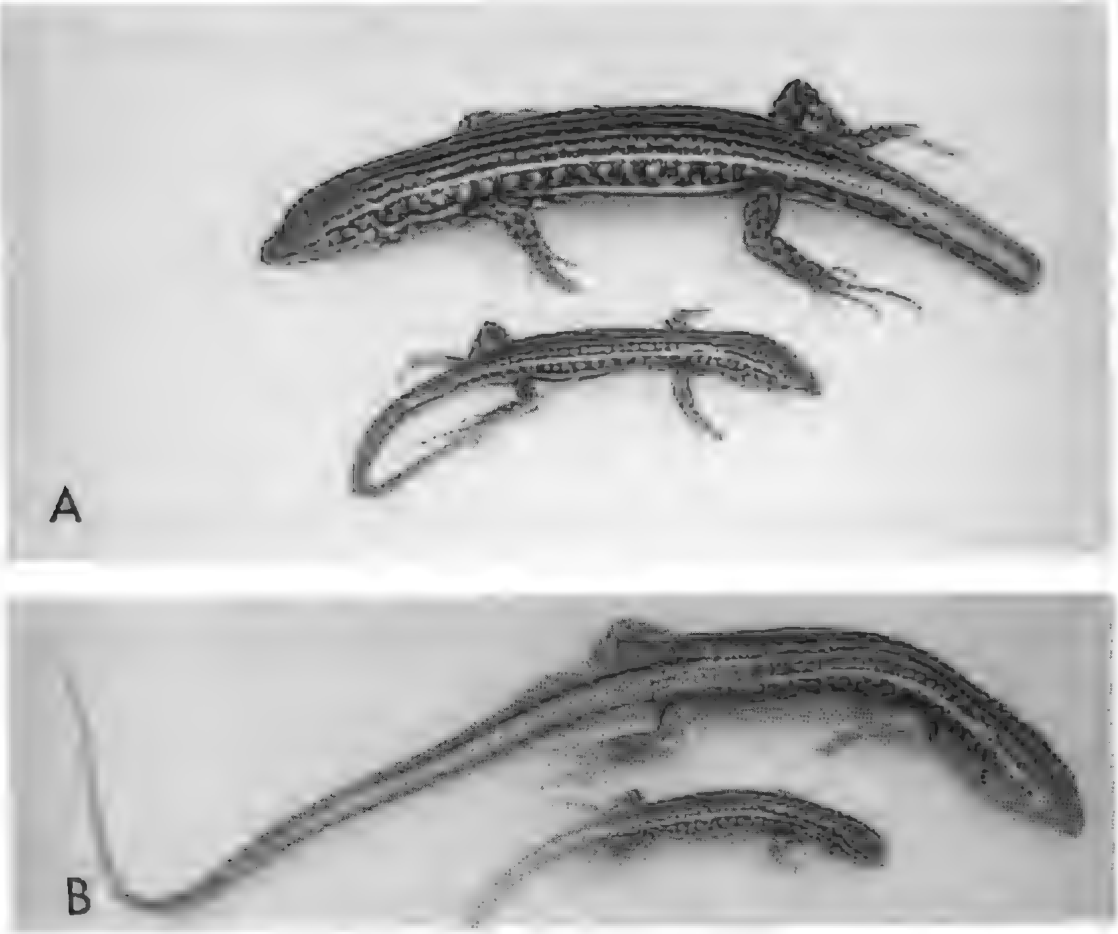

Fig. 2. Syntypes (*sensu* Storr) of *Lygosoma schomburgkii* Peters. A, ZMB 4713a (upper; lectotype of Storr) and 4713b (lower) and B, ZMB 41236 (upper; lectotype designated herein) and 41237 (lower; paralectotype).

(Fig. 2), and provided useful comments on the manuscript. T. D. Schwaner and A. Edwards permitted us to examine South Australian Museum material, and checked locality data. N. Shea translated much of Peters' paper. B. Coulson provided Fig. 1B. A. E. Greer and R. Sadlier also commented on the manuscript.

Our field work was supported by a grant from the Reserves Board of South Australia. B. Coulson and B. Miller are thanked for field assistance.

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ON THE INDETIFICATION OF CTENOTUS SCHOMBURGKII (PETERS)

Summary

BRIEF COMMUNICATION

ON THE IDENTIFICATION OF *CTENOTUS SCHOMBURGKII* (PETERS)

In preparation for a paper on the *Ctenotus* of the Eastern Division of Western Australia, I borrowed the types of *Lygosoma schomburgkii* Peters from the Berlin Museum. Two of the specimens belonged to a wide-ranging Western Australian species; the other two could not be matched with any *Ctenotus* I then knew (they were later found to agree with *C. uber orientalis* Storr, 1971). I therefore settled the name *schomburgkii*, by lectotype designation, on the taxon I knew.

Twenty years later, when my usage of the names *schomburgkii* and *uber* is well-established in the literature, Peterson and Shea attempt to upset the above designation on the grounds that the lectotype and paralectotype were not part of Peters' original material. They argue thus:

(1) *Lygosoma schomburgkii* (*sensu* Storr) does not occur within 50 km of Buchsfeld;
(2) Boulenger, after examining specimens in the Berlin Museum, placed *L. schomburgkii* in the synonymy of *L. lesueurii*; and
(3) Peters' description does not fit *Ctenotus schomburgkii* (*sensu* Storr) but agrees "in all respects" with *C. uber orientalis* Storr.

The first two arguments are frivolous grounds for upsetting a lectotype designation, and the third is untrue.

There is no evidence that Schomburgk ever provided Peters with locality data. If he had obtained his specimens of *schomburgkii* in the Murray Mallee, would he have informed Peters of it? The locality "Buchsfeld" applies more to Schomburgk's place of residence than to the provenance of his specimens. At any rate Peterson and Shea admit that other specimens, apart from *Lygosoma schomburgkii*, could not have come from the vicinity of Buchsfeld.

Boulenger's concept of *Lygosoma lesueurii* was so grossly composite that it tells us nothing about the specimens of *L. schomburgkii* that he may have seen in Berlin. The subdigital lamellae of *L. pantherinum* Peters are finely keeled (as in *L. schomburgkii*) but that did not deter Boulenger from synonymizing *pantherinum* with *lesueurii* (a species whose subdigital lamellae are widely callose).

was composite. His description of the back as "black with four white or green stripes" could only apply to spirit specimens of eastern *Ctenotus schomburgkii* (*sensu* Storr), in spirit specimens of *C. uber orientalis* the back is brown or grey and the stripes brownish white or greyish white. Peters' description of the side of the body is almost as certainly based on the specimens of *C. uber orientalis*.

It is not surprising that Peters was unable to separate two such superficially similar taxa as *Ctenotus schomburgkii* and *C. uber orientalis* (no one could until I pointed the way). Believing his material to comprise a single species, Peters was free to base his description on any or all four of his specimens; and I, as first reviser, was equally free to choose any of them as lectotype.

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ON THE OCCURRENCE OF BRACHYLAIMA SP. (TREMATODA) IN THE FERAL HOUSE MOUSE, MUS MUSCULUS, IN SOUTH AUSTRALIA

Summary

BRIEF COMMUNICATION

ON THE OCCURRENCE OF *BRACHYLAIMA* SP. (TREMATODA) IN THE FERAL HOUSE MOUSE, *MUS MUSCULUS*, IN SOUTH AUSTRALIA

During a study of the ecology of the house mouse, *Mus musculus*, conducted in the Lower Light area of South Australia, mice were trapped overnight in break-back traps. In the morning the stomachs and intestines were removed from the dead mice and preserved in 70% ethanol for gut analysis. Trematodes identified as *Brachylaima* sp. were found in the small intestine of nine of 95 mice examined between February 1985 and June 1986. The greatest numbers of infected mice were found in September/October 1985. Infection data for the period September 1985–June 1986 are more reliable than earlier observations. During this period, seven of 45 animals were infected. The restriction of the infection to the small intestine is not certain as examination of other parts of the gut was less thorough.

Numbers of trematodes found in individual mice ranged from one to 34. Trematode-infected mice were found in all parts of the study area, living under dense roadside vegetation from one to five kilometres north of Lower Light.

A large number of *Brachylaima* spp. have been described from the small intestine and caecum of birds and mammals, but only three species are recognised from Australia.[1,2,3] Two are from small marsupials and one from a bird. *Brachylaima dasyuri* (S. J. Johnston, 1913)[4] was described from the native cat, *Dasyurus viverrinus*, "in the vicinity of Sydney, N.S.W."

Sandars, (1957)[5] gave a further description of *B. dasyuri* from the short-nosed bandicoot, *Isoodon obesulus*, from Queensland, and placed *B. simile* (S. J. Johnston, 1913)[4] described from *Dasyurus viverrinus*, as a synonym of *B. dasyuri*. *Brachylaima pulchellum* (S. J. Johnston, 1917)[6] was described from the Wonga pigeon, *Leucosarcia melanoleuca*, from Northwestern N.S.W. and *Brachylaima antechini* Peisley & Howell, 1975[7] was described from marsupial mice, *Antechinus stuartii* and *A. swainsonii*, from the vicinity of Canberra, A.C.T.

Because of the method of preserving the mice with the trematodes still in the alimentary canals, the trematodes were rather distorted and identification was difficult. Two specimens which were recovered from a deep frozen mouse (2.xii.1985) were fixed in formol alcohol under coverslip pressure. They measure (1) 4.0 mm by 0.51 mm and (2) 3.9 mm by 0.44 mm. These measurements lie within the ranges given for the three Australian *Brachylaima* spp. We have only been able to get a comparison of sizes of the oral sucker and the acetabulum in one (flattened) specimen; the diameter of the oral sucker was 0.24 mm and of the acetabulum 0.27 mm.

In describing *B. antechini*, Peisley & Howell did not mention *B. dasyuri* (syn. *Harmostomum dasyuri*) and it is possible that comparison of the two species will show that *B. antechini* is a synonym of *B. dasyuri*.

Certainly our species appears to resemble *B. dasyuri* and *B. antechini* more closely than it does *B. pulchellum*. The figures of *B. pulchellum* differ from those of the other two species in the relationship of the organs[6]; also, Johnston states that the gonads are not as close together as is usual in the genus. However, our species must be considered distinct from *B. dasyuri* and *B. antechini* because of the forward extent of the uterus. The uterine coils in *B. dasyuri* have been described as reaching the middle of the acetabulum[4], and reaching the posterior margin of the acetabulum[5]. In *B. antechini* they are confined posteriorly to the acetabulum[7]. In the specimens examined here, the uterus extends from beyond the anterior border of the acetabulum to the region of the pharynx.

It is unlikely that the species was introduced with *Mus musculus* in the early days of occupation of South Australia. Trematodes have not been recorded previously in *M. musculus* in Australia[8]. The latter study occurred in habitat and climate that are very similar to those at Lower Light, and the area was subject to similar agricultural practices. Fifteen species of endo- and ectoparasites were recorded, but did not include trematodes. In a continuation of the Victorian study[9], a further 981 mice collected at regular intervals since November 1983 were also recently examined, and found to be free of trematodes.

In 1971[10] thirty species of *Brachylaima* were recognised and since then some sixty more have been described. Four of the species recorded by Yamaguti[10] were from *M. musculus*; *B. musculi* (Rud, 1819)[11], *B. recurvum* Duj., 1845[12], *B. aequans* (Looss, 1899)[13] and *B. peromysci* Reynolds, 1938[14], the last three as synonyms of *B. musculi*. *B. aequans* and *B. recurvum* were recovered experimentally from white mice[15,16]. *B. ruminae* Mas-Coma & Montoliu, 1986[17] was found, naturally and experimentally, in *Mus musculus* in Spain.

It is also unlikely that the trematode has been acquired from *Rattus rattus*, which has been captured at the study site, or *R. norvegicus* which may have been in the area in the past and may be still extant[18]. Although a few *Brachylaima* spp. have been found experimentally in rats, only *B. migrans* Dujardin, 1845[12] from *Mus rattus* (now *Rattus rattus*) and *Mus decumanus* (now *Rattus norvegicus*) in Europe, and *B. ratti* Baugh, 1962[19] (from *Rattus rattus* in India) are listed as natural infections[10]. *B. ishigakiense* Kamiya & Machida, 1977[20], has since been recorded from *R. rattus* in Japan, and *Brachylaima ruminae* Mas-Coma & Montoliu, 1986[17] from *R. rattus* in Spain.

It is most likely that the trematode originated from a small mammal (though a bird cannot be excluded) which was once, or perhaps still is, an inhabitant of the general area in which the trematode was found. The animal must include snails in its food as these are second intermediate hosts in all seven species of *Brachylaima* for which life history data are available[21].

Twenty-nine mammals have been recorded within a radius of 30 km of 34°32'S, 138°26'E (Lower Light)[15]. The habitat within this area is not homogeneous. Three of these mammals (*Trichosurus vulpecula*, *Bettongia lesueur* and *Saccolaimus flaviventris*) are known to be or to have been in the study area, others may have been in the area in the past while some may be still extant. Nine small marsupials and four rodents are considered as possible original hosts of our *Brachylaima* sp. on the basis of dietary habits. The marsupials are *Dasyurus maculatus*, *D. viverrinus*, *Phascogale tapoatafa*, *Perameles bougainville*, *Macrotis lagotis*, *Antechinus flavipes*, *Sminthopsis murina*, *S. crassicaudata* and *Isoodon obesulus*; and the rodents are *Hydromys chrysogaster*, *Rattus fuscipes*, *R. lutreolus* and *Notomys mitchellii*.

We cannot exclude the native rodents as original hosts of our *Brachylaima* sp., but we consider that they are less likely hosts than are the marsupials. The presence in the study area at any time of the last three rodents on our list is considered doubtful[18]. *Hydromys chrysogaster* almost certainly is or was in the general area and is very common in neighbouring areas. *Brachylaima* was not found in 49 *H. chrysogaster* examined from S. Aust. and six from Victoria[22], or in 32 from Tasmania[23]. No trematodes were found in 47 *Rattus fuscipes* from Victoria[24]. *Brachylaima* sp. was collected from *R. fuscipes* from Brindabella Ranges, A.C.T.[25]. Thirty *R. fuscipes* fed with metacercariae of *Brachylaima antechini* did not develop adult trematodes, nor did seven white mice[7].

Of the recorded hosts of *Brachylaima* spp. in Australia, *Dasyurus viverrinus* and *Isoodon obesulus* are regarded as once possible inhabitants of the study area. Though *Dasyurus viverrinus* is now locally extinct, and *Isoodon obesulus* probably extinct in that area, the latter is still living in the Adelaide Hills, and may have been formerly in the Lower Light area[18].

Antechinus flavipes is the only species of the genus which has possibly been in the area. It may still be extant. *Antechinus swainsonii* and *A. stuartii* have never been found in S. Aust.[18].

Leucosarcia melanoleuca does not occur in South Australia. Native birds evident in the experimental area which are likely to eat snails are *Gymnorhina tibicen*, *Corvus coronoides*, *C. mellori*, *Colluricincla harmonica*, *Strepera versicolor*, *Corcorax melanorhamphos* and *Pomatostomus superciliosus*, and the introduced birds, starlings and blackbirds. We know of no trematodes from starlings or blackbirds in Australia, and there are no records of *Brachylaima* spp. from the native birds mentioned[3].

Life History: Metacercariae have been found in the kidneys of 16 of 30 of the gastropod *Strangesta capillacea*, from the areas where *Antechinus stuartii* was trapped[7]. There were no other stages found — i.e. no cercariae in slime trails nor sporocysts in the digestive gland. Two other snail genera were not infected. Feeding experiments showed that the metacercariae were the larval stage of *Brachylaima antechini*.

Although we have looked for snails in the study area since we first became interested in the trematodes from mice, we have not found any native species. The introduced snails, *Cernuella virgata* and *Theba pisana*, are locally abundant.

As mice in the area are known to eat a variety of invertebrates, infection of the mice presumably occurs by eating snails containing metacercariae. Invertebrate tissue was found in the stomachs of 39% of mice living in and adjacent to rice stubble in N.S.W. and it is considered likely that mice would eat snails when available[26]. Invertebrate tissue is also a common dietary component in mice from the Victorian mallee[9].

We wish to thank friends and colleagues for advice and help given in this project

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REPRODUCTION AND GROWTH IN CAPTIVE DEATH ADDERS *ACANTHOPHIS ANTARCTICUS* (SQUAMATA: ELAPIDAE)

Summary

REPRODUCTION AND GROWTH IN CAPTIVE DEATH ADDERS *ACANTHOPHIS ANTARCTICUS* (SQUAMATA: ELAPIDAE)

A captive colony of *Acanthophis antarcticus* has been maintained at Whyalla, South Australia since 1975. Several papers have described the birth of individual clutches into the colony[1,2,3]. Mirtschin has outlined the maintenance schedule for the colony[4] and the release of death adders bred at Whyalla[5]. This paper presents new data on the biology of *A. antarcticus* kept at Whyalla, including seasonality of mating and births, primary sex ratio, clutch size, caudal luring, growth and maturity.

Adult snakes were collected from Iron Duke (33°18'S, 137°08'E), Port Germein (33°01'S, 138°00'E), Tumby Bay (34°23'S, 136°06'E) and Ardrossan (34°25'S, 37°54'E). They were housed in enclosures described by Mirtschin[4] at temperatures of 27–30°C and fed entirely on house mice (*Mus musculus*) and rats (*Rattus norvegicus*). Neonates accepted pink mice. Snakes were fed older, larger mice or rats commensurate with increasing body size and their ability to consume larger food items.

Dates of mating and births have been recorded from the foundation of the colony. Weight (gm) using a Mettler top-loading balance and total length (cm) using a centimetre rule were measured for snakes in the colony of known age in February, June, August and December 1982. Snakes were measured and weighed from clutches born in 1979, 1981 and 1982. Primary sex ratios were determined by probing[6] for seven clutches born between January 1982 and April 1983 (Table 1). Clutch size was determined for 14 clutches born between February 1976 and April 1983.

Length and weight against time and length against weight were examined by least-squares regression[7]. Linear ($Y = a + bX$), exponential ($\ln Y = a + bX$), logarithmic ($Y = a + b\ln X$) and power ($\ln Y = a + b\ln X$) equations were used to find the best fit to the data, where Y = the dependent variable, X = the independent variable, a = the y-intercept and b = the slope of the fitted line. For each regression the coefficient of determination (R^2) was used as the criterion for which equation best fit a given set of data. Data were treated without regard to sex.

The *A. antarcticus* reported here show an annual reproductive cycle[9], mating shortly after winter brumation and giving birth before brumation the following year. Mating was observed 24 times prior to March 1983 and fourteen clutches totalling 285 neonates were born into the colony during the same period (Fig. 1, Table 1). Mating was at its height in October and births peaked in February and March. Gestation takes four-five months over summer. Minor mating activity occurs shortly after parturition.

TABLE 1. *Dates of birth, sex ratios and clutch sizes for death adder clutches born in captivity at Whyalla.*

Clutch	Date	male	female	unsexed	total
1	10.iii.1976	—	—	—	24
2	20.iii.1976	—	—	—	19
3	13.iii.1977	—	—	—	10
4	10.iii.1979	—	—	—	24
5	28.i.1981	—	—	—	11
6	3.ii.1981	—	—	—	18
7	6.ii.1982	7	8	2	17
8	10.ii.1982	12	15	—	27
9	10.ii.1983	7	17	—	24
10	10.ii.1983	5	11	—	16
11	11.ii.1983	16	17	—	33
12	21.ii.1983	7	14	—	21
13	1.iii.1983	8	17	—	25
14	22.iii.1983	9	7	—	16

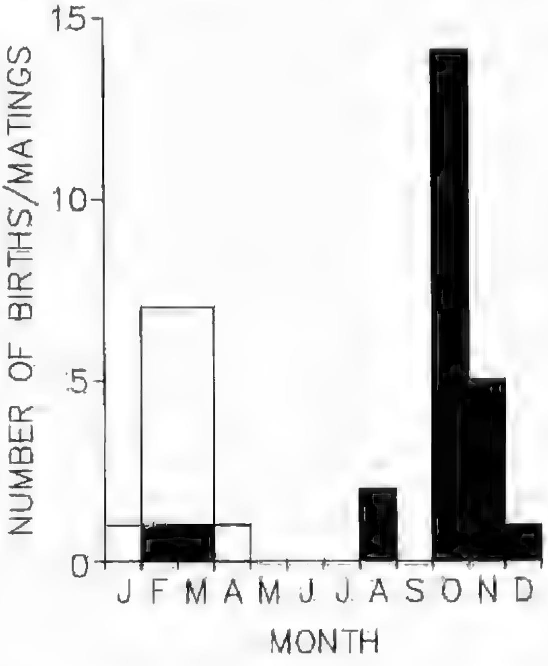

Fig. 1. Monthly occurrence of births (open bars) and matings (solid bars) recorded in *A. antarcticus* at the Whyalla Fauna Park, South Australia between 1976 and 1983.

Mating has been reported previously for *A. antarcticus* in January-April[10,11], and August-December[2,10]. Shine[12] found that ovulation takes place in late spring to early summer and embryos were present in females collected between December and March. Males were in reproductive condition throughout the year.

One female *A. antarcticus* born in 1980 is known to have produced clutches in four successive years. Hay & Magnusson[10] reported a female who bore clutches for three years in succession. However, Shine[12] found that approximately 50% of wild adult females were not in reproductive condition over the summer months and concluded they show reproductive asynchrony such that individuals reproduce biannually but the population reproduces each year. Discrepancies between annual reproductive cycles reported for captive death adders and biennial cycles in the field are probably due to a shift in the relative adaptive value of low frequencies of reproduction in captive versus field conditions[13]. Food availability and low thermal stress may be prime factors involved here.

The mean primary sex ratio differed significantly from expected[8], with females outnumbering males ($X^2[df = 1] = 44.032$, $P < 0.001$), although there was considerable variation between clutches (Table 1). Hay & Magnusson[10] have also noted a significant bias toward females in death adders. The variation from expected sex ratio cannot be explained by differential reproductive investments by females to hatchlings of each sex. Twenty seven female neonates from clutches 7 & 8 (Table 1) measured within 24 hrs of parturition were significantly heavier ($\bar{x} = 5.84$, $SD = 0.426$ gm, range = 5.22–6.65) than 15 males from the same clutches ($\bar{x} = 5.09$, $SD = 0.269$, range = 4.38–5.54) ($t[df = 40] = 6.499$, $p < 0.001$). Data contained in Shine's[12] table 1 show a significantly higher number of adult males than adult females in wild populations ($X^2[df = 1] = 4.300$, $P < 0.05$). As elapids have heteromorphic sex chromosomes[14] it is probable that sex determination in *A. antarcticus* is genetically controlled[15]. It is interesting to note that the sex ratio bias reverses between captive neonates and wild adults, indicating differential mortality between the sexes in wild populations.

Clutch sizes of 2–24 have been reported previously for *A. antarcticus*[10,12]. The captive clutch sizes reported here (Table 1) ($\bar{x} = 20.4$, $SD = 6.31$) and by Hay & Magnusson[10] ($\bar{x} = 20.8$, $SD = 2.30$, $N = 12$) are considerably larger than those reported for clutches in the field ($\bar{x} = 7.9$)[12].

Neonates have been observed on several occasions caudal luring immediately post-parturition. This indicates that caudal luring is an innate behaviour and not learned. Heatwole & Davison[16] found that most species which exhibit caudal luring do so only as juveniles. Adult death adders in the Whyalla colony have always been observed to wriggle their tails vigorously whenever an enclosure is approached and especially when a food item is placed in the enclosure. Carpenter, Murphy & Carpenter also have reported adult *Acanthophis* caudal luring[17].

At parturition neonates averaged 15.85 cm ($SD = 1.20$) in total length and 5.93 gm ($SD = 1.09$) in weight. Growth by weight was best described by the exponential equation:

$$\ln W = 1.822 + 0.123T$$

where W = weight (gm) and T = age (mo) (Fig. 2). Correlation coefficients (r) were significantly different between exponential and logarithmic models ($P < 0.001$)[18] but linear and power models were similar to the exponential model (P's > 0.05) (Table 2). Growth by total length was best described by the linear equation:

$$L = 15.907 + 1.211T$$

where T is as above, and L = length (cm) (Fig. 3). Correlation coefficients of exponential and logarithmic models where significantly different from the linear model (P's < 0.001) but the power model was similar ($P > 0.5$) (Table 2). The relationship between weight and total length is given by the power equation:

$$\ln W = -6.761 + 3.085 \ln L$$

where W and L are as above. Correlation coefficients for the linear, logarithmic and exponential models were all significantly different from the power model (P's < 0.005) (Table 2, Fig. 4).

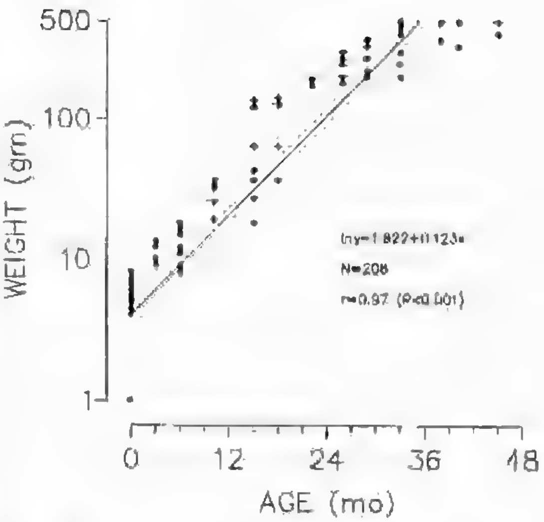

Fig. 2. Growth by weight (gm) of captive *A. antarcticus* over a four year period. Each symbol may represent more than one data point.

In the field newborn *A. antarcticus* appear in autumn measuring 12 cm snout-vent length and grow to 20 cm by the end of the calendar year and 30 cm by 21 mo[12]. This curve considerably underestimates the curve reported here over that time period for captive animals, but it does predict actual fourth year size accurately if extended on at the same gradient. The results reported here may be taken as an optimum curve for captive death adders. The initial difference in the growth curves may be because juvenile death adders at Whyalla are fed mice and wild populations take mostly reptiles in younger life[7].

Wild *A. antarcticus* do not reach sexual maturity until 24 and 42 mo for males and females, respectively[7].

TABLE 2. *Comparison of regression equations for growth on weight, growth on total length and weight on total length in captive death adders at Whyalla.*

Equation	R^2
Weight vs Age	
$W = 4.009 + 9.434T$	0.869
$W = 230.233 + 147.134 \ln T$	0.682
$\ln W = 1.822 + 0.123T$	0.942
$\ln W = 0.217 + 1.533 \ln T$	0.885
Length vs Age	
$L = 15.907 + 1.211T$	0.941
$L = -4.067 + 16.330 \ln T$	0.811
$\ln L = 2.789 + 0.039T$	0.923
$\ln L = 2.356 + 0.462 \ln T$	0.893
Weight vs Length	
$W = -121.041 + 7.499L$	0.855
$W = -613.020 + 220.401 \ln L$	0.770
$\ln W = 0.286 + 0.098L$	0.939
$\ln W = -6.761 + 3.085 \ln L$	0.966

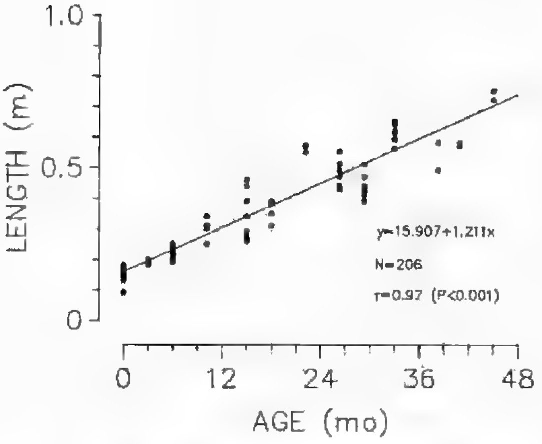

Fig. 3. Growth by length (cm) of captive *A. antarcticus* over a four year period. Each symbol may represent more than one data point.

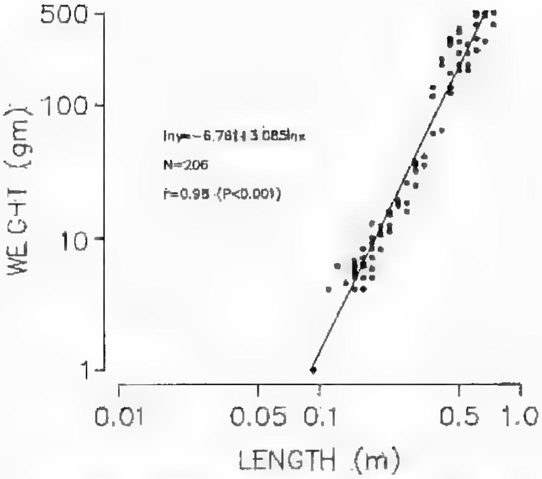

Fig. 4. Relationship between weight (gm) and length (cm) in captive *A. antarcticus*. Each symbol may represent more than one data point.

Newly mature females measure approximately 30 cm in length and males 44 cm[7]. In captivity these lengths may be reached in ten and fifteen months, respectively. Hay & Magnusson's death adders matured at similar ages to wild populations[10]. Maturity is generally related to size rather than age in reptiles[19,20]. This would explain why some specimens held at Whyalla have been observed mating at 19 mo[3].

R. Angus, P. Fennell, P. Hudson, W. Ingall, P. Mirtschin, H. Nygren, J. O'Reilly and H. Van Dyke helped maintain the snakes upon which this study is based at the Whyalla Fauna Park. K. Bradley, B. Doherty, T. Guster and M. Klessens assisted in taking measurements. Dr J. Miller assisted with the analysis of growth. Dr R. Shine and Mr B. Roberts read draft manuscripts.

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PARATACAMITE FROM SOUTH AUSTRALIA

Summary

BRIEF COMMUNICATION

PARATACAMITE FROM SOUTH AUSTRALIA

Atacamite and paratacamite are important crystalline modifications of copper(II) trihydroxychloride, $Cu_2(OH)_3Cl$, found in the upper portion of the oxidized zones of many copper deposits throughout the world. Atacamite, the orthorhombic polymorph of $Cu_2(OH)_3Cl$, has previously been reported from over twenty different localities in South Australia, the most important being the mines in the Moonta-Wallaroo district.[1,2] In contrast, paratacamite, the rhombohedral polymorph, has only been reported from two localities in South Australia; Dome Rock Copper Mine on Boolcoomata Station, Olary, and the Mount Gunson Mine near Pernatty Lagoon. We now report three new occurrences of paratacamite in this State; see Fig. 1.

Fig. 1. Map showing paratacamite localities in South Australia.

Small, well formed, dark-green rhombohedral crystals of paratacamite (Fig. 2) were found associated with brochantite and quartz in cavities in a brecciated hematitic greywacke from the upper workings at Wallaces Gully gold prospect, 10 km NNW of Mt Painter in the Flinders Ranges. A small crystal fragment was examined by single crystal X-ray diffraction methods with the use of an Enraf Nonius CAD4F diffractometer fitted with MoKα (graphite monochromator) radiation. Accurate unit cell dimensions were obtained from a least-squares refinement on the setting angles of twenty-five well-centred reflections in the range $7 \leq \theta \leq 22^\circ$. The cell obtained had parameters $\underline{a}$=9.169(6) Å and α=96.25(7)° (hexagonal setting $\underline{a}$=13.659(6) and $\underline{b}$=14.047(5) Å). The mineral was identified from its cell constants using the NBS Crystal Data Identification File incorporated in the Chemical Data Service VAX computer system, operated by the Science and Engineering Research Council at Daresbury in the U.K. The crystal structure of paratacamite has been reported.[3]

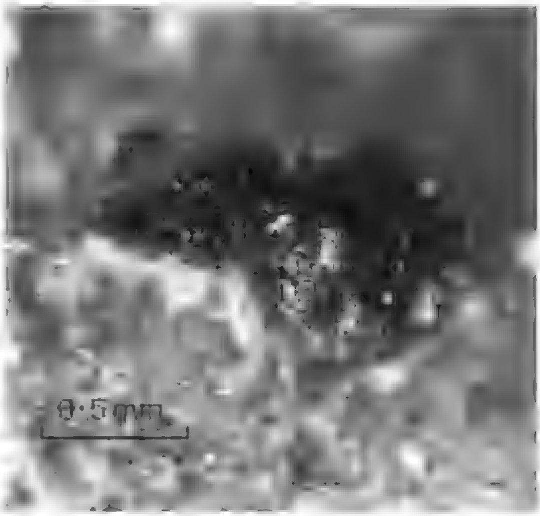

Fig. 2. Paratacamite crystals on quartz from Wallaces Gully gold prospect, 10 km NNW of Mt Painter, Flinders Ranges (Specimen SAM G13208).

The identification of paratacamite from Wallaces Gully prompted a systematic examination of the atacamite specimens held in the collection of the South Australian Museum. Paratacamite was identified, by powder X-ray diffraction methods, on six specimens from the New Cornwall Mine, Kadina, and on two specimens from the Wallaroo Mines, also at Kadina.

At the New Cornwall Mine, paratacamite occurs as fine grained masses honeycombed with vugs containing small groups of atacamite crystals up to 1 mm in length. The coexistence of the two polymorphs indicates two periods of crystallization, paratacamite being formed earlier than atacamite. The formation of paratacamite is favoured by relatively low concentrations of $CuCl_2$.[4] At higher concentrations (greater than 0.04 $\underline{F}$) atacamite is the favoured crystallization product. Such variations in conditions could be associated with movements in the level of the watertable.

Paratacamite at Wallaroo Mines is associated with aragonite, chalcocite and cuprite in an altered vein calcite. Here the paratacamite has been formed by the oxidation of cuprite. The mineral occurs both as a fine crust replacing cuprite crystals (Fig. 3) or as partially spherical masses of small crystals, 0.5 mm thick, surrounding a core of unaltered cuprite.

At the three localities cited, paratacamite appears to be restricted to the upper part of the oxidized zone.

We would like to thank Mr C. Johnston for providing the material from Wallaces Gully and to Ms F. Gommers for assistance with powder X-ray diffraction and

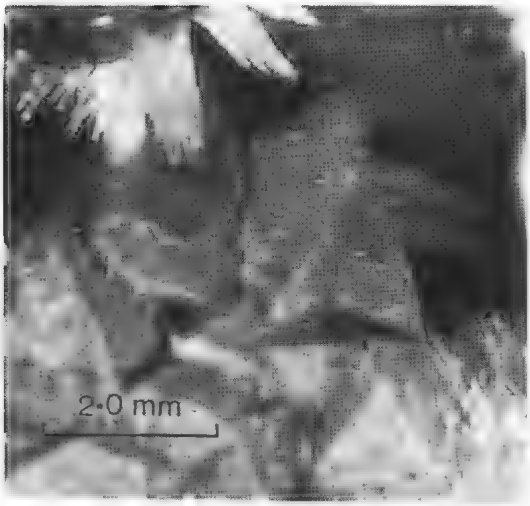

Fig. 3. Paratacamite replacing cuprite crystals with groups of radiating aragonite crystals from Wallaroo Mines, Kadina (Specimen SAM G11409).

photography. The financial support of the Australian Research Grants Scheme is gratefully acknowledged.

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PARASITES OF THE WOMBAT VOMBATUS URSINUS FROM GIPPLAND REGION, VICTORIA

Summary

PARASITES OF THE WOMBAT *VOMBATUS URSINUS* FROM THE GIPPSLAND REGION, VICTORIA

There have been a number of taxonomic papers on the helminths of the common wombat *Vombatus ursinus* but no detailed studies of their parasite fauna. Fascioliasis, an economically important disease of domestic ruminants, is sometimes found in wombats grazing contaminated agricultural pasture.[1] But in a study on the prevalence of *Fasciola hepatica* infection in south eastern Australia, no hosts were collected from the Central Gippsland region.[2] The womat is commonly and widely distributed across Gippsland[3], pasture damage and fence destruction being such that it is still legally designated vermin. From 1982 to 1984 wombat road kills were collected and examined to determine their parasite fauna, and the results are presented here.

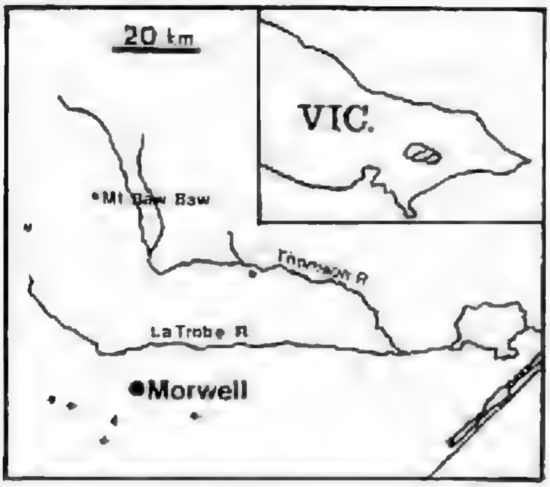

Fig. 1. Localities in the Gippland region where wombats were collected.

Although a number of road kills were sighted within the study area, only seven were suitable for further examination (Fig. 1). The internal viscera were examined for gross pathological changes, then the lungs, liver and gut contents were examined under a dissecting microscope for internal parasites. Nematodes and cestodes were fixed in 10% formalin. Nematodes were stored in 70% alcohol with 5% glycerol and identified in lactophenol. Ticks were stored in 70% alcohol.

Of the seven individuals examined, one was infected with the mite, *Sarcoptes scabiei* Degeer, 1778 while five harboured ticks, *Aponomma auruginans* Schultz, 1936. No gross pathological conditions were found and no helminths were observed in sites other than the digestive tract. Two hosts harboured cestodes, *Phascolotaenia comani* Beveridge, 1976 in the ileum of one and *Triplotaenia undosa* Beveridge, 1976 in the duodenum of another. All seven hosts were infected with the nematodes *Phascolostrongylus turleyi* Canavan, 1931 and *Oesophagostomoides longispicularis* Beveridge, 1978 while four hosts also were infected with *O. giltneri* Schwartz, 1928 (Table 1). The parasite burdens were not high and except for the wombat with mange all the hosts seemed to be in good physical condition. No trematode infections, and more specifically no *Fasciola hepatica* infections were found.

This is the first record of *T. undosa*, previously known only from macropodids, in a wombat. *Triplotaenia undosa* is found in a number of macropodid hosts including *Wallabia bicolor* and *Macropus fuliginosus*, both of these being common throughout Victoria[4]. However, the only record of *T. undosa* from Gippsland hosts is from *W. bicolor* collected at Bonang in East Gippsland, and not from either *W. bicolor* or *M. fuliginosus* sharing their range with wombats in the present study area. *Oesophagostomoides giltneri* was the least common of the nematode species found and had not previously been noted in hosts from Central Gippsland. Usually recorded as parasites of the colon all three species were also found in the small intestine and on one occasion the caecum. This distribution is probably a function of post mortem migration from the colon. Although there is moderate resistance by wombats to *F. hepatica*[1], it is more likely in this case that no infections of *F. hepatica* were found because the specimens collected were not grazing in infected areas. Central Gippsland is not one of the main habitats for *Lymnaena tomentosa* the intermediate host snail,[5] and nor is fascioliasis a significant problem of sheep and cattle from the study area (Regional Veterinary Laboratory, Bairnsdale, pers. comm.).

My thanks to I. Beveridge for identifying the cestodes and D. Kemp for identifying the ticks.

TABLE 1. *Site in host and abundance of infections with* Oesophagostomoides longispicularis, O. giltneri *and* Phascolostrongylus turleyi *from seven wombats.*

	Site in Host Ileum		Caecum		Colon	
	No. Parasites/Host					
Parasite	Mean	Range	Mean	Range	Mean	Range
O. longispicularis	17	0-58	0.71	0-5	23.7	0-62
O. giltneri	5.4	0-29	0.14	0-1	3.7	0-15
P. turleyi	46	0-293	0	0	47.7	0-113

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THE OCCURRENCE OF DESMONEMA GAUDICHAUDI (LESSON) (SCYPHOZOA, SEMAEOSTOMEAE) IN SOUTH AUSTRALIAN WATERS WITH RECORDS OF FISH-JELLYFISH SYMBIOSES

Summary

BRIEF COMMUNICATION

THE OCCURRENCE OF *DESMONEMA GAUDICHAUDI* (LESSON) (SCYPHOZOA, SEMAEOSTOMEAE) IN SOUTH AUSTRALIAN WATERS WITH RECORDS OF FISH-JELLYFISH SYMBIOSES

The genus *Desmonema* L. Agassiz, 1862 (Scyphozoa, Semaeostomeae) currently contains three species.[1] It has an Antarctic to sub-Antarctic distribution[2,3] but is unrecorded in Australian waters (the record of *D. rosea* Agassiz & Mayer from Largs Bay, S. Aust.,[4] refers to a species of *Cyanea* — see comment at end of this note).

Two specimens of *D. gaudichaudi* (Lesson) are recorded here for South Australian waters. Both were found in symbiotic relationship with fishes. Other jellyfish-fish symbioses from southern and eastern Australian waters are documented. Material is deposited in the South Australian Museum (SAM). Numbers prefixed by A refer to registrations in the notebooks of R.V.S.

Desmonema gaudichaudi (Lesson) (SAM H348 (A1156)).

Bell width to turnover edge 11 cm; same measurement with bell laid flat 14 cm; 10-15 tentacles/group. Coll. S. A. Shepherd, 29.iv.1969, 1 m depth, West Island (N. side), Encounter Bay. With SAM F5615 (A1157), a juvenile trevally *Pseudocaranx dentex* (Bloch & Schneider) (earlier *Usacaranx georgianus* (Cuvier & Valenciennes)) "living under the mantle".

D. gaudichaudi SAM H349

Bell width to turnover edge 13 cm; same measurement with bell laid flat 15 cm; *c.* 20 tentacles/group. Coll. W. Potts and D. Phillips, 19.ii.1986, opposite Point Campbell, Coorong. SAM F5616, with 9 small hardyheads, family Atherinidae (partially decomposed), among tentacles (possibly *Atherinosoma microstoma* (Günther), the only member of the family currently recorded from the Coorong[5]).

Previous records of *D. gaudichaudi* with "juvenile fishes, mostly of the genus *Trachurus*", family Carangidae, have been recorded from New Zealand[6].

Symbioses between jellyfishes and fishes have been reviewed comprehensively.[7] Further records from Australian waters are as follows:

1. Unnamed species in association with juvenile yellowtail scad, *Trachurus mccullochi* Nichols.[8,9]
2. *Pseudorhiza haeckeli* Haacke (Rhizostomeae)
(a) A1015, coll. S. A. Shepherd, 1.iii.1968, near surface, Aldinga Reef, S. Aust. (off "Aldinga drop-off"). SAM F5614 (A1017), 3 small *Pseudocaranx dentex* and several *Eirene menoni* Kramp (Hydrozoa, Leptomedusae) (A1016) in association with the rhizostome.
(b) SAM H350 (A1391). Coll. S. A. Shepherd, 25.i.1973, depth 3 m. West Island, 15–16 small *P. dentex* (four sampled, SAM F3905), and one small amphipod in association with the jellyfish.
(c) Jellyfish identified but not retained, 23.i.1975, Glenelg, S. Aust., with juvenile *P. dentex* (SAM F4238).
3. *Catostylus mosaicus* (Quoy & Gaimard) (Rhizostomeae) SAM H351 (A884). Bell width 27 cm. Coll. R. V. Southcott, 7.viii.1965, Port Hacking, N.S.W., with juveniles of *T. mccullochi* (SAM F5617 (A886)). This association has been figured previously, Plate 15[10].
4. *Chrysaora* sp. (Semaeostomeae). Coll. R. V. Southcott, 17.i.1980, "Cape Jervis Station" of S. Aust. Dept. Fisheries, Gulf St Vincent, near surface, from F. R. V. Joseph Verco,
(a) SAM H352 (A2305) with *P. dentex*, SAM F5611 (A2315).
(b) SAM H353 (A2306) with *P. dentex*, SAM F5612 (A2316).
(c) SAM H354 (A2307) with one juvenile mosaic leatherjacket, *Eubalichthys mosaicus* (Ramsay & Ogilby), SAM F5613 (A2335). (illustrated previously, Plate 14[10]).
(d) A2311, with *P. dentex*, SAM F5610 (A2317).

(There were 0–4 *P. dentex* symbiotic with each *Chrysaora*.)

5. *Cyanea capillata* (L.) (Semaeostomeae), with juvenile leatherjackets (family Monacanthidae) (illustrated previously, Plates 14, 16[10]).
6. *Catostylus mosaicus*. Bass Strait, with juveniles of *E. mosaicus*[11].

Nomenclatorial note

Desmonema rosea Agassiz & Mayer, 1898,[4] from Largs Bay, South Australia, is clearly a *Cyanea* and not a *Desmonema*, since it has both radial and concentric muscle strands in the subumbrella, and the tentacle origin sites are U-shaped, not linear. Mayer[12] synonymized this species with *Cyanea annaskala* von Lendenfeld, including in the synonymy also *C. muellerianthe* Haacke, 1887,[13] from Gulf St Vincent, South Australia. Kramp (1965)[14] concluded that both of these last-named species are synonyms of *C. capillata* (L.). It may be safely stated that in Gulf St Vincent there occurs one species of *Cyanea*, *C. capillata* (L.). By transferring *D. rosea* to *Cyanea* in 1910, Mayer created a potential secondary homonym of *Cyanea rosea* Quoy & Gaimard, 1824, from the Great Barrier Reef, which Kramp[2,14] has regarded as a doubtful species of *Cyanea*, but possibly also a synonym of *C. capillata*. Thus four synonyms are available for *C. rosea* (Agassiz & Mayer).

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VOL. 111, PARTS 3 & 4
30 NOVEMBER, 1987

Transactions of the
Royal Society of South Australia
Incorporated

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PUBLISHED AND SOLD AT THE SOCIETY'S ROOMS
SOUTH AUSTRALIAN MUSEUM, NORTH TERRACE, ADELAIDE, S.A. 5000

TRANSACTIONS OF THE

ROYAL SOCIETY OF SOUTH AUSTRALIA

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VOL. 111, PART 3

EIGHTEEN NEW SPECIES OF *STIGMODERA (CASTIARINA)* (COLEOPTERA: BUPRESTIDAE)

BY S. BARKER*

Summary

Eighteen new species of *Stigmodera* (*Castiarina*) are described: S. aglaia sp. nov., *S. alecgemmelli* sp. nov., *S. arida* sp. nov., *S. atra* sp. nov., *S. caillaina* sp. nov., *S. chamelauci* sp. nov., *S. duggunensis* sp. nov., *S. earina* sp. nov., *S. gardnerae* sp. nov., *S. gordonburnsi* sp. nov., *S. goudiana* sp. nov., *S. jimturneri* sp. nov., *S. kanangara* sp. nov., *S. lauta* sp. nov., *S. lividा* sp. nov., *S. sundholmi* sp. nov., *S. vanderwoudeae* sp. nov. *S. viridissima* sp. nov.

KEY WORDS: Coleoptera, Buprestidae, *Stigmodera* (*Castiarina*), New species.

EIGHTEEN NEW SPECIES OF *STIGMODERA (CASTIARINA)* (COLEOPTERA: BUPRESTIDAE)

by S. BARKER*

Summary

BARKER, S. (1987) Eighteen new species of *Stigmodera (Castiarina)* (Coleoptera: Buprestidae). *Trans. R. Soc. S. Aust.* 111(3), 133-146, 30 November, 1987.

Eighteen new species of *Stigmodera (Castiarina)* are described: *S. aglaia* sp. nov., *S. alecgemmelli* sp. nov., *S. arida* sp. nov., *S. atra* sp. nov., *S. caillaina* sp. nov., *S. chamelauci* sp. nov., *S. dugganensis* sp. nov., *S. earina* sp. nov., *S. gardnerae* sp. nov., *S. gordonburnsi* sp. nov., *S. goudiana* sp. nov., *S. jimturneri* sp. nov., *S. kanangara* sp. nov., *S. lauta* sp. nov., *S. livida* sp. nov., *S. sundholmi* sp. nov., *S. vanderwoudeae* sp. nov. *S. viridissima* sp. nov.

KEY WORDS: Coleoptera, Buprestidae, *Stigmodera (Castiarina)*, New species.

Introduction

Eighteen new species of *Stigmodera (Castiarina)* are described herein and placed in species groups. This brings the number of known species to about four hundred. Most of the new species have emerged from recent collecting, however several have been known for a long time, but confused with other species. All of them have been placed in species groups on the basis of the structure of their male genitalia and external morphology. All previously recognised species groups are listed in Barker (1986); an additional three groups are detailed here.

Materials and Methods

Male genitalia were dissected from selected specimens, cleaned of attached muscle and glued dry onto a piece of card before they were photographed and printed at the same magnification. Genitalia of known species are included for comparative purposes. The abbreviations used in the text for museum and private collections are as follows (Watt 1979): ASSA Mr A. Sundholm, Sydney, N.S.W.; BMNH British Museum (Natural History), London; EAQA Mr E. E. Adams, Edungalba, Qld; GBVA Mr G. G. Burns, Mornington, Vic.; JGAA Dr J. Gardner, Adelaide, S. Aust.; JHAQ Mrs J. Harslett, Amiens, Qld; JSBQ Mr J. Sedlacek, Brisbane, Qld; JTNA Mr J. R. Turner, Hazelbrook, N.S.W.; MHSA Mr T. M. S. Hanlon, Ryde, N.S.W.; MPWA Mr M. Powell, Attadale, W.A.; NMVA National Museum of Victoria; MMSA Macleay Museum, Sydney; QMBA Queensland Museum, Brisbane; RMBB L'Institut Royal de Sciences Naturelles de Belgique, Brussels; SAMA South Australian Museum, Adelaide; WAMA Western Australian Museum, Perth.

Stigmodera (Castiarina) alecgemmelli sp. nov.
FIGS 1A, 2D

Holotype: ♂, Stanthorpe, Qld, Dec. 1958, *A. Gemmell*, SAMA I 21178.

Allotype: ♀, Stanthorpe, Qld, *E. Sutton*, SAMA I 21179.

Paratypes: Qld: 1 ♂, same data as holotype; 1 ♂, 1 ♀, Stanthorpe, 27.xi.1926, *S. M. Watson*, SAMA; 1 ♀, Stanthorpe, Nov. 1925, SAMA; 1 ♂, Stanthorpe, *E. Sutton*, SAMA; 1 ♀, Glen Aplin, 26.xi.1941, *A. Gemmell*, JHAQ; 1 ♂, 2 ♀♀, Amiens, 26.xi.1984, *J. Harslett*, JHAQ; 1 ♂, Fletcher, *E. Sutton*, SAMA; 1 ♂, Stanthorpe, *E. Sutton*, JSBQ; 3 ♀♀, Stanthorpe, 20.xii.1981, *J. Turner*, JTNA; 1 ♂, Milmerran Dec. 1947/Jan. 1948, *J. Macqueen*, ASSA. N.S.W.: 1 ♂, Coonabarabran, 7.xi.1975, *S. Barker*, SAMA; 1 ♀, 4 km E Rocky Glen, 3.xi.1981, *S. Barker, P. Kempster, H. Vanderwoude*, SAMA; 1 ♂, 6 km SW Rocky Glen, 3.xi.1981, *S. Barker, P. G. Kempster, H. Vanderwoude*, SAMA; 2 ♂♂, 9 km N Coonabarabran, 5/6.xi.1983, *A. Sundholm*, ASSA; 1 ♂, 8 km N Coonabarabran, 8.xi.1983, *A. Sundholm*, ASSA; 1 ♂, 7 km N Coonabarabran, 5.xi.1982, *A. Sundholm*, ASSA; 1 ♂, Coonabarabran, 6.xi.1982, *A. Sundholm*, ASSA; 2 ♂♂, 1 ♀, 5 km N Coonabarabran, 4.xi.1983, *A. Sundholm, J. Bugeja*, ASSA.

Colour: Head, antennae, pronotum dull green. Scutellum blue. Elytra yellow with following black markings with blue reflections: narrow basal margin; broad pre-medial fascia not reaching margin; broad post-medial fascia reaching margin, projecting anteriorly in centre of each side of anterior margin; pre-apical mark covering apex, all

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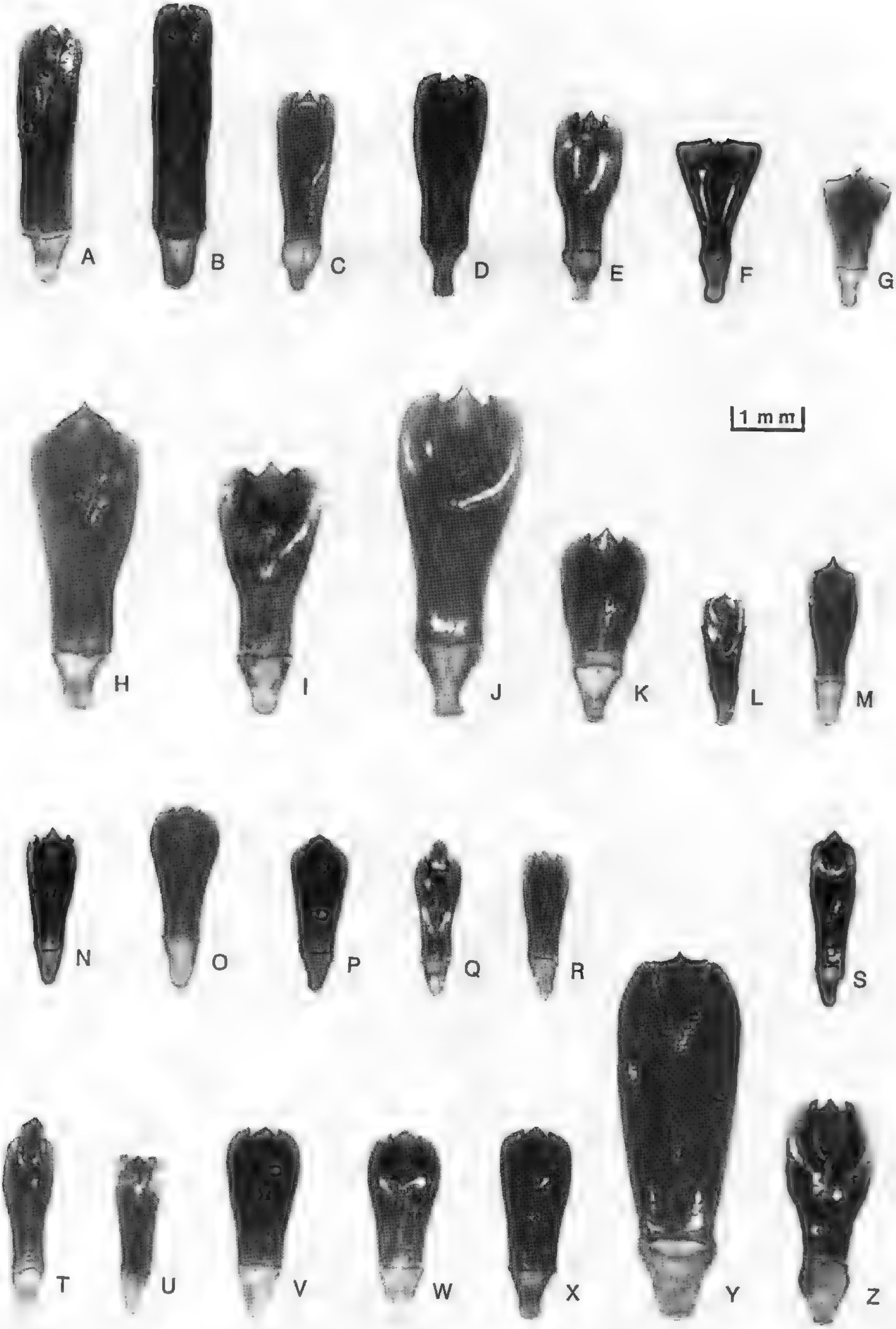
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marks confluent along suture. Ventral surface and legs dull green. Hairs silver.

Shape and sculpture: Head closely punctured, median sulcus, short muzzle. Antennae, segments: 1–3, obconic; 4, half toothed; 5–11, toothed. Pronotum closely punctured, very small basal fovea extending to apical margin as glabrous line, basal notches on each side more lateral than medial; apical margin projecting medially, basal margin almost straight; laterally parallel-sided at base, angled inwards, rounded to widest part before centre, rounded and narrowed to apex. Scutellum scutiform, glabrous, excavate. Each elytron punctate-striate, intervals convex, heavily punctured laterally and apically, smooth medially; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly then narrowed to bispinose apex; both spines small, margin rounded between, apices diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, dense medium length hairs. S_7: truncate in males; rounded in females.

Size: Males, 13.0 ± 0.24 × 5.3 ± 0.09 mm (17). Females, 14.2 ± 0.28 × 5.8 ± 0.13 mm (11).

Male genitalia: (Fig. 1A). Parameres more or less parallel-sided for most of length, slightly widened, rounded apically. Median lobe blunt, sides angled away. Apophysis of basal piece medium width, angled to apex.

Remarks: Member of *S. simulata* C & G species group. Has been confused with *S. burchelli* C & G (Holotype, MNHN). Aedeagus of *S. burchelli* C & G (Fig. 1B) similar shape but longer and narrower. Apex of median lobe pointed, sides acutely angled away. Apophysis of basal piece medium width but not tapered apically. *S. burchelli* is coastal species with red margins on elytra. *S. alecgemmelli* is found inland and does not have red margins. Named after the late Mr A. Gemmell, Glen Aplin, Qld.

Stigmodera (Castiarina) arida sp. nov.
FIGS 1C, 2B

Holotype: ♂, Vic., NMVA.

Allotype: ♀, Sofala, N.S.W., 26.xii.1983, *A. Sundholm*, SAMA I 21180.

Paratypes: Vic.; 1 ♂, 3 ♀♀, NMVA.

Colour: Head dark blue. Antennae, segments: 1, 2, dark blue; 3–11, bronze. Pronotum dark blue medially, red laterally. Scutellum dark blue. Elytra red with following dark blue elytral markings: narrow basal margin; very broad pre-medial fascia not reaching margin, but expanded anteriorly to basal margin, enclosing basal spot on each side; very broad post-medial fascia expanded anteriorly from centre of anterior margin on each side and on suture, expanded posteriorly from centre of posterior margin on each side and on suture; mark covering apex. Ventral surface: pre-sternum variably dark blue medially, red laterally; meso- and meta-sternum dark blue or variably dark blue and red laterally; abdomen red. Legs: femora and tibiae blue; tarsi blue-green. Hairs silver.

Shape and sculpture: Head closely punctured, broad median sulcus, short muzzle. Antennae, segments: 1–3, obconic; 4–11, toothed. Pronotum closely punctured, basal fovea extending to apical margin as impressed line; apical margin projecting medially, basal margin barely bisinuate; laterally angled outwards from base, rounded to widest part anteriorly, rounded and narrowed to apex, dorso-ventrally flattened for one third of distance from base. Scutellum scutiform, glabrous, excavate. Each elytron punctate-striate, intervals convex; punctured more heavily laterally than medially; laterally slightly angled out from base, rounded at humeral callus, concave, rounded posteriorly then tapered, rounded to spineless apex; minute indentation from apical margin to suture without obvious spines, apices diverging slightly, apical margin rough. Ventral surface with shallow punctures, edges of abdominal segments glabrous, sparse very short hair. S_7: narrowly truncate in males; rounded and pointed in females.

Size: Males, 12.7 × 4.9 mm (2). Females 13.4 × 5.1 mm (4).

Male genitalia: (Fig. 1C). Parameres parallel-sided basally, rounded posteromedially, slightly widened, rounded apically. Median lobe sharp, sides acutely angled away. Apophysis of basal piece short and slender.

Remarks: A member of *S. distinguenda* Saunders species group. External morphology most closely resembles *S. militaris* Carter (Holotype male, RMBB), but male genitalia are different. In *S.*

Fig. 1. Photomicrographs of male genitalia of the following *Stigmodera (Castiarina)* species: A. *S. alecgemmelli* sp. nov., B. *S. burchelli* C & G, C. *S. arida* sp. nov., D. *S. militaris* Carter, E. *S. dugganensis* sp. nov., F. *S. chamelauci* sp. nov., G. *S. vanderwoudeae* sp. nov., H. *S. gordonburnsi* sp. nov., I. *S. klugi* C & G, J. *S. caillaina* sp. nov., K. *S. goudiana* sp. nov., L. *S. livida* sp. nov., M. *S. viridissima* sp. nov., N. *S. earina* sp. nov., O. *S. sundholmi* sp. nov., P. *S. imitator* Carter, Q. *S. aglaia* sp. nov., R. *S. gentilis* Kerremans, S. *S. atra* sp. nov., T. *S. obliqua* Kerremans, U. *S. gracilior* Carter, V. *S. gardnerae* sp. nov., W. *S. mustelamajor* Thomson, X. *S. erasma* Carter, Y. *S. jimturneri* sp. nov., Z. *kurrangura* sp. nov.

militaris (Fig. 1D) parameres are wider at apex, median lobe blunt and obtusely angled away. Basal piece is not circular but protrudes in centre. Apophysis of basal piece narrow, constricted in middle and elongate. *S. militaris* is smaller species with blue and yellow markings. The name refers to the habitat and is derived from *aridus* L., dry.

Stigmodera (Castiarina) dugganensis sp. nov.

FIGS 1E, 2C

Holotype: ♂, Duggan, W.A., 27.ix.1974, *K. & E. Carnaby*, SAMA I 21178.

Allotype: ♀, Lake Cronin, W.A., 17.x.1981, *M. Powell*, WAMA.

Paratypes: W.A.: 2 ♂♂, 80 km E Hyden, 28.x.1984, *M. Powell*, MPWA; 1 ♂, Lake Cronin, 18.x.1981, *M. Powell*, MPWA. Vic.: 1 ♂, 1 ♀, Sea Lake, Nov. 1916, *W. Goudie*, NMVA.

Colour: Head blue. Antennae bronze-green. Pronotum blue medially, red laterally from one third of distance from base to apex, base blue. Scutellum blue. Elytra red with following dark blue markings: narrow basal margin; pre-medial fascia not reaching margin but extending anteriorly to basal margin, enclosing basal spot on each side; broad post-medial fascia; mark covering apex, marks may or may not be confluent along suture. Ventral surface: sternum dark blue; abdomen blue in centre, red at sides. Legs: femora and tibiae blue-green; tarsi green. Hairs silver.

Shape and sculpture: Head closely punctured, broad median sulcus, short muzzle. Antennae, segments: 1–3, obconic; 4–11, toothed. Pronotum closely punctured, narrow basal fovea extending to anterior margin as thin impressed line, small basal notches on each side more lateral than medial; apical margin projecting medially, basal margin bisinuate; laterally rounded from base to widest part posteromedially, rounded to apex. Scutellum scutiform, glabrous, flat. Each elytron punctate-striate, intervals convex, punctured and wrinkled; laterally parallel-sided at base then angled out, rounded at humeral callus, faintly concave, rounded posteriorly and narrowed to bispinose apex; small blunt marginal spine, minute sutural spine, margin indented between, apices diverging slightly. Ventral surface with shallow punctures, sparse medium length hairs. S_7: truncate in males; rounded and slightly pointed in females.

Size: Males, 12.3 × 4.5 mm (5). Females, 13.9 × 5.0 mm (2).

Male genitalia: (Fig. 1E). Parameres parallel-sided basally, widened posteromedially, more or less parallel-sided, rounded apically. Median lobe pointed, sides acutely angled away. Apophysis of basal piece narrow and tapered apically.

Remarks: Member of the *S. distinguenda* Saunders species group on basis of pronotal markings, external morphology and male genitalia. Although distinct within its species group, could be confused with *S. rufa* Barker, a member of the *S. gibbicollis* Saunders species group, which has similar colour and pattern. Male genitalia are very different Barker (1986, Fig. 2E). The name is derived from the type locality.

Stigmodera (Castiarina) chamelauci sp. nov.

FIGS 1F, 2F

Holotype: ♂, Spalding Park, Bluff Pt, Geraldton District, W.A., 5.ix.1973, *N. McFarland*, BMNH.

Allotype: ♀, Spalding Park, Bluff Pt, Geraldton District, W.A., 21.ix.1973, *N. McFarland*, BMNH.

Paratypes: W.A.: 25 ♂♂, Dongarra (sic), 6–19.ix.1935, 20–25.ix.1935, 26.ix–3.x.1935, 4–10.x.1935, 11–28.x.1935, *R. E. Turner*, BMNH & SAMA.

Colour: Head dark blue. Antennae, segments: 1, blue; 2–11, blue-green. Pronotum dark blue with bronze reflections. Scutellum dark blue. Elytra orange with red margin and following black markings with blue reflections: narrow basal margin; pre-medial fascia not reaching margin or represented by spot over each humeral callus and one on suture; post-medial fascia reaching margin, expanded anteriorly on suture and on anterior margin on each side more lateral than medial, expanded posteriorly on suture and on posterior margin on each side more lateral than medial; pre-apical mark also covering spines, confluent in more heavily marked specimens, post-medial fascia and apical mark confluent along suture. Ventral surface dark blue. Legs: femora and tibiae dark blue; tarsi blue-green. Hairs silver.

Shape and sculpture: Head closely punctured, broad median sulcus, short muzzle. Antennae, segments: 1–4, obconic; 5–11, toothed. Pronotum closely punctured, narrow basal fovea extending to apical margin as glabrous line, basal notches represented by glabrous area on each side more lateral than medial; apical margin straight, basal margin bisinuate; laterally rounded from base, widest posteromedially, rounded and narrowed to apex. Scutellum scutiform, glabrous, excavate. Each elytron punctate-striate, intervals convex; punctured, more so laterally than medially; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly and narrowed, rounded again to bispinose apex; sharp marginal spine, small sutural spine, margin rounded and indented

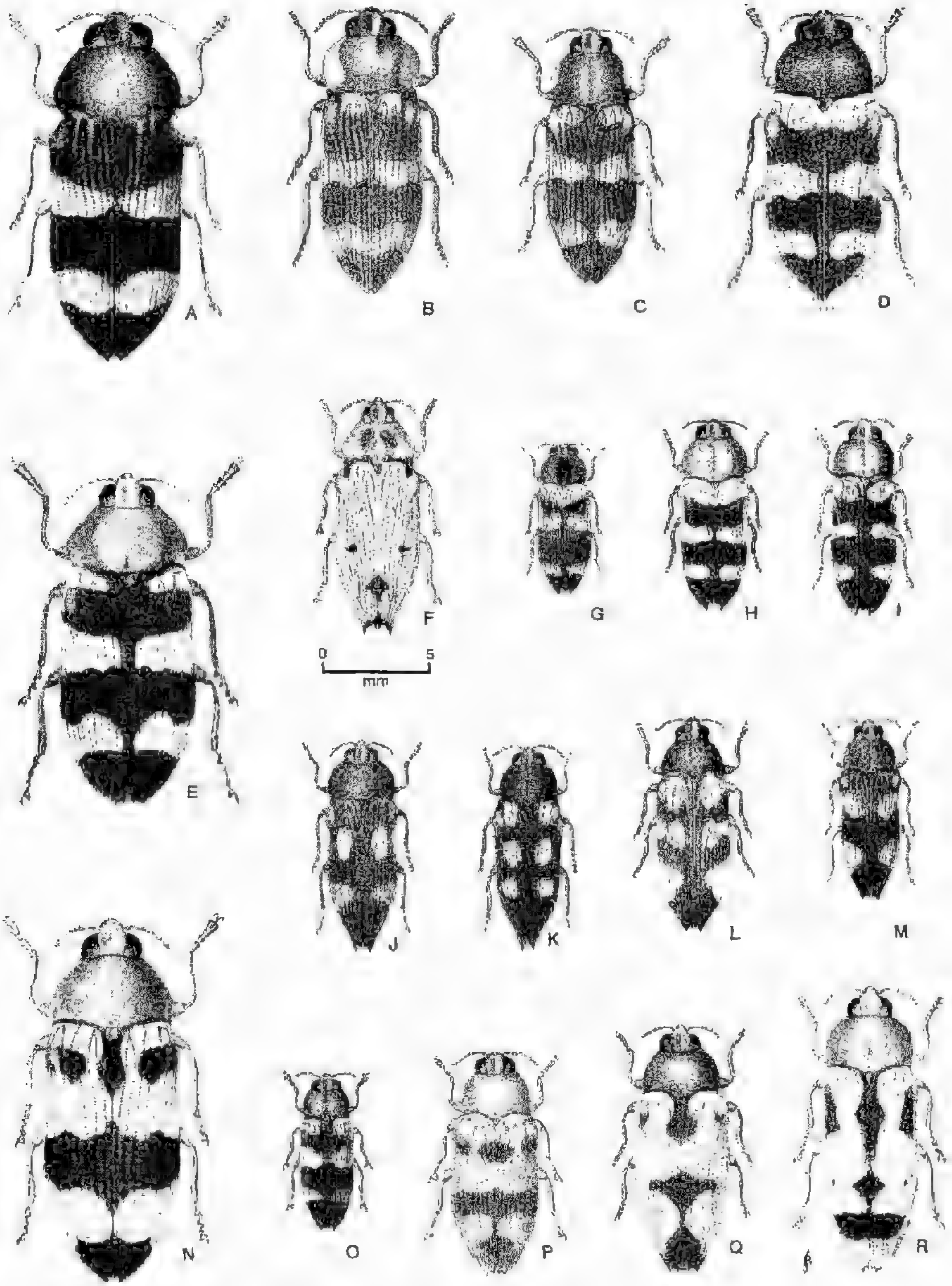

Fig. 2. A, *Stigmodera gordonburnsi* sp. nov., B. *S. arida* sp. nov., C. *S. dugganensis* sp. nov., D. *S. alecgemmelli* sp. nov., E. *S. caillaina* sp. nov., F. *S. gardnerae* sp. nov., G. *S. livida* sp. nov., H. *S. viridissima* sp. nov., I. *S. earina* sp. nov., J. *S. lauta* sp. nov., K. *S. atra* sp. nov., L. *S. sundholmi* sp. nov., M. *S. aglaia* sp. nov., N. *S. jimturneri* sp. nov., O. *S. vanderwoudeae* sp. nov., P. *S. chamelauci* sp. nov., Q. *S. goudiana* sp. nov., R. *S. kunangaru* sp. nov.

between, apices diverging, apical margin subserrate. Ventral surface with shallow punctures, edges of abdominal segments glabrous, moderately hairy, hairs medium length. S_7: truncate in males; truncate and indented medially in females. Legs, male: tarsal pads absent on legs 2 and 3 on tarsomeres 1-3, replaced by median spine.

Size: Males, 10.8 ± 0.13 × 4.1 ± 0.05 mm (26). Female, 11.9 × 4.5 mm (1).

Male genitalia: (Fig. 1F). Wedge-shaped with relatively narrow basal piece, apophysis and parameres.

Remarks: Member of *S. sexplagiata* Gory species group on basis of its wedge-shaped male genitalia and external morphology. Elytral colour and red margins distinguish this species from others in group. Named after *Chamelaucium uncinatum* Schau., Geraldton wax, on which adults are collected.

Stigmodera (Castiarina) vanderwoudeae sp. nov.
FIGS 1G, 2O

Holotype: ♂, Lake Gilles Conservation Pk, 27 km E Kimba, S. Aust., 25.x.1982, *S. Barker, P. G. Kempster, H. Vanderwoude*, SAMA I 21182.

Allotype: ♀, same data as holotype, SAMA I 21183.

Paratypes: S. Aust.: 15 ♂♂, 8 ♀♀, same data as holotype, SAMA.

Colour: Head black with blue reflections. Antennae, segments: 1, 2, blue; 3-11, blue-green. Pronotum and scutellum black with blue reflections. Elytra orange with following dark blue markings: narrow basal margin; pre-medial fascia not reaching margin, projecting slightly anteriorly on suture; broad post-medial fascia projecting anteriorly on suture at anterior margin and in centre of each side of anterior margin, projecting posteriorly on suture at posterior margin; mark covering apex, marks confluent along suture. Ventral surface and legs dark blue. Hairs silver.

Shape and sculpture: Head closely punctured, median sulcus, short muzzle. Antennae, segments: 1-4, obconic; 5-11, toothed. Pronotum closely punctured, narrow basal fovea extending to centre as glabrous line, then to apical margin as impressed line; apical margin straight, basal margin bisinuate; laterally angled inwards from base, rounded to widest part posteromedially, rounded and narrowed to apex. Scutellum scutiform, glabrous, excavate. Each elytron punctate-striate, intervals convex, punctured more heavily laterally than medially; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly and narrowed to bispinose apex; sharp marginal spine, minute sutural spine, margin rounded and indented between, apices diverging slightly, apical margin subserrate. Ventral surface with shallow punctures, edges of abdominal segments glabrous, moderately hairy, hairs short. S_7 truncate in both sexes. Legs, male: tarsal pads absent on legs 2 and 3 on tarsomeres 1-3 each replaced by small double, median spine.

Size: Males, 7.9 ± 0.20 × 3.0 ± 0.09 mm (16). Females, 8.6 ± 0.24 × 3.4 ± 0.04 mm (9).

Male genitalia: (Fig. 1G). Wedge-shaped. Parameres parallel-sided at base, widened posteromedially, slightly rounded then abruptly rounded near apex, apical edge concave. Median lobe pointed, rounded apically. Apophysis of basal piece narrowed.

Remarks: Member of *S. sexplagiata* species group on basis of its wedge-shaped male genitalia and external morphology. Most closely resembles *S. cornishi* Barker (1983, Fig. 1R) but is smaller. Male genitalia are smaller and not as wide apically and spines on ventral surface of tarsomeres are much less prominent than in *S. cornishi*. All specimens were collected on flowers of *Eremophila scoparia* (R.Br.) F. Muell. Named after Ms H. Vanderwoude, Adelaide.

Stigmodera (Castiarina) gordonburnsi sp. nov.
FIGS 1H, 2A

Holotype: ♂, Grampians, Vic., 22.xi.1982, *G. G. Burns*, NMVA.

Allotype: ♀, Grampians, Vic., 19.xii.1983, *G. G. Burns*, NMVA.

Paratypes: Vic.: 1 ♂, same data as holotype, GBVA; 1 ♂, Inglewood, Nov. 1952, *E. Smith*, NMVA; 1 ♀, same data as allotype, GBVA; 1 ♂, Grampians, 23.xi.1982, *G. G. Burns*, SAMA; 1 ♂, Grampians, 24.xi.1982, *G. G. Burns*, GBVA; 1 ♀, 16 km N Benambra, 14.i.1979, *P. J. Gullen*, SAMA.

Colour: Head dark blue. Antennae, segments: 1, 2, blue-green; 3-11, bronze-green. Pronotum dark blue medially, blue laterally. Scutellum dark blue. Elytra red with following dark blue markings: broad basal margin, red spot at lateral margin on each side; broad post-medial fascia; mark covering apex, all marks confluent along suture. Ventral surface blue. Legs: femora blue; tibiae and tarsi blue-green. Hairs silver.

Shape and sculpture: Head closely punctured, broad median sulcus, short muzzle. Antennae, segments: 1-3, obconic; 4-11, toothed. Pronotum closely punctured, basal fovea extending to apical margin as glabrous line, basal notches on each side more lateral than medial; apical margin projecting medially, basal margin almost straight; laterally parallel-sided at base, angled outwards, rounded to widest part posteromedially, rounded and narrowed to apex. Scutellum scutiform, glabrous, flat. Each elytron punctate-striate, intervals convex, punctured and wrinkled; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly to bispinose apex; both spines small and blunt, margin rounded and indented between, apices diverging slightly, apical margin subserrate. Ventral surface with shallow punctures, edges of abdominal segments glabrous, sparse short hairs. S_7: truncate in male; rounded in females.

Size: Males, 16.2 × 6.5 mm (5). Females, 17.3 × 7.3 mm (3).

Male genitalia: (Fig. 1H). Parameres parallel-sided basally, rounded posteromedially, widened, rounded apically. Median lobe pointed, sides acutely angled away then rounded and obtusely angled away. Apophysis of basal piece medium width.

Remarks: Member of *S. klugi* species group. In closest species *S. klugi* C & G (Fig. 1I), aedeagus is shorter, apices of parameres are more abruptly rounded, median lobe blunter. Only red and blue species in group, *S. klugi* is yellow and blue and *S. rubicunda* Carter is red and purple. Named after Mr G. G. Burns, Mornington.

Stigmodera (Castiarina) caillaina sp. nov.
FIGS 1J, 2E

Holotype: ♂, Vic., *Blackburn*, SAMA I 21184.

Allotype: ♀, Hornsby, N.S.W., *Schrader*, SAMA I 21185.

Paratype: 1 ♂, no data, RMBB.

Colour: Head and antennae blue-green. Pronotum green medially, blue laterally. Scutellum blue. Elytra yellow with following black markings with blue reflections: narrow basal margin; pre-medial fascia reaching margin with projection from posterior margin; post-medial fascia reaching margin, concave posteriorly; mark covering apex, all marks confluent along suture. Ventral surface dark blue. Legs blue-green. Hairs silver.

Shape and sculpture: Head closely punctured, median sulcus, short muzzle. Antennae, segments: 1-3, obconic; 4-11 toothed. Pronotum closely punctured, small basal fovea extending to centre as glabrous line; apical margin slightly projecting medially, basal margin barely bisinuate; laterally angled outwards from base, rounded to widest part posteromedially, tapered to apex, dorso-ventrally flattened on basal half, shallow fovea at each basal angle. Scutellum scutiform, glabrous, flat. Each elytron punctate-striate, intervals convex, punctured; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly and narrowed to bispinose apex; small marginal spine, small sutural spine, margin rounded and indented between, apices diverging, apical margin subserrate. Ventral surface with shallow punctures, edges of abdominal segments glabrous, moderately hairy, hairs medium length. S_7: truncate in both sexes.

Size: Males, 14.9 × 6.2 mm (2). Female: 19.7 × 8.5 mm (1).

Male genitalia: (Fig. 1J). Parameres parallel-sided basally, widened posteromedially, parallel-sided anteromedially, rounded apically. Median lobe pointed, sides acutely rounded away. Apophysis of basal piece narrowed.

Remarks: Belongs in *S. cupricollis* Saunders species group. Most resembles *S. deyrollei* Thomson but male genitalia are smaller, apically wider and apophysis more constricted than in *S. deyrollei* Barker (1986, Fig. 1M). *S. caillaina* is smaller than *S. deyrollei*, pronotum of *S. deyrollei* is green and underside green not dark blue as in *S. caillaina*. Name refers to colour of pronotum and is derived from *caillainus* L., blue-green.

Stigmodera (Castiarina) goudiana sp. nov.
FIGS 1K, 2Q

Holotype: ♂, Sea Lake, Vic., Nov. 1916, *W. Goudie*, NMVA.

Allotype: ♀, same data as holotype, SAMA I 21186.

Paratypes: N.S.W.: 1 ♂, Roto, 30.x.1981, *J. R. Turner*, ASSA; 2 ♂♂, 1 km S Matakana, 30.xi.1984, *A. Sundholm, J. Bugeja*, ASSA, SAMA; 1 ♀, Roto-Matakana, 28.xi.1981, *A. Sundholm*, ASSA.

Colour: Head black with bronze and blue reflections, muzzle blue. Antennae and pronotum black with bronze and blue reflections. Scutellum black. Elytra yellow with following black markings: narrow basal margin; incomplete pre-medial fascia, represented by mark on each humeral callus and one on suture confluent with basal margin around scutellum; incomplete post-medial fascia represented by mark on each side and one on suture, confluent in some specimens; mark covering apex and spines, last two marks may or may not be confluent along suture. Ventral surface black with bronze and blue reflections. Legs: femora and tibia blue; tarsi blue-green. Hairs silver.

Shape and sculpture: Head closely punctured, median sulcus, short muzzle. Antennae, segments: 1-3, obconic; 4-11, toothed. Pronotum shallowly punctured, narrow basal fovea, basal notches on each side more lateral than medial; apical margin straight, basal margin bisinuate; laterally rounded from base, widest posteromedially, rounded and narrowed to apex. Scutellum scutiform, glabrous, excavate. Each elytron punctate-striate, intervals convex, punctured, lateral margin flattened; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly and narrowed to bispinose apex; both spines sharp, margin rounded between, apices diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, sparse short hairs. S_7: truncate in both sexes.

Size: Males, 10.8 × 4.3 mm (4). Females, 11.8 × 5.2 mm (2).

Male genitalia: (Fig. 1K). Short. Parameres widened basally, rounded posteromedially then widened, rounded apically. Median lobe pointed, sides acutely angled away. Apophysis of basal piece narrow.

Remarks: Member of *S. delectabilis* Hope species group, closest to *S. dessarti* Barker (1986, Fig. 3O) from W.A. Parameres in that species are narrower and its has red elytra. Named after late Mr W. Goudie, Sea Lake, Vic.

Stigmodera (Castiarina) livida sp. nov.

FIGS 1L, 2G

Holotype: ♂, Eukey, Qld, Jan. 1934, *F. W. Wilson*, NMVA.

Allotype: ♀, MacPherson State Forest, 27 km NW Central Mangrove, Qld, 17.xii.1979, *J. & D. Gardner*, SAMA I 21187.

Paratypes: Qld: 1 ♂, 1 ♀, Eukey, 29.x.1975, *S. Barker*, SAMA; 3 ♀♀, Glen Aplin, 28.x.1975, *S. Barker*, SAMA; 2 ♂♂, same data as holotype, NMVA; 1 ♂, 1 ♀, Mt Tambourine, 26.xii.1937, *C. Oke*, NMVA; 1 ♀, Durack via Brisbane, 19.x.1978, *G. G. Burns*, GBVA; 1 ♀, Amiens, 9.xii.1979, *T. M. S. Hanlon*, MHSA; 1 ♀, Stanthorpe, Dec. 1981, *A. Sundholm*, ASSA. N.S.W.: 1 ♂, Grafton, SAMA: 4 ♂♂, 2 ♀♀, Armidale, Dec. 1953, *C. G. L. Gooding*, SAMA; 5 ♂♂, 2 ♀♀, Glenbrook, *T. J. Hawkeswood*, SAMA: 5 ♂♂, 2 ♀♀, 9.6 km SE Cessnock, 14.xii.1979, *J. & D. Gardner*, JGAA; 14 ♂♂, 6 ♀♀, Appin, Nov., *C. Deuquet*, RMBB; 8 ♂♂, 4 ♀♀, Glenreagh, Oct. 1922, *C. Deuquet*, RMBB; 1 ♂, 4 ♀♀, Mendouran, Nov. 1933, *C. Deuquet*, RMBB; 1 ♀, 73 km ENE Windsor, 18.xi.1984, *T. M. S. Hanlon*, MHSA; 7 ♂♂, 3 ♀♀, Dunnedoo, 1.xii.1985, *A. Sundholm*, ASSA; 1 ♂, Sandy Pt, Sydney, 1.xii.1980, *A. Sundholm*, ASSA; 1 ♂, Hassans Walls, Lithgow, 28.xi.1982, *J. R. Turner*, ASSA; 1 ♀, Hill End, 24.xi.1983, *J. R. Turner*, JTNA; 1 ♀, Dangar Falls, 14.xii.1983, *J. R. Turner*, JTNA; 1 ♂, 1 ♀, Fitzroy Falls, Jan. 1941, *C. Deuquet*, MMSA. Vic.: 2 ♂♂, Rushworth, 7.xi.1976, *G. G. Burns*, GBVA; 1 ♂, 1 ♀, Inglewood, 9.xi.1977, *G. G. Burns*, GBVA.

Colour: Head and antennae blue. Pronotum variably black medially, blue laterally. Scutellum black. Elytra yellow with following black markings with blue reflections: narrow basal margin; premedial fascia not reaching suture but expanded anteriorly over humeral callus and posteriorly reaching lateral margin in some specimens, not expanded posteriorly in others; very broad postmedial fascia; mark covering apex and spines, last three marks confluent down suture. Ventral surface and legs blue. Hairs silver.

Shape and sculpture: Head closely punctured, shallow median sulcus, very short muzzle. Antennae, segments: 1–4, obconic; 5–11, toothed. Pronotum closely punctured, narrow basal fovea extending to apical margin as glabrous line; apical margin straight, basal margin bisinuate; laterally parallel-sided at base, angled outwards and rounded to widest part anteromedially, rounded and narrowed apically. Scutellum scutiform, glabrous, flat. Each elytron punctate-striate, intervals flat medially, convex elsewhere, smooth; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly then narrowed, rounded to bispinose apex; small sharp marginal spine, very small sutural spine, margin rounded and indented between, apices diverging slightly. Ventral surface with shallow punctures, edges of abdominal segments glabrous, sparse short hair. S_7: truncate in males; rounded in females. Legs, male: tarsal pads missing on all legs from tarsomeres 1 and 2, each replaced by single median spine.

Size: Males, 7.5 ± 0.08 × 2.8 ± 0.03 mm (57). Females, 8.1 ± 0.10 × 3.0 ± 0.04 mm (36).

Male genitalia: (Fig. 1L). Parameres widened basally, notched anteromedially; parallel-sided, rounded apically. Median lobe pointed medially, sides angled away obtusely. Basal piece medium width.

Remarks: Member of *S. flavopicta* (Boisduval) species group. Most like *S. bicolor* C & G from S. Aust., figured under its synonym *S. aliceae* Barker (1980, Figs 2E, 3E). Apophysis of basal piece is wider than in *S. bicolor* and median lobe sharper. Also *S. bicolor* has unicolorous pronotum. Often misidentified in museum collections as *S. flavovaria* Saunders (replacement name for *S. flavopicta* C & G, primary homonym of *S. flavopicta* (Boisduval)). Original description and illustration indicate that *S. flavovaria* Saunders is known green morph of *S. flavopicta* (Boisduval). Name refers to bicolourous pronotum and is derived from *lividus* L., black and blue.

Stigmodera (Castiarina) viridissima sp. nov.
FIGS 1M, 2H

Holotype: ♂, Dunmore State Forest, Qld, 2.i.1985, *M. Powell*, SAMA I 21188.

Allotype: ♀, same data as holotype, SAMA I 21189.

Paratype: Qld: 1 ♂, same data as holotype, MHSA.

Colour: Head, antennae, pronotum and scutellum green. Elytra yellow with following black markings: narrow basal margin; pre-medial fascia not reaching margin, expanded anteriorly to humeral callus; post-medial fascia reaching margin; mark covering apex and spines, last three marks confluent along suture. Ventral surface and legs green. Hairs silver.

Shape and sculpture: Head closely punctured, shallow median sulcus, very short muzzle. Antennae compressed, segments: 1-4, obconic; 5-11, toothed. Pronotum closely punctured, narrow basal fovea extending to apical margin as impressed line, basal notches on each side more lateral than medial; apical margin straight, basal margin bisinuate; laterally angled outwards from base, rounded at widest part anteromedially, rounded and narrowed apically. Scutellum scutiform, glabrous, excavate. Each elytron punctate-striate, intervals flat medially, convex elsewhere, 3rd and 5th raised at apex, 10th raised for most of its length; laterally angled out from base, rounded at humeral callus (widest part), concave; rounded posteriorly and narrowed to bispinose apex; small blunt marginal spine, minute sutural spine, margin indented between, apices diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, moderately hairy, hairs medium length. S_7: truncate in males; truncate and indented medially in females.

Size: Males, 8.8 × 3.4 mm (2). Female, 8.9 × 3.5 mm (1).

Male genitalia: (Fig. 1M). Parameres parallel-sided basally, rounded posteromedially, parallel-sided anteromedialy, faintly notched, rounded apically. Median lobe pointed, sides acutely angled away. Apophysis of basal piece wide.

Remarks: Member of *S. cruentata* (Kirby) species group. Because of its colour, pattern, shape of pronotum and raised intervals on elytra this species is distinct within *S. cruentata* species group. Name refers to colour of head and body and is derived from *viridis* L., green.

Stigmodera (Castiarina) carina sp. nov.
FIGS 1N, 2I

Holotype: ♂, 13 km N Israelite Bay, W.A., 24.x.1980, *S. Barker, P. G. Kempster*, WAMA.

Allotype: ♀, same data as holotype, WAMA.

Paratypes: W.A.: 9 ♂♂, 3 ♀♀, same data as holotype, WAMA & SAMA.

Colour: Head, antennae, pronotum and scutellum green or blue-green. Elytra orange with following black markings with blue reflections: narrow basal margin; broad pre-medial fascia, not reaching margin but expanded anteriorly to humeral callus and posteriorly reaching lateral margin; broad post-medial fascia reaching margin; apical mark, all marks confluent along suture. Ventral surface and legs green or blue-green. Hairs silver.

Shape and sculpture: Head closely punctured, shallow median sulcus; short muzzle. Antennae, segments: 1–4, obconic; 5–11, toothed. Pronotum closely punctured, narrow basal fovea extending to near apical margin as impressed line; apical margin straight, basal margin bisinuate; laterally parallel-sided at base, rounded to widest medially, rounded and narrowed to apex. Scutellum scutiform, glabrous, excavate. Each elytron punctate-striate, intervals convex, punctured; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly and narrowed to bispinose apex; both spines small, margin rounded and indented between, apices diverging slightly. Ventral surface with shallow punctures, edges of abdominal segments glabrous, sparse short hair. S_7: truncate in both sexes.

Size: Males, 9.3 ± 0.25 × 3.1 ± 0.09 mm (10). Females, 9.7 ± 0.28 × 3.3 ± 0.08 mm (4).

Male genitalia: (Fig. 1N). Parameres parallel-sided basally, rounded posteromedially and slightly widened, faintly indented, rounded apically. Median lobe pointed, sides acutely angled away. Apophysis of basal piece median width.

Remarks: Member of *S. cruentata* (Kirby) species group. Most resembles *S. montigena* Oke which has blunter median lobe and broader parameres (Barker 1983, fig. 1W). *S. montigena* has bicolorous pronotum and occurs in Australian Alps. Name refers to colour of head and body and is derived from *carinus* L., green.

Stigmodera (Castiarina) sundholmi sp. nov.
FIGS 1O, 2L

Holotype: ♂, 4 km W Paluma, Qld, 5.i.1986, *E. E. & E. W. J. Adams*, SAMA I 21190.

Allotype: ♀, 4 km W Paluma, Qld, 7.i.1986, *E. E. & E. W. J. Adams*, SAMA I 21191.

Paratypes: Qld: 3 ♂♂, 2 ♀♀, 4 km W Paluma, 4.i.1986, *A. Sundholm*, ASSA; 10 ♂♂, 5/6/7.i.1986, Paluma, *E. E. & E. W. J. Adams*, EEAA; 14 ♂♂, 5 ♀♀, 4 km W Paluma, 6/7/8/10.i.1986, *J. Bugeja & A. Sundholm*, ASSA.

Colour: Head black with blue-green reflections. Antennae, segments: 1, 2, blue-green; 3–11, bronze. Pronotum black with blue-green reflections. Scutellum black with blue reflections. Elytra yellow with following black markings: narrow basal margin; pre-medial fascia reaching margin, expanded anteriorly from anterior margin over humeral callus, enclosing elongate yellow basal mark and variably an elongate yellow mark on margin at humeral callus; post-medial fascia reaching margin and expanded anteriorly from anterior margin, in some specimens fascia confluent enclosing yellow mark in middle of elytra and one on lateral margin; mark covering apex and spines with large mark between it and post-medial fascia, yellow closest to suture, red from centre to margin, all marks broadly confluent along suture. Ventral surface green with blue reflections. Legs: femora and tibiae blue; tarsi blue-green. Hairs silver.

Shape and sculpture: Head closely punctured, median sulcus, short muzzle. Antennae, segments: 1–3, obconic; 4 half toothed; 5–11, toothed. Pronotum closely punctured, basal fovea extending to apical margin as impressed line; apical margin straight, basal margin bisinuate; laterally widest at base, rounded and narrowed to apex, elongate shallow fovea at each angle. Scutellum cordiform, punctured, excavate. Each elytron punctate-striate, scutellary, 3rd at anterior part, 5th and 7th intervals slightly raised and smooth, rest flat and heavily punctured, lateral margin flattened; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly and narrowed to bispinose apex; small sharp marginal spine, minute sutural spine, margin rounded and indented between, apices diverging slightly. Ventral surface with shallow punctures, edges of abdominal segments glabrous, moderately hairy, hairs short. S_7: truncate in males; truncate and indented medially in females.

Size: Males, 9.5 ± 0.10 × 3.6 ± 0.04 mm (28). Females, 10.1 ± 0.20 × 3.8 ± 0.09 mm (8).

Male genitalia: (Fig. 1O). Parameres parallel-sided basally, widened posteromedially, rounded apically. Median lobe blunt, sides obtusely angled away. Apophysis of basal piece broad.

Remarks: Member of *S. bella* Saunders species group (listed under next species). Although this species resembles *S. gentilis* Kerremans, genitalia are most like those of *S. imitator* Carter (Fig. 1P), which, although broad apically are not spoon-shaped. Elytral colour resembles *S. gentilis* but upper surface of *S. gentilis* is heavily punctured, while that of *S. sundholmi* is glabrous and elytral patterns are quite different. Also *S. gentilis* is much smaller species than *S. sundholmi*. Named after Mr A. Sundholm, Sydney.

Stigmodera (Castiarina) aglaia sp. nov.

FIGS 1Q, 2M

Holotype: ♂, 4 km W Paluma, Qld, 4.i.1986, *A. Sundholm*, SAMA I 21200.

Allotype: ♀, same data as holotype, SAMA I 21201.

Colour: Head black, muzzle blue. Antennae green. Pronotum and scutellum black with bronze reflections. Elytra yellow with following black markings: broad basal margin; broad post-medial fascia angled anteriorly but reaching margin; apical mark, all marks broadly confluent along suture enclosing a pre-medial yellow mark on each side reaching margin, large red pre-apical mark along each margin, merging into yellow closest to suture. Ventral surface green with gold reflections. Legs: femora and tibiae blue; tarsi blue-green. Hairs silver.

Shape and sculpture: Head closely punctured, median sulcus, short muzzle. Antennae, segments 1–4, obconic; 5–11, toothed. Pronotum closely punctured, basal fovea extending to apical margin as impressed line; apical margin projecting medially, basal margin bisinuate; laterally parallel-sided at base, rounded posteromedially and narrowed to apex, round fovea on each side more basal than medial, shallow fovea at each basal angle. Scutellum scutiform, glabrous, excavate. Each elytron punctate-striate, intervals convex, punctured lightly from suture to 6th, punctured heavily from 7th interval to margin; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly and narrowed to bispinose apex; sharp marginal spine, small sutural spine, margin rounded and indented between, apices diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, moderately hairy, hairs short. S_7: truncate in both sexes.

Size: Male, 3.0 × 8.5 mm (1).

Male genitalia: (Fig. 1Q). Parameres widened basally, rounded and narrowed apically. Median lobe sharp, sides angled away. Apophysis of basal piece moderately wide.

Remarks: Belongs in *S. bella* Saunders species group comprising *S. bella* Saunders, *S. aglaia* sp. nov., *S. doddi* Carter, *S. gentilis* Kerremans, *S. imitator* Carter, *S. kerremansi* Blackburn, *S. kershawi* Carter, *S. marginata* Barker, *S. sundholmi* sp. nov. Closest to *S. gentilis* Kerremans (Fig. 1R) which has parameres more or less parallel-sided on apical half, sides of median lobe acutely angled away. *S. gentilis* has four yellow spots on each elytron while *S. aglaia* has two. Only female specimen available is headless. Name derived from *aglaos* Gr., beautiful.

Stigmodera (Castiarina) atra sp. nov.

FIGS 1S, 2K

Holotype: ♂, 4 km W Paluma, Qld, 6.i.1986, *A. Sundholm*, SAMA I 21192.

Allotype: ♀, 4 km W Paluma, Qld, 5.i.1986, *E. E. Adams*, SAMA I 21193.

Paratypes: Qld: 1 ♂, 1 ♀, 4 km W Paluma, 4.i.1986, *A. Sundholm*, ASSA; 1 ♂, same data as allotype, EAQA.

Colour: Head black with blue reflections. Antennae, segments: 1, blue; 2–11, bronze-green. Pronotum and scutellum black with bronze-green and blue reflections. Elytra yellow with following black markings: basal margin; pre-medial fascia; post-medial fascia; apical mark, all confluent and reaching margin enclosing eight yellow spots, three in middle of each elytron and one on lateral margin at each humeral callus. Ventral surface bronze green. Legs blue. Hairs silver.

Shape and sculpture: Head closely punctured, median sulcus, medium length muzzle. Antennae, segments: 1–3, obconic; 4–11, toothed. Pronotum closely punctured, basal fovea extending to apical margin as impressed line, basal notches represented by glabrous area on each side more lateral than medial; apical margin with slight medial projection, basal margin bisinuate; laterally parallel-sided at base, rounded to widest posteromedially, rounded and narrowed to apex. Scutellum cordiform, glabrous, excavate. Each elytron punctate-striate, intervals convex, glabrous, 3rd, 5th and 7th faintly raised at apex; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly and narrowed to bispinose apex; attenuated marginal spine, minute sutural spine, margin indented between, apices diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, moderately hairy, hairs short. S_7: truncate both sexes.

Size: Males, 9.4 × 3.3 mm (3). Females, 11.1 × 3.8 mm (2).

Male genitalia: (Fig. 1S). Sinuous in lateral profile, apex curved upwards. Parameres parallel-sided basally, rounded medially, straightened, widened, rounded apically. Median lobe pointed, sides angled away. Apophysis of basal piece moderately wide.

Remarks: Second member of *S. obliqua* species group. In *S. obliqua* Kerremans (Fig. 1T), parameres are slightly widened basally, rounded at middle then slightly narrowed, rounded to apex. Median lobe blunt, sides angled away. Apophysis of basal piece broad. The two species are easily distinguished as *S. obliqua* has green head, pronotum and undersurface and has yellow, black and red markings on the elytra. *S. atra* could be confused with *S. octosignata* Carter which has similar markings. That species has: antennal segments 1–4, obconic; bispinose elytral apices; marginal spine not attenuated to the same degree. Name refers to predominant colour and is derived from *atra* L., black.

Stigmodera (Castiarina) lauta sp. nov.

FIG. 2J

Holotype: ♀, 4 km W Paluma, Qld, 4.i.1986, *A. Sundholm*, SAMA I 21194.

Paratype: ♀, same data as holotype, ASSA.

Colour: Head black with blue muzzle. Antennae, segments: 1, blue; 2–11, bronze-green. Pronotum and scutellum black. Elytra yellow with confluent black markings enclosing an elongate pre-medial yellow mark on each elytron and yellow mark at each humeral callus; red post-medial mark broader on margin, not reaching suture. Ventral surface bronze-green. Legs blue. Hairs silver.

Shape and sculpture: Head closely punctured, glabrous, median sulcus, medium length muzzle. Antennae, segments: 1–4, obconic; 5–11, toothed. Pronotum shallowly punctured, glabrous, basal fovea extending to near apical margin as glabrous line; apical margin with slight medial projection, basal margin bisinuate; laterally parallel-sided at base, rounded to widest part posteromedially, rounded and narrowed to apex. Scutellum cordiform, glabrous, excavate. Each elytron punctate-striate, intervals flat medially, convex at base and apex, glabrous; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly, tapered to bispinose apex; marginal spine larger than minute sutural spine, margin rounded and indented between, apices diverging slightly. Ventral surface with shallow punctures, edges of abdominal segments glabrous, sparse short hairs. S_7: truncate and indented medially in females.

Size: Females, 10.3 × 3.8 mm (2).

Male genitalia: Unknown in this species. Male genitalia of *S. gracilior* Carter are illustrated (Fig. 1U) as only species in group for which males are available. Parameres are curved upwards, spoon-like apically. Parallel-sided basally, widened, rounded apically. Medial lobe pointed, sides angled away. Apophysis of basal piece medium width.

Remarks: Fourth member of *S. gracilior* species group on basis of external morphology. Easily distinguished from other members of group by elytral colour. *S. gracilior* is red and black, *S. sulfurea* Deuquet is yellow and black and *S. octosignata* Carter is black with yellow spots. Name is derived from *lautus* L., splendid.

Stigmodera (Castiarina) gardnerae sp. nov.
FIGS 1V, 2F

Holotype: ♂, between Black Hill and Swan Reach, S. Aust., 6.xii.1984, *S. Barker, H. Vanderwoude*, SAMA I 21195.

Allotype: ♀, between Black Hill and Swan Reach, S. Aust., 9.xii.1984, *J. & D. Gardner*, SAMA I 21196.

Paratypes: W.A.: 1 ♂, 1 ♀, Afghan Rock, Balladonia, 1.iii.1975, *S. Barker*, SAMA; 2 ♂♂, Pindar, 21.i.1955, *S. Barker*, SAMA; 2 ♂♂, Borden, 27.ii.1956, *J. A. L. Watson*, SAMA; 1 ♂, Beverly, *W. DuBoulay*, SAMA; 2 ♂♂, 1 ♀, Bejoording, 29.xii.1951, *R. P. McMillan*, SAMA; 1 ♂, Piawanning, 22.i.1950, *R. P. McMillan*, SAMA; 2 ♂♂, Eucla, 6.iii.1979, *T. J. Hawkeswood*, SAMA; 3 ♂♂, Cranbrook, 4.ii.1954, *A. M. Douglas*, WAMA; 1 ♂, Yellowdine, 21.i.1962, *L. McKenna, A. M. Douglas*, WAMA; 1 ♀, Lake Grace, 8/12.xii.1969, *K. & E. Carnaby*, WAMA; 3 ♂♂, Fitzgerald Riv. N.P., 8/12.ii.1984, 23.ii.1985, *R. P. McMillan*, WAMA; 3 ♂♂, Yellowdine, 14.i.1979, 28.i.1979, *T. M. S. Hanlon*, WAMA; 3 ♂♂, 5 km S Mt Holland, 27.i.1979, *T. M. S. Hanlon*, WAMA; 1 ♂, Dedari, 20.i.1982, *B. Hanisch, T. F. Houston*, WAMA; 1 ♂, Forrestfield, 10.ii.1979, *T. M. S. Hanlon*, WAMA; 1 ♂, 5 km N Galena, 20.xii.1979, *M. Powell*, WAMA; 2 ♂♂, 1 ♀, Dedari, WAMA; 1 ♀, Cunderdin, Dec./Jan. 1919, WAMA; 1 ♂, Piawanning, WAMA; 1 ♂, Lake Grace, WAMA. S. Aust.: 1 ♂, 1 ♀, Mundoora N.P., 31.xii.1969, *S. Barker*, SAMA; 2 ♂♂, McDonald-Ferries N.P., 7.i.1970, 16.i.1980, *S. Barker*, SAMA; 3 ♂♂, same data as Holotype, JGAA; 1 ♀, between Black Hill and Swan Reach, 2.xii.1984, *J. & D. Gardner, S. Barker*, JGAA; 1 ♀, Lyndoch, SAMA; 3 ♂♂, 1 ♀, S. Aust., SAMA; 1 ♂, no data, White coll., SAMA. Vic.: 1 ♂, Birchip, 10.i.1902, SAMA; 2 ♂♂, Mallee district, *E. T. Smith*, NMVA; 1 ♂, Merrinee, Jan. 1937, *F. E. Wilson*, NMVA; 1 ♂, Gypsum, Nov. 1926, *C. Oke*, NMVA; 1 ♂, Inglewood, 1.i.1928, *C. Oke*, NMVA; 2 ♂♂, Hattah, 25.xi.1950, *J. Plant*, NMVA; 1 ♂, Sea Lake, 12.i.1916, *Goudie*, NMVA; 1 ♂, 1 ♀, Inglewood, *J. Dixon*, NMVA; 1 ♂, 1 ♀, Mallee district, French coll., NMVA; 2 ♂♂, 2 ♀♀, Little Desert, *K. Hateley*, GBVA; ♀, Glemlee via Kiata, 8.ii.1978, *G. G. Burns*, GBVA; 1 ♀, 30.5 km NW Yanac, 15.ii.1986, *G. G. Burns*, GBVA; 1 ♂, Benetook, 25.xi.1957, *A. L. Brown*, NMVA.

Colour: Head blue. Antennae, segments: 1, 2, blue; 3-11, bronze. Pronotum variably divided medial blue mark, testaceous laterally, scutellum blue. Elytra yellow with following blue markings: narrow basal margin; elongate mark over humeral callus meeting basal margin; small pre-medial spot on each side closer to suture than margin; elongate post-medial mark from margin to middle of each elytron or reduced to a medial spot; diamond-shaped pre-apical mark on suture may or may not reach apex, reduced to small spot in some specimens; mark covering apex and spines, apical margin red. Ventral surface testaceous. Legs: femora and tibiae blue; tarsi bronze-green. Hairs silver.

Shape and sculpture: Head closely punctured, broad median sulcus. Antennae, segments: 1-4, obconic; 5-11, toothed. Pronotum closely punctured, basal fovea extending to centre as impressed line; apical margin straight; basal margin bisinuate; laterally parallel-sided at base, angled outwards then rounded at widest part ⅓ distance from base, tapered to apex. Scutellum scutiform, glabrous, excavate. Each elytron punctate-striate, intervals convex and punctured, the inner intervals shallowly the outer intervals deeply; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly; tapered to bispinose apex; very large marginal spines, small, sharp sutural spines; margin rounded and indented between, apices diverging, margin subserrate from centre to apex. Ventral surface with shallow punctures, edges of abdominal segments glabrous, hairy, hairs short, S_7: truncate in both sexes. Legs, male: tarsal pads absent on legs 2 and 3 on tarsal segments 1-3 replaced by median spine.

Size: Males, 10.1 ± 0.10 × 3.7 ± 0.05 mm (54). Females, 10.7 ± 0.21 × 4.0 ± 0.09 mm (17).

Male genitalia: (Fig. 1V). Parameres gradually widened, medially parallel-sided for short distance then gradually rounded, abruptly rounded apically. Median lobe pointed, sides angled away. Apophysis of basal piece narrowed.

Remarks: Third member of *S. mustelamajor* Thomson (Holotype male, Australia, MNHN) species group. *S. mustelamajor* occurs in eastern Australia in moderately high rainfall areas. Lateral surfaces of pronotum and ventral surface red, elytral markings are similar to *S. gardnerae* but much heavier and it is much broader than *S. gardnerae*. *S. erasma* Carter (Holotype male, Gippsland, NMVA) was synonymised with *S. mustelamajor* by Barker (1979). It has heavy black markings with elytral vittae and occurs in sub-alpine eastern Australia. *S. gardnerae* occurs in mallee habitat and has lighter elytral markings than other two. Genitalia of all three are illustrated (Figs. 1V, 1W, 1X). I consider all three valid species on basis of their male genitalia and disjunct distribution. Named after Dr J. Gardner, Adelaide.

Stigmodera (Castiarina) jimturneri sp. nov. FIGS 1Y, 2N

Holotype: ♂, Hill End, N.S.W., 17.i.1984, *J. R. Turner*, SAMA I 21197.

Allotype: ♀, Hill End, N.S.W., 9.xii.1983, *J. R. Turner*, SAMA I 21198.

Colour: Head, antennae, pronotum and scutellum coppery with dark blue reflections. Elytra pale yellow with following black markings with dark blue and purple reflections: narrow basal margin; pre-medial fascia represented by elongate mark on each side reaching margin but not suture and by elongate mark along suture, in allotype marks confluent forming fascia angled anteriorly from suture, reaching margin; broad post-medial fascia reaching margin, projecting anteriorly and posteriorly along suture and anteriorly in centre on each side from anterior margin; mark covering apex; marks may or may not be confluent along suture. Ventral surface: sternum and legs coppery-red with dark blue reflections; abdomen testaceous. Hairs silver.

Shape and sculpture: Head closely punctured, median sulcus, medium length muzzle. Antennae, segments: 1–3, obconic; 4–11, toothed. Pronotum closely punctured, basal fovea extending to centre as glabrous line, basal notches on each side more lateral than medial; apical margin projecting medially, basal margin barely bisinuate; laterally angled outwards from base, rounded and slightly bulbous posteromedially, tapered to apex. Scutellum scutiform, glabrous, flat. Each elytron punctate-striate, intervals convex, punctured, more so laterally than medially; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly and narrowed to bispinose apex; sharp marginal spine, minute sutural spine, margin rounded and indented between, apices diverging, apical margin subserrate. Ventral surface with shallow punctures, edges of abdominal segments glabrous, moderately hairy, hairs moderately long. S_7: truncate in male; rounded and slightly pointed in female.

Size: Male, 16.7 × 6.6 mm (1). Female, 17.6 × 6.8 mm (1).

Male genitalia: (Fig. 1Y). Parameres widened basally, rounded and narrowed apically. Median lobe with sharp point, sides rounded away until they are horizontal, then dropping away vertically. Apophysis of basal piece short, medium width.

Remarks: Member of *S. fulviventris* Macleay species group. Aedeagus not as heavily chitinised as other members of *S. fulviventris* Macleay species group (Barker 1986, Figs 2J, 2K, 2L). Closest to *S. athertonensis*, larger species. Distinguished from other members by coppery-red colours of head, thorax and legs. Named after Mr J. R. Turner, Hazelbrook.

Stigmodera (Castiarina) kanangara sp. nov. FIGS 1Z, 2R

Holotype: ♂, Kanangara Walls, N.S.W., 20.xii.1982, *J. R. Turner*, SAMA I 21199.

Paratypes: 2 ♂♂, Hill End, N.S.W. 14/19.i.1984, *J. R. Turner*, JTNA.

Colour: Head, antennae, pronotum and scutellum green with gold reflections. Elytra orange with following green or blue-green markings: narrow basal margin; pre-medial fascia represented by angled vitta over each humeral callus and elongate mark along suture; post-medial fascia reaching margin, extending anteriorly and posteriorly along suture or represented by medial mark on each side, diamond-shaped mark on suture; pre-apical mark on each side angled anteriorly and meeting at suture; mark covering apex and spines or absent in some specimens, marks may or may not be confluent along suture. Ventral surface: sternum and all or part of 1st abdominal segment green; at least last four visible abdominal segments testaceous. Legs green with gold reflections. Hairs silver.

Shape and sculpture: Head closely punctured, median sulcus, short muzzle. Antennae, segments: 1–3, obconic; 4–11, toothed. Pronotum closely punctured, basal fovea extending to centre as glabrous line, basal notches on each side more lateral than medial; apical margin projecting medially, basal margin bisinuate; laterally parallel-sided at base, angled outwards, rounded to widest posterobasally, rounded and narrowed to apex, lateral margins compressed for more than half basal length. Scutellum scutiform, elongate, glabrous, flat. Each elytron punctate-striate, intervals convex and wrinkled; laterally angled out from base, rounded at humeral callus, concave, rounded posteriorly and narrowed to bispinose apex; small marginal spine slightly angled inwards, small sutural spine, margin rounded and indented between, apices diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, moderately hairy, hairs medium length. S_7: truncate in males.

Size: Males, 12.5 × 4.7 mm (3).

Male genitalia: (Fig. 1Z). Parameres parallel-sided basally, rounded outwards posteromedially, rounded then parallel-sided, rounded off apically. Median lobe pointed, sides obtusely angled away. Apophysis of basal piece medium width.

Remarks: Member of *S. straminea* Macleay species group (Barker 1986, Fig. 2N). Elongate body, flattened pronotum and angle of marginal spine distinguish it from other group members. Named after type locality, an aboriginal place name.

Errata: Barker, S. (1986) *Trans. R. Soc. S. Aust.* **110**(1), 1–36, 30 May, 1986.

p. 2 insert [g] *S. cupricollis* Saunders.

p. 9 paratypes of *S. rufa* sp. nov. 2 ♂♂, 3 ♀♀, Meekatharra, W.A., 5.viii.1972, not Mary Springs, W.A., 8.ix.1970.

p. 20 paratypes of *S. blackdownensis*, 3 ♂♂, 1 ♀, Blackdown Tableland, 23.ix.1973, *E. E. Adams*, ANIC, AWHQ *not* EAQA, AWHQ.

p. 24 *Allotype* ♀, WAMA not SAMA I 21172.

p. 33 insert *pseuderythroptera* Barker 1983, *Trans. R. Soc. S. Aust.* **107**, 162 ♀.

Acknowledgments

I wish to thank the following for assistance: Dr G. F. Gross and Dr E. G. Matthews, South Australian Museum; Dr J. Lawrence and Mr T. Weir, Division of Entomology, C.S.I.R.O.; Dr G. B. Monteith, Queensland Museum; Dr T. F. Houston, Western Australian Museum; Dr A. Neboiss and Mr K. Walker, National Museum of Victoria; Miss C. M. H. von Hayek, British Museum (Natural History), London; Dr P. Dessart and M. J. Cools, Institut Royal des Sciences Naturelles de Belgique, Brussels; M. A. Descarpentries, Muséum National d'Histoire Naturelle, Paris; Mr K. T. Richards, Department of Agriculture, South Perth; Mr R. I. Storey, Department of Primary Industry, Mareeba; Miss M. Schneider, Department of Entomology, University of Queensland; Dr D. Horning, Macleay Museum, Sydney; Mr E. E. Adams, Edungalba; Mr and Mrs G. G. Burns, Mornington; Mr & Mrs K. Carnaby, Wilga; Mr H. Demarz, Quinn's Rocks; Mr T. M. S. Hanlon, Sydney; Mrs J. Harslett, Amiens; Mr A. Hiller, Mt Glorious; Mr M. Powell, Attadale; Mr. R. P. McMillan, Cottesloe; Mr J. Sedlacek, Brisbane; Mr A. Sundholm, Sydney; Mr J. R. Turner, Hazelbrook; Mr A. Walford-Huggins, Molloy; Mr S. Watkins, Summer Hill; Mr G. Williams, Lansdowne; Miss H. Vanderwoude, Dr J. Gardner, Mr P. Kempster and Mr D. J. Williams, Department of Zoology, University of Adelaide; Australian Biological Resources Committee for grants-in-aid of research.

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Barker, S. (1979) New species and a catalogue of *Stigmodera (Castiarina)* (Coleoptera: Buprestidae). *Trans. R. Soc. S. Aust.* **103**, 1–23.

——— (1980) New species and synonyms of *Stigmodera (Castiarina)* (Coleoptera: Buprestidae). *Ibid* **104**, 1–7.

——— (1983) New synonyms and new species of *Stigmodera (Castiarina)* (Coleoptera: Buprestidae). *Ibid* **107**, 139–169.

——— (1986) *Stigmodera (Castiarina)* (Coleoptera: Buprestidae); Taxonomy, new species and a checklist. *Ibid* **110**, 1–36.

Watt, J. C. (1979) Abbreviations for entomological collections. *N.Z. Zool.* **6**, 519–520.

LACISTORHYNCHUS DOLLFUSI SP. NOV. (CESTODA: TRYPANORHYNCHA) IN ELASMOBRANCH FISHES FROM AUSTRALIAN AND NORTH AMERICAN COASTAL WATERS

BY IAN BEVERIDGE & J. A. SAKANARI†*

Summary

Lacistorhynchus dollfusi sp. Nov. is described from the spiral intestine of *Mustelus antarcticus* Gunther, 1870 (type host), *Pristiophorus cirratus* (Latham, 1947), *Galeorhinus australis* (Macleay, 1881) and *Hypnos monopterygium* (Shaw & Nodder, 1795) from Australian coastal waters, and from *Mustelus henlei* (Gill, 1863) and *Triakis semifasciata* Girard, 1854 from California. Metacestodes attributable to the species were identified from *Synodus lucioceps* (Ayres, 1855) and *Sebastes paucispinis* Ayres, 1854, also from California. The new species is distinguished by the presence of four characteristic bill-hooks on the base of the tentacle, and by the distinctive shapes of hooks 1(11), 7(7') and 8(8') also at the base of the tentacle. The basal armature of *L. tenuis* (van Beneden, 1858) is briefly described and illustrated and evidence provided that *L. tenuis* may be a composite species. Cestodes from Californian elasmobranchs formerly assigned to L. *tenuis* are re-identified as L. *dollfusi,* indicating a pan-Pacific distribution for the latter cestode.

KEY WORDS: Cestoda, Lacistorhynchidae, *Lacistorhynchus,* elasmobranchs.

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Summary

BEVERIDGE, I. & SAKANARI, J. A. (1987) *Lacistorhynchus dollfusi* sp. nov. (Cestoda: Trypanorhyncha) in elasmobranch fishes from Australian and North American coastal waters. *Trans. R. Soc. S. Aust.* **111**(3), 147-154, 30 November, 1987.

Lacistorhynchus dollfusi sp. nov. is described from the spiral intestine of *Mustelus antarcticus* Günther, 1870 (type host), *Pristiophorus cirratus* (Latham, 1947), *Galeorhinus australis* (Macleay, 1881) and *Hypnos monopterygium* (Shaw & Nodder, 1795) from Australian coastal waters, and from *Mustelus henlei* (Gill, 1863) and *Triakis semifasciata* Girard, 1854 from California. Metacestodes attributable to the species were identified from *Synodus lucioceps* (Ayres, 1855) and *Sebastes paucispinis* Ayres, 1854, also from California. The new species is distinguished by the presence of four characteristic bill-hooks on the base of the tentacle, and by the distinctive shapes of hooks 1(1'), 7(7') and 8(8') also at the base of the tentacle. The basal armature of *L. tenuis* (van Beneden, 1858) is briefly described and illustrated and evidence provided that *L. tenuis* may be a composite species. Cestodes from Californian elasmobranchs formerly assigned to *L. tenuis* are re-identified as *L. dollfusi*, indicating a pan-Pacific distribution for the latter cestode.

KEY WORDS: Cestoda, Lacistorhynchidae, *Lacistorhynchus*, elasmobranchs.

Introduction

Lacistorhynchus tenuis (van Beneden, 1858) is an apparently cosmopolitan cestode parasite of the spiral intestine of sharks and rays. Dollfus (1942) provided a detailed synonymy and description of the parasite and summarized distribution records. The type specimens were collected from *Galeorhinus galeus* (Linnaeus, 1758) in the North Sea, but the cestode is also known to occur in the English Channel, off the European and American coasts of the North Atlantic, the African coasts of the Atlantic and in the Mediterranean. Dollfus (1969) subsequently provided additional morphological details based on specimens collected from the Mediterranean. *L. tenuis* has been reported from sharks and teleosts from the Pacific coasts of North America (Young 1954a; Riser 1956; Voge & Edmonds 1969; Pappas 1970; Mudry & Dailey 1971; Buteau *et al.* 1971; Heinz & Dailey 1974; Jensen *et al.* 1979, 1982; Moser *et al.* 1985) and South America (Carvajal 1974; Duran & Oliva 1980; Escalante & Carvajal 1984). Limited life cycle studies were carried out on material of Californian origin by Young (1954b), Riser (1956) and Mudry & Dailey (1971), while the life cycle was completed experimentally by Sakanari & Moser (1985a) using the copepod *Tigriopus californicus* (Baker, 1912) and the teleost *Gambusia affinis* (Baird & Girard, 1853) as intermediate hosts, and *Triakis semifasciata* Girard, 1854 as the definitive host.

Studies on the effects of temperature and salinity on life cycle stages (Sakanari & Moser 1985b) and pathology induced by the plerocercoid in *Morone saxatilis* (Walbaum, 1792) have also been carried out (Moser *et al.*1984; Sakanari & Moser 1986).

The genus has not been reported from Australian waters (Beumer *et al.* 1982) but has been recorded from *Galeorhinus australis* (Macleay, 1881) and several species of teleosts from New Zealand (Robinson 1959; Hewitt & Hine 1972). Recent collections indicate that the genus is not uncommon in several shark species from South Australian coastal waters including *G. australis*. In comparing South Australian material with the description given by Dollfus (1942), several discrepancies were noted and it became evident that despite the detail of his description, certain critical features of the onchotaxy of *L. tenuis* have not been adequately described. Examination of specimens in the Dollfus collection in Paris and material from Californian hosts indicated that two distinct cestode species have in the past been confused under the name *L. tenuis*. In this paper, the Australian and Californian material is described as a new species, and additional details of the morphology of *L. tenuis* are provided to enable differentiation of the two species now considered to exist in the genus. Evidence is also provided indicating that *L. tenuis*, as currently understood, may be a composite of two or more species.

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Materials and Methods

Cestodes collected from elasmobranchs were washed in sea water and fixed with hot 10% buffered formalin or hot 70% ethanol. In the absence of laboratory facilities (material collected on boats), spiral valves were flooded with boiling water and a small quantity of concentrated formalin was subsequently added. In the laboratory, cestodes were removed from the content, washed in water and stored in 70% ethanol. Cestodes were stained with Celestine Blue, dehydrated, cleared in clove oil and mounted in balsam. Tentacles were removed from some specimens and were cleared in glycerol, then mounted in glycerine jelly.

Specimens of *Lacistorhynchus* were borrowed from the British Museum (Natural History), London (BMNH), the United States National Museum Helminth Collection, Washington (USNMHC), the Dollfus collection from the Muséum national d'Histoire naturelle, Paris (MNHN), the Commonwealth Institute of Parasitology, St Albans (CIP), and the Australian Helminth Collection (AHC), South Australian Museum, Adelaide (SAM). Unless otherwise stated, all Australian specimens have been deposited in AHC, and American specimens in USNMHC.

Measurements are given in the text in millimetres, as the range of 10 individual measurements followed by the mean in parentheses. Terminology for the morphology of trypanorhynch cestodes follows Dollfus (1942) and Schmidt (1986). The hook numbering system employed is that of Dollfus (1942).

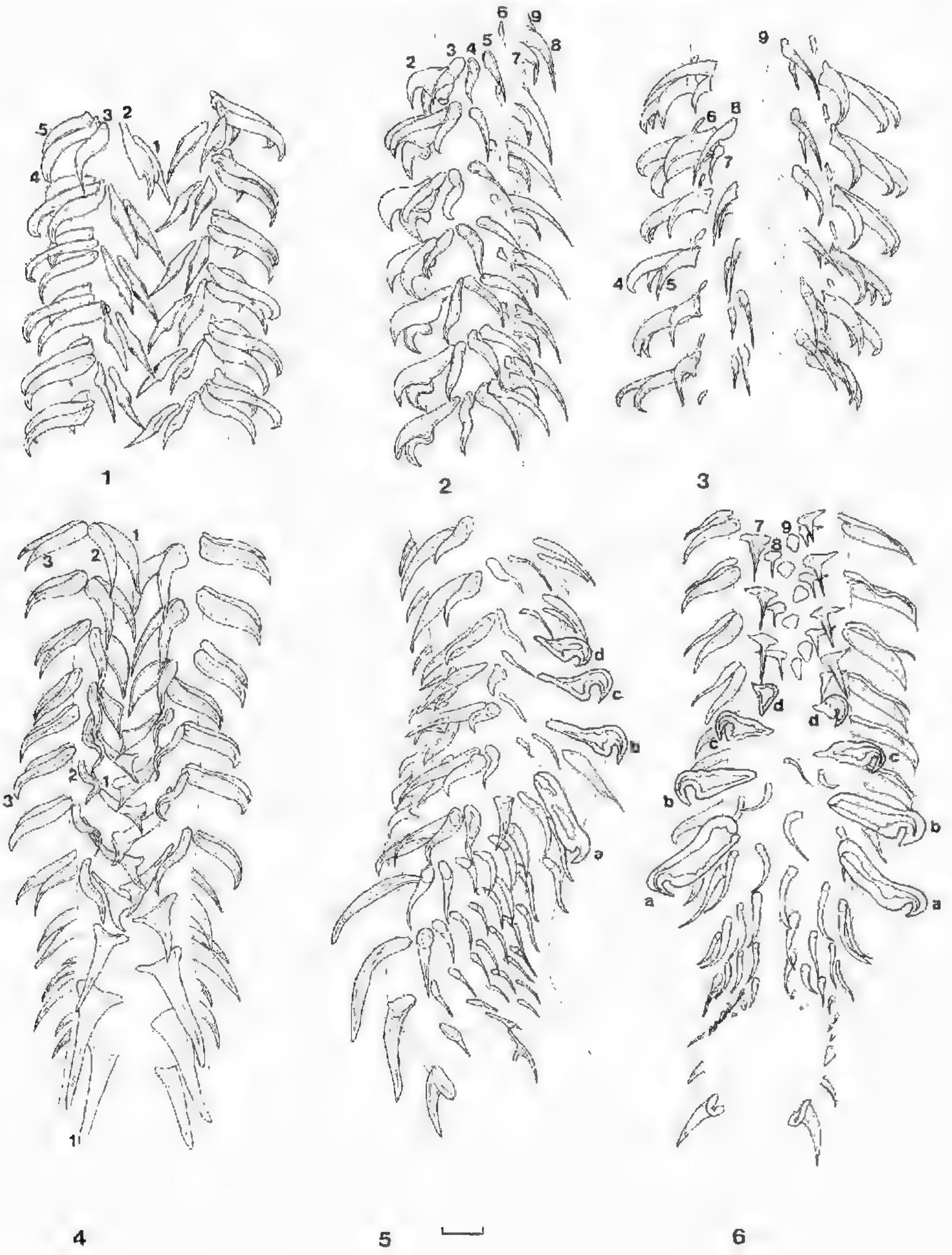
Lacistorhynchus dollfusi sp. nov.
FIGS 1-16

Types: Holotype, from spiral valve of *Mustelus antarcticus* Günther, 1870, Young Rocks, south coast of Kangaroo Island, S. Aust., 23.v.1985, collector B. G. Robertson, SAM V4085; 4 paratypes, same data, SAM V4086; 7 paratypes, same data, AHC S2753; 1 paratype, south coast of Kangaroo Island, S. Aust., 10.ii.1985, collector B. G. Robertson, USNMHC 79544; 40 paratypes, same data AHC S2754; 3 paratypes, Goolwa, S. Aust., 21.xi.1984, collector R. R. Martin, BMNH 1986. 9.29. 20-22; 19 paratypes, same data, AHC S2755.

Material examined: from *Mustelus antarcticus* Günther, 1870: types; from *Pristiophorus cirratus* (Latham, 1947): 33 specimens, south coast Kangaroo Island, S. Aust. (AHC S2756); from *Galeorhinus australis* (Macleay, 1881): 3 specimens, Young Rocks, Kangaroo Island, S. Aust. (AHC S2757); 5 specimens, Pt Willunga, S. Aust. (AHC 312, 593); 1 specimen, north-western Tasmania (CIP 104/81); from *Notorhynchus cepedianus* (Péron, 1807): 2 specimens, Young Rocks, Kangaroo Island, S. Aust. (AHC S2758); from *Hypnos monopterygium* (Shaw & Nodder, 1795): 1 specimen, Holdfast Bay, S. Aust. (AHC S2759); from *Mustelus henlei* (Gill, 1863): 14 specimens, Monterey Bay, California, U.S.A. (MNHN Bb28); 1 specimen, Bodega Bay, California, U.S.A. (MNHN Bb28); from *Triakis semifasciata* Girard, 1854: 13 specimens, Monterey Bay, California, U.S.A. (USNMHC 79591) from *Synodus lucioceps*: 2 metacestodes, Malibu, California, U.S.A. (USNMHC 74836); from *Sebastes paucispinis* Ayres, 1854: 1 metacestode, Malibu, California, U.S.A. (USNMHC 76804).

Description (from types): Small cestodes, maximum length 50, maximum width 1.20, maximum number of proglottides 48. Scolex acraspedote, 1.52-2.40 (1.74) long, maximum width in pars bothridialis 0.26-0.41 (0.35); bothridia 2, patelliform, with slightly indented posterior margin, shallow, without prominent rim (Fig. 7); diameter of bothridia 0.33, 0.38; pars bothridialis 0.28-0.42 (0.36); pars vaginalis narrower than pars bothridialis, extremely variable in length, 0.86-1.70 (1.12); pars bulbosa slightly wider than pars vaginalis; tentacle sheaths arranged in regular spirals; bulbs elongate, 4-6 times as long as wide, 0.33-0.46 (0.39) long by 0.06-0.11 (0.09) wide; origin of retractor muscle in anterior third of bulb, continued posteriorly by band of nucleated, non-muscular tissue (Fig. 13); scolex markedly swollen immediately posterior to bulbs, swelling variable in length, stains intensely; bulbs terminate either just anterior to swelling or extend into it; pars post-bulbosa, when present, 0.10-0.29 (0.16); scolex covered with prominent microtriches, visible under light microscope.

Tentacles very long and slender, up to 1.9 long, 0.20-0.40 (0.29) in diameter; slight swelling at base, 0.30-0.54 (0.41) in diameter; armature heteromorphic, poeciloacanthous; armature at base of proboscis distinctive; remainder relatively uniform; hooks hollow. Base of proboscis with bare area on external suface (Fig. 6); bothridial and antibothridial surfaces at base with 5 oblique rows of filiform hooks ranging in length from 0.006-0.014 (0.012) diminishing in size posteriorly (Fig. 5); external surface of basal swelling with four pairs of large bill-hooks or four on antibothridial side and three on bothridial side, each with sharply recurved blade, no guard and extremely broad base; hooks of first pair (a) 0.022-0.026 (0.024) long, second pair (b) 0.020-0.024 (0.021), third pair (c) 0.016-0.022 (0.019), fourth pair (d) 0.08-0.014 (0.012) long; space between pairs of bill-hooks on external surface of proboscis occupied by six filiform hooks. Basal hooks 1(1') on internal surface (Fig. 4), represented by three-four pairs of large, stout, spiniform hooks followed anteriorly by four-five pairs of overlapping hooks with small triangular blades, small guards and narrow, elongate handles; anteriorly in metabasal region, hooks 1(1') become larger, more uncinate 0.012-0.018 (0.014) long, with relatively large blade and broad base. Basal hooks 2(2'):



Figs 1–6. *Lacistorhynchus dollfusi* sp. nov. Tentacular armature. 1, metabasal region, internal surface 0.35 mm anterior to base of tentacle; 2, metabasal region, bothridial surface; 3, metabasal region, external surface; 4, basal region, internal surface; bothridial surface to right; 5, basal region, bothridial surface; a–d, bill-hooks; 6, basal region, external surface, bothridial surface to right; a–d, bill-hooks. Scale line 0.01 mm. Hook numbering system follows Dollfus (1942).

hooks of first four or five rows acicular, small; anteriorly, next five pairs adjacent to elongate handle of hooks 1(1'), sinuous, apex usually directed externally; in meta-basal region, hooks 2(2') become large, uncinate, 0.012–0.018 (0.015) long with prominent blade and extremely broad handle. Hooks 3(3'), 4(4'), 5(5') similar in basal and meta-basal regions, long, slender, with diminitive base, handles absent, blade recurved at apex; lengths in meta-basal region; hooks 3(3'), 0.018-0.022 (0.019) long; hooks 4(4'), 0.018–0.020 (0.018) long; hooks 5(5'), smaller, 0.008–0.014 (0.011). Hooks 6(6') tiny, acicular, slightly larger in basal region compared with meta-basal region, with thickened base, inserted in meta-basal region, slightly anterior to level of hooks 5(5') and 7(7'), 0.003–0.006 (0.005) long in meta-basal region. Hooks 7(7') and 8(8') commence anterior to large bill-hooks; initially, 7 larger than 8, both with large, expanded bases and acicular shafts; anteriorly, in meta-basal region, 8 larger than 7, both uncinate with gently curving blades, bases insignificant; hooks 7(7') 0.006–0.010 (0.008) long; hooks 8(8') 0.010–0.018 (0.014) long. Hooks 9(9'), in form of double chainette, commence anterior to level of bill-hooks as deltoid plaques; hooks become smaller and acicular in meta-basal region with slightly thickened bases, 0.003-0.006 (0.004) long.

Neck region extremely long and slender, 4.0–14.0 (7.6), tegument with prominent folds, giving appearance of segmentation; mature segments longer than wide, length 1.3–3.6 (2.3), width 0.08–1.12 (1.97), acraspedote. Genital atrium in posterior part of lateral margin, 0.9–2.2 (1.6) from anterior end, surrounded by sphincter-like condensation of muscle fibres and parenchyma. Hermaphroditic sac pyriform, thin-walled, 0.32-0.40 (0.37) by 0.13–0.19 (0.15); common genital duct of variable length, divides within hermaphroditic sac into straight vagina and coiled cirrus, both surrounded by glandular cells. Cirrus unarmed, gland cells reach greatest density in proximal region of cirrus, prior to entry into small, internal, crescentic seminal vesicle. External seminal vesicle absent; vas deferens greatly coiled, passes slightly anteriorly, then coils posteriorly along mid-line to region of ovary; vasa efferentia not seen. Testes numerous, approximately 340 in number, occupying entire proglottis medulla. Vagina pierces posterior wall of hermaphroditic sac; passes towards ovary, terminating in very slight enlargement adjacent to ovarian isthmus. Ovary bilobed in dorso-ventral view, each lobe 0.20–0.40 (0.28) by 0.17–0.40 (0.26). Mehlis' gland between ovarian lobes, 0.14–0.21 (0.16) in diameter. Uterus in midline, extends almost to anterior extremity of segment; vitellaria follicular, circumcortical, follicles 0.016–0.032 (0.024) in diameter. Uterine pore slit-like, clearly visible in mature segments, at level of anterior end of uterus. Single gravid segment seen; free in gut lumen; 9.8 long by 2.2 wide; testes absent, ovarian lobes well developed, each lobe 1.04 by 0.48; Mehlis' gland 0.36 by 0.26; most of proglottis occupied by uterus; uterus terminates below anterior extremity of segment; eggs ellipsoidal, operculate, 0.046–0.050 (0.048) by 0.032–0.044 (0.033), non-embryonated when laid.

Etymology: The new species is named after R. Ph. Dollfus in recognition of his important contributions to the systematics of the genus.

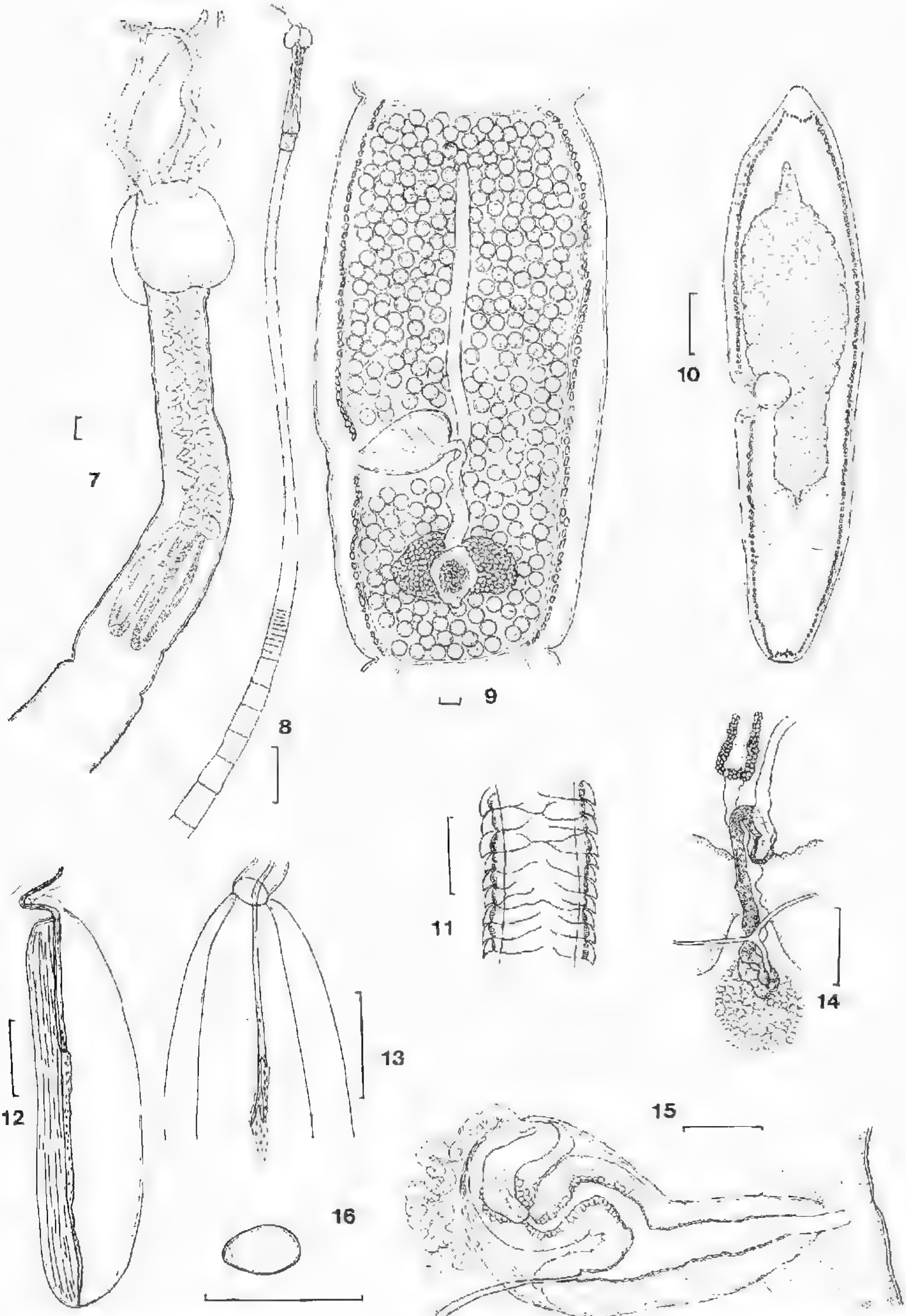
Lacistorhynchus tenuis (van Beneden, 1858)
FIGS 17–22

Material examined: from *Galeorhinus galeus* (Linnaeus, 1758): 5 specimens, English Channel (BMNH 1985. 11.7.17–20); 1 specimen, Scarborough, England (BMNH 1979. 12.89–80); from *Belone belone* (Linnaeus, 1758): 3 metacestodes, Sete, France (MNHN Bb16: 55, 56, 58); 2 metacestodes, Concarneau, France (MNHN Bb); from *Mustelus canis* (Mitchell, 1815): 9 specimens, Woods Hole, U.S.A. (determined as *Rhynchobothrium bulbifer* by E. Linton) (USNMHC 4746, 4752, 7699); 7 specimens, Woods Hole, U.S.A. (USNMHC 7950).

Description of tentacular armature: Meta-basal armature similar to *L. dollfusi*. Base of proboscis with bare area on external surface; bothridial and antibothridial surfaces with five oblique rows of filiform hooks, diminishing in size posteriorly; three pairs of large bill-hooks with sharply recurved blades and extremely broad bases. Basal hooks 1(1') on internal surface represented by three to four pairs of stout spiniform hooks followed anteriorly by large triangular hooks with broadly curved blades and diminitive handles, considerable discrepancy in size between hooks of bothridial and anti-bothridial rows. Basal hooks 2(2') elongate, triangular to subulate, slightly twisted. Hooks 3(3'), 4(4') and 5(5') slender, with dimunitive bases, no handles, blade recurved at tip, diminish in size 3–5. Hooks 6(6') tiny, acicular. Hooks 7(7') and 8(8') sub-triangular, large, with prominent, broad blade and expanded bases; base of hook 8 overlain by blade of hook 7. Hooks 9(9') in form of double chainette, blades tiny, bases swollen. Specimens from *M. canis* differ in shape of hooks 1(1') at base; greater disparity in size between hooks of bothridial and antibothridial rows than in European specimens; large hooks with extremely elongate blades.

Discussion

The account of the taxonomic history of *Lacistorhynchus tenuis*, complete list of synonyms, and detailed account of its anatomy given by Dollfus (1942), apparently have been accepted by all subsequent authors, together with his tentative con-



Figs 7-16. *Lacistorhynchus dollfusi* sp. nov. 7, scolex; 8, anterior region of strobila showing extremely long neck region; 9, mature proglottis; 10, gravid proglottis; 11, neck region of cestode showing folding of surface tegument giving impression of proglottisation; 12, tentacular bulb, showing insertion of retractor muscle; 13, detail of retractor muscle insertion, showing continuation of retractor along internal wall of bulb by nucleated, non-muscular tissues; 14, female genital complex; 15, cirrus sac and genital atrium; 16, egg. Scale lines 0.1 mm.

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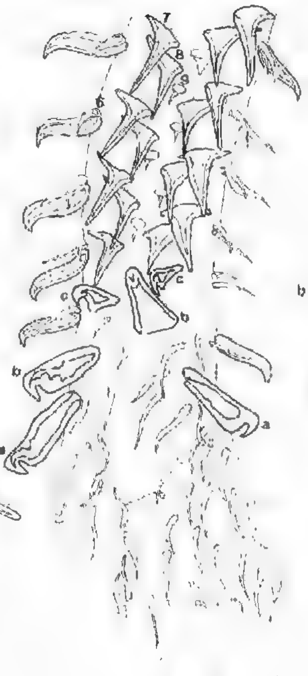

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clusion that there is a single, widely distributed species in this genus.

However, in examining Australian specimens of *Lacistorhynchus*, certain discrepancies with Dollfus' (1942) description were noted. Australian specimens have four pairs of bill-hooks (= "serpe à bec" hooks of Dollfus), or three pairs and a single extra hook on the external surface of the base of the tentacle, yet Dollfus (1942) was not able to determine the exact number on his specimens. Furthermore, the shape of hooks 1(1') on the base of the tentacle clearly differed from those illustrated by Dollfus (1942, fig. 246). An examination of the specimens upon which Dollfus had based his description and his drawings (Figs 244–254) showed that although the drawings were extremely accurate, the specimens were very poor indeed, and the requisite morphological details were not available to him. However, Mediterranean material in Dollfus' collection as well as British material from the type host *Galeorhinus galeus* collected from the North Sea indicated that the Australian and Californian material described above is different from *L. tenuis*. Because descriptions of the basal armature of *L. tenuis* are incomplete and contain key distinguishing features, a series of drawings is given (Figs 17–22). In *L. tenuis*, there are three pairs of large bill-hooks on the external base of the tentacle, compared with four pairs or four and three hooks in Australian specimens. Hooks 1(1') of the basal region of *L. tenuis* are large and broadly curved with insignificant handles, as shown by Dollfus (1942, fig. 246), with a considerable disparity in size between hooks in the bothridial and antibothridial rows. By contrast, in the Australian specimens, hooks 1(1') have a small blade and very long handles (Fig. 4). In addition, hooks 7(7') and 8(8') of the basal region are much more robust in *L. tenuis* than in Australian specimens. Because of these three major differences, the Australian specimens are considered to constitute a species distinct from *L. tenuis*. Material conspecific with that described above from Australian hosts also occurs in elasmobranchs and teleosts from Californian coasts. Specimens of *Lacistorhynchus* collected by N. W. Riser from *Mustelus henlei* (syn. *Rhinotriacis henlei*) in Monterey Bay, California, and now in the Dollfus collection (MNHN) as well as a further specimen from the same host species from Bodega Bay, California (MNHN bD28) and a series of specimens from *Triakis semifasciata* from California are identical with Australian specimens, as are metacestodes collected from the teleosts *Synodus lucioceps* and *Sebastes paucispinis* both from Malibu, California, listed in the material examined.

Because of the presence of the new species in American waters, specimens of *Rhyncobothrium bulbifer* Linton, 1889, identified by Linton, were re-examined. This cestode species was described from *Mustelus canis* from the north-eastern Atlantic, and was placed by Dollfus (1942) as a synonym of *L. tenuis*. Linton (1890) described a further species, *R. heterospine*, which he himself subsequently synonymised with *R. bulbifer*. No material of *R. heterospine* appears to be extant (J. R. Lichtenfels, pers. comm.) and Linton's own synonymy of *R. heterospine* with *R. bulbifer* has therefore been accepted.

Material from the western Atlantic, from the same host and locality as Linton's *R. bulbifer*, differs from European material in having a greater disparity in size between hooks 1 and 1' at the base of the tentacle, and a different hook shape. Owing to the limited amount of material available from European hosts, the extent of variation in onchotaxy is impossible to determine. The data available at present suggest that two species may be present, and that *R. bulbifer* may represent an independent species within *Lacistorhynchus*. However, an extensive collection of European specimens is required and the full extent of intra-specific variation documented before such decisions can be made. Adequate collections do not exist in European museums to enable the problem to be pursued at present.

Examination of material currently available suggests that specimens of *L. tenuis* from the Mediterranean, the North Sea and the English Channel are morphologically similar. MacKenzie (1985) has suggested, on biological grounds, that more than one species of *Lacistorhynchus* occurs in fish in the North Atlantic.

By contrast, the specimens of *Lacistorhynchus* from Australian and Californian elasmobranchs clearly represent a species distinct from *L. tenuis* as presently defined and can be readily distinguished by features of the onchotaxy.

"*L. tenuis*" as reported by Riser (1956) and Jensen *et al.* (1979) from California is now attributed to *L. dollfusi*. Likewise, the life-cycle studies of Sakanari & Moser (1985 a, b), Moser *et al.* (1984) and Sakanari & Moser (1986) are also attributed to *L. dollfusi* rather than *L. tenuis*. In view of the findings reported here, all other western American

Figs 17–22. *Lacistorhynchus tenuis* (van Beneden, 1858). Tentacular armature, specimens from *Mustelus canis*, Woods Hole, U.S.A. 17, basal region, internal surface; 18, basal region, external surface; 19, basal region, bothridial surface. Tentacular armature, specimens from *Belone belone*, Sète, France: 20, basal region, internal surface; 21, basal region, external surface; 22, basal region, bothridial surface. Scale lines 0.01 mm. Hook numbering system follows Dollfus (1942); a–c, bill-hooks.

records should be verified before the occurrence of *L. tenuis* in the Pacific region is accepted.

Acknowledgments

Thanks are due to B. G. Robertson, M. G. O'Callaghan and R. R. Martin for collecting elasmobranchs and/or cestodes; to Drs R. Bray, J. R. Lichtenfels, A. Petter and A. Jones for the loan of specimens; and to the Australian Biological Resources Survey for financial support.

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A MEGAFOSSIL FLORA FROM THE EOCENE OF GOLDEN GROVE, SOUTH AUSTRALIA

*BY D. C. CHRISTOPHEL & D. R. GREENWOOD**

Summary

A new Eocene plant megafossil locality is reported from near Golden Grove, South Australia. Well preserved mummified leaves, fruits and flowers and impressions are abundant in a lens structure within the East Yatala Sand Pit operated by Monier. Preliminary analysis has identified a rainforest flora containing Elaeocarpaceae (*Sloanea/Elaeocarpus*), Lauraceae, Myrtaceae (*Myrtaciphyllum*), Proteaceae (*Banksieaephyllum*, aff. *Neorites*), Sterculiaceae (*Brachychiton*), Podocarpaceae (*Decussocarpus, Podocarpus*), and the fern *Lygodium*. Physiognomic analysis of the leaves suggests that the closest analogue is with Complex Notophyll Vine Forest. The Monier Golden Grove Eocene flora has some taxonomic similarity in common with other southern Australian Eocene floras, but has a distinctive character which supports the idea of a regionally diversified rainforest vegetation in southern Australia in the Eocene.

KEY WORDS: Fossil, Eocene, Golden Grove, South Australia.

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Introduction

In January 1986, a fossiliferous clay lens was uncovered during sand quarrying operations at the Monier East Yatala Sand Pit in Golden Grove, South Australia (138°43'30", 34°47'10") located approximately 25 km north-east of Adelaide city centre (Fig. 1). The lens was found amidst cross bedded, fresh water sands and the entire depositional sequence suggests a meandering stream system with possible lacustrine elements.

While this is the first megafossil flora described from the Golden Grove area, other plant fossils have been reported from the region.

Eocene clays containing dispersed plant fossils have been described in several papers (e.g. Lange 1978a, 1978b, 1980), but a precise description of the location of the deposit is not given in any of them. As a recent drilling program by the S. Aust. Mines and Energy Department has indicated that the lateral extent of the new lens is extensive (Neville Alley pers. comm.), it is possible that these earlier reports were based on material from the same system. However, it is known that the earlier material did not come from the Monier quarry, and hence precise geological comparison between the earlier reported material and the Monier Golden Grove Locality may never be possible. They may be palynologically correlated, however.

A preliminary palynological analysis (W. K. Harris, Western Mining Co. pers. comm.) placed the lens at the base of the *Proteacidites pachypolis* Zone of the Eocene. A second palynological analysis (Neville Alley pers. comm.) supports placement in this zone. The deposit is therefore either just younger than the Maslin Bay deposit located 30 km south of Adelaide or equivalent to it. The Monier Golden Grove deposit is slightly older than the Anglesea deposit in Victoria (Christophel, Harris & Syber 1987) (Fig. 1).

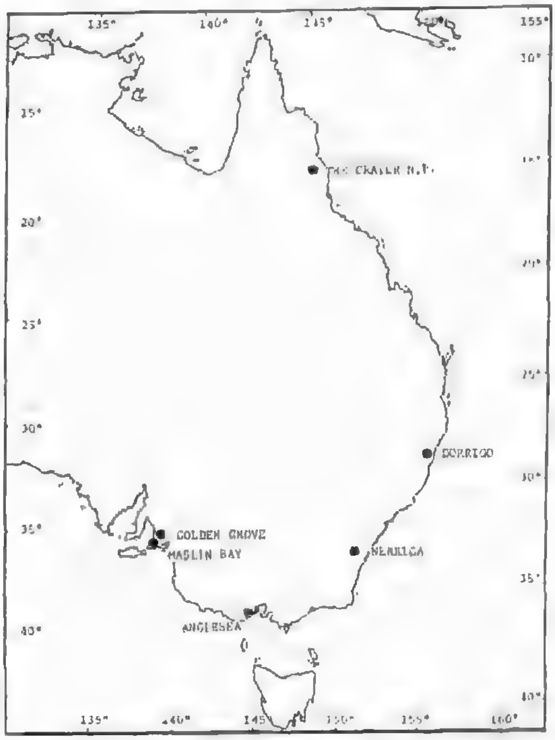

Fig. 1 Map of eastern Australia giving the location of the Golden Grove locality relative to the Eocene localities of Maslin Bay, Anglesea and Nerriga, and two of the sites from which litter was collected for the physiognomic comparison.

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Materials and Methods

Portions of the lens are highly oxidised and plant remains are preserved as brown impressions in beige matrix with no organic remains present. The majority of the lens contains carbonized remains within a grey matrix, and mummified leaves are floated from this material by placing blocks of the clay in a 2–3% hot aqueous solution of hydrogen peroxide to disaggregate the matrix. Many of these leaves are naturally translucent and can be photographed directly with transmitted light (Figs 2–6). The rest are black, opaque, and were observed and photographed with UV light to study the venation detail using the technique of Christophel *et al.* (1987). This type of preservation is shown in Figs 7–9.

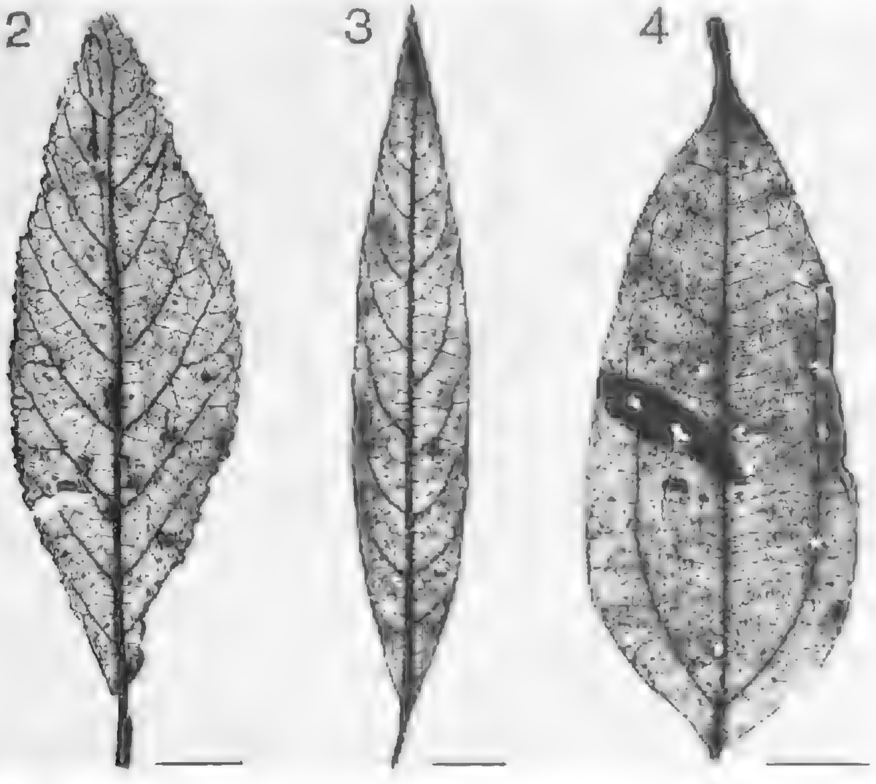
A sample cuticle is then prepared using the method discussed in Christophel *et al.* (1987) and the leaf is mounted between glass slides in Phenol Glycerin Jelly.

All leaves illustrated in this paper are housed in the Adelaide University Palaeobotany collection. Fruits and flowers obtained from the macerate are stored in 1% phenol in 50% ethanol in sealed vials, in the same collection.

Components of the Megafossil Flora

The commonest leaf taxon from the mummified horizons at Golden Grove is a serrate-margined notophyll (Fig. 2). This taxon has superficial similarities to *Sloanea/Elaeocarpus* (Elaeocarpaceae). A recent study of extant species of this family found that leaves of *Elaeocarpus* L. and *Sloanea* L. could not be separated, but that they consistently clustered distinctly from other genera in the family and from other architecturally similar families (Moira Turnbull Adelaide University pers. comm.). The Golden Grove fossils similar to Fig. 2 consistently clustered with the extant *Sloanea/Elaeocarpus* complex.

Another common taxon in the Monier Golden Grove flora is *Banksieaephyllum* Cookson & Duigan (Fig. 9). As the name suggests, the leaf is very similar to those found in the tribe Banksieae (Proteaceae), but as Christophel & Greenwood (1987) suggested, this could also represent the foliar organ of *Musgraveinanthus* Christophel (1984). This is supported by the occurrence of *Musgraveinanthus* in the Monier Golden Grove deposit, which is the only locality other than the type locality (Anglesea) from which it has been



Figs 2–4. Transparent mummified leaves from Golden Grove. Scale bars = 1 cm. Fig. 2. Elaeocarpaceae aff. *Sloanea/Elaeocarpus*; Figs 3., 4. Lauraceae.

reported. *Banksieaeidites arcuatus* Stover, the pollen type found in *Musgraveinanthus* inflorescences, is also found as a dispersed grain at Golden Grove.

The Lauraceae has been suggested as an important family in Australian Early Tertiary floras. Based on the characters discussed by Hill (1986) as diagnostic of the family, we have confirmed at least two common leaf taxa at Golden Grove (Figs 3, 4) which may be assigned to that family. The importance of the family in the Monier Golden Grove flora is therefore confirmed.

Leaves of *Myrtaciphyllum* Christophel & Lys are also frequently encountered in the Golden Grove flora (Fig. 7). However, a preliminary investigation indicates that the Golden Grove Myrtaceae leaves belong to different species than the two described by Christophel & Lys (1986).

Two leaf types collected at the Monier Golden Grove locality are known only rarely from other Early Tertiary deposits, Table 1. These are leaves of *Brachychiton* (Sterculiaceae) and the fern *Lygodium* (Schizeaeaceae). *Brachychiton* Scott & Endl. is very common as impressions in the leached portion of the lens, where it is recovered in both a three and five lobed form. Less common in the mummified portions of the lens, it has thus far only been collected in a three-lobed form from that material (Fig. 8). *Lygodium* is not only recovered as sterile pinnules (Fig. 6) but has also been collected as numerous fertile fronds. These can be seen to contain spores, which have yet to be studied and compared to their extant counterparts.

The gymnosperms are represented at Golden Grove by two genera of the Podocarpaceae, *Decussocarpus* Laubenf. and *Podocarpus* L'Herit. ex Pers. *sens. strict. Decussocarpus* twigs are common, and appear morphologically intermediate between *D. maslinensis* Blackburn, described from Maslin Bay, S. Aust., and *D. brownei* (Selling) Greenwood, from Anglesea (Greenwood 1987). It is quite likely that the three therefore represent a range of forms in one highly variable taxon. Similar variation can be seen in modern examples of the genus [e.g. *D. vitiensis* (Seeman) Laubenf., Greenwood 1987]. Golden Grove material of this species has been illustrated earlier by Christophel & Greenwood (1988).

Podocarpus leaves are less common, and while much longer, have epidermal features identical to *Podocarpus platyphyllum* Greenwood described from Anglesea (Greenwood 1987).

One further leaf type is reasonably common and has not been reported previously. These leaves are pinnately compound (Fig. 5) and on the basis of their stomatal arrangement and epidermal hair bases can be ascribed to the Proteaceae. They bear a superficial similarity to immature leaves of *Neorites* L.S.Sm.

While the identity of no other leaf taxa have been confirmed, a preliminary estimate of approximately 30-35 leaf types for the deposit is made. However, the present collection contains only approximately 400 leaves, and so the preliminary nature of the estimate must be emphasized. Four fruit/flower types have been thus far recovered, but only specimens of *Musgraveinanthus* have been identified.

Physiognomic Analysis

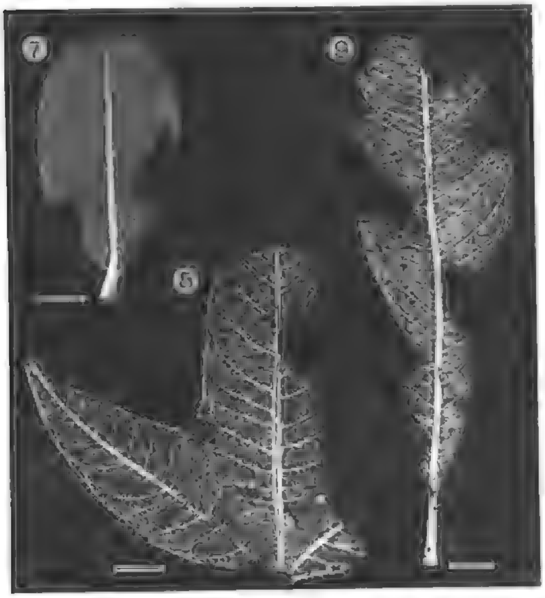
The general elliptic shape, broad lamina, and the presence of well developed 'drip tips' on many leaves (e.g. Fig. 4), strongly suggest that the Golden Grove flora was derived predominantly from rainforest vegetation. These features are often cited as being characteristic of rainforest leaves, particularly lowland tropical rainforest (Richards 1957). The presence of typical rainforest taxa e.g. Elaeocarpaceae (*Sloanea/Elaeocarpus*), Proteaceae (Musgraveinae, *Neorites*), Myrtaceae (*Syzygium*

TABLE 1. *Megafossil taxa at Australian Localities.*

Locality / Taxa	Golden Grove	Maslin Bay	Anglesea	Nerriga
Austrodiospyros	?	R	C	
Musgraveinanthus	X		X	
Elaeocarpaceae	C	?	C	?
Myrtaciphyllum	C		X	
Brachychiton	C		R	
Decussocarpus	C	X	C	
Podocarpus	X		X	
Gymnostoma		R	C	R
Zamiaceae			C	R
Lauraceae	C	X	C	C
Lygodium	C	R	X	
Banksieaephyllum	C	X	X	
Total Diversity	30-35	100+	100+	25-30

C – common (> 10%); X – present (1-10% — possibly more common, but not assessed); R – rare (< 1% of flora); ? = similar but unconfirmed.

Figs 5, 6. Transparent mummified leaves from Golden Grove. Scale bars = 1 cm. Fig. 5. Proteaceae aff. *Neorites*; Fig. 6. Fern pinnule, *Lygodium*.



Figs 7–9. Opaque mummified leaves photographed using UV light source. Scale bars = 1 cm. Fig. 7. *Myrtaciphyllum*; Fig. 8. *Brachychiton*; Fig. 9. *Banksieaephyllum*.

type), Lauraceae, Podocarpaceae (*Decussocarpus, Podocarpus*) strengthens this impression, although representatives of some of these families are also found in more open forest types. It is appropriate therefore to compare the foliar physiognomy of the Golden Grove flora to that of modern rainforest.

The use of foliar physiognomic analysis for the interpretation of fossil leaf-beds based on forest canopy data has been criticized for ignoring the effect of transportation and the differential input and preservation of leaves prior to sedimentation (Martin 1986; Christophel & Greenwood 1988). Recent research, however, suggests strongly that leaf-litter from each of the main rainforest types recognized by Webb (1959, 1968) and Tracey (1982) has a unique physiognomic "signature" and that this signature is often retained in stream-deposited leaf-litter (Christophel & Greenwood 1988). Work in progress by the second author supports this. The physiognomic features of primary importance are length, width, shape and margin type. Leaf length only will be considered in this paper, as it is sufficient to illustrate the physiognomic signature.

Fig. 10 shows the frequency distribution of leaf-length for the four main rainforest types recognised by Webb (1959, 1968) and the frequency distribution for the Golden Grove flora using mummified leaves. As can be seen from the figure, the extant rainforest types can be clearly separated on leaf-length alone. Fig. 11 shows the same data plotted as a cumulative percentage for each length class. The CNVF (Complex Notophyll Vine Forest) forest type has been presented as two separate sites to better illustrate the intrinsic physiognomic variability of litter from NE Queensland (The Crater) and N.S.W. (Dorrigo) from this type. Standard errors for the data from these sites are presented in Table 2. These results indicate that the Golden Grove Eocene vegetation was physiognomically closest to CNVF from The Crater N.P. and less so to CNVF from Dorrigo in northern N.S.W. Dorrigo and The Crater fall within the Mesotherm seasonal Torresian zone of Nix's bioclimatic classification of Australia (Nix 1982).

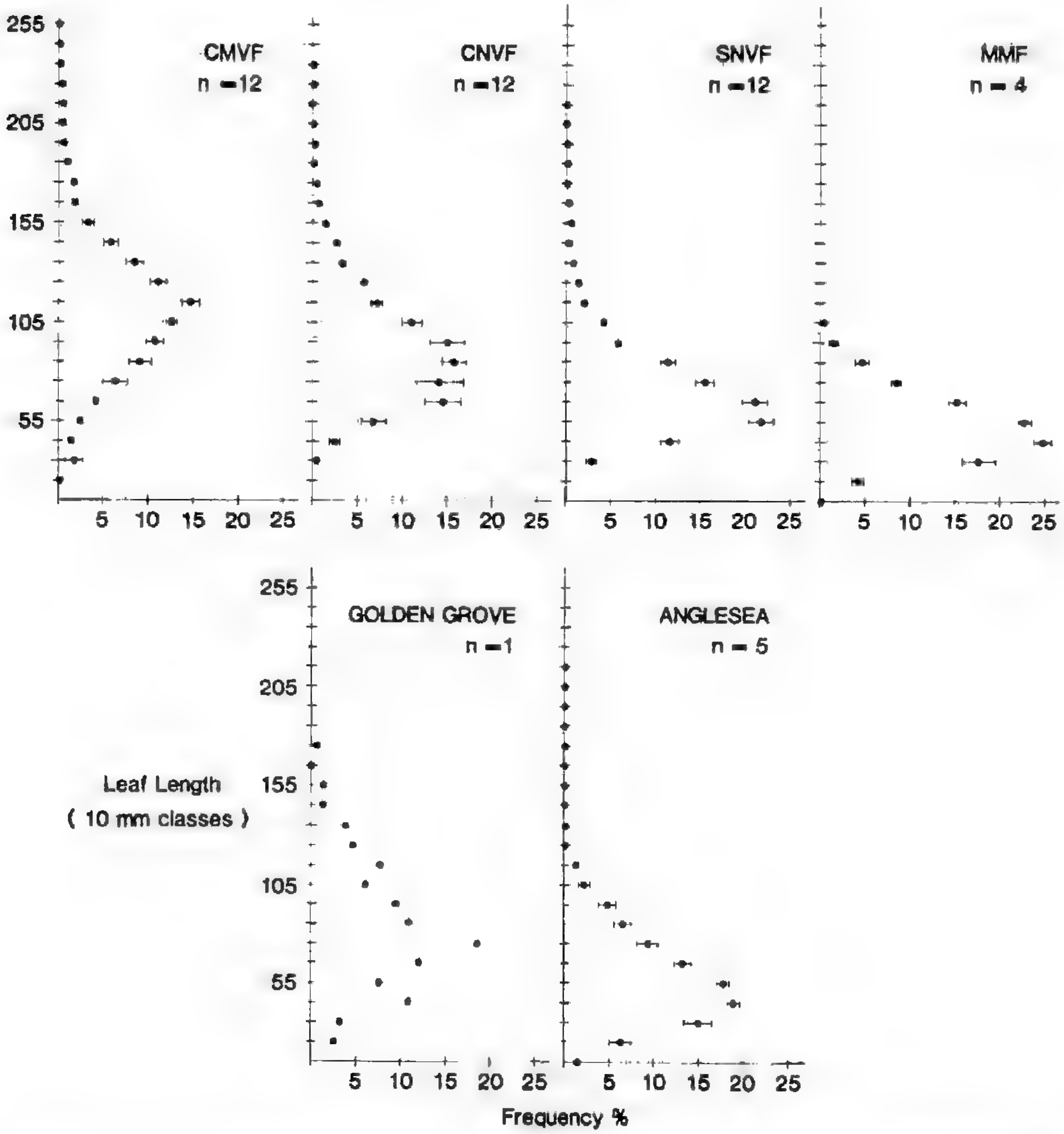


Fig. 10. Frequency distributions of leaf length (10 mm classes) for Microphyll Mossy Forest (MMF), Simple Notophyll Vine Forest (SNVF), Complex Notophyll Vine Forest (CNVF), Complex Mesophyll Vine Forest (CMVF), Golden Grove, and Anglesea. Forest nomenclature follows Webb (1959, 1968) and Tracey (1982). Each of the data sets for the modern forests is based on four samples of 200 leaves collected from litter (Christophel & Greenwood 1988). Golden Grove data are based on 156 complete leaves from the initial 1986 collections. Standard Errors are plotted.

Comparison with other Eocene Floras

As mentioned above, the Monier Golden Grove flora is similar in age to the Maslin Bay flora and is somewhat older than the Eocene Anglesea flora. It is younger than the Nerriga flora (Hill 1982) but can still be usefully compared with it, as all are Eocene. Table 1 compares the major (as well as some of the unique minor) taxa from the four deposits.

Perhaps the strongest similarities to the Golden Grove megafossil flora may be seen in the Anglesea locality. While the diversity of the Anglesea flora is shown as much higher (100+), this represents a composite of six separate fossiliferous lenses. Taken separately, the lenses at Anglesea have a diversity much more similar to Golden Grove (Christophel *et al.* 1987). The strongest links between the two are the very similar Elaeocarpaceae leaves, *Musgraveinanthus*, *Myrtaciphyllum* and *Brachychiton*. They also have in common *Decussocarpus*, *Podocarpus*, Lauraceae, *Banksieaephyllum* and *Lygodium*, but these are not restricted to those localities. Physiognomically, however, Golden Grove is interpreted as CNVF, whereas the New Site lenses at Anglesea were interpreted by Christophel (1981) and Christophel & Greenwood (1988) as being closest to SNVF (Simple Notophyll Vine Forest) from N.E. Queensland (Fig. 11).

The diversity of Golden Grove is similar to Nerriga, but there are very few shared taxa, and the only feature in common is really the shared importance of the Lauraceae. Maslin Bay has a few taxa in common with Golden Grove, but in general Maslin Bay has a high diversity with no truly common taxa, while Golden Grove has fewer, well represented taxa and hence suggests a quite different floristic association. Preliminary physiognomic analysis of the Maslin Bay flora by the second author has detected minor differences which suggest that the Maslin Bay flora was sourced from a warmer vegetation type (Greenwood unpubl.).

The absence of both the Zamiaceae and *Gymnostoma* Johnson at the Golden Grove locality is surprising considering the commonness of both at Anglesea and their presence in the other deposits. While further collecting may reveal either or both of these taxa, their absence to date may be taken as evidence that they are not major components of the Monier Golden Grove flora.

The preliminary investigation of the Golden Grove flora has revealed a vegetation typical of the southern Australian Eocene floras studied to date, in that it appears to have been sourced from a rainforest vegetation (Complex Notophyll Vine Forest *sensu* Webb, 1959, 1968) of reasonable diversity in a mesotherm environment (*sensu* Nix 1982). There are differences between it and the other documented floras of similar age, as is expected based on the temporal and spatial differences in the localities. While numerous similarities in taxa present have been highlighted in Table 1, it must be emphasized that these are similarities in natural and form genera, and there is no evidence yet (possible excluding Podocarpaceae) to suggest that

TABLE 2. *Standard Error Values for Cumulative Frequency of Length for Fig. 11.*

Length class (mm)	MMF†	SNVF†	Dorrigo*	The Crater*	CMVF*
15	0.2	—	—	—	—
25	0.7	0.2	—	—	0.1
35	2.1	2.3	0.2	1.3	2.0
45	2.3	5.5	0.9	3.7	3.0
55	2.0	6.4	0.7	3.1	3.2
65	1.4	5.3	0.8	1.4	2.9
75	1.5	3.8	1.5	1.8	2.3
85	0.8	3.0	4.0	1.2	3.1
95	0.4	3.2	3.9	1.1	4.6
105	0.2	2.3	2.2	0.9	4.2
115	—	1.6	1.7	0.9	3.7
125	—	1.3	1.3	1.1	4.2
135	—	1.0	0.9	1.5	2.9
145	—	0.9	0.6	1.0	1.8
155	—	0.6	0.5	0.8	1.0
165	—	0.6	0.2	0.6	0.7
175	—	0.5	0.2	0.5	0.5
185	—	0.5	0.2	0.2	0.4
195	—	0.4	0.3	—	0.3
205	—	0.4	0.1	—	0.4
215	—	0.2	0.1	—	0.2
225	—	0.1	-	—	0.1

* n = 4 samples of 224 leaves.
† n = 4 samples of 224 leaves for 3 sites.

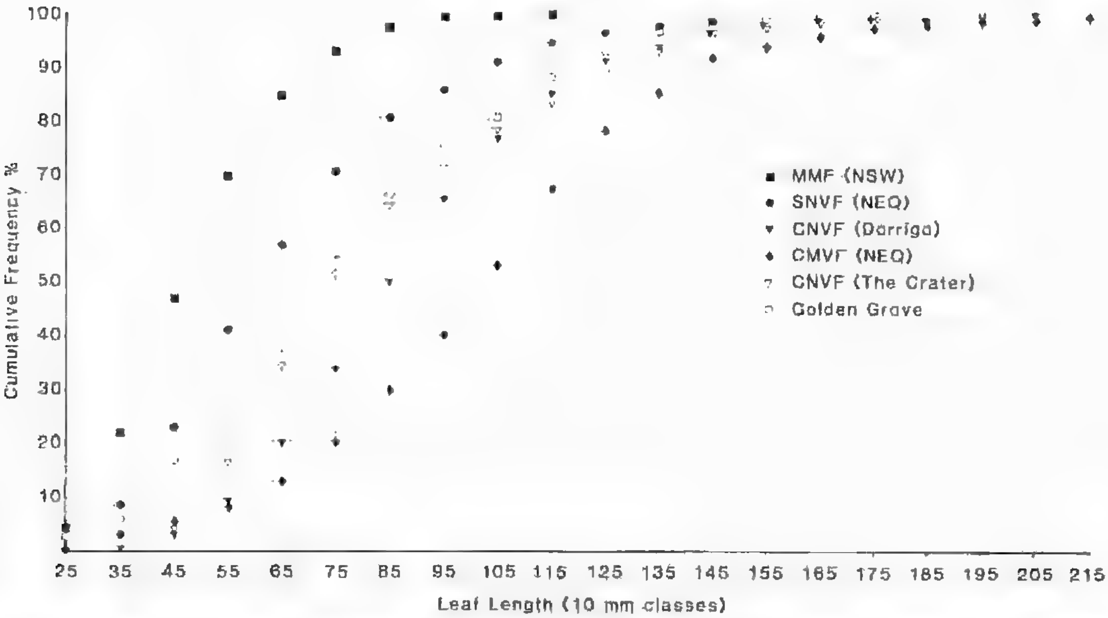


Fig. 11. Cumulative frequency histograms for the data presented in Fig. 10. Two separate localities for CNVF are given: the Crater National Park (open triangles) and Dorrigo (solid triangles). These two localities reflect the extremes of the range seen in litter samples from N.E. Queensland and N.S.W.

the same species are occurring in the different localities.

The Monier Golden Grove flora represents South Australia's only known mummified leaf flora still available for collection and study (a collection of several thousand Maslins Bay specimens exists in the Botany Department of Adelaide University, but the locality is no longer collectable), and it is hoped that further work will provide us with deeper insights into the evolution of South Australia's flora. Much of South Australia's coal reserve which is currently being considered for development is Eocene in age, and hence Golden Grove will hopefully provide a benchmark for studies of these floras when they are eventually developed.

Acknowledgments

The authors wish to acknowledge the help and cooperation of David Keane, Rex Rowley and Maurice Burton of Monier Ltd. We are also grateful to Neville Alley (S.A. Mines and Energy Department) and Neville Pledge (S.A. Museum) for bringing the deposit to our attention. Research on this locality is supported by a joint grant from the S.A. Mines & Energy Department, S.A. Department of the Environment and Planning, and Monier Ltd. The plates were prepared by Susan M. Shaw.

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TRZMACRACALVTHUS GEN. NOV. (CESTODA: TRYPANORHYNCHA: EUTETRARHYNCHIDAE), WITH REDESCRIPTIONS OF *T. AETOBATZDZS* (ROBINSON, 1959) COMB. NOV. AND *T. BZNUNCUS* (LINTON, 1909) COMB. NOV.

BY IAN BEVERIDGE & R. A. CAMPBELL†*

Summary

Trimacracanthus gen. nov. is erected within the Eutetrarhynchidae Guiart, 1927 for two species, *Prochristianella aetobatis* Robinson, 1959 and *Rhynchobothrium binuncum* Linton, 1909. Both species are redescribed. The new genus is most similar to *Prochristianella* Dollfus, 1946 in possessing a large basal swelling of the tentacle and a distinct basal armature, but differs in having an asymmetrical swelling and a triad of grossly enlarged hooks on the external surface of the swelling. The two species are distinguished from one another by number of hooks in each principal row, size of hooks and number of testes in mature segments.

KEY WORDS: Cestoda, Trypanorhyncha, Eutetrarhynchidae, *Trimacracanthus, Prochristianella aetobatis, Rhynchobothrium binuncum.*

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Summary

BEVERIDGE, I. & CAMPBELL, R. A. (1987) *Trimacracanthus* gen. nov. (Cestoda: Trypanorhyncha: Eutetrarhynchidae), with redescriptions of *T. aetobatidis* (Robinson, 1959) comb. nov. and *T. binuncus* (Linton, 1909) comb. nov. *Trans. R. Soc. S. Aust.* 111(3), 163-171, 30 November, 1987.

Trimacracanthus gen. nov. is erected within the Eutetrarhynchidae Guiart, 1927 for two species, *Prochristianella aetobatis* Robinson, 1959 and *Rhynchobothrium binuncum* Linton, 1909. Both species are redescribed. The new genus is most similar to *Prochristianella* Dollfus, 1946 in possessing a large basal swelling of the tentacle and a distinct basal armature, but differs in having an asymmetrical swelling and a triad of grossly enlarged hooks on the external surface of the swelling. The two species are distinguished from one another by number of hooks in each principal row, size of hooks and number of testes in mature segments.

KEY WORDS: Cestoda, Trypanorhyncha, Eutetrarhynchidae, *Trimacracanthus*, *Prochristianella aetobatis*, *Rhynchobothrium binuncum*.

Introduction

Recent collections of cestodes from South Australian elasmobranchs included the trypanorhynch *Prochristianella aetobatis* Robinson, 1959 which is apparently a prevalent parasite of some of the species of rays occurring in coastal waters. In preparing a redescription of the species a number of significant differences from congeners became apparent. In addition it was noted that another species of trypanorhynch, *Rhychobothrium binuncum* Linton, 1909, described from a stingray from the northwestern Atlantic and currently considered a *species incertae sedis* (Yamaguti 1959; Schmidt 1986) shared several of the distinctive features found in *P. aetobatis*. In this paper we redescribe both species and show that they constitute a new genus within the Eutetrarhynchidae, related to *Prochristianella*.

Materials and Methods

Specimens of *P. aetobatis* were obtained from the spiral valves of rays from South Australian coastal waters. Cestodes were either washed in sea water, relaxed briefly in tap water, then fixed in 10% buffered formalin, or the spiral valve contents were fixed with hot formalin and the cestodes were subsequently removed in the laboratory. Cestodes were stained with Celestine blue, dehydrated in ethanol, cleared in clove oil and mounted in balsam. Six specimens were also examined by scanning electron microscopy. Type specimens of *P. aetobatis* were borrowed from the National Museum of New Zealand (NMNZ). All new material collected has been deposited in the Australian Helminth Collection (AHC) of the South Australian Museum, Adelaide. Additional specimens of *P. aetobatis* have been deposited in the British Musem (Natural History), London (BMNH), and the United States National Museum Helminth Collection, Washington (USNMHC). Type specimens of *R. binuncum* were borrowed from USNMHC.

Measurements are presented in the text in micrometres, unless otherwise stated. The range is followed by the mean in parentheses. Unless otherwise indicated, 10 measurements were made of each organ.

Terminology for the various elements of trypanorhynchan anatomy follows Dollfus (1942) and Schmidt (1986).

Trimacracanthus gen. nov.

Generic diagnosis: Eutetrarhynchidae Guiart, 1927. Scolex slender, elongate, acraspedote. Pars bulbosa and pars vaginalis much longer than pars bothridialis. Bulbs long and slender. Tentacle sheaths sinuous but not spiral. Prebulbar organs present. Retractor muscle attached at posterior extremity of bulbs. Two bothridia, margins thick, free, not contiguous apically, may be notched posteriorly suggesting incipient subdivision. Tentacles long with asymmetrical basal swelling

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bearing distinctive basal armature. Metabasal armature heteroacanthous, heteromorphous, typical. Hooks solid. Metabasal armature of alternate half spiral rows beginning with large hook 1 (1') with recurved point and long base of implantation. Hooks 2 (2') also large but smaller than 1 (1'); remaining hooks diminish in size becoming slender and shorter as row continues towards external face. Strobila acraspedote, hyperapolytic. Genital pore marginal. Testes medullary, preovarian. External seminal vesicle present. Ovary posterior, 4-lobed in cross section. Seminal receptacle present. Uterus median. Vitellaria circumcortical.

Type species: *T. aetobatidis* (Robinson, 1959) comb. nov.

Other species: *T. binuncus* (Linton, 1909) comb. nov.

Trimacracanthus aetobatidis (Robinson, 1959) comb. nov.
FIGS 1–15

Prochristianella aetobatis Robinson, 1959, pp. 390–391, figs 26–34.

Types: Holotype from spiral valve of *Aetobatus narinari* Mueller & Henle, 1841 (syn. *A. tenuicaudatus*), New Zealand (precise locality unknown), March 1955, coll. E. S. Robinson, holotype NMNZ ZQ203, paratypes NMNZ ZW 204–206.

Material Examined: from *Aetobatus narinari*: paratypes NMNZ (ZW 205–6). From *Trygonorhina guanerius* Whitley, 1932 (new host record): 23 specimens, Goolwa, S. Aust. (AHC S2760, USNMHC 79592); 1 specimen, Marion Bay, S. Aust.; 38 specimens, Middleton, S. Aust. (AHC S2358); 1 specimen, Port Stanvac, S. Aust. (AHC S2763); 3 specimens, Cowell, S. Aust. (AHC S2762).

From *Myliobatis australis* Macleay, 1881 (new host record): 8 specimens, Middleton, S. Aust. (AHC S2355); 1 specimen, Young Rocks, Kangaroo Island, S. Aust. (AHC S2764); 11 specimens, Goolwa, S. Aust. (AHC S2756); 1 specimen, Port Lincoln, S. Aust. (AHC S2766).

From *Dasyatis brevicaudatus* (Hutton, 1875) (new host record): 11 specimens, Northaven, S. Aust. (AHC S2768); 1 specimen, Port Vincent, S. Aust. (AHC S2769); 10 specimens, Streaky Bay, S. Aust. (AHC S2767).

From *Dasyatis thetidis* Waite, 1899 (new host record): 4 specimens, Cowell, S. Aust. (AHC S2770).

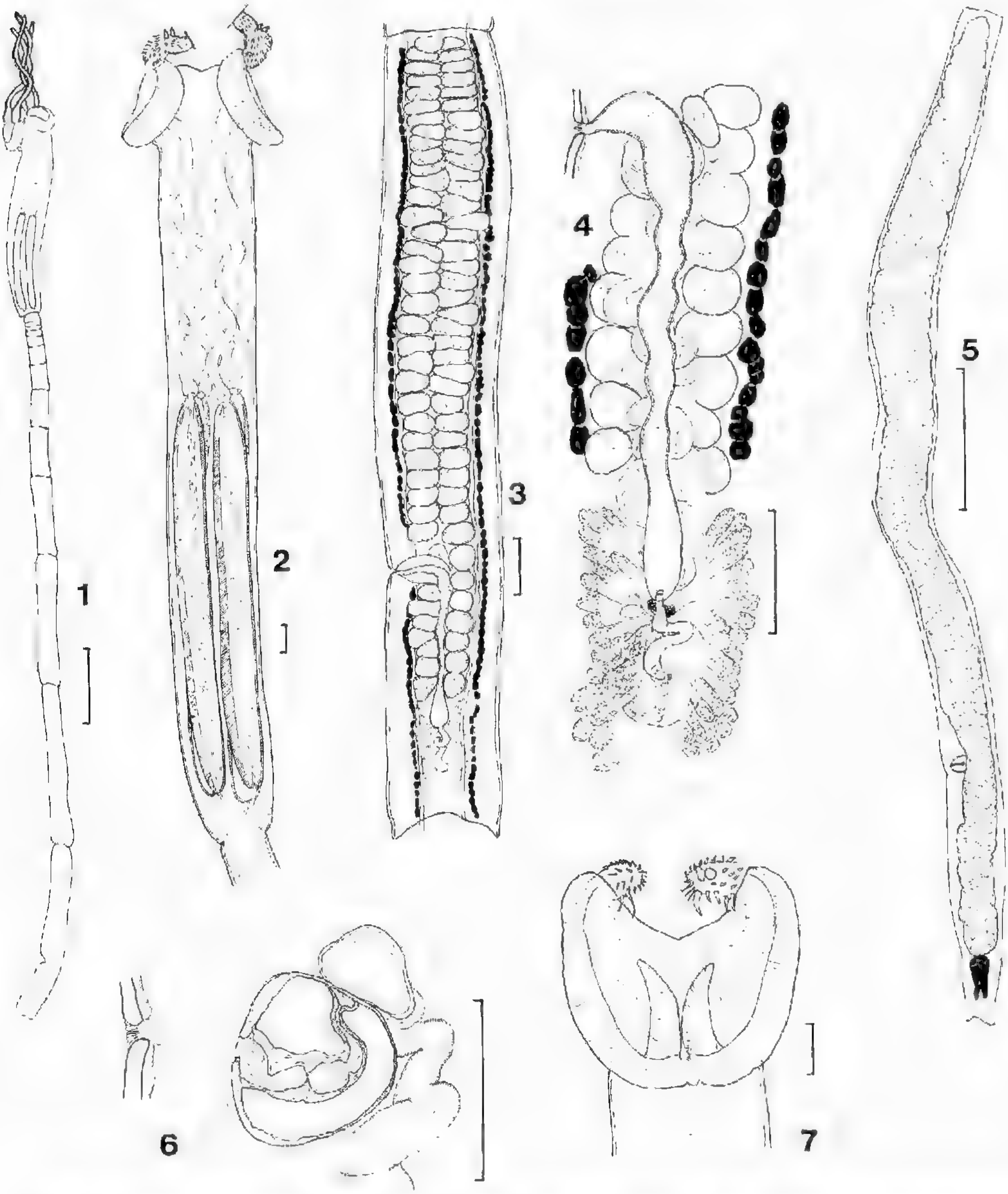
From *Mustelus antarcticus* (Günther, 1870) (new host record): 1 specimen, Goolwa, S. Aust. (BMNH 1987.4.7.4).

Description: Slender, delicate worms, up to 15 mm long, consisting of up to 15 acraspedote segments. Scolex acraspedote (Fig. 2), 2.54–2.99 (2.77) mm long, 380–530 (410) wide with two, well separated patelliform bothridia 350–470 (400, n=5) in diameter. Bothridial margins free, indented posteriorly, borders thick, terminating as short ridges on internal surface of bothridium (Fig. 7). Pars bothridialis 360–460 (420); pars vaginalis 1.2–1.4 (1.31) mm; pars bulbosa 1.18–1.50 (1.38) mm. Ratio of pars bulbosa to pars vaginalis 1:0.95. Tentacles up to 2.22 mm long, 40–70 (50) in diameter excluding hooks; prominent asymmetrical basal swelling, 50–110 (80) wide (Figs 12–14). Tentacle sheaths sinuous with some coils, not spiral. Bulbs at least eight times longer than wide, 1180–1500 (1300) by 140–180 (160); origin of retractor muscles at base of bulb, surrounded by irregular clumps of gland cells; prebulbar organs present. Red pigmentation anterior to bulbs in living specimens. Pars postbulbosa very short, 35–110 (67).

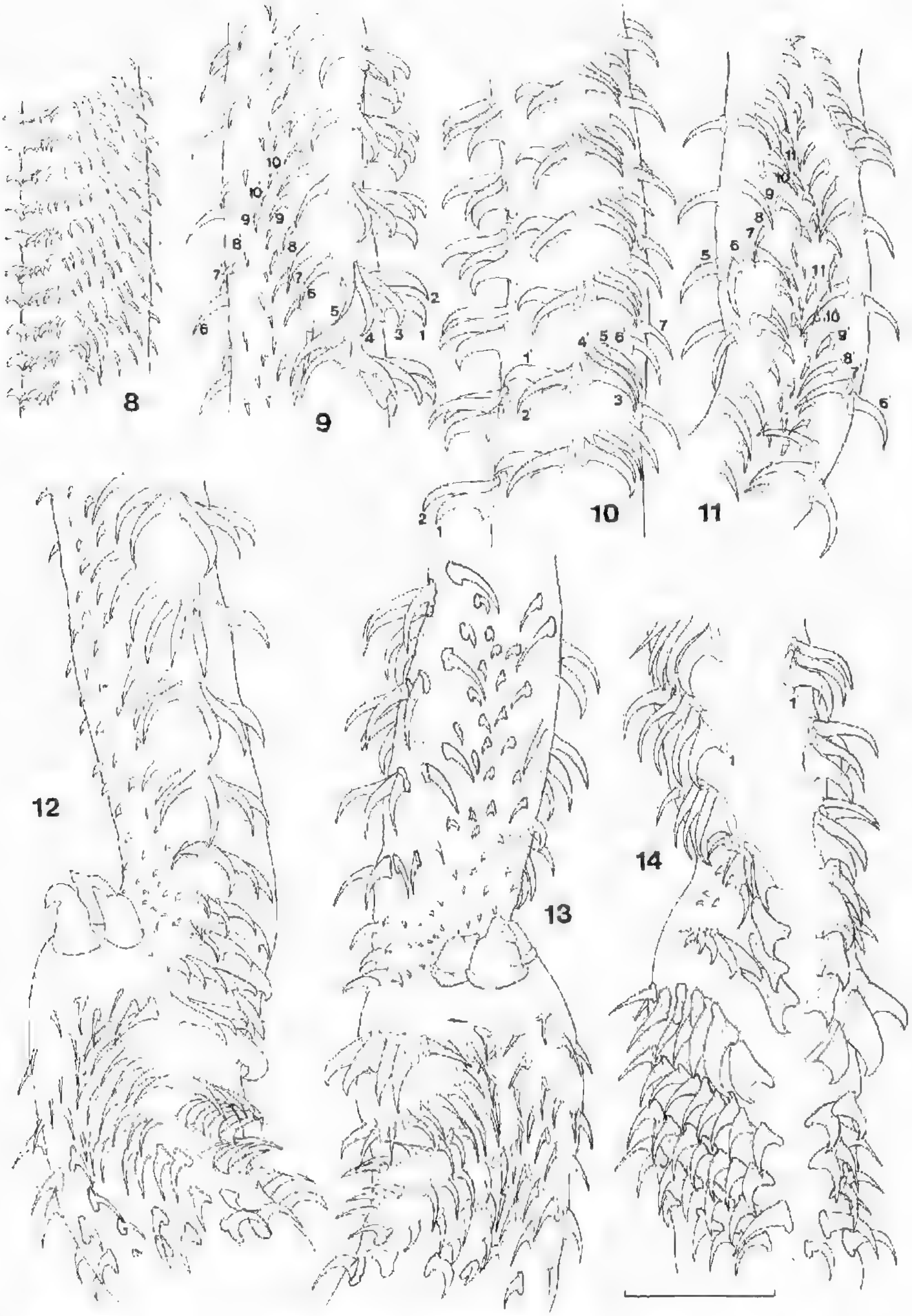
Armature heteroacanthous, heteromorphous typical; hooks solid. Metabasal armature (Figs 9–11) consists of alternating, ascending, half spiral rows of 10–11 hooks at mid-tentacle; 12–14 hooks per half spiral row near tip of tentacle. Rows begin on internal face with hooks 1 (1') well separated, ending on external face where half spiral rows meet to form inverted V. Hooks of principal rows begin with single large hook with long base of implantation, remaining hooks become more slender with shorter bases on bothridial and antibothridial faces; hooks of external face much reduced in size. All hooks become smaller toward tip of tentacle. Hook dimensions in mid-region of tentacle: 1 (1') arcuate, stout, 34–46 (43) long, base length 20–30 (24); hooks 2 (2') straighter (Fig. 10), more slender, tip curved, 38–54 (44) long, base length 16–18 (17); hooks 3 (3') slender, spiniform with short base 38–50 (46), base 10–18 (16); hooks 4 (4') 38–48 (44) long, base 14–24 (17); hooks 5 (5') 32–46 (40) long, base 12–16 (15); hooks 6 (6') 28–40 (32) long, base 10–14 (13); hooks 7 (7'), 18–32 (23) long; 8 (8'), 12–20 (16) long; 9 (9')–11' (11'), 10–20 (15) long.

Basal armature (Figs 12–14) consists of eight rows of hooks on basal swelling of tentacle; hooks dissimilar on external and internal surfaces. Hooks of internal surface organized into alternate, ascending half spiral rows with hooks 1 (1') well separated. Proximal rows one to four consist of series of large spiniform hooks, gradually decreasing in size as rows continue towards external surface. Rows five to eight begin with stout rose-thorn shaped hooks 1 (1'); row five continues as series of spiniform hooks much stouter than those of proximal rows one to four. Half spiral rows one to five terminate in series of four to eight small spiniform hooks on external surface in inverted V-formation. Rows six to eight with reduced numbers of hooks. On external surface, opposite rows six to eight, distinct promontory present, surmounted by triad of large cone-shaped hooks with rounded, festooned bases (Figs 12, 13). Central hook 24–42 (36) long with recurved point, base diameter 18–32 (26). Posterolateral hooks of triad dissimilar, more slender of pair 30–38 (33) long with rebated point; base diameter 18–24 (21); stouter hook 30–36 (33) long, base 16–24 (21).

Mature segments 1.19–3.09 (1.99) mm by 180–310 (260); detached gravid segments 2.30–4.21 (3.11) mm by 220–400 (300). Genital pores irregularly alternate, in posterior 1/3 of mature segment, 67% of segment length from anterior end; 75% of segment length from anterior end of gravid segments. Genital atrium small. Cirrus sac globose, 70–140



Figs 1–7. *Trimacracanthus aëtobatidis* (Robinson). 1, entire cestode; 2, scolex; 3, mature segment; 4, female genitalia; 5, gravid segment; 6, cirrus sac with external seminal vesicle; 7, bothridia. Scale lines: fig. 1, 5, 1.0 mm; figs 2–4, 6–7, 0.1 mm.



Figs 8-14. *Trimacracanthus aetobatidis* (Robinson), tentacular armature. 8, bothridial surface of tentacle, 0.1 mm from tip of fully extended tentacle; 9, bothridial surface, metabasal region, 0.8 mm from base; 10, antibothridial surface, metabasal region, 0.8 mm from base; 11, external surface, metabasal region, 1.9 mm from base; 12, basal region of tentacle, bothridial surface; 13, basal region, external surface; 14, basal region, internal surface. Scale line: 0.1 mm.

(100) by 30-110 (80); cirrus unarmed. External seminal vesicle pyriform (Fig. 6), adnate to cirrus sac; vas deferens coiled, located in midline between cirrus sac and ovary. Testes preovarian, subspherical, 50–100 by 40–50, forming two parallel rows; testes number 68–85 (76) per segment; testis distribution: postvaginal and poral 6–8 (7); prevaginal and poral 28–35 (31); antiporal row 34–43 (38). Vagina passes anteroventral to cirrus pouch, turns sharply posterior in midventral line and descends to ovary. Vagina divided into two segments; first segment greatly expanded from genital atrium to anterior level of ovary where sperm are stored, wall lined by simple epithelium; constricts forming second segment, narrow sperm duct passes ventral to ovarian isthmus and joins ootype. Ovary bilobed in dorsoventral view, lobes subequal, 130-270 (190) by 30–60 (40); Mehlis' gland 80–220 (150) in diameter. Vitelline follicles circumcortical, 80 in diameter. Uterus sacciform in detached gravid segments, filling entire preovarian medullary region.

Trimacracanthus binuncus (Linton, 1909)
comb. nov.
FIGS 16–25

Rhynchobothrium binuncum Linton, 1909, pp. 181-182; figs 55–64.

Types: Lectotype from spiral valve of *Dasyatis say* (Le Sueur, 1886), Tortugas, Florida, USNMHC No. 9010; paralectotypes, USNM 9010.

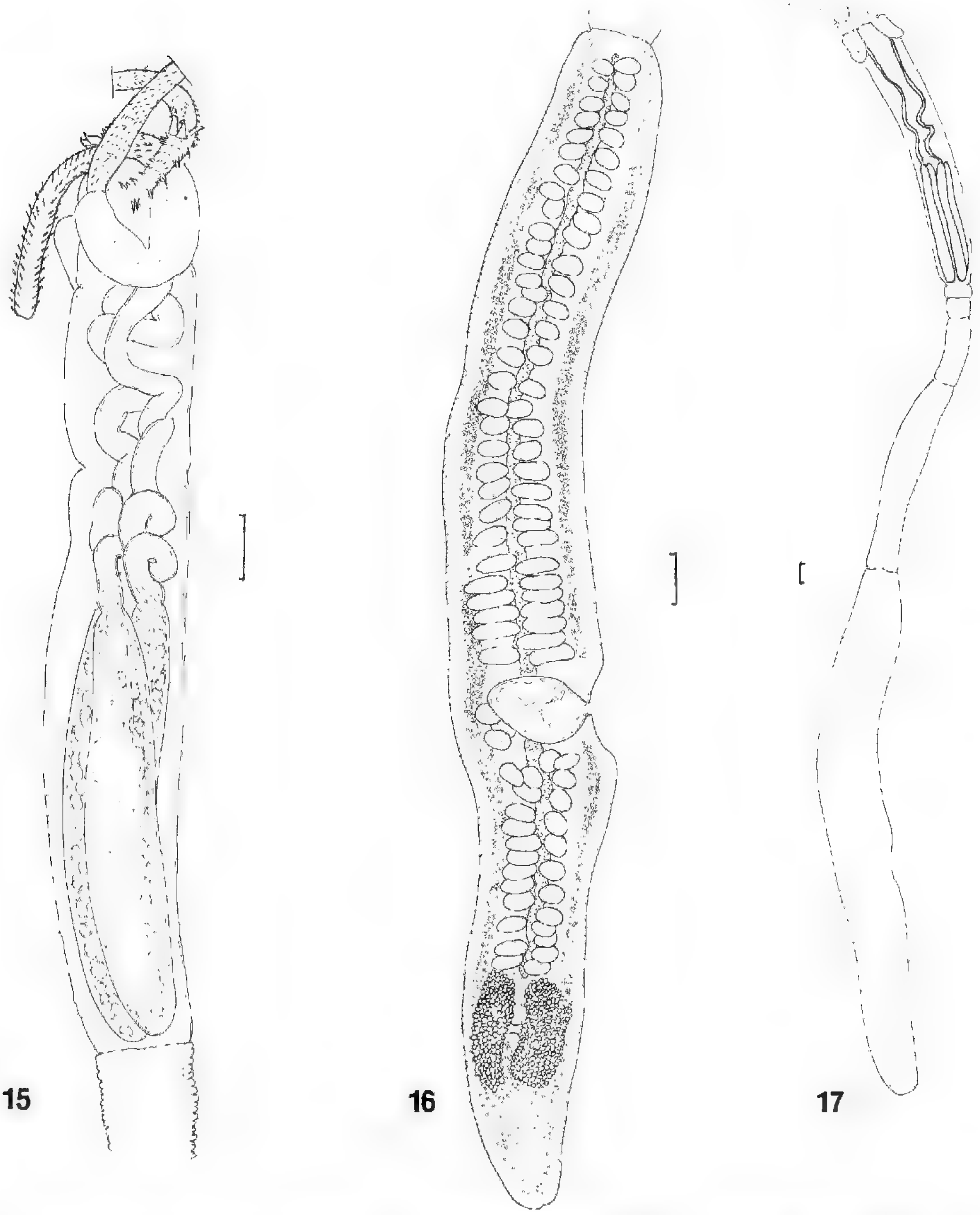
Material examined: from Dasyatis say: 4 types, USNMHC 9010

Description: Small, delicate worms, 4.9-6.4 (5.7) mm (n=2) long, consisting of 5–6 (n=4) acraspedote segments, last segment comprising 65% or more of total length of worm (Fig. 16). Scolex acraspedote (Fig. 15), 1.30-1.65 (1.53) mm (n=4) long by 190–280 (248) (n=3) wide, with two rounded, well separated, bothridia, 175–250 (216) (n=4) long by 160–250 (203) (n=3) in diameter. Bothridial margins free, borders thick, no indentation or incipient division on posterior border. Pars bothridialis 175–250 (223) (n=4); pars vaginalis 800–960 (853) (n=4); pars bulbosa 750–830 (787) (n=4). Ratio of pars bulbosa to pars vaginalis 1:1.09. Tentacles extended to 550 but not fully everted. Tentacle widths, excluding hooks, 80 wide at basal swelling in lateral view, lower metabasal diameter 55, mid-tentacle diameter 45, tip diameter 45. Tentacle sheaths sinuous with few coils. Bulbs elongate, 770–830 (778) (n=4) by 70-100 (83) (n=4), retractor muscle originates at base of bulb, surrounded by irregular mass of gland cells; prebulbar organ present. Pars postbulbosa absent.

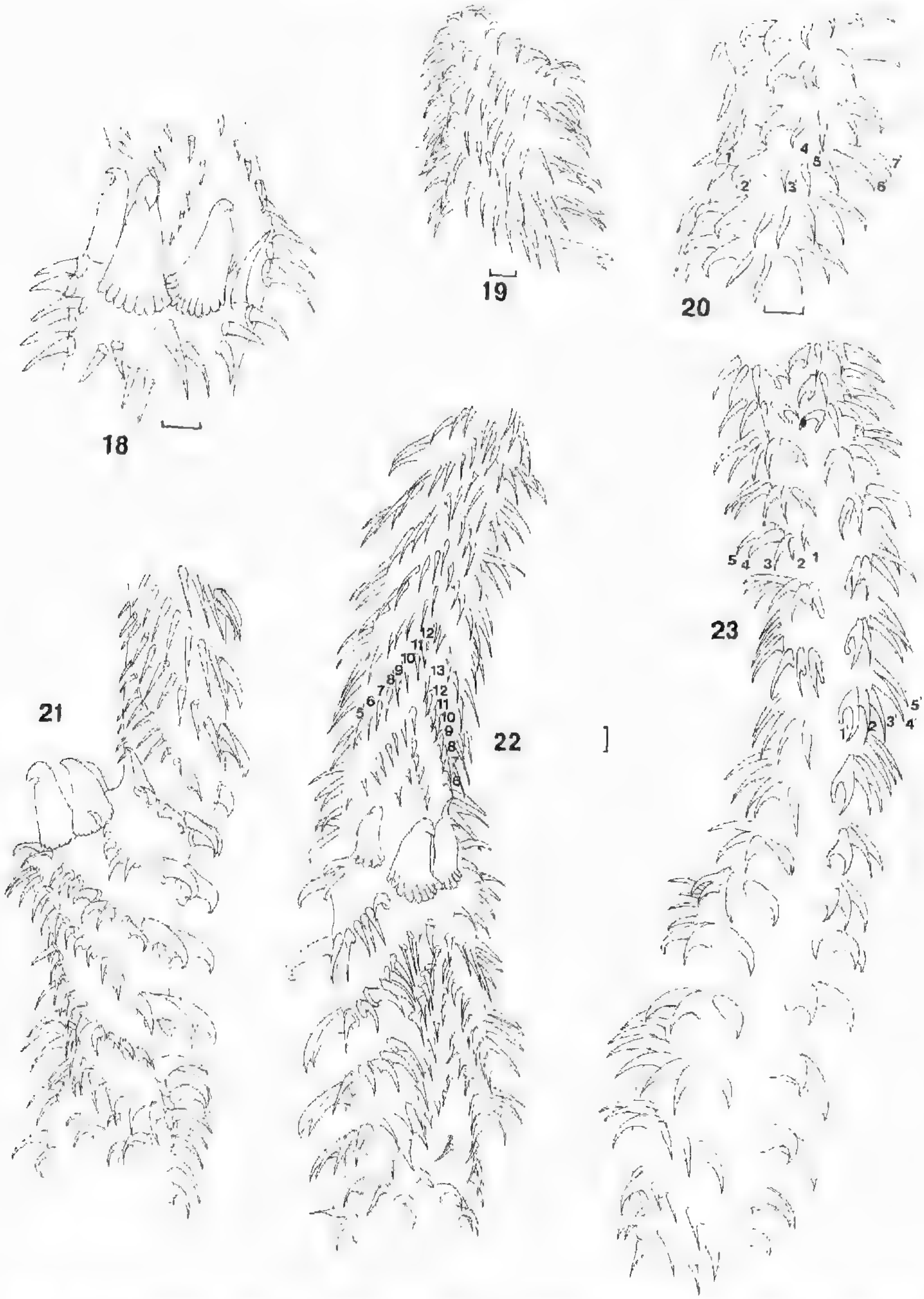
Armature heteroacanthous, heteromorphous, typical; hooks solid. Metabasal armature (Figs 19, 20, 22, 23) consists of alternating, ascending, half spiral rows of 12–14 hooks each. Rows begin on internal surface with hooks 1 (1') well separated, ending on external surface in inverted V-formations. Hooks 1 (1') large, falciform, with extended posterior heel; remaining hooks of principal rows straighter, falciform then spiniform, gradually decreasing in size. Hook dimensions in mid-region of tentacle: 1 (1') stout, strongly recurved, with extended heel, 16–32 long, base length 15–20, heel 4–5 long, height 9–23; hooks 2 (2') similar to 1 (1') except straighter and with reduced base, length 19-20, base length 11–12, height 10-11; hooks 3 (3') spiniform, length 15–18, base length 6-8, height 10–11; hooks 4 (4')-9 (9') decreasing in length from 25–20; hooks 10 (10')–14 (14') only 17-18 long.

Basal armature (Figs 21–23) consists of six rows of hooks on basal swelling of tentacle; hooks dissimilar on external and internal faces. Hooks of internal face organised into alternate ascending half spiral rows with hooks 1 (1') widely separated. Rows begin with stout falciform hooks with long posterior heel, oriented transversely; remaining hooks of proximal rows spiniform, gradually decreasing in size as rows continue toward external surface. Smaller spiniform hooks on external face meet in inverted V formations (Fig. 22). Distinct promontory on external face surmounted by triad of large cone-shaped hooks with rounded, festooned bases and recurved points (Fig. 18). Foremost hook of triad largest, length 34–42, base diameter 18–25. Posterolateral hooks of triad unequal; hook adjacent bothridial side larger, length 28–38, base diameter 16–28; hook adjacent to antibothridial face smallest of triad, length 24–28, base diameter 8-12.

Mature segments 1.07–1.27 (1.17 mm) (n=3) long by 150-210 (187) (n=3) wide; terminal segments, 3,12–4,45 (3.67 mm) (n=4) long by 200-400 (300) (n=4) wide, nongravid. Genital pores irregularly alternate, in posterior half of mature segment. Detached gravid segments not present. Cirrus sac pyriform, 60-90 (69) (n=4) by 23–34 (29) (n=4), external seminal vesicle 40–50 (n=2) in diameter, adnate to cirrus sac. Vas deferens coiled, forming loop, extending in medial line posteriorly to level of ovaries. Testes preovarian, ovoid, dimensions 60–70 wide by 20 long, forming two parallel rows. Testes number 105-109 (107) (n=2) per segment; testis distribution, postvaginal, poral 13-15 (n=2); prevaginal, poral 35-39 (n=2), antiporal 54–56 (n=2). Ovary bilobed in dorso-ventral view; lobes subequal, 240-260 (n=2) by 160-220 (n=2). Vagina forms seminal receptacle 80 in diameter. Mehlis' gland well developed, postovarian. Vitelline follicles circumcortical, continuous from anterior to posterior margins of segment.



Figs 15-17. *Trimacracanthus binuncus* (Linton). 15, scolex; 16, terminal segment; 17, entire worm. Scale lines: fig. 17, 1.0 mm; figs 15-16, 0.1mm.



Figs 18–23: *Trimacracanthus binuncus* (Linton). 18, triad of enlarged hooks on external surface of basal swelling; 19, metabasal region, antibothridial surface; 20, metabasal region, internal surface to left; 21, basal armature, bothridial surface; 22, basal and metabasal armature, external surface; 23, basal and metabasal armature, internal surface; note long guards on hooks 1 (1') of metabasal region. Scale line: 0.1 mm.

Discussion

The two species described above possess a combination of characters not found together in other eutetrarhynchid cestodes, in particular, an asymmetrical basal swelling armed with a triad of large hooks and a metabasal armature composed of ascending half-spiral rows of hooks with hooks which diminish in size from the internal to the external surface suggesting that a new genus is needed to accommodate them.

Dollfus (1942) assigned two genera to the Eutetrarhynchidae, namely *Eutetrarhynchus* Pintner, 1913, and *Christianella* Guiart, 1933. He later (1946) added *Diesingella* Guiart, 1931, and *Tetrarhynchobothrium* Diesing, 1850 and created two new genera, *Prochristianella* Dollfus, 1946 and *Parachristianella* Dollfus, 1946 bringing the total number of eutetrarhynchid genera to six. Dollfus (1969) subsequently removed *Tetrarhynchobothrium* from the Eutetrarhynchidae and made it the type genus of a new family, Tetrarhynchobothriidae Dollfus, 1969 which remains monotypic. *Mecistobothrium* Heinz & Dailey, 1974 is a more recent addition to the family Eutetrarhynchidae. Unfortunately *Diesingella* and *Christianella* remain very poorly defined and require a thorough redescription to be properly included in current systematics. *Mecistobothrium* appears, from its description (Heinz & Dailey, 1974), to be very similar to *Renibulbus* Feigenbaum, 1975, originally placed in its own family, Renibulbidae (Feigenbaum, 1975). Subsequently, *Renibulbus* was placed as a synonym of *Eutetrarhynchus* along with *Tetrarhynchobothrium* by Schmidt (1986). Schmidt (1986) also added *Oncomegas* Dollfus, 1929 to the family.

Limits of the genera, *Eutetrarhynchus*, *Prochristianella* and *Parachristianella* are not clear and this has resulted in confusion in the allocation of species to genera. In defining the genus *Prochristianella*, Dollfus (1946) emphasized two principal characters; the increase and subsequent decrease in metabasal hook size from internal to external surfaces in *Prochristianella* compared with a decline in hook size in *Parachristianella*; and the presence of a tentacular basal swelling with a characteristic armature in *Prochristianella* but not in *Parachristianella*. He placed two species in *Prochristianella*, the type species, *P. trygonicola* with a heteromorphous metabasal armature and *P. tenuispine* (Linton, 1890) with a homeomorphous armature. Dollfus (1946) defined *Parachristianella* as having a decrease in hook size from internal to external surface and lacking a basal swelling of the tentacle. Subsequently, Kruse (1959) added two new species to the genus which conformed closely with Dollfus' definition. Yamaguti (1959), however, ignored the nature of the metabasal armature in his key to genera of the family relying instead on the presence of a basal swelling and it is evident from the literature that some workers have followed Yamaguti's key rather than Dollfus' original diagnosis. Of specific concern here is Robinson's (1959) description of *Prochristianella aetobatis* from New Zealand which combines the metabasal armature of *Parachristianella* with the basal armature on a tentacular basal swelling like *Prochristianella*. Following the key of Yamaguti (1959), Robinson (1959) placed the species in *Prochristianella* but with some hesitation, as museum records show he had originally considered using a new generic name for the species, *Trimacracanthus*. We consider that the two species described above fit neither *Prochristianella* nor *Parachristianella*, and that a new genus is required to accommodate them, for which we propose to use the name initially suggested by Robinson in notes attached to the type specimens.

Distinctive characters of the new genus *Trimacracanthus* are the combination of a metabasal armature similar to *Parachristianella* but with a prominent, asymmetrical tentacular basal swelling bearing a distinctive armature including the presence of a triad of enlarged hooks. The two species placed in the new genus are *T. aetobatidis* and *T. binuncus*. *T. binuncus* was originally described by Linton (1909) and regarded by Yamaguti (1959) and Schmidt (1986) as *incertae sedis*. The syntypes of *Rhynchobothrium binuncum* (USNM 9010) were examined and the oncotaxy and anatomical features were found to be very similar to but distinct from those of *T. aetobatidis*. Both species possess a metabasal armature of the typical heteracanthous type in which the hook sizes begin with very large hooks then decrease in size towards the external surface. Also, both species have a pronounced asymmetrical basal swelling with a distinct basal armature. There are three cone-shaped hooks on the external face of the basal armature in both species. *T. aetobatidis* may be distinguished from *T. binuncus* by the following features: number of hooks per principal row at mid-tentacle (10–11 versus 12–14); hooks 1 (1') in the principal rows lack an extended posterior heel in *T. aetobatidis* but a heel is pronounced in *T. binuncus*; a sharp transition in hook size on the external face (*T. aetobatidis*) versus a gradual decrease in hook size (*T. binuncus*); testis number per segment (68–85 in *T. aetobatis* versus 105–109 in *T. binuncus*); number of segments (15 versus 6); nonspinous scolex and strobila of *T. aetobatidis* versus a spinous condition in *T. binuncus*, and presence of a short pars postbulbosa in *T. aetobatidis* which *T. binuncus* lacks.

Robinson (1959) used two names, *P. aetobatis* and *P. aetobatidis*, in his description of the species. As the host genus is *Aetobatus*, we assume that *P. aetobatis* is a typographical error, and have adopted the name *aetobatidis*.

Southwell (1929) reported a single specimen of *R. binuncum* (as *Tentacularia binunca*) from *Dasybatus*? *walga* from the "Ceylon Pearl Banks", and reproduced Linton's (1909) figures of the species. The whereabouts of Southwell's specimen is not known, and hence its identity cannot be ascertained.

Acknowledgments

Thanks are due to B. G. Robertson, R. R. Martin and M. G. O'Callaghan for collecting specimens and to J. R. Lichtenfels (USNMHC) and R. L. Palma (NMNZ) for the loan of type specimens. This study was supported financially by the Australian Biological Resources Study.

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TRANSACTIONS OF THE

ROYAL SOCIETY OF SOUTH AUSTRALIA

INCORPORATED

VOL. 111, PART 4

CHANGES IN SALINITY AND IN THE DISTRIBUTION OF MACROPHYTES, MACROBENTHOS AND FISH IN THE COORONG LAGOONS, SOUTH AUSTRALIA, FOLLOWING A PERIOD OF RIVER MURRAY FLOW

*BY M. C. GEDDES**

Summary

This study was carried out to investigate the effects of the above average flow in the River Murray in 1983-84 on the salinity and the distribution of the biota in the Coorong Lagoons. Salinities fell only slightly in 1983, but by mid 1984 salinities had fallen significantly to be brackish (< 30°/oo) in the North Lagoon and moderately hypersaline (55-70°/oo) in the South Lagoon. The biology and distribution of the biota showed changes that correlated with the freshening of the Coorong. *Ruppia megacarpa* flowered profusely in the North Lagoon in October 1983, and *R. tuberosa* grew extensively in the South Lagoon in 1984. The "estuarine-lagoonal" macroinvertebrate fauna in the North Lagoon extended its distribution to the southern extent of that lagoon; the species richness remained low with only two previously unrecorded species being collected. None of the typically estuarine-lagoonal macroinvertebrates occurred in the South Lagoon within the study period, although salinities were generally within their tolerance range in winter-spring 1984. Some freshwater fish occurred in the North Lagoon and *Aldrichetta forsteri* and *Acanthopagrus butcheri* (estuarine-marine species) moved into the South Lagoon for a brief period in spring 1984.

KEY WORDS: Coorong Lagoons, salinity, macroinvertebrates, fish, *Ruppia.*

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Summary

GEDDES, M. C. (1987) Changes in salinity and in the distribution of macrophytes, macrobenthos and fish in the Coorong Lagoons, South Australia, following a period of River Murray flow. *Trans. R. Soc. S. Aust.* 111(4), 173-181, 30 November, 1987.

This study was carried out to investigate the effects of the above average flow in the River Murray in 1983-84 on the salinity and the distribution of the biota in the Coorong Lagoons. Salinities fell only slightly in 1983, but by mid 1984 salinities had fallen significantly to be brackish (<30‰) in the North Lagoon and moderately hypersaline (55-70‰) in the South Lagoon. The biology and distribution of the biota showed changes that correlated with the freshening of the Coorong. *Ruppia megacarpa* flowered profusely in the North Lagoon in October 1983, and *R. tuberosa* grew extensively in the South Lagoon in 1984. The "estuarine-lagoonal" macroinvertebrate fauna in the North Lagoon extended its distribution to the southern extent of that lagoon; the species richness remained low with only two previously unrecorded species being collected. None of the typically estuarine-lagoonal macroinvertebrates occurred in the South Lagoon within the study period, although salinities were generally within their tolerance range in winter–spring 1984. Some freshwater fish occurred in the North Lagoon and *Aldrichetta forsteri* and *Acanthopagrus butcheri* (estuarine-marine species) moved into the South Lagoon for a brief period in spring 1984.

KEY WORDS: Coorong Lagoons, salinity, macroinvertebrates, fish, *Ruppia*.

Introduction

The Coorong is an elongate coastal lagoon system which extends from the mouth of the River Murray some 100 km southeast along the South Australian coast (Fig. 1) and is characterized by a great range of salinity fluctuations (Geddes & Butler 1984). Exchange of water into the Coorong is from the Murray Mouth region at the northern end of the Coorong. Here either sea water from Encounter Bay or fresh water from the River Murray via Lake Alexandrina, can enter the Coorong. The formerly estuarine nature of the Murray Mouth region has been changed by River Murray regulation and by the erection of the River Murray Barrages, a system of low levees and gates (approximately 600 in all) across the outflow from Lake Alexandrina (Fig. 1). At times of low River Murray flow the water entering South Australia is sufficient only to meet abstraction requirements and evaporative losses and at these times the gates of the barrages are shut and the barrages separate fresh water retained in Lake Alexandrina from sea water in the Murray Mouth region. At periods of moderate or high River Murray flow, the gates on the barrages are opened to varying degrees and fresh water flows into the Murray Mouth region and the Coorong. Therefore the flow conditions in the River Murray determine the salinity of the water in the Murray Mouth region which is available for mixing into the Coorong and thus are a major factor controlling salinity in the Coorong Lagoons. The nature and distribution of the biota of the Coorong Lagoons is influenced by salinity (Geddes & Butler 1984; Kangas & Geddes 1984) and so River Murray flow is likely to influence the biology of the Coorong Lagoons.

A previous study of the Coorong (Geddes & Butler 1984; Kangas & Geddes 1984) was undertaken during a 16-month period (December 1981 to March 1983) of no outflow from the barrages. During this time the Coorong's salinities were marine to moderately hypermarine in the North Lagoon (35–50‰) and strongly hypersaline (80-110‰) in the South Lagoon. These conditions greatly restricted the distribution of the marine-derived estuarine-lagoonal fauna in the Coorong. In 1983 and 1984 there were moderate to high flows in the River Murray; the Murray flow year 1983–84 recorded a flow of 8.08 million Ml at Lock 1 compared with the long term median (1949-50 to 1982-83) of 5.96 million Ml. In mid 1983 there began a considerable outflow from the barrages so that the Coorong received diluting flows. This paper describes the changes in the salinity patterns in the Coorong from March 1983 until March 1985 and the effects of these changes on the distributions of macroinvertebrates, fish and macrophytes in the North and South Lagoons.

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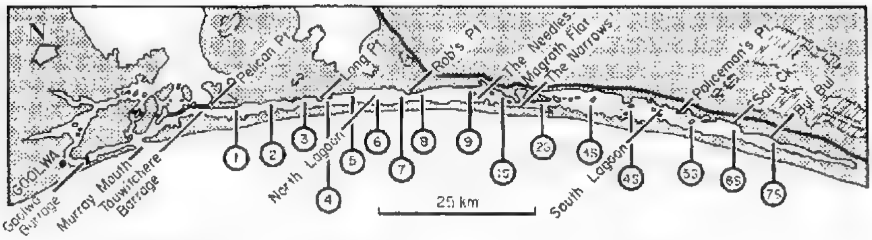
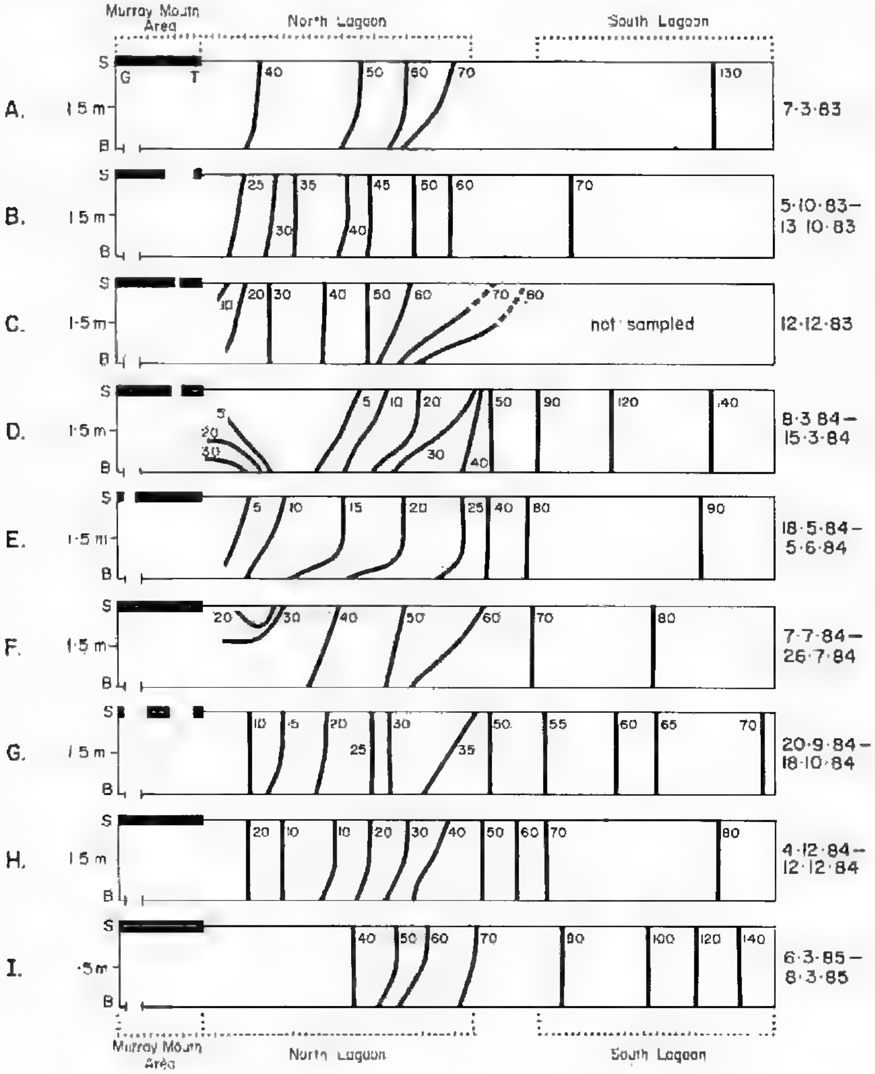

N
GOOLWA
Goolwa Barrage
Murray Mouth
Tauwitchere Barrage
Pelican Pt
Long Pt
Rob's Pt
The Needles
Magrath Flat
The Narrows
Policeman's Pt
Salt Ck
Bul Bul
North Lagoon
South Lagoon
25 km
1
2
3
4
5
6
7
8
9
1S
2S
4S
4S
5S
6S
7S


Murray Mouth Area
North Lagoon
South Lagoon
S
B
G
T
A.
1·5 m
40
50
60
70
130
7·3·83
B.
1·5 m
25
30
35
40
45
50
60
70
5·10·83–
13·10·83
C.
1·5 m
10
20
30
40
50
60
70
80
not sampled
12·12·83
D.
1·5 m
5
20
30
5
10
20
30
40
50
90
120
140
8·3·84–
15·3·84
E.
1·5 m
5
10
15
20
25
40
80
90
18·5·84–
5·6·84
F.
1·5 m
20
30
40
50
60
70
80
7·7·84–
26·7·84
G.
1·5 m
10
15
20
25
30
35
50
55
60
65
70
20·9·84–
18·10·84
H.
1·5 m
20
10
10
20
30
40
50
60
70
80
4·12·84–
12·12·84
I.
·5 m
40
50
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70
80
100
120
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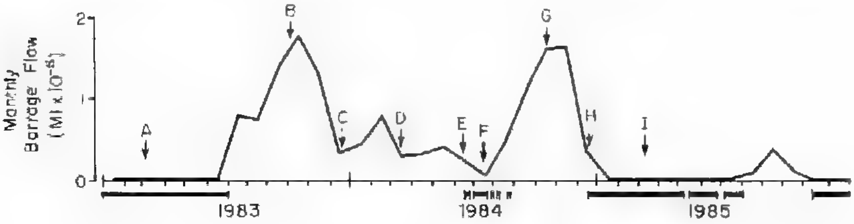
6·3·85–
8·3·85
Murray Mouth Area
North Lagoon
South Lagoon


Monthly Barrage Flow (Ml x 10⁻⁶)
2
1
0
A
B
C
D
E
F
G
H
I
1983
1984
1985

Methods

Eight visits, at approximately three monthly intervals, were made to the North and South Lagoons from October 1983–March 1985. The visits to the two lagoons were generally within two weeks of each other. In the North Lagoon physicochemical measurements and biological samples were taken from the nine stations of Geddes & Butler (1984). The methods for measuring conductivity at 25°C (K_{25}), salinity (measured as total dissolved solids, TDS), chlorophyll, turbidity, Secchi disc transparency (or Secchi depth) and O_2 concentration and for collecting benthic and littoral invertebrates, fish and macrophytes were as in Geddes & Butler (1984). In the South Lagoon K_{25}, TDS and turbidities were measured and benthic and littoral invertebrates were collected from seven stations (Fig. 1). The first of these stations (1S) was at Magrath Flat which is within the constricted region between the North and South Lagoons. The other six were in the South Lagoon from Vila de Yumpa to just north of Tea Tree Point. Additional information on the distribution of chironomids, macrophytes and fish in the South Lagoon were provided by Dr David Paton (Zoology Department, University of Adelaide) and Mr David Hall (Department of Fisheries, South Australia). Data on estimated outflows from the River Murray Barrages and on the patterns of opening and closing of the gates of the barrages were obtained from the Engineering and Water Supply Department, S. Aust.

Results

Physicochemical

Longitudinal and vertical patterns in salinity (TDS) in the North and South Lagoons, estimated outflows from the River Murray Barrages to the Murray Mouth and Coorong, and patterns of opening and closing of the barrages during 1983 and until mid 1985 are shown in Fig. 1. The barrages were closed from December 1981 (see Geddes & Butler 1984) until 1 July 1983. In March 1983 salinities were hypermarine throughout the Coorong ranging from 40‰–130‰ (Fig. 1A). By October 1983 (Fig. 1B), after 3 months of barrage outflow around 1 million Ml per month, salinities had fallen and ranged from 25 to 60‰ in the North Lagoon and were about 70‰ in the South Lagoon. By December (Fig. 1C), after continued good flows, salinities at the northern end of the North Lagoon had fallen slightly while those at the southern end of the North Lagoon had risen. There were considerable vertical salinity gradients at the northern and southern ends of the North Lagoon presumably caused by deeper level incursion of sea water and highly saline South Lagoon water respectively. A major freshening of the North Lagoon occurred between December 1983 and March 1984 (Fig. 1D) with the entire lagoon becoming brackish and the northern half having surface salinities below 5‰. There were sharp vertical salinity gradients as fresher water overlaid denser saline water. Outflows over this period were moderate (approx. 0.3–0.8 million Ml per month) and by March the barrage gates were mostly closed. In the South Lagoon there was a longitudinal salinity gradient from 90–140‰ presumably as a result of high evaporation at the shallow southern extremity and limited longitudinal mixing. By May–June (Fig. 1E), after a continued period of moderate flow (0.3–0.4 million Ml), an even longitudinal gradient from <5–25‰ had developed in the North Lagoon and there was a steep gradient between the two lagoons, although there had been some freshening of the South Lagoon. In June and July monthly outflows were low and sea water moved from the Murray Mouth into the North Lagoon. Furthermore, by July 26 there had been a considerable movement of saline water from the South Lagoon into the North Lagoon (Fig. 1F), presumably as a result of changes in the water levels in the lagoons. This is clearly shown in Fig. 2, where longitudinal salinity patterns show that salinities rose from 24‰ and 41‰ at Stations 9 and 1S on June 5 to 34‰ and 72‰ on June 14. This exchange between the lagoons broke down the steep salinity discontinuity that had existed between them. During August and September of 1984 (Fig. 1G) barrage outflow increased and the North Lagoon showed an even longitudinal salinity gradient from <10–30‰. Exchange from the North Lagoon and seasonal rainfall further freshened the South Lagoon. High outflows (>1.5 million Ml per month) were recorded in October and early November, but by early December all gates on the barrages were closed. This reduced flow allowed seawater to enter the Coorong so that on December 4 (Fig. 1H) the longitudinal salinity pattern in the North Lagoon showed a block of fresher (<10‰)

Fig. 1. Longitudinal and vertical patterns in salinity (TDS ‰) in the North and South Lagoons of the Coorong at 9 sampling times from March 1983 until March 1985 and estimated monthly barrage outflow from the River Murray. The sampling localities in the North Lagoon (1-9), in the constricted region between the lagoons (1S), and in the South Lagoon (2S–7S) are indicated. Closure of the barrages is indicated by the solid horizontal bars in the Murray Mouth region. The degree of opening of the main barrages at Goolwa (G) and Tauwitcherie (T) is indicated by the position and size of the breaks in the bars representing the barrages.

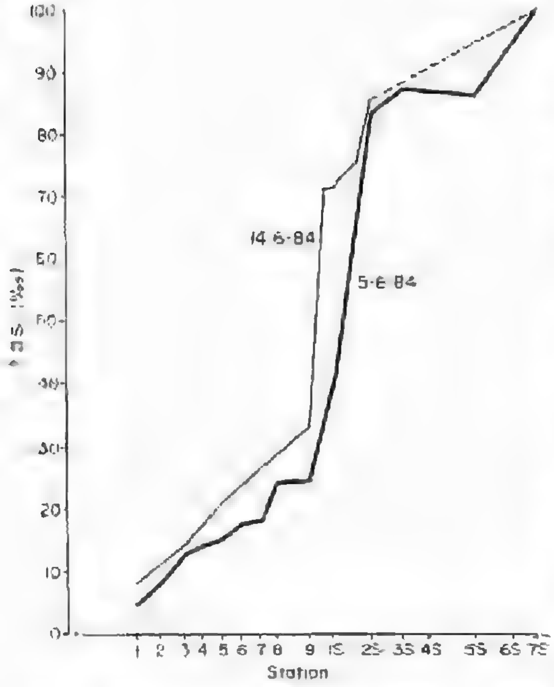


Fig. 2. Longitudinal patterns of surface salinity on 5 and 14 June 1984. Note the sharp gradient between Station 9 and Station 2S and the movement of saline water into the region 2S and 9 on June 14.

water half way down the lagoon bounded by saltier water to the northern and southern ends. All barrages remained closed until the final sampling date in March 1985 (Fig. 1I) by which time salinities in the North Lagoon had risen above 35‰ and those in the South Lagoon to 140‰, so that the salinity pattern for the Coorong was very similar to that in March 1983.

Water temperature in the North Lagoon showed a seasonal pattern from a high of 24°C to a low of 11°C. On calm days a small vertical gradient existed, with surface temperatures up to 1.5°C higher than bottom temperatures. Secchi disc transparencies were high (up to 2.2 m) at the northerly stations in the period of no flow in March 1983 and then fell to around 0.5 m in October. Subsequently, they fluctuated generally between 0.5 and 1.5 m with no apparent pattern, probably reflecting local wind-driven turbulence. In the South Lagoon Secchi disc transparencies were lower varying between 0.3 and 0.7 m.

Biological

Chlorophyll *a* levels in the North Lagoon showed a longitudinal increase from Station 1 to 9 in March 1983. Diatoms, along with flagellates at Stations 7 and 9, were the dominant phytoplankters. During the flow period from mid 1983 until late 1984 chlorophyl levels fluctuated usually between 5 and 30 mg m^{-3} but higher levels were recorded at Stations 1 and 3 when *Planktonema lauterbornei* was the dominant phytoplankter (presumably a wash-out from Lake Alexandrina where it is usually abundant (Geddes 1984)). By March 1985 chlorophyll levels were low at Stations 1 and 3, and high at Stations 7 and 9 where flagellates bloomed.

During 1983 and 1984 *Ruppia megacarpa* continued to be the dominant macrophyte in the North Lagoon with *Lepilaena cylindricarpa* also common and *Zostera muelleri* common at the more northerly stations. The *Ruppia* and *Lepilaena* beds were vigorous, extensive and flowering profusely in October 1983 along the length of the North Lagoon, especially from Station 5 southwards. They remained extensive until June 1984 and then died back. They became extensive and vigorous again by December 1984 but no flowering was observed in October or December 1984.

In the South Lagoon *Ruppia tuberosa* was the dominant macrophyte with *Lamprothamnion* sometimes common. Over the period October 1983 until July 1984 small specimens of *Ruppia* were observed in restricted areas. By September 1984 extensive beds of *Ruppia* occurred throughout the South Lagoon. These were probably produced from seeds that germinated in the freshening water (D. Paton pers. comm.). In December the northern and middle areas of the South Lagoon were fringed with extensive beds of *Ruppia* growing thickly in the shallows and flowering profusely. *Ruppia* died back during summer as water levels dropped and salinity rose. By April 1985 *Ruppia* was recorded only in the northern half of the Lagoon to Station 6S.

The macroinvertebrates and fish collected in the North Lagoon are listed in Table 1. Most species were collected on most occasions at Stations 1 to 5 where salinities usually ranged from 5–45‰, although some species including the polychaete *Australonereis ehlersi*, the gastropod *Salinator fragilis* and the bivalve *Notospisula trigonella*, were much less common than in the earlier study (Geddes & Butler 1984). In March 1984, when salinities fell to 2‰ at Stations 1 and 3 and 5‰ at Station 5, the polychaetes *Ceratonereis aequisetis* (formerly *C. pseudoerythraensis*), *Nephtys australiensis* and *Capitella capitata* were not collected from Station 1 although *C. aequisetis* was present at Station 3 and all three species were present at Station 5. Numerical dominant species that remained in high abundance in the littoral area during the estuarine phase in the North Lagoon were the amphipods *Melita zeylanica*, *Paracorophium* and *Megamphopus*, the

TABLE 1. *Macroinvertebrates and fish collected in hand net and benthic grab samples from the North Lagoon of the Coorong from October 1983 until March 1985.* (Those marked * were not recorded when similar samples were taken in 1982 (Geddes & Butler 1984).)

Fish		*Arenigobius bifrenatus* (Kner)
		Pseudogobius olorum (Sauvage)
		Atherinosoma microstoma (Günther)
		* *Philypnodon grandiceps* (Krefft)
		* *Pseudaphritis urvilli* (Valenciennes)
		* *Nematalosa erebi* (Günther)
Crustaceans	Decapods	*Macrobrachium intermedium* (Stimpson)
	Amphipods	*Melita zeylanica* Stebbing
		Paracorophium cf. *excavatum*
		[1] *Megamphopus/Podoceropsis/Gammaropsis*
	Ostracod	*Osticythere reticulata* Hartmann
Polychaetes		[2] *Ceratonereis aequisetis* (Augener)
		Nephtys australiensis (Fauchald)
		Australonereis ehlersi (Augener)
		* *Prionospio cirrifera* (Wiren)
		Ficopomatis enigmaticus (Fauvel)
		Boccardia chilensis Blake & Woodwick
		Capitella capitata (Fabricius)
		Capitellides spp.
		Fabriciinae
		* Questidae
Gastropods		*Hydrobia buccinoides* (Quoy & Gaimard)
		Salinator fragilis (Lamarck)
		* *Tatea rufilabris* (Adams)
Bivalves		*Notospisula trigonella* (Lamarck)
		Arthritica semen (Menke)
		Soletellina donacioides Reeve
Insects	Chironomid	*Tanytarsus barbitarsis* Freeman
	Ephydrid	*Ephydrella* sp.

[1] This population was identified as *Megamphopus* sp. in Geddes & Butler (1984) and Kangas & Geddes (1984), but is more properly assigned to this multi-genus group, which is in need of revision (J. L. Barnard pers. comm.). *Megamphopus* sp. is used elsewhere in this paper for brevity.

[2] This population was identified as *C. pseudoerythraensis* Hutchings in Geddes & Butler (1984), but has been synonymized with *C. aequisetis* (Augener) (Hutchings & Glassby 1985).

polychaetes *Ceratonereis aequisetis* and *Ficopomatus enigmaticus*, and the gastropod *Hydrobia buccinoides*. The dominants in the benthic samples were *Capitella capitata* and *Paracorophium* with the bivalves *Notospisula trigonella* and *Arthritica semen* and the polychaetes *Nephtys australiensis* and *Prionospio cirrifera* common.

At Stations 7 and 9 high salinities (54–74‰) in March 1983 restricted the fauna so that only *Capitella capitata*, dipterans and the hardyhead *Atherinosoma microstoma* occurred at Station 9, and these plus *Salinator fragilis* and *Hydrobia buccinoides* at Station 7 (Fig. 3). By December 1983 after salinities at Station 7 had fallen below 50‰ in October, *Paracorophium*, *Megamphopus* and *Capitellides* were present and this last was also collected from Station 9. When salinities dropped sharply in March 1984 *Ficopomatus enigmaticus*, the fabriciine polychaetes, *Arthritica semen* and *Pseudogobius olorum* were collected from Station 7, and then *Melita zeylanica*, *Ceratonereis aequisetis* and *Notospisula trigonella* appeared in June and *Prionospio cirrifera*, *Macrobrachium intermedium* and *Tatea rufilabris* appeared later. Thus by October 1984 almost all of the common estuarine-lagoonal species that occur in the Coorong had colonized Station 7. The same pattern occurred at Station 9 except that colonization was generally later and *Melita zeylanica*, *Tatea rufilabris* and *Macrobrachium intermedium* were not found. When salinities rose from December 1984 to March 1985 many species disappeared from Stations 7 and 9 (Fig. 3).

None of the common estuarine-lagoonal invertebrates of the North Lagoon were collected from the South Lagoon. Here, the macroinvertebrate fauna was very restricted, comprising only the chironomid *Tanytarsus barbitarsis*, the ephydrid *Ephydrella*, other dipteran larvae, the isopod *Haloniscus searlei* and ostracods including *Diacypris compacta*.

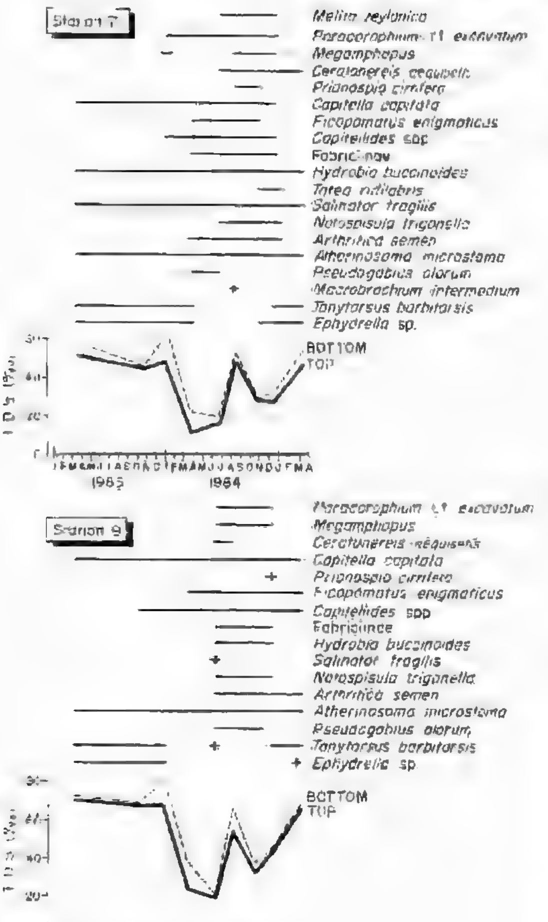


Fig. 3. Surface and bottom salinities (TDS ‰) and the occurrence of macroinvertebrates and fish at Stations 7 and 9 in the North Lagoon from March 1983 to March 1985.

Tanytarsus barbitarsis was easily the dominant littoral and benthic animal and it occurred throughout the South Lagoon on most occasions although with high salinities in March 1984 (Fig. 4) and March and April 1985 (Fig. 4) it did not occur at Stations 6S or 7S. At Stations 2S to 5S the abundance of *T. barbitarsis* was seasonal with highest numbers in summer (D. Paton pers. comm.).

Six fish species were collected in the North Lagoon (Table 1). The small mouthed hardyhead, *Atherinosoma microstoma*, and the blue spot goby, *Pseudogobius olorum*, were the ones most commonly collected by hand net. *A. microstoma* was distributed throughout the North Lagoon while *P. olorum* was restricted to more northerly areas until mid 1984 when salinities fell (Fig. 3). The other four species were collected only occasionally.

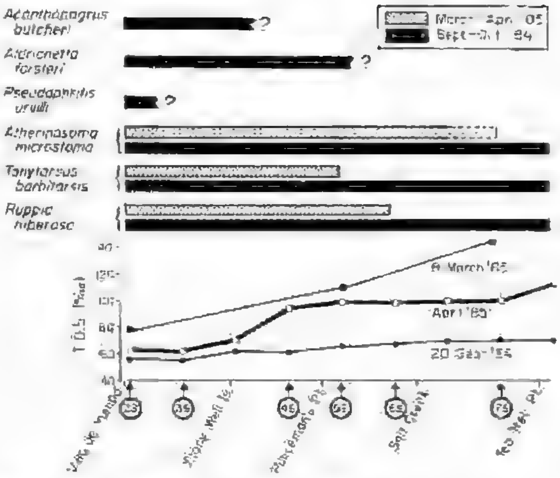


Fig. 4. Longitudinal salinity profiles and the distribution of biota in the South Lagoon during a low salinity period in spring (September–October) 1984 and a high salinity period in autumn (March–April) 1985.

A much more complete fish sampling program was conducted in the North Lagoon of the Coorong during 1984 by David Hall of the S. Aust. Dept of Fisheries. The common species in his catches, along with those in the present study comprise a complete list of the common fish occurring in the Coorong in 1984 (Table 2). They include freshwater species presumably washed in with the River Murray flow, marine species that use the Coorong as a nursery-growing area, and species that generally complete their life cycles in the estuarine-lagoonal system.

The hardyhead, *A. microstoma*, was the only fish that persisted in the South Lagoon. Hardyheads occurred in large numbers throughout the South Lagoon in winter, spring and early summer. Increasing salinities in late summer and autumn restricted their southerly distribution so that only a few specimens were collected at Station 7S in March 1985 when the salinity was 149‰, and they were still rare in April 1985 when the salinity had fallen to 100‰ (Fig. 4). In late winter and spring 1984 when salinities fell as low as 55‰, congolli (*Pseudaphritis urvilli*), black bream (*Acanthopagrus butcheri*) and yellow-eye mullet (*Aldrichetta forsteri*) also occurred in the South Lagoon (Fig. 4). Yellow-eye mullet and black bream were caught by professional fishermen in the northern section of the South Lagoon in August, September and October 1984 and recreational catches of mullet were recorded as far south as Salt Creek (D. Hall pers. comm.). No catches of congolli, black bream or yellow-eye mullet were recorded in July or November when TDS was around or above 70‰.

Discussion

The high River Murray outflows from July-November 1983 had little immediate impact on the salinities in the North and South Lagoons. In December 1983 salinities were as high as 60‰ at the south end of the North Lagoon and above 80‰ in the South Lagoon. The major drop in salinities in the North Lagoon occurred between December 1983 and March 1984, resulting in salinities below 30‰ throughout the lagoon. During this period outflows from the barrages were moderate. Thus mixing of fresh water southwards in the Coorong is not simply controlled by River Murray flow but other factors such as sea levels, lagoon levels, wind direction and evaporation are probably involved (Noye 1975). Freshening of the South Lagoon occurred in the latter half of 1984 so that in September-October salinities were 50-70‰. These salinities were still well above those recorded in November 1975 (30-40‰) following a period of very heavy River Murray flow in 1973 and up to 1975 (Geddes & Butler 1984).

The River Murray flow produced significant effects upon the *Ruppia* populations in 1983 and 1984. In the North Lagoon, *Ruppia megacarpa*, a species which usually reproduces vegetatively and sets little seed (Brock 1982), flowered profusely in October 1983 after the first heavy outflows from the River Murray and the slight fall in salinity. In the South Lagoon, *Ruppia tuberosa* became abundant in 1984 and thick and extensive beds of flowering plants were observed in October-December 1984. This followed a drop in salinity to 55-70‰ along the South Lagoon in September 1984. This abundance of *R. tuberosa* contrasted with its scarcity during 1982, when salinities were generally above 90‰ (Geddes & Butler 1984), and supports observations made by others (Delroy *et al.* 1965[1]; Womersley 1975; Paton 1982[2]) that growth of *R. tuberosa* is inhibited at salinities above twice seawater.

The minor dilution of the North Lagoon during 1983 did not produce any changes in the distribution of macroinvertebrates. However, with the marked salinity fall in March 1984, most species extended their distributions southwards although there was a lag period with most species not occurring at the most southerly station until June. No members of the estuarine-lagoonal macroinvertebrate fauna were collected in the South Lagoon although salinities there were within their tolerance limits in September-October 1984. Presumably longer periods at moderate salinity are necessary for the establishment of the estuarine-lagoonal fauna in the South Lagoon. The "salt lake" association of dipterans, ostracods, *Haloniscus searlei* and *Atherinosoma microstoma* persisted in the South Lagoon throughout 1983 and 1984.

The more estuarine conditions in 1983-84 did not see any significant increase in the number of species of macroinvertebrates in the North Lagoon. Only one further polychaete, *Prionospio cirrifera*, and one further gastropod, *Tatea rufilabris*, were collected. *Prionospio* sp. is a commonly encountered polychaete in the Leschenault and Peel-Harvey estuaries in south-western Australia (E. P. Hodgkin pers. comm.) and *Prionospio cirrifera* is common in many estuaries on the south east Australian coast, especially where there is considerable freshwater input or eutrophication (Rainer & Fitzhardinge 1981; Collett *et al.* 1984). *Tatea rufilabris* is a hydrobiid found in southern Australian estuaries (Ponder pers. comm.). Thus, even during periods of River Murray flow and moderate salinities, the number of species in the Coorong (23 species of macroinvertebrates) was much lower than those recorded in some other Australian estuaries (Rainer & Fitzhardinge 1981; Geddes & Butler 1984).

River Murray flow and the changed salinity pattern brought about changes in the fish fauna and the distributions of particular species. The freshwater species, *Cyprinus carpio, Nematalosa erebi* and *Philypnodon grandiceps*, occurred in the North Lagoon along with the marine and estuarine fish. The three freshwater species presumably were washed in with the River Murray flow, but large populations of *N. erebi* persisted along the entire length of the North Lagoon for considerable periods in 1983-84. Three species previously restricted to the North Lagoon, *Pseudaphritis urvilli, Acanthopagrus butcheri*, and *Aldrichetta forsteri*, entered the South Lagoon for a brief period in August-October 1984 when salinities were below 70‰. The distributions of these commercial fishes seem to respond rapidly to the establishment of favourable salinities, although catch per unit effort data suggest that only small numbers of fish were present (D. Hall pers. comm.).

The fish fauna of the Coorong, like that of the invertebrates, is very restricted compared to that in other estuaries (Pollard 1984). This is mostly due to the minor representation of marine fish in the Coorong. Of the 17 common species (Table 2), only five are marine species that use the Coorong

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[1] Delroy, L. B., Macrow, P. M. & Sorrell, J. B. (1965) The food of waterfowl (Anatidae) in salt water habitats of South Australia. Unpublished report of Fisheries and Fauna Conservation Department of South Australia.

[2] Paton, P. (1982) Biota of the Coorong. South Australian Department of Environment and Planning, Nov. 1982. S.A.D.E.P. 55 (unpublished).

TABLE 2. *Common fish in the North Lagoon of the Coorong during 1984. Species are grouped according to their habitat as follows: estuarine — can complete lifecycle in the Coorong; marine — generally reproduce at sea; freshwater — generally reproduce in fresh water.*

Family	Species name	Common name
ESTUARINE		
Atherinidae	[1] *Atherinosoma microstoma* (Günther)*	Small mouthed hardyhead
Gobiidae	*Pseudogobius olorum* (Sauvage) *Arenogobius bifrenatus* (Kner) *Callogobius mucosus* (Günther)	Blue-spot goby Bridled goby Sculptured goby
Bovichyidae	[1] *Pseudophritis urvilli* (Valenciennes)*	Congolli
Sparidae	*Acanthopagrus butcheri* (Munro)	Black bream
Bothidae	*Rhombosolea tapirina* (Günther)	Greenback flounder
Hemiramphidae	*Hyporhamphus regularus* (Günther)	River garfish
Engraulidae	[2] *Engraulis australis* (Shaw)	Southern anchovy
MARINE		
Sciaenidae	*Argyosomus hololepidotus* (Lacépède)	Mulloway
Mugilidae	*Aldrichetta forsteri* (Valenciennes)	Yellow-eye mullet
Clupeidae	[3] *Sardinops neopilchardus* (Steindachner)	Australian pilchard
Galaxiidae	[4] *Galaxias maculatus* (Jenyns)	Common galaxias
FRESHWATER		
Clupeidae	*Nematalosa erebi* (Günther)	Bony bream
Eleotridae	*Philypnodon grandiceps* (Krefft)	Big-headed gudgeon
Cyprinidae	*Cyprinus carpio* (Linneaus)	European carp

[1] These species can breed in fresh water (Lloyd unpublished).

[2] Breeds in estuaries as far as is known.

[3] Breeds at sea as far as is known.

[4] Breeds in estuaries but larvae then spend time at sea before returning to estuary of fresh water (Pollard 1971).

lagoons as a nursery-growing area, while there are perhaps nine species that are resident within the system. A similar, but not so severe, restriction of usage by marine species has been noted for the Peel-Harvey system (Potter *et al.* 1983) and the Swan-Avon estuary (Prince & Potter 1983) in Western Australia. These authors suggest that the presence of a narrow channel and of extensive peripheral bays within the estuaries, make these systems conducive to an estuarine mode of life. Conversely these same factors make it difficult for marine fish to move in and out of the estuaries. The extreme salinity fluctuations in the Coorong may also limit fish diversity.

Hypersalinity can be a major factor limiting fish distribution within estuarine-lagoonal systems. Only six fish species occurred in Hamelin Pool, the hypersaline (~54‰) region of Shark Bay (Lenanton 1977), and while most species in South African estuaries-lagoons could tolerate salinities up to 55‰, only a few could tolerate salinities up to 70‰ (Hill 1981). A similar dimunition of fish fauna between 55 and 70‰ appears to occur in the Coorong. The most tolerant species in the Shark Bay and South African studies included members of the Atherinidae, the Mugilidae and the Sparidae, families which also include the most salt tolerant species in the Coorong. Considering the effects of salinity on the distributions of fishes within the Coorong, it appears that under the present hydrological and salinity regimes the fish faunas will sometimes be restricted in the southern end of the North Lagoon and on most occasions only the highly tolerant *Atherinosoma microstoma* will occur in the South Lagoon.

The effects of the River Murray flow of 1983–84 on salinity patterns and the distribution of biota in the Coorong were short-lived. Following the barrage closure in December 1984, salinities quickly rose to 36–70‰ in the North Lagoon and 80–140‰ in the South Lagoon by March 1985. This is an almost identical salinity pattern to that of March 1983 after a period of extended barrage closure. It seems that consistently high River Murray flows are needed to maintain an estuarine-marine situation in the North Lagoon and moderately hypermarine conditions in the South Lagoon of the Coorong.

Acknowledgments

Thanks to Helen Vanderwoude, David Paton, Greg Powell and Julie Francis for help in the field and the laboratory and the following people for identifying specimens; Pat Hutchings (polychaetes), Jerry Barnard (amphipods), Winston Ponder (gastropods) and Lance Lloyd and David Hall (fish). David Paton and David Hall also allowed access to unpublished data. The Engineering and Water Supply Department provided unpublished data on outflow from the River Murray Barrages and the South Australian Fisheries Department provided data on fish species and distribution. Thanks to Sandra Lawson for typing the manuscript, to Ruth Evans for the artwork and to the Zoology Department, University of Adelaide for support.

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SALINA BED INSTABILITY AND GEODETIC STUDIES AT LAKE EYRE, SOUTH AUSTRALIA

by J. A. DULHUNTY*

Summary

DULHUNTY, J. A. (1987) Salina bed instability and geodetic studies at Lake Eyre, South Australia. *Trans. R. Soc. S. Aust.* **111**(4), 183-188, 30 November, 1987.

Horizontal compressional forces in saltcrusts of Lake Eyre cause fracturing with overthrusting in thin crusts of marginal areas, and warping or buckling in central areas where crusts are thicker and stronger. Unconsolidated Holocene sediments adjust by deformation to warping of overlying saltcrusts and the true equilibrium level of the lakebed surface is elevated or depressed. When the lake is filled saltcrusts are dissolved and deforming pressures are released, allowing the surface of the sediments to return towards equilibrium level under gravity. Claims that any one place, in any one bay, is the lowest place in Australia, are doubtful. A more appropriate concept may be that the lowest landsurfaces on the Australian continent are in the southern bays of Lake Eyre North.

KEY WORDS: Lake Eyre, saltcrusts, lateral forces, overthrusting, warping.

Introduction

Lake Eyre is a large arid ephemeral terminal lake (Johns 1955; Bonython 1955, 1956; Dulhunty R. 1975, 1984, 1986; Dulhunty J. A. 1977, 1978, 1982; Allan *et al.* 1986; Callen & Wells 1986). It is the sump of an internal drainage basin, consisting mostly of semiarid and arid country covering almost one sixth of the Australian continent. River courses draining the Lake Eyre Basin seldom carry flowing water as far as the lake, as it is mostly lost to evaporation in desert country of low relief through which it must pass. Small amounts of water which do reach the lake, at intervals of 2 to 3 years, cover only parts of the bed and usually dry up in less than one year. Infrequent major fillings, once in 25 to 50 years, cover the whole of the bed to depths of 5 to 10 m, and may require 4 to 6 years to dry up (Bye *et al.* 1978; Dulhuntry R. 1984; Allan 1985).

Lake Eyre lies in the most arid region of Australia, with an average annual rainfall of less than 127 mm, maximum summer temperatures up to 61°C (Price 1955), and an annual evaporation rate of about 2.5 m (Bonython 1955; Penman 1955).

The purpose of this paper is to record evidence of lakebed instability or warping of saltcrusts and deformation of Holocene sediments in the salina area of Lake Eyre North, and its significance in geodetic studies and the concept of the lowest place on the Australian continent.

Saltcrusts

Saltcrusts up to about 50 cm in thickness occur in the three southern bays of Lake Eyre North, where final evaporation of brines takes place. The salt has been transported into Lake Eyre, dissolved in riverwater and groundwater, after the lake became terminal following the onset of late Pleistocene aridity which has persisted through Holocene to the present day (Bowler 1978; Dulhunty J. A. 1982). When sufficient water enters the salina area during major fillings, pre-existing saltcrusts are dissolved; new sediments are deposited, and finally, with evaporation of water, salt is reformed into new crusts (Dulhunty J. A. 1982).

Three generations of saltcrusts have been recorded at Lake Eyre. The first occurred prior to the 1949-50 filling (Madigan 1930); the second occurred between the 1949-50 and 1974 fillings (Dulhunty J. A. 1974; Dulhunty R. 1975; Bonython 1956; Johns 1963), and the third formed after the water of the 1974 filling dried up in about 1979 (Dulhunty R. 1984). In addition to the three recorded crusts, a long series of prehistoric saltcrusts of gradually increasing volume, must have existed between major fillings in late Pleistocene and Holocene times.

In 1972 a survey of saltcrust thicknesses was carried out by Dulhunty over Madigan Gulf and Jackboot and Belt Bays. The publication of results (Dulhunty J. A. 1974) included records of crust thicknesses measured previously in Madigan Gulf by Madigan (1930); Bonython (1956), and the South Australian Geological Survey (Johns 1963). Differences in salt thicknesses measured at different times, in the same places in Madigan Gulf, were also recorded and discussed.

Levelling surveys of the lakebed surface at the base of the saltcrust in Madigan Gulf were made in 1954 by Bonython (1956); in 1969 by the South

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Australian Lands Department (Simmons 1969)[1] and in 1972 by Dulhunty J. A. (1974). The upper surface of the sediments at the base of the saltcrust is regarded as the present stratigraphical surface of the lakebed (Bonython 1956; Dulhunty J. A. 1974). The overlying saltcrusts are removed periodically by solution during major fillings, and when reformed after evaporation of water, they occupy a younger statigraphical horizon. Therefore saltcrusts cannot be regarded as specific strata, or dated as such. Differences in level values of the lakebed surface at different times in the same places over a total period of 18 years emerged from the three above surveys during the life of the one saltcrust.

When results of both lakebed levelling and saltcrust thickness surveys were considered in relation to time and place, it was evident that there had been "normal" changes in thickness which occur as crusts mature, resulting in migration of salt from higher marginal areas to lower central regions of the shallow saucer-shaped bottoms of the bays, as described by Bonython (1956). In addition, however, there appeared to be evidence of another factor which had influenced changes in crust thickness and lakebed surface levels during the life of the crust between the 1949-50 and 1974 fillings. This operated independently of "normal" thickness changes in marginal and central positions. It elevated or depressed relatively small areas of saltcrust and underlying lakebed surface, which lead to thinning or thickening of the crust respectively, by migration of salt as illustrated in Fig. 2.

Lakebed instability

Subsequent research between 1978 and 1983, during the formation of a new saltcrust following the drying up of the 1974 filling, has provided a clearer understanding of the factors involved in what may now be described as lakebed instability.

A series of lakebed profiles based on results of crust thicknesses and lakebed surface levels, has been constructed in Fig. 1 to illustrate lakebed instability within a limited area in the central region of Madigan Gulf. Section 1A of Fig. 1 is a map showing points A to J at which it was possible to compare crust thicknesses and lakebed surface levels at different times during the life of the crust from about 1951 to 1974, between the 1949-50 and 1974 fillings of the lake. Section 1B of Fig. 1 shows two lakebed profiles along the line ABCDEFG with saltcrust thicknesses and lakebed surface levels based on surveys by Bonython (1956) in 1954 when the crust was about 1 year old, and Dulhunty (1974) in 1972 when it was about 19 years old. The differences in forms of the profiles show the amounts of change in lakebed surface levels between the two surveys. Also, crust thicknesses indicated by S values along the profiles show the amounts of change in crust thicknesses which had occurred between the two surveys.

Section 1C of Fig. 1 shows lakebed profiles along the line HD, in 1954 and 1972. Section 1D of Fig. 1 shows three profiles with level values along IHG. Two of these have crust thicknesses indicated by S values based on surveys in 1954 and 1972. The third profile without crust thicknesses in Section 1D, is based on the level survey by the South Australian Lands Department in 1969, during which no crust thicknesses were reported. However, the relatively low level value of this profile in 1969, in relation to the higher values of earlier and later surveys, indicates the complex nature of changes in level values that had occurred between 1954 and 1972.

Where saltcrust and lakebed surface rise over an upward buckle, the crust becomes thinner by transfer of salt to a lower area such as a nearby downward buckle as illustrated in Fig. 2, B and C. Conversely, when the crust and lakebed surface sink over a downward buckle, the crust thickens by transfer of salt from a nearby higher area. As well as thickness changes due to buckling, and superimposed upon them, "normal" transfers of salt from higher marginal areas to lower central areas, take place during the life of the crust. Thus thicknesses in a buckled area are the net result of both factors. In the buckled areas illustrated in Figure 1 there are 8 points at which lakebed surface levels and crust thicknesses were both determined by Bonython in 1954 and Dulhunty in 1972. Of these 8 points, over the period of 18 years, 3 (AB & C) went up and crust thinned and 4 (GHI & J) went down and crust thickened. At only 1 point (D) had the net crust thickness not conformed to thinning with rise and thickening with fall. At this point addition of salt due to some other factor such as migration from marginal to central areas, or a nearby rise on an upward buckle, must have been greater than loss of salt due to rise in lakebed surface level.

It is now concluded that lateral compressional forces, generated in saltcrusts as they mature, are responsible for lakebed instability. Evidence of the operation of horizontal compressional forces in thin and relatively weak saltcrusts up to about 10 cm thick, in marginal areas, is seen in extensive fracturing of the crust with overthrust movement, illustrated by photographs in Fig. 3. The horizontal displacement associated with overthrusting on individual fractures is as much 30 cm in some places, but usually less than 15 cm. There is a great

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[1] Simmons, P. B. (1969) Measurement of test range for laser ARP at Lake Eyre. South Australia Lands Department, Adelaide (unpublished).

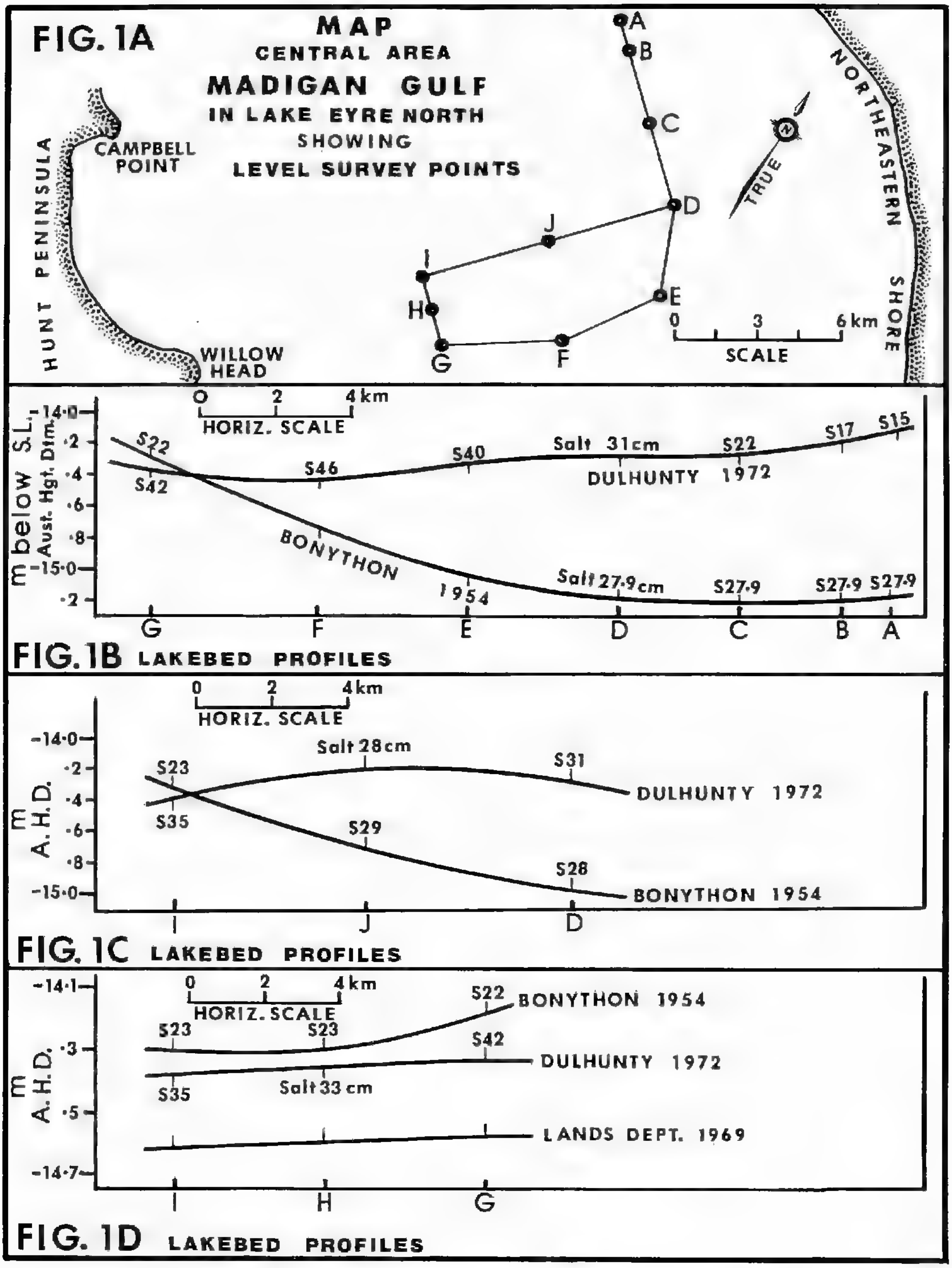

Fig. 1 Lakebed surface profiles and saltcrust thickness along lines in central Madigan Gulf of Lake Eyre North.

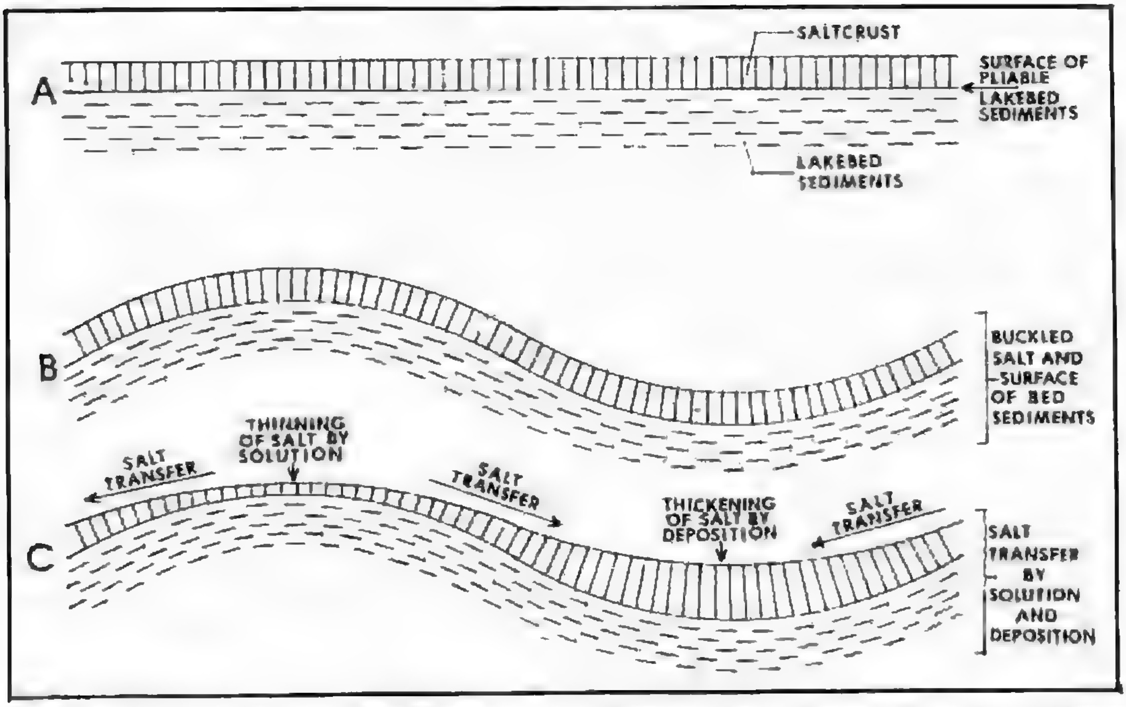

Fig. 2. A — diagrammatic illustration of surface of unconsolidated Holocene sediments beneath saltcrust. B — buckling of saltcrust and underlying sediments by lateral compressional forces. C — salt transfer from higher to lower place by solution and redeposition of salt giving thinning and thickening of crust.

deal of fracturing in all marginal areas surrounding the principal sheets of saltcrust, as well as in small areas formed in washouts which occur in river estuaries and form waterholes after flowing ceases (Wopfner H. 1982, pers. comm).

In central areas of the main saltsheets, where crusts are 30 to 50 cm thick, and stronger, they do not fracture but warp either up or down, above or below the true or equilibrium lakebed surface level under gravity, by as much as 0.5 m. Warping may occur over limited areas up to several kilometres in width. The watery pliable nature of the underlying, unconsolidated Holocene sediments allows adjustment by deformation to the warping of the more rigid saltcrusts, and so the level of the lakebed surface is elevated or depressed.

Fracturing, with up to 10 cm of horizontal overthrust movement, occurs in small isolated areas of crust, from 100 to 300 m across, such as those formed in washouts along river estuaries. This suggests that appreciable amounts of compressional force, or expansion of the crust, are generated throughout both marginal and central regions of the large saltsheets in the southern bays of Lake Eyre North. Also, it suggests that fracturing and buckling in marginal and central regions is due to compressional forces generated within those regions, and not necessarily transmitted long distances from one region to another across the saltsheet.

In addition to well-defined fracturing of thin crusts with overthrust movement, and warping of thick crusts, a polygonal jointing pattern is developed in saltcrusts. Brine rises from groundwater along the cracks to the surface, where it dries and deposits new crystalline salt. If the crust is very thin (less than about 7 cm) new salt may be deposited along cracks beneath the polygons, producing upturned edges around the slabs which vary from about 1 to 4 m in diameter. Where the saltcrust is thicker (10 cm or more) the new salt forms low ridges up to 5 cm high over the cracks, but it is eventually dissolved in rainwater which dries and the salt is added to the pre-existing crust (Madigan 1930; Bonython 1956; Johns 1963).

It has been suggested by Prof. C. C. von der Borch (1986, pers. comm.) that the fracturing, warping and polygonal jointing described in this paper may be analogous to processes which produce "tepee" structures (Assereto & Kendall 1977; Reeves 1970) which commonly occur in expanding supratidal carbonate crusts analogous to expanding halite crusts. This is very probably so, but the actual physical or chemical mechanism in the origin of tepee structures in relatively short-lived salt crusts, is a complex matter well worth further investigation.

FLORICEPS MINACANTHUS SP. NOV. (CESTODA: TRYPANORHYNCHA) FROM AUSTRALIAN FISHES

BY *R. A. CAMPBELL** *& I. BEVERIDGE*†

Summary

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KEY WORDS: *Floriceps,* Trypanorhyncha, new species, Cestoda.

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Floriceps minacanthus sp. nov. is described from adult worms in sharks and from plerocerci obtained from the viscera of teleosts taken in Australian coastal waters off Queensland, New South Wales and South Australia. Selachian hosts are *Carcharhinus brachyurus* (Guenther, 1870) (type host), and *C. amboinensis* (Mueller & Henle, 1841). Plerocerci were obtained from the teleosts *Platycephalus laevigatus* Cuvier, 1829, *Plectropomus ? leopardus* (Lacépède, 1802) and *Sphyraena novaehollandiae* Guenther, 1860. Descriptions of the adult and metacestode stages are provided. Characteristics of both the adult worms and plerocerci are consistent, with the exception that the scolex of adults is more elongated than plerocerci thereby increasing the ratio of bulb length to pars vaginalis. Characters differentiating *F. minacanthus* from other species of *Floriceps* are the shape of principal hooks 1(1'), shorter bulbs (<0.9 mm), ratio of pars bulbosa to pars vaginalis (almost 1:6) and genital pore in posterior ¼ of segment.

KEY WORDS: *Floriceps*, Trypanorhyncha, new species, Cestoda.

Introduction

Species of the trypanorhynch cestode genus *Floriceps* Cuvier, 1817 are common parasites of the spiral valves of sharks in many regions of the world (Dollfus 1942) with the metacestode stages (plerocerci) occurring encapsulated in the viscera of teleosts. The genus has not previously been reported from fish in Australian coastal waters (Beumer *et al.* 1982). Recent cestode collections from sharks and teleosts contain both adults and plerocerci of a new species of *Floriceps* and the description of the new species forms the basis of this paper.

Materials and Methods

Adult cestodes were removed from the spiral valves of sharks and were either killed by relaxing in tap water and fixing in 10% formal saline, or were fixed live with hot 10% formalin. Plerocerci were fixed in 10% formalin or the scoleces were dissected free, the tentacles everted by placing in fresh water, and they were then fixed in formalin or Berland's fluid. Whole mounts were stained with celestine blue, dehydrated in ethanol, cleared in clove oil and mounted in balsam. Tentacles were dissected free from scoleces, and were mounted in glycerine jelly. Measurements are presented in the text in micrometres, unless otherwise stated, as the range followed by the mean in parentheses. The number of measurements made is shown in the form n=. Terminology for trypanorhynch morphology follows that of Dollfus (1942). Specimens have been deposited in the South Australian Museum (SAM), Adelaide, the British Museum (Natural History) (BMNH), London, the United States National Museum Helminth Collection (USNMHC), Washington, and the Australian Helminth Collection (AHC), in SAM.

Floriceps minacanthus sp. nov.
FIGS 1-17

Description: Measurements of eight adult specimens from *Carcharhinus brachyurus* (types). Scolex and strobila slightly craspedote, strobila up to 18.5 cm long, segments hyperapolytic. Scolex length 3550-5950 (4770) (n=8), width at bulbs 800-1470 (1060) (n=8). Two bothridia, heart-shaped, each with small indentation on posterior margin, length 930-1140 (1030) (n=8) by 1300; anterior margins curled toward midline (Fig. 15). Pars vaginalis 2860-5500 (4050) (n=8), tentacle sheaths coiled; gland cells scattered in parenchyma of penduculus scolecis. Bulbs 680-800 (720) (n=8) long, 140-250 (200) (n=8) in diameter; retractor muscle attached near posterior extremity. Pars postbulbosa lacking. Ratio of pars bulbosa to pars vaginalis 1:4.2 to 1:7.3 (1:5.6) (n=8). Metabasal armature poeciloacanthous, with single chainette of V-shaped hooks; no basal armature. Metabasal armature consists of alternating half spiral rows of 7 hooks each; single satellite hook located posterior to seventh hook of each principal row (Fig. 3).

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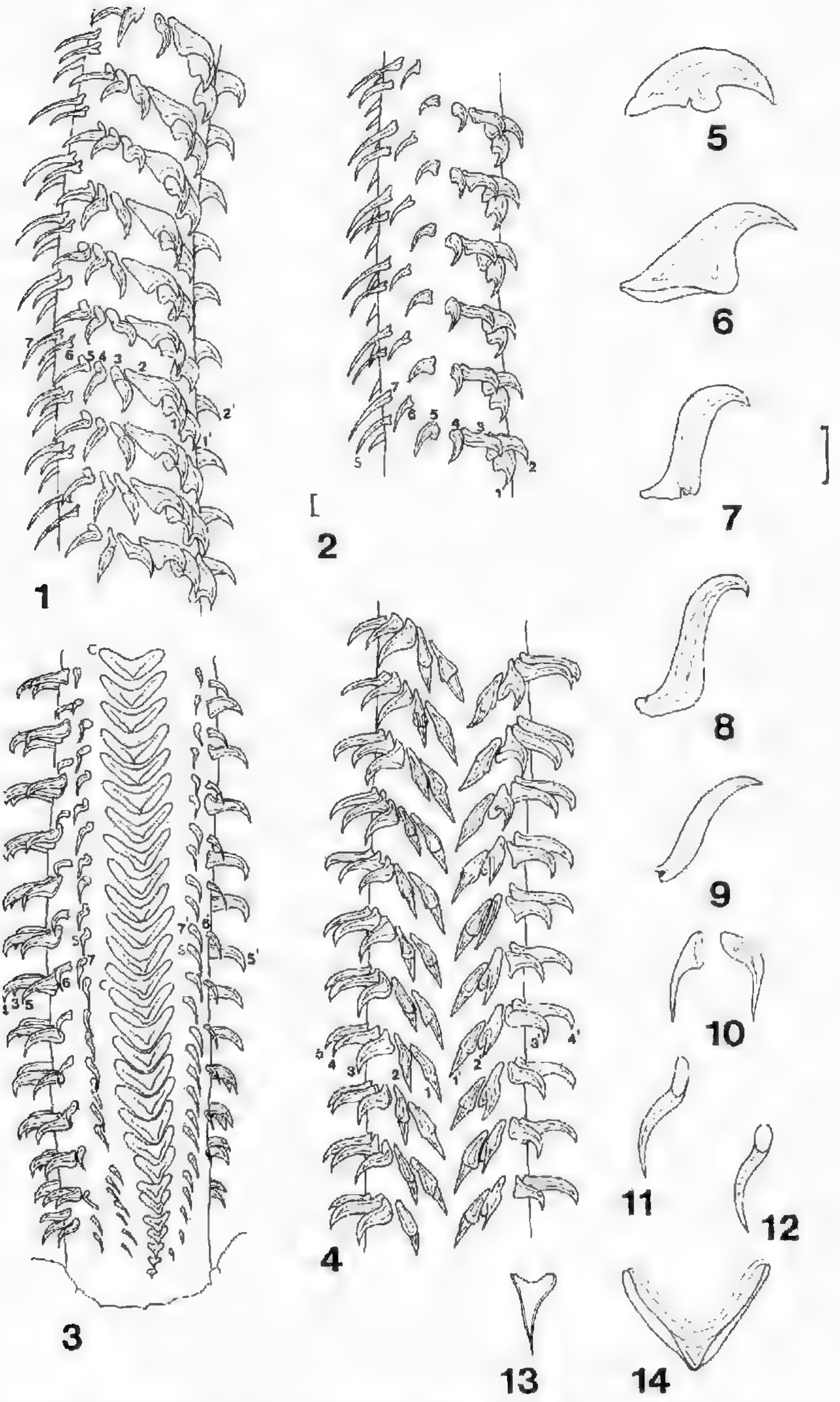


Figs 1–14. *Floriceps minacanthus* sp. nov. 1, 2, metabasal armature, bothridial surface; 3, basal and metabasal armature of tentacle, external surface; 4, metabasal armature, internal surface; 5–11, profiles of hooks 1, 2, 3, 4, 5, 6 and 7 respectively; 12, profile of satellite hook or hook 8; 13, chainette element from mid-tentacular region; 14, chainette element from metabasal region. Scale lines: figs 1–4, 0.1 mm; figs 5–14, 0.01 mm. Legend: bothridial hooks 1, 2 . . . . . . 7; antibothridial hooks 1', 2' . . . . . 7'; satellite hooks S; chainette C.

Hooks hollow; hooks of principal rows and chainette smallest in basal region, reaching maximum size 8 to 10 rows from base, decreasing in size beyond midlength of tentacle. Hooks 1(1') and 2(2') on inner face large, thorn-shaped; 1(1') strongly curved toward tentacle, length 21–30 (28) (n=10), base length 15–20 (19) (n=10), maximum height 10–25 (18) (n=10); hooks 2(2') erect, recurved at tip, length 24–31 (29) (n=10), base 18–20 (19) (n=10), height 15–20 (17). Hooks 3(3') to 7(7') sinuous, becoming spiniform in shape as row reaches external face: 3(3'), length 25–32 (30) (n=10), base length 10–14 (12) (n=10); 4(4') length 22–32 (29) (n=10), base length 8–11 (10) (n=10); 5(5') length 16–24 (22) (n=10), base length 5–8 (7) (n=10); 6(6') spiniform, length 16–22 (20) (n=10), base length 3–6 (5) (n=10); 7(7') spiniform, length 23–30 (28) (n=10), base length 4–6 (5.2) (n=10). Satellite hook (=hooks 8(8')) spiniform, length 18–26 (24) (n=10), base length 5–8 (6) (n=10). Chainette single, consisting of large hooks with basal winglike processes; maximum dimensions at base of tentacle, length 6–10 (8) (n=10) by 12–14 (13) (n=10); in metabasal region, width across wings 24–30 (29) (n=10) by 17.5–20 (18) (n=10). Tentacle diameter, 70–80 (75) (n=4) at base, 20–25 (21) (n=4) at midlength.

Number of segments 69–83 (n=3). Segments appear 6.0–9.5 mm posterior to scolex. First segments wider than long, rapidly becoming longer than wide with maturity. Mature segments 4200–6850 (5070) (n=10) by 1400–1700 (1550) (n=10). Testes medullary, spherical, 50–65 (60) (n=10) in diameter, filling all available space between longitudinal osmoregulatory canals and extremities of segment, including postovarian region. Testes number about 1200 per segment. Genital pores marginal, irregularly alternating, posterior, located 69–79% (73) (n=10) of segment length from anterior margin. Cirrus sac 430–570 (500) (n=10) by 200–300 (240) (n=10), containing internal seminal vesicle. External seminal vesicle absent. Vas deferens coils medially then posteriorly to level of ovary. Vagina posterior to cirrus sac. Ovary bilobed, maximum dimensions 180–260 (190) (n=10) by 200–300 (270) (n=10). Mehlis' gland ventral to ovarian isthmus; c. 50 in diameter. Vitellaria follicular, forming a layer enclosing osmoregulatory canals and reproductive organs. Uterus simple, median, extending about three-fourths of segment length.

Measurements of 7 specimens from *Carcharhinus amboinensis*: Scolex 3250–4500 (3870) (n=7), maximum width 600–1200 (830) (n=6); pars bothridialis 710–960 (870) (n=6); width of bothridia 750; pars vaginalis 2300–3340 (2930) (n=7); bulbs 650–910 (810) (n=6) long by 180–290 (220) (n=6) in diameter; ratio of bulbs to pars vaginalis 1:2.9–1:4.5 (1:3.6) (n=7).

Plerocerci: 28 plerocerci obtained from viscera and body cavity of three species of teleost fishes. Armature and scolex features agree with adult worms from sharks. Three specimens from *Plectropomus* measured: Scolex 3000–3600 (3330) by 830–1380 (1100); bothridial length 930–1040 (970); pars vaginalis 2330–2700 (2520); bulbs 750–840 (800) by 200–250 (230); ratio of bulbs to pars vaginalis 1:2.8 to 1:3.6 (1:3.2); tentacle diameter 70 (base), 40–60 (midlength). Eight plerocerci obtained from *Platycephalus laevigatus*; measurement of 3 specimens with extended tentacles: Scolex 4320–5000 (4680) by 850–1200 (1030); bothridial length 1000–1060 (1040); pars vaginalis 3470–4050 (3740); bulbs 750–830 (800) by 140 to 220 (190); ratio bulbs to pars vaginalis 1:4.2–1:5.4 (1:4.7); tentacle diameter 70 (base), 40 (midlength). Single plerocercus from *Sphyraena novaehollandiae* Guenther, 1860: Scolex 4760; bothridial length 1010; pars vaginalis 3050; bulbs 775–800 by 170–215; ratio bulbs to pars vaginalis 1:3.8; tentacle diameter 78 (base), 60 (midlength).

Hosts and localities: adults: *Carcharhinus brachyurus* (Guenther, 1870) (type host), Tathra, N.S.W. (type locality) (5 specimens); Port Lincoln, S. Aust. (4 specimens). *C. amboinensis* (Mueller & Henle, 1841), St Lawrence, Qld. (7 specimens) (AHC S2652).

Site in host: Spiral valve.

Types: Holotype SAM V4035, 2 paratypes SAM V4036-4037; 2 paratypes USNMHC 79545, 79546; 4 paratypes AHC S2650, S2651.

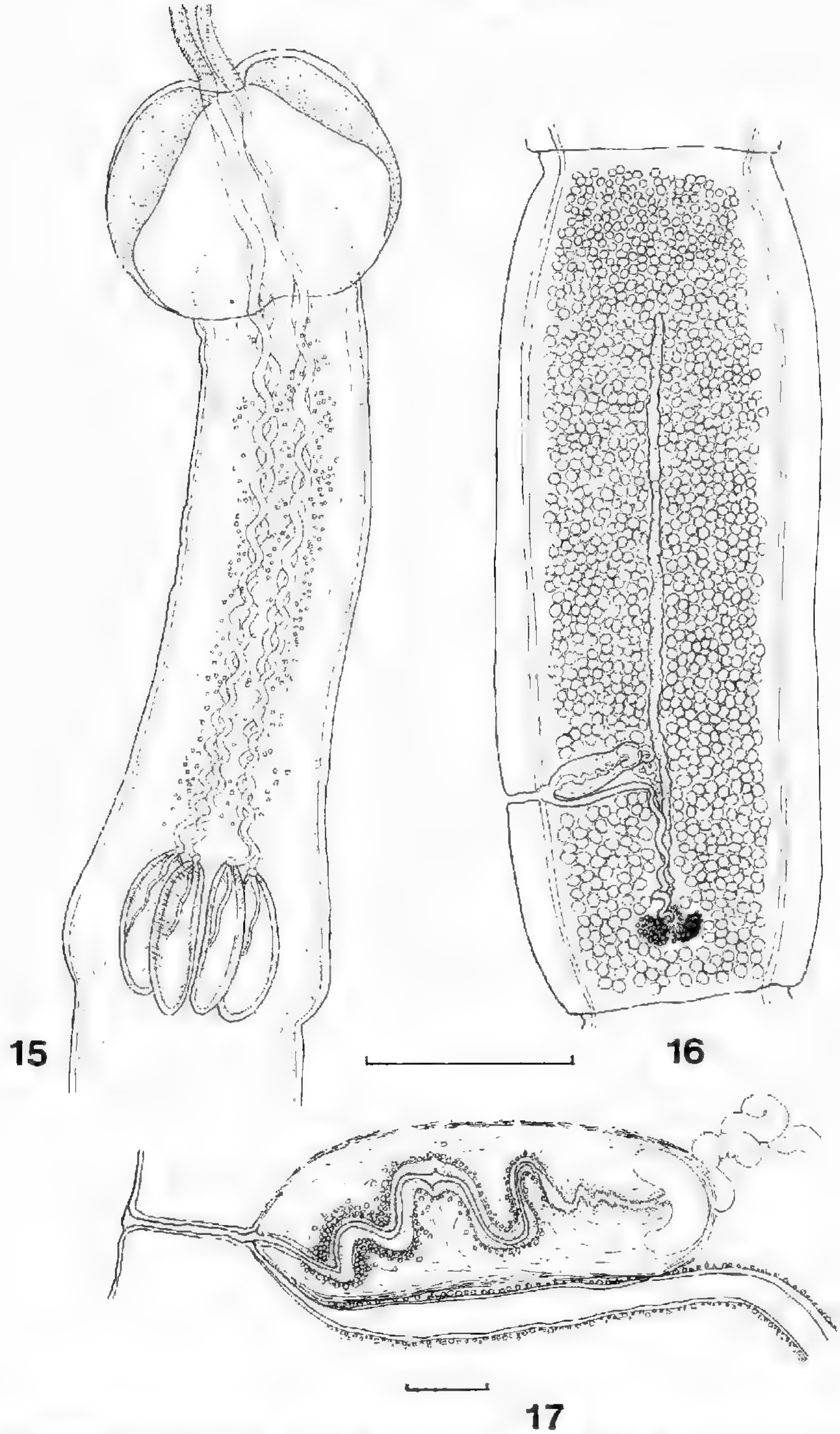
Plerocerci: From *Plectropomus? leopardus* (Lacépède, 1802), Heron Island, Qld (3 specimens) (AHC S2653); *Platycephalus laevigatus* (Cuvier 1829), Northhaven, S. Aust. (8 specimens) (SAM V4038) (BMNH 1986.10.14.2-3); *Platycephalus* sp. from fish shop, Adelaide, S. Aust. (16 specimens) (AHC S2511, 2512, 2513); *Sphyraena novaehollandiae* Guenther, 1860, Northhaven, S. Aust. (1 specimen) (BMNH 1986.10.14.1).

Site in host: serosa of viscera and in body cavity.

Etymology: The specific name is derived from Latin, *minax*, meaning "strongly recurved" and refers to the shape of hooks 1(1').

Discussion

Schmidt (1986) listed four species belonging to the genus *Floriceps*, namely the type species, *F. saccatus* Cuvier, 1817, *F. caballeroi* Cruz-Reyes, 1977, *F. lichiae* Pintner, 1929 and *F. thxneri* Gulart, 1938,



Figs 15-17. *Floriceps minacanthus* sp. nov. 15, scolex; 16, mature proglottis; 17, cirrus sac and distal vagina. Scale lines: figs 15, 16, 1.0 mm; fig. 17, 0.1 mm.

F. saccatus differs from *F. minacnathus* sp. nov. in having hooks 1(1') and 2(2') of the same shape rather than with hooks 1(1') almost recumbent, larger bulbs (3 mm or more in length), pars bulbosa to pars vaginalis ratio of less than 1:3, and bothridia that are more triangular in shape. In contrast hooks 1(1') of *F. minacanthus* is extremely arched and almost recumbent whereas hooks 2(2') stand erect as in *F. saccatus*, the bulbs are short (900 or less), the ratio of pars bulbosa to pars vaginalis averages 1:5.6, and the bothridia are more rounded in shape.

Gland cells within the pedunculus scolecis extend from the bothridia to the anterior end of the bulbs in *F. minacanthus*; while in *F. saccatus* they are either restricted to the anterior part of the pendunculus scolecis (Dollfus 1942, figs 198, 200), or are concentrated in this region (Linton 1924, fig. 1, as *Rhyncobothrium ingens*).

A series of characters present in the mature segment may also serve to separate the two species. Yamaguti (1934) estimated that in *F. saccatus* (as *Dasyrhynchus ingens* (Linton)), 200 testes were present in a single sagittal section, compared with about 1200 per segment found in *F. minacanthus*. Even allowing for several layers of testes in *F. saccatus*, testis number may differ between the two species. In *F. minacanthus*, an internal but not an external seminal vesicle is present (Fig. 17), whereas both Linton (1921) and Yamaguti (1934) describe both vesicles as being present. Linton (1921) has the two vesicles incorrectly labelled in his figures (A and 12), while Yamaguti's figures of the external seminal vesicle are not convincing. This feature of the anatomy of *F. saccatus* should be re-investigated as it may be a further character separating the two species.

All reports of *F. saccatus* in which measurements are given, summarised by Dollfus (1942), agree in having bulbs approximately 3.0 mm long. Subhapradha (1955) however, reported "*F. saccatus*" from *Carcharhinus* sp. from Madras, in which the bulbs were 0.75 mm long and hooks 1(1') are clearly drawn as being recurved (Figs 13b, 14). This specimen is considered to be *F. minacanthus* and considerably extends the geographic range of the new species.

Cruz-Reyes (1977) provided a single view of the armature of *F. caballeroi* and his figure of the chainette (4a) shows hooks quite unlike those of *F. minacanthus*. The correct orientation and detail of the armature of *F. caballeroi* is quite unclear from his description and it needs to be redescribed before any critical assessment of its status can be made. *F. caballeroi* can be distinguished from *F. minacanthus* because the bulbs of *F. caballeroi* are long (3 mm). Cruz-Reyes (1977) described the mature segment of *F. caballeroi* as having the genital pores in the anterior fourth of the segment, the vagina passing anterior to the cirrus sac, the uterus terminating at the level of the cirrus sac and the testes being numerous though few are shown in his drawing (Fig. 5). It is highly unlikely that the mature segment described by Cruz-Reyes (1977), which is in fact a detached segment, is that of a trypanorhynch.

Dollfus (1942; p. 395) noted that *F. lichiae* of Pintner (1929) is very similar to *Molicola horrida* (Goodsir, 1841). This means that Pintner's species possessed four bothridia unlike species of *Floriceps* which have only two (see Pintner 1929). Guiart's (1938) description of *F. oxneri* is very poor, such that it cannot be identified to any specific trypanorhynch family. The two micrographs of the plerocercus show no detail of the bothridia or armature. We consider *F. oxneri* as *incertae sedis*.

Other trypanorhynchs that have been wrongly assigned to *Floriceps* are *F. uncinatus* (Linton, 1924), *F. crassicolle* (Diesing, 1850), *F. elongatus* (Rudolphi, 1819), *F. macrocercus* (Rudolphi, 1819), and *F. granulus* (Rudolphi, 1819). Yamaguti's (1952) description and figures of *F. uncinatus* appear to be a species of *Gymnorhynchus* though he does not list the species in his subsequent synopsis of the trypanorhynchs (1959). According to Dollfus (1942) all of the remainder belong in the Gymnorhynchidae except *F. granulus* which is a synonym of *Lacistorhynchus tenuis* (Beneden, 1858).

The only major difference between adults and plerocerci of *F. minacanthus* is the increase in scolex length of the adult worms as compared to that of the plerocerci. The increased length affects the length of the pars vaginalis and accounts for the difference in the ratios of bulb length to pars vaginalis. However, the bulbs are the same size in both the plerocerci and adults and are the smallest bulbs of any species in the genus *Floriceps*.

The hook numbering system used by Dollfus (1942) for *F. saccatus* has been utilised in the above description. However, the so-called "satellite hooks", which lie immediately posterior to hooks 7(7') in *Floriceps* occur in an exactly analogous position in *Callitetrarhynchus* Pintner, 1931 and *Lacistorhynchus* Pintner, 1913, in which genera they are simply described as hooks 8(8'). There is complete homology between the hook arrangements of the metabasal armature of these three genera, and this homology could be stressed by the utilisation of a uniform system of hook numbering.

Acknowledgments

Thanks are due to B. G. Robertson, D. M. Spratt, R. G. Lester, R. A. Bray, K. L. Gowlett-Holmes and

D. C. Lee for the collection and provision of specimens described in this paper. This work was supported financially by the Australian Biological Resources Survey.

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HORNELLZELLA MACROPORA (SHIPLEY & HORNELL, 1906) COMB. NOV. (CESTODA: TRYPANORHYNCHA) FROM AUSTRALIAN ELASMOBRANCH FISHES AND A RE-ASSESSMENT OF THE FAMILY HORNELLIELLIDAE

BY R. A. CAMPBELL & I. BEVERIDGE†*

Summary

Hornelliella macropora (Shipley & Hornell, 1906) comb. nov. is redescribed from the elasmobranches *Stegostoma fasciatum* and *Chiloscyllium punctatum* from northern Queensland. H. *annandalei* (Hornell, 1912) is considered a synonym of *H. macropora.* The armature is described for the first time and consists of a unique poeciloacanthous type in which large, alternating pairs of hollow hooks form a double chainette on the external surface of the tentacle. The presence of an hermaphroditic vesicle is confirmed and illustrations are provided. The family Hornelliellidae Yamaguti, 1954 is considered justified, based on a combination of the unique features of the armature and the genitalia, and is re-defined.

KEY WORDS: Cestoda, Trypanorhyncha, Hornelliellidae, *Hornelliella,* elasmobranchs.

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KEY WORDS: Cestoda, Trypanorhyncha, Hornelliellidae, *Hornelliella*, elasmobranchs.

Introduction

Yamaguti (1954) erected the genus *Hornelliella* and the family Hornelliellidae for a single species of trypanorhynch cestode, *Tetrarhynchus annandelei* Hornell, 1912 described from a shark, *Stegostoma fasciatum* (Hermann, 1783) (syn. *S. tigrinum* (Gmelin)), from the Bay of Bengal. The new family was distinguished primarily by the presence of a unique structure within the reproductive system, termed an hermaphroditic vesicle, which was not illustrated, and was supported by several minor characters including the distribution of testes and vitellaria. In trypanorhynchan systematics, the tentacular armature is of prime importance (Dollfus 1942), but neither Hornell (1912) nor Yamaguti (1954) described the armature in sufficient detail to determine the taxonomic position of the family. In addition, Southwell (1929) synonymised *T. annandalie* with *Tentacularia macropora* (Shipley & Hornell, 1906), a fact which Yamaguti (1954) either overlooked or ignored. Cestodes of this family have not been reported previously from the Australian region, however, specimens have recently been collected from *Stegostoma fasciatum* and *Chiloscyllium punctatum* off the coast of Queensland. In this paper the species is described in full for the first time, the taxonomic position of the family Hornelliellidae reassessed, and the family re-defined.

Materials and Methods

Cestodes from the spiral valves of sharks were fixed in 10% formalin, and were stained with celestine blue, dehydrated in ethanol, cleared in clove oil and mounted in balsam. Tentacles were dissected free and cleared in glycerol. Measurements are given in micrometres, unless otherwise stated, as the range of 10 measurements followed, in parentheses, by the mean.

Terminology for trypanorhynch morphology follows Dollfus (1942). Specimens have been deposited in the Australian Helminth Collection (AHC) of the South Australian Museum, Adelaide. Southwell's specimens of *Tentacularia macropora* were borrowed from the British Museum (Natural History), London (BMNH).

Hornelliella macropora (Shipley & Hornell, 1906) comb. nov.

FIGS 1-11

Tetrarhynchus annandalei Hornell, 1912

Hornelliella anandalei (Hornell, 1912) Yamaguti, 1954

Tetrarhynchus macroporus Shipley & Hornell, 1906

Tentacularia macropora (Shipley & Hornell, 1906) Southwell, 1929

Description: Cestodes up to 76 mm long, with up to 63 segments in gravid strobilae. Scolex acraspedote, 7.25–11.2 (8.62) mm long, maximum width at bulbs 0.85–1.02 (0.94) mm. Two bothridia, 1.7–2.6 (2.09) mm by 1.36, 1.38 mm, oval or slightly dumb-bell shaped, notched posteriorly, rim broad, median ridge within each bothridial cavity. Pars

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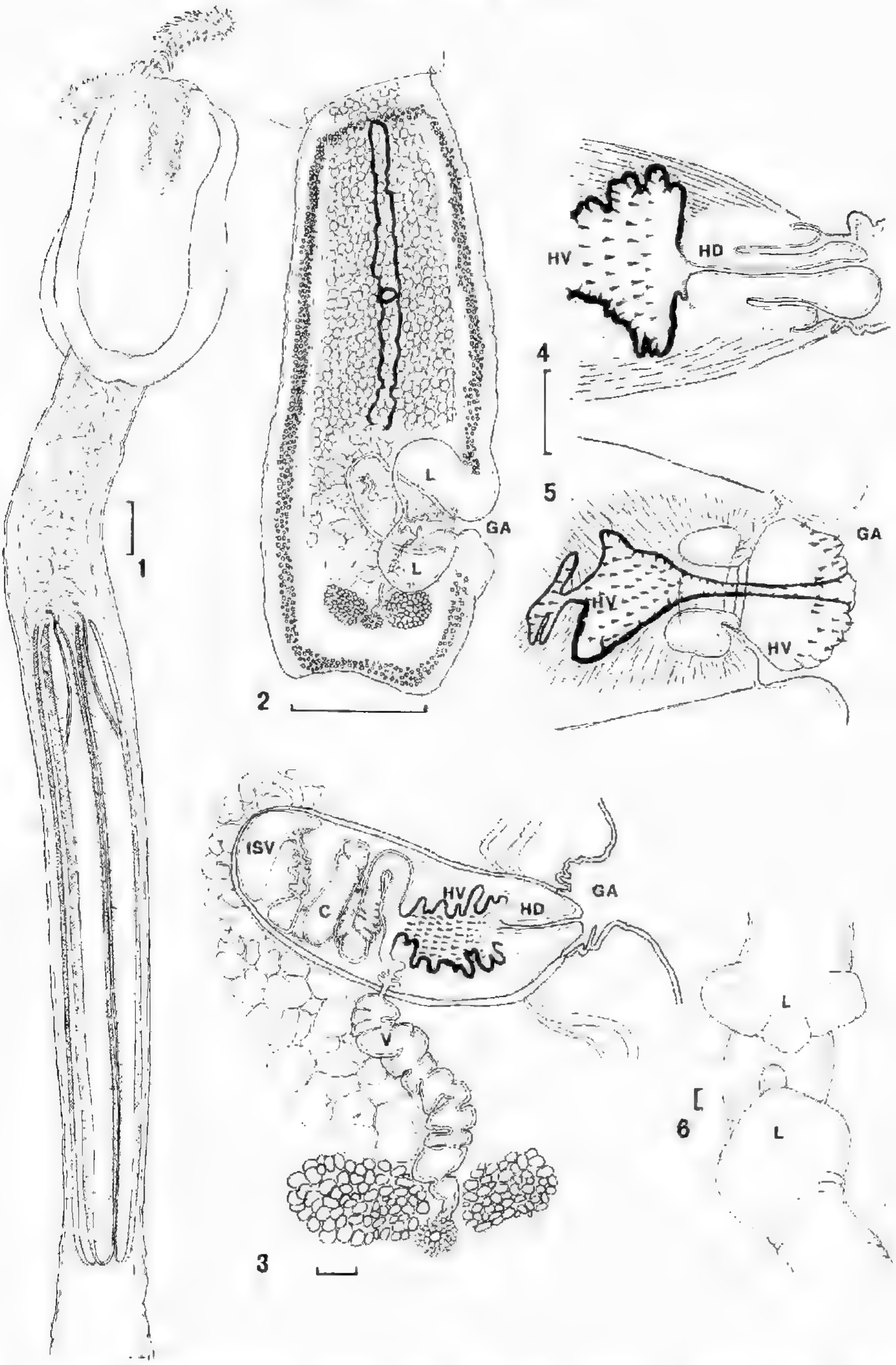


Figs 1–6. *Hornelliella macropora* (Shipley & Hornell) from *Stegostoma fasciatum*. 1, scolex; 2, mature segment; 3, genital system; 4, genital atrium with partial eversion of the hermaphroditic duct; 5, genital atrium with partial eversion of the hermaphroditic vesicle; 6, genital pore, lateral view showing lappets anterior and posterior to pore. Scale lines: Figs 1, 2: 1.0 mm; Figs 3–6: 0.1 mm. Legend: c, cirrus; ga, genital atrium; hd, hermaphroditic duct; hv, hermaphroditic vesicle; isv, internal seminal vesicle; l, lappet; v, vagina.

vaginalis 3.35–5.05 (3.82) mm, sheaths coiled. Bulbs 12 to 15 times longer than wide, 3.57–5.72 (4.74) mm by 0.28–0.38 (0.31) mm in diameter; prebulbar organs absent; retractor muscle attached at anterior end of bulb; pars postbulbosa absent. Scolex not sharply delineated from strobila, merging into neck.

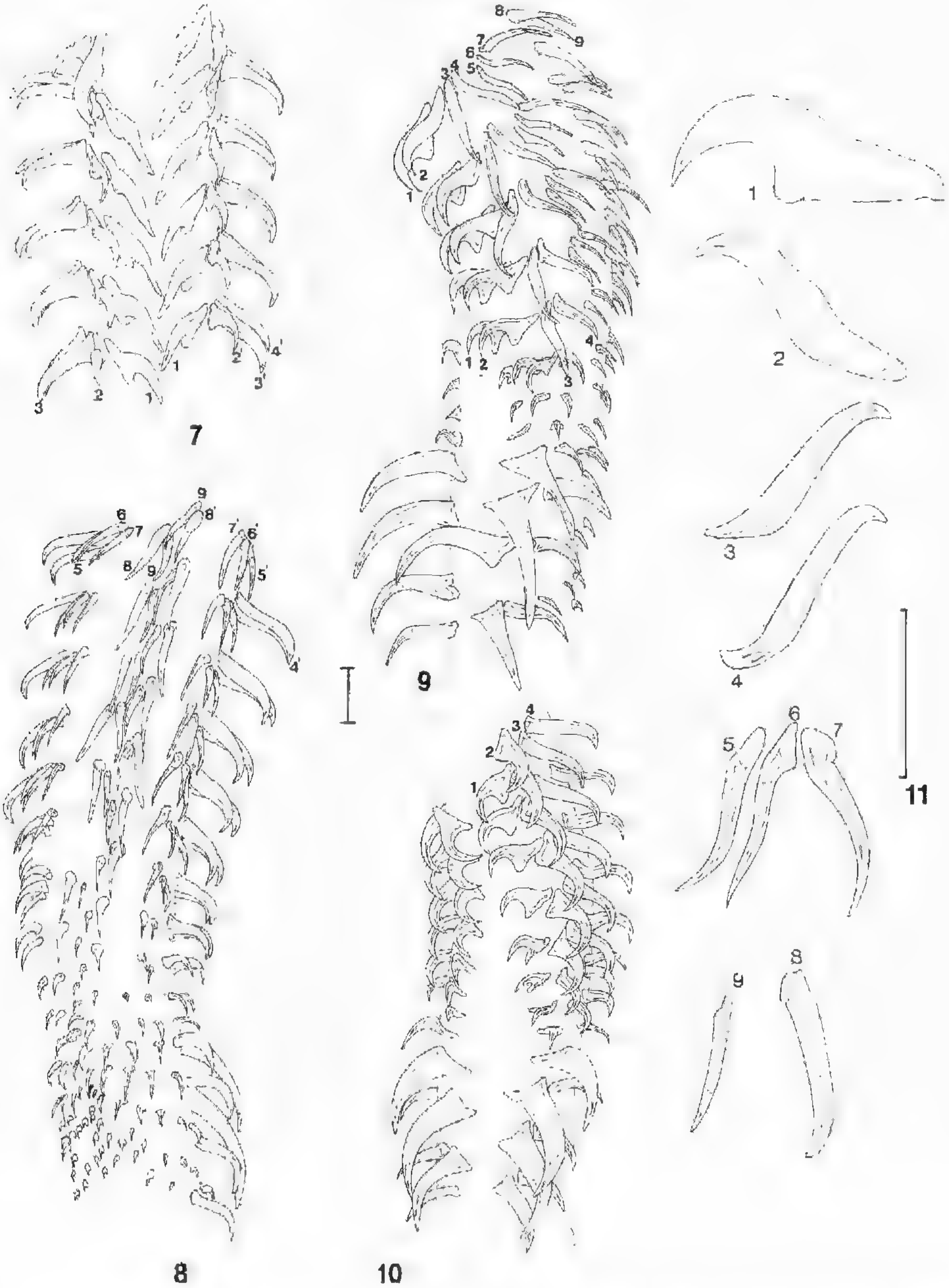
Armature: poeciloacanthous, with a chainette of two rows of large, paired hooks on middle of external face in metabasal region; principal rows alternate, forming ascending half spirals beginning on internal face; distinctive basal armature present; no basal swelling; hooks hollow. Tentacle diameter 130–170 (160). Basal armature: about eight ascending half spiral rows of small hooks on each side of external surface; rows alternate. Median, hook-free area present on internal surface of base, tapering toward metabasal region. Hooks 1(1') of proximal four rows of basal armature large, falciform with broad transverse bases; hooks 1(1') of basal rows 2–3 largest, 150–216 (184) long, base 44–90 (62); hooks 2 (2') also large, recurved; remaining hooks small, spiniform, opposing rows meet to form inverted-V formations on external face; spiniform hooks of rows four-six larger than more distal or proximal rows. Basal armature merges gradually into metabasal armature. Metabasal armature: ascending rows with seven hooks per half spiral. Hooks 1(1') widely separated, rose-thorn shaped, length 126–160 (149), base 76–102 (93), smaller near base of tentacle; hooks 2(2') large, falciform, length 110–142 (136), base 50–74 (67); hooks 3(3') slender, falciform, length 130–150 (136), base 32–50 (40); hooks 4(4') slender, falciform, length 110–130 (124), base 20–30 (24). Hooks 5(5')–7(7') spiniform, forming triad, offset at oblique angle and slightly posterior to hooks 4(4'); hooks 5(5'), length 88–100 (93), base 24–32 (26); hooks 6(6'), 82–110 (94) long, base 18–26 (24); hooks 7(7'), 104–120 (112) long, base 18–24 (21). Hooks 8(8') and 9(9') widely separated from hooks 7(7') forming alternate pairs in chainette, each pair opposite a single principal row. Hooks 8(8') and 9(9') spiniform, similar to hooks 5(5')–7(7') of principal rows; hooks 8(8'), 72–112 (99) long, base 20–26 (23); hooks 9(9') smaller, 68–90 (73) long, base 16–28 (22).

Segments appear 1.0–1.5 mm posterior to scolex, initially segments very narrow, becoming elongated, craspedote; mature segments 1.76–2.57 (2.10) mm by 0.89–1.41 (1.18) mm. Testes numerous, 50–60 (50) in diameter, arranged in layers, occupying entire medulla anterior to hermaphroditic sac, traversing dorsal osmoregulatory canals but not ventral pair of osmoregulatory canals; testes absent posterior to hermaphroditic sac. Vas deferens greatly coiled, distended, occupying much of available space between ovary and proximal pole of hermaphroditic sac, penetrating sac from anterior side. Hermaphroditic sac, 520–700 (626) by 250–390 (310), pyriform, thick-walled, proximal pole deviated anteriorly; contains crescentic internal seminal vesicle and coiled cirrus armed with tiny, aciculate spines. Cirrus joins thick-walled, corrugated, hermaphroditic vesicle armed with prominent sagittate spines. Hermaphroditic vesicle joins genital atrium through short, muscular, eversible hermaphroditic canal. Genital pore marginal, irregularly alternate; genital atrium deep, situated in posterior ⅓ of segment, 68–71% of segment length from anterior margin, surrounded anteriorly and posteriorly by two large, fleshy semi-lunar lappets. Ovary tetralobed in cross-section, set forward from posterior margin of segment, lobes subequal, 130–250 (170) by 210–290 (230). Mehlis' gland large, about 280 in diameter, postovarian. Vagina thick-walled, coiled, ascending from Mehlis' gland on poral side of vas deferens to penetrate posterior wall of hermaphroditic sac and join hermaphroditic vesicle. Seminal receptacle absent. Uterus simple, median, walls irregularly lobulate, terminating near anterior extremity of segment. Preformed uterine pore almost mid-way between genital pore and anterior margin of segment. Vitellaria follicular, circumcortical, filling postovarian space, surrounding all internal organs except most anterior testes. Eggs ovoid, pale in colour. Longitudinal osmoregulatory canals paired, ventral canals with transverse commissure at posterior margin of segment; dorsal canal medial to ventral canals.

Material examined: 11 specimens from spiral valve of *Stegostoma fasciatum* (Hermann 1783), Balgal, Qld, 14.ix.1985, coll. B. G. Robertson (S2771); 1 specimen from *Chiloscyllium punctatum* Mueller & Henle, 1841, Balgal, Qld, 17.ix.1985, coll. B. G. Robertson (S2772).

Discussion

Southwell (1929) synonymised *Tetrarhynchus macroporus* and *T. annandalei* under the combination *Tentacularia macropora*, having examined a range of specimens from different host species, including the type host of *T. annandalei*. Shipley & Hornell's description (1906) of *Tetrarhynchus macroporus* was based on specimens from *Himantura uarnak* (Forsskål, 1775) (Syn. *Trygon uarnak*). The whereabouts of their specimens is unknown, and no specimens have since been recovered from this host. Their description of the species is brief, and as Southwell (1929) pointed out, differs little from that of *T. annandalei*. Southwell (1929) considered the difference between the two species, namely the presence or absence of a longitudinal



Figs 7-11. Tentacular armature of *Hornelliella macropora* (Shipley & Hornell). 7, internal surface, metabasal region; 8, external surface, basal region; 9, bothridial surface, basal region; 10, internal surface, basal region; 11, profiles of hooks 1(1') to 9(9'). Scale lines: 0.1 mm; figs 7-10 same scale.

division of the bothridium, to be due to intraspecific variation, and noted that contracted specimens are more likely to have a medium sub-division of the bothridia. Southwell's (1929) conclusions are considered justified since if specimens are examined unstained using incident light, there is a prominent, median longitudinal ridge in each bothridium, which becomes virtually invisible when the specimens are cleared. Hornell (1912) also stated that the length of "proboscis hooks" differed between the two species, though no measurements were given in either of the original descriptions. Marked differences occur in hook size and shape on a single tentacle, and hence such comparisons are useless if the position of the hooks being compared is not clearly specified.

Hornell's (1912) specimens of *T. annandalei* were taken from *Stegostoma fasciatum* (Hermann, 1783) (syn. *S. tigrinum* (Gmelin, 1789)), as were those of Yamaguti (1954) and the new specimens described herein. The material examined by Southwell (1929) included specimens from *S. fasciatum* from Sri Lanka (BMNH 1977.11.14.36) as well as specimens from *Galeocerdo cuvier* (Peron & Le Sueur, 1822) (syn. *G. arcticus* (Faber, 1829) and *G. tigrinus* Mueller & Henle, 1839) from Sri Lanka (BMNH 1977.11.14 32–35) and specimens from a host identified on the label simply as *Trygon* sp. (BMNH 1977.11.14.9 and 1977.11.14.21–24) but identified in the text of his paper as *Dasybatus* sp. All specimens clearly belong to a single species, with a wide host range. We therefore support Southwell's (1929) conclusion that *T. macroporus* and *T. annandalei* are conspecific though material from *Himantura uarnak* is needed to confirm this view. Yamaguti (1954) appears to have overlooked this synonymy in his redescription of *T. annandalei*, and hence the correct combination for his new genus becomes *Hornelliella macropora* (Shipley & Hornell, 1906) comb. nov. (syn. *H. annandalei* (Hornell, 1912) Yamaguti, 1954).

Hornelliella palasoorahi Zaidi & Khan, 1976 is the only other nominal member of the genus. The species was said to differ from *H. macropora* only in the size of the cirrus sac (Zaidi & Khan 1976). However, the description is very poor and it is clear from the drawings that it does not belong to the genus *Hornelliella*. Its systematic position cannot be determined and it is considered *incertae sedis*.

The description given herein confirms most of Yamaguti's (1954) observations, except for the single seminal vesicle which appears, from his description, to be external to the cirrus sac, but which in fact, is internal (see Fig. 3).

The armature, described here for the first time, presents several unique features. The large falciform hooks of the basal armature are similar to species of *Gymnorhynchus* Rudolphi, 1819 and *Molicola* (Dollfus, 1935). Also, the external surface of the metabasal armature bears what we have described as a double chainette of hooks which are similar in form to those of the principal rows. The hooks of the chainette are well separated from and opposite to the alternating principal rows as occurs in genera such as *Lacistorhynchus* Pintner, 1913 and *Callitetrarhynchus* Pintner, 1931. All of the hooks are hollow and are not accompanied by satellite hooks or by intercalating rows of hooks. Although a poeciloacanthous type of hook arrangement fitting the orderly arrangement found in a chainette, it could also be interpreted as a "band" of hooks such as is found on the external surface of the tentacles of species *Molicola* and *Grillotia* (see Dollfus 1942). However, such bands of hooks in poeciloacanth trypanorhynchs frequently show little or no orderly linear arrangement of their elements and the hooks may vary both in size and in form. We therefore prefer to consider the hook arrangement seen in *Hornelliella* as a modified chainette.

A double chainette with hooks in a tandem position, occurs in *Lacistorhynchus* and *Eulacistorhynchus* Subhapradha, 1957 (Lacistorhynchidae), in *Callitetrarhynchus* (Dasyrhynchidae), *Gymnorhynchus* (Gymnorhynchidae) and some species of *Dasyrhynchus* Pintner, 1928 (Dasyrhynchidae). Simple chainettes with hooks in a single row occur in *Floriceps* Cuvier, 1817 (Dasyrhynchidae), *Halysiorhynchus* Pintner, 1913 (Pterobothriidae), *Mixodigma* Dailey & Vogelbein, 1982 (Mixodigmatidae) and in some species of *Dasyrhynchus*. No genus described to date has a chainette composed of pairs of hooks in tandem, and the structure seen in *Hornelliella* is unique among the Trypanorhyncha.

Yamaguti (1954) erected a new family and genus for the species based primarily on the presence of a unique, hermaphroditic vesicle, which he did not illustrate. Yamaguti's description is correct, and both cirrus and vagina join a large, thick-walled vesicle armed with sagittate spines. The vesicle leads, via a highly muscular hermaphroditic duct, to the genital atrium. A fully everted cirrus was not observed but the hermaphroditic duct appears to be eversible and the vesicle is capable of being partially protruded through the duct, with the characteristic sagittate spines being visible on the external surface (Fig. 5). Although the vesicle appears to be unique, a union of male and female ducts within the "cirrus sac" (=hermaphroditic pouch of Yamaguti (1954)) occurs in *Lacistorhynchus* (see Dollfus 1942) but in the latter case there is no armed vesicle, merely a simple hermaphroditic duct referred to as the "genital atrium" by Dollfus (1942) because the "atrium" is everted first, followed by the cirrus. A similar mechanism of evagination may operate in *H. macropora*. We consider the terminology used by Yamaguti (1954) of hermaphroditic duct and hermaphroditic vesicle preferable to that used by Dollfus (1942) for *Lacistorhynchus tenuis*.

Yamaguti (1954) erected the family Hornelliellidae based on the presence of an hermaphroditic vesicle, testes anterior to the "cirrus sac", presence of paired lappets around the genital atrium, a series of muscular rings in the tentacle sheaths and circumcortical vitelline follicles which formed a band posterior to the ovary. Of these characters, the muscular rings of the tentacle sheaths were not visible in our specimens, and we doubt whether such precise distribution of the testes and vitellaria will prove to be family characters. However, the armature is unique in that each pair of hooks in the chainette is contributed by a single, principal row, in alternating fashion. Furthermore, the hooks of the chainette are similar in shape to those of the principal rows instead of being markedly different.

On the basis of its armature and the hermaphroditic vesicle we consider that the Hornelliellidae is valid and that it is most closely related to the poeciloacanthous families Lacistorhynchidae Guiart, 1927 and Gymnorhynchidae Dollfus, 1935. A redefinition is given below.

Hornelliellidae Yamaguti, 1954. *Hornelliella* Yamaguti, 1954. Scolex elongate, acraspedote; two oval bothridia each with median longitudinal ridge. Metabasal armature poeciloacanthous, chainette of two rows of large paired hooks; intercalary hooks absent; distinctive basal armature present; no basal swelling. Tentacle sheaths coiled; prebulbar organ absent; retractor muscle originates in anterior third of bulb. Pars postbulbosa absent. Genital pores marginal, irregularly alternate. Testes numerous, scattered, anterior to genital pore; internal seminal vesicle present; male and female ducts unite to form armed hermaphroditic vesicle; genital pore surrounded by lappets. Vitellaria follicular, circumcortical, pre and post-ovarian. Uterus simple, median, tubular; preformed uterine pore present. Parasites of sharks and rays.

Acknowledgments

Thanks are due to B. G. Robertson for collecting the specimens, and to Dr D. Gibson (BMNH) for lending specimens.

This project was supported financially by the Australian Biological Resources Survey.

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NEW RECORDS OF *UPEROLEZA* (ANURA: LEPTODACTYLIDAE) FROM WESTERN AUSTRALIA WITH SUPPLEMENTARY OSTEOLOGICAL DATA ON *UPEROLEIA MICROMELES*

Summary

BRIEF COMMUNICATION

NEW RECORDS OF *UPEROLEIA* (ANURA: LEPTODACTYLIDAE) FROM WESTERN AUSTRALIA WITH SUPPLEMENTARY OSTEOLOGICAL DATA ON *UPEROLEIA MICROMELES*

Uperoleia Gray, 1842 comprises 23 species[1] of which ten occur in Western Australia: two from the Pilbara and eight from the Kimberley Division. Recently significant range extensions of two species into W.A. have been discovered.

Uperoleia trachyderma Tyler, Davies & Martin, 1981

On 13.ii.1987 we collected *U. trachyderma* during heavy thunderstorms on the irrigation flats of the Ord River Scheme at Kununurra (WAM R96781, 8.5 km NNE Kununurra, at the junction of Ivanhoe and Research Stations Rds). This represents an addition to the fauna of W.A.

The species was collected on self-mulching grey cracking clay.[2] *U. trachyderma* is the only member of the genus to be associated with a particular soil type,[3] and all previously collected specimens have this fidelity.

Self-mulching grey cracking clays are distributed disjunctly throughout W.A., the N.T. and Qld;[2] those on the Barkly Tableland are considered to have evolved *in situ*.[4] Distribution along current drainage patterns would explain the presence of the species on the Georgina River and at Lawn Hill in Qld[1] but the occurrence of the species at Newry Station in the far northwest of the N.T.[5,6] and at Kununurra remains an enigma.

Two other vertebrates have comparable disjunct distributions on grey cracking clays: the monitor *Varanus spenceri*[7] and the planigale *Planigale ingrami*;[8,9] while two species of bird, the flock pigeon *Histriophaps histrionica* and the red-chested quail *Turnix pyrrothorax*, have their centres of abundance on these soils.[10] Perhaps the question of the origins of the Barkly Tableland soils should be examined in the light of the endemicity of the associated fauna.

An additional species of *Uperoleia* has been recorded in W.A.[6] A specimen of *U. micromeles* was collected by A. A. Burbidge and P. J. Fuller on 25.iv.1979, 1 km S Staffords Bore (22°22'S, 127°24'E) (WAM R64073). Previously known only from the Tanami Sanctuary, N.T., the species is unusual in a number of morphological and osteological features. Re-examination of the paratype alizarin has enabled the clarification of some osteological features not included in the original description.[11] Here we redefine the species and report these features.

Uperoleia micromeles Tyler, Davies & Martin, 1981

Definition: A relatively large species (♂ 27 mm, ♀♀ 24–31 mm S–V) of gross habitus; maxillary teeth present as vestiges; narrowly exposed frontoparietal fontanelle; short, flattened unwebbed toes; internarial span greater than eye to naris distance; carpus of six elements; ilial crest present. Advertisement call not known.

Osteology: Ilium with small dorsal crest (Fig. 1). Dorsal prominence very large, mesa-shaped. Dorsal protuberance lateral; pubis calcified.

Carpus of six elements. O. radiale larger than O. ulnare. These elements articulate proximally with O. radioulna, with each other on their proximomedial border, with large transversely elongated O. centrale postaxiale distally. O. radiale articulates laterally with O. centrale preaxiale.

Fig. 1 Lateral view of the pelvis of *Uperoleia micromeles* (Paratype).

O. centrale postaxiale articulates distally with bases of O. metacarpi III, IV and V; small flange extends proximally from lateroproximal corner (Fig. 2). O. centrale prexiale articulates laterally with O. radiale, distally with O. centrale postaxiale and carpal elements of O. distale carpale 2 and 3, laterally with basal prepollical element.

Three distal tarsal elements. Lateral element largest, lies at base of O. metatarsus III, extending laterally to articulate with medioproximal side of base of O. metatarsus IV, medially to base of O. metatarsus II. Medial element lies at base of O. metatarsus I, articulates with O. centrale prehallucis. Distal prehallical element long, elliptic, extending for approximately 2/3 the length of O. metatarsus I (Fig. 2).

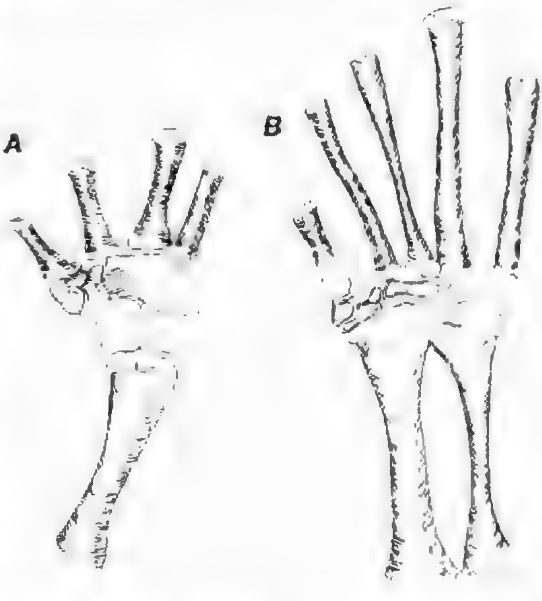

Fig. 2 (A) Palmar view of the carpus and (B) plantar view of the tarsus of *Uperoleia micromeles* (Paratype).

Comparison with other species: *Uperoleia micromeles* is a functionally edentate species (the teeth are vestigial) with a poorly exposed frontoparietal fontanelle. This species is unique amongst *Uperoleia* in a number of features: presence of vestigial teeth; a broad snout (E N/IN 0.83–0.90[11]); anteromedial extensions to the nasals; and the presence of a moderately developed ilial crest.

We thank Michael J. Tyler for reading the manuscript, John and Judy Caratti for hospitality in Kununurra, and Chris Done and the W.A. Department of Conservation and Land Management for field assistance. This work was supported by research funds from the Departments of Zoology, Universities of Adelaide and Melbourne.

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AUSTRALIAN PLANT NEMATODES: *LONGIDORUS* MICOLETZKY, 1922 AND PARA *LONGIDORUS* SIDDIQI, HOOPER & KHAN, 1963 (NEMATODA: DORYLAIMIDA)

Summary

BRIEF COMMUNICATION

AUSTRALIAN PLANT NEMATODES: *LONGIDORUS* MICOLETZKY, 1922 AND *PARALONGIDORUS* SIDDIQI, HOOPER & KHAN, 1963 (NEMATODA: DORYLAIMIDA)

In a continuing study of the distribution and laxonomy of plant parasitic nematodes associated with naturally occurring native vegetation, species of *Paralongidorus* and *Longidorus* were identified. The distribution of both these genera in Australia is poorly known. All records here are from areas of natural vegetation, many of which are National Parks (NP), Conservation Parks (CP) and State Forests (SF) (excluding *Pinus radiata* and other planted forests). Nematode specimens are held in the Waite Institute Nematode Collection (WINC). Measurements are from specimens mounted in glycerol.

The genus *Longidorus* has been recorded from three locations around Sydney (N.S.W.)[1] and from Charleville, Qld,[2] but none is identified to species. Soil samples collected from four localities in South Australia contained specimens of *Longidorus taniwha* Clark, 1963, a New Zealand species, not previously recorded in Australia. The localities are all on the Fleurieu Peninsula, south of Adelaide, in *Eucalyptus* L'Hér., forest at Mt Compass, Kyeema CP and Spring Mount CP, and an area of mallee at Myponga CP. Apart from a more posterior guiding ring (53–57 μm from anterior end), South Australian specimens are similar in most respects to the type population. Small numbers of males were collected from each locality except Spring Mount.

Three species of *Paralongidorus* have been recorded in Australia. Two of these, *P. eucalypti* Fisher, 1964 and *P. sacchari* Siddiqi, Hooper & Khan, 1963 have been identified by the author, from bushland soils. *P. eucalypti* has only previously been recorded from the type locality (S. Aust.)[3] and three localities in N.S.W.[1] Specimens of *P. eucalypti* have been identified from more than 35 different localities, in all States of mainland Australia. Most of the localities are *Eucalyptus* woodland or mallee, rarely forest, none from rainforest. Soil samples have been collected from 24 sites, within 14 separate areas of rainforest (totalling 176 soil samples) in eastern Qld, and N.S.W. No species of *Paralongidorus* have been recovered from these soils.

Females of *Paralongidorus eucalypti* were studied, and the morphometrics of specimens from eight localities are given in Table 1. The specimens are similar to the original description, with minor differences in tail length and shape. The papillae near the amphid apertures, a peculiarity of this species, are clearly visible in most specimens. There are some differences between measurements of specimens from differing localities. The S. Aust. specimens are similar to those from the type locality. The Qld specimens are shorter than those from S. Aust. and also have a shorter stylet and a more anteriorly situated guiding ring. Some specimens from Marne Valley (S. Aust.) and Mt Topper (N.S.W.) have a slightly more posteriorly situated vulva. One female specimen, identified from Dongarra (W.A.) has an unusually short stylet (127.1 μm) but is similar in other respects to *P. eucalypti*. The measurements given here considerably extend the range for this species.

Localities from which *P. eucalypti* were collected are as follows:

S. Aust.: Gulleys to the east and west of Northern Flinders Ranges, in association with *Eucalyptus camaldulensis* Dehnh; mid-north, associated with *Eucalyptus* woodland and mallee; frequent on sandy soils associated with *Eucalyptus* woodland and mallee, including: Sandy Creek CP (near Gawler); Ferries McDonald CP (near Murray Bridge); Marne Valley CP (near Swan Reach); Aldinga Scrub (Adelaide coast).

Vic.: Sunraysia district, associated with *Eucalyptus camaldulensis* or mallee; *Eucalyptus* woodland at Victoria Valley, Grampian Mountains.

N.S.W.: Sunraysia district; north-eastern State Forests, including Mt Topper SF; Jacks Creek SF; Nundle SF; Unumgar SF; Beaury SF.

Qld: *Eucalyptus* woodland west of Mt Garnett (north Qld); brigalow association, Thangool (near Biloela); *Casuarina littoralis* Salisb., (outside rainforest area) Eungella NP (near Mackay); mallee and mulga, Charleville

N.T.: *Eucalyptus* woodland with tall perennial grasses, Katherine.

W.A.: *Eucalyptus calophylla* R.Br., west of Northam, *E. erythrocorys* F. Muell., south of Dongarra (near Geraldton).

The male of *P. eucalypti* has not be described. One male has been collected from S. Aust. and one from W.A., which are described here.

Measurements (S. Aust. male, n = 1): L = 5.58 mm; a = 142.7; c = 128.2; c′ = 1.28; odontostyle = 106.4 μm; odontophore = 49.5 μm; total stylet = 155.9 μm; guiding ring 43.4 μm from anterior end; T = 63.3; spicules = 43.4 μm (measured along curvature); lateral guiding pieces 14.1 μm; tail = 43.5 μm.

(W.A. male, n = 1): L = 5.39 mm; a = 121.9; c = 122.3; c′ = 1.35; odontostyle = 101.2 μm; odontophore = 46.8 μm; total stylet = 148.0 μm; guiding ring 34.9 μm from anterior end; T = 48.0; spicules 56.3 μm; lateral guiding pieces 11.1 μm; tail = 44.03 μm.

Description: Body ventrally curved when relaxed (Fig. 1A), more strongly curved in posterior region than females. Anterior region similar to females, with offset lip region (Fig. 1B, C), papillae near amphid apertures and stirrup shaped amphids. Odontostyle shorter than females from type population. Hemizonid 5.8–6.8 μm long. Cionail rather obscure. Spicules arcuate; lateral guiding pieces slightly curved. In the S. Aust. specimen, supplements consisting of an adanal pair, unequal distances from the anus, with a ventro-median series of fourteen. In the W.A. specimen there are thirteen ventro-median supplements. The most anterior supplement is 85.1–95.2 μm from anus (measured along curvature). Tail rounded-conoid, terminus slightly bulbous in both specimens (Fig. 1D, E).

Localities: (S. Aust.) Collected from Aldinga Scrub, S. Aust. in December 1981 by the author. This site is low

TABLE 1. *Morphometrics of* Paralongidorus eucalypti *from nine localities.*

Locality	n	L (mm)	Stylet (μm)	Odontostyle (μm)	Odontophore (μm)	g.r. (μm)	V	a	c	c'	tail (μm)	WINC
Coorong (S. Aust.) Type Loc.	10	5.72 4.80–6.20	—	146.0 (133–151)	51.8 (48–55)	39.9 (39–42)	47.9 (46–49)	119.0 (105–138)	136.0 (111–151)	—	—	1a9
Marne Valley (S. Aust.)	10	5.23 (4.8–5.9)	187.8 (183–200)	135.5 (130–141)	52.4 (43–60)	38.9 (35–41)	50.0 (47–52)	109.0 (93–120)	138.0 (103–172)	1.14 (1.0–1.3)	38.5 (31–49)	312E 313D, F
Aldinga Scrub (S. Aust.)	1	5.66	200.6	149.8	50.8	41.8	47.9	108.3	184.9	0.9	30.6	175D
Sandy Creek (S. Aust.)	4	6.1 (5.6–6.4)	198.3 (191–210)	154.4 (150–162)	43.9 (38–44)	46.2 (46–49)	48.5 (47–49)	105.0 (98–112)*	149.6 (136–161)	1.0*	40.9 (39–43)	90F 97F 99F
Mt Topper (N.S.W.)	7	5.4 (4.6–5.9)	184.6 (174–197)	136.5 (126–143)	48.1 (36–56)	42.5 (38–45)	51.1 (49–53)	113.6 (103–131)	138.5 (122–146)	1.1 (1.0–1.3)	38.8 (35–42)	274A, E
Thangool (Qld)	18	4.03 (3.5–4.7)	141.5 (135–151)	99.7 (92–109)	41.8 (36–47)	32.4 (29–34)	48.9 (45–51)	84.8 (66–99)	115.2 (101–129)	1.13 (1.0–1.3)	35.3 (33–41)	216A, B, E, F 217A–D
Eungella (Qld)	2	3.8–3.9	139–146	99–100	40–46	31–32	49–50	68–80	97–116	1.1–1.2	33–39	215C
Dongarra (W.A.)	2	4.9–6.8	127–218	84–162	43–56	33–48	47–50	139–151	151–187	1.0–1.2	32–36	294B, C
Katherine (N.T.)	4	5.3 (5.1–5.5)	179.0 (171–183)	131.6 (125–136)	47.3 (46–48)	41.2 (39–43)	48.7 (48–49)	111.5 (108–114)*	136.4 (126–142)	1.2 (1.1–1.3)	39.1 (37–41)	253A, E

*n = 2. g.r. – distance of guiding ring from anterior end.

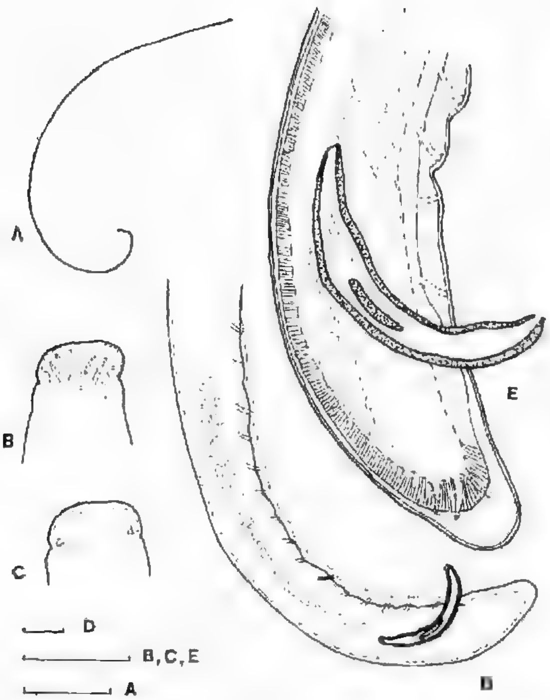

Fig. 1. *Paralongidorus eucalypti*—male. A—relaxed body posture; B, C—lip region; D—posterior region; E-tail. Bar scales: A = 1 mm, B–E = 20 μm.

lying, sandy soil with *Eucalyptus camaldulensis* and numerous *Isolepis nodosa* (Rottb.) R.Br. (Knobby Club-Rush) WINC: 176A.

(W.A.) Male and juveniles collected from dam reserve at "The Humps", Hyden, W.A., by P. Orr and P. Laidlaw in September 1986. *Casuarina* sp. dominant, with associated *Acacia* sp., *Eucalyptus* sp., *Santalum acuminatum* (R.Br.) A.D.C. and tussock grasses. WINC 332A.

Paralongidorus sacchari, first described from north Qld and India[4] and also recorded from Fiji[5] has not been recorded elsewhere in Australia. Specimens have been identified from two localities in S. Aust. and are morphologically similar to the original description, but differ in some measurements.

Black Rock CP, females (n = 10). L = 3.7–5.5 mm; c = 100–141; c' = 1.1–1.3; V = 47–52; odontostyle = 119–134 μm; odontophore = 36–60 μm; total stylet = 162–190 μm; guiding ring 32–37 μm from anterior end; tail = 30–44 μm.

Locality: Black Oak, *Casuarina cristata* ssp. *pauper* (F. Muell. ex Miq) L. Johnson and Blue Bush, *Maireana sedifolia* (F. Muell). P. G. Wilson association at Black Rock CP (near Orroroo) S. Aust.

Females and juveniles collected in 1974. WINC 59–63. Martins Well, females (n = 3). L = 3.7–4.8 mm; c = 109–157; c' = 1.0–1.2; V = 48–50; odontostyle = 115–130 μm; odontophore = 38–62 μm; total stylet = 154–192 μm; guiding ring 35–38 μm from anterior end; tail = 30–35 μm.

Locality: 118 km south-east of Blinman, towards Martins Well (outside northern Flinders Ranges), from gully margin. Associated vegetation includes *Eucalyptus camaldulensis* and *E. intertexta* R. T. Baker, and *Ptilotus* spp. Females and juveniles collected in 1973. WINC 29 A, D.

Sincere thanks to people who collected soil, in particular; J. A. Simpson, Forestry Commission of N.S.W., R. G. Silcock, Dept of Primary Industries, Qld, M. H. Andrew, CSIRO Division of Tropical Crops and Patures, N.T., J. H. Warcup and P. McGee of the Waite Institute, P. Laidlaw and P. Orr, Adelaide. Thanks also to the S. Aust. and Qld National Parks and Wildlife Services, S. Aust. Planning Commission and the Forests Commission of Victoria for co-operation with soil sampling in their reserves. Technical assistance by P. Fuhlbohm is gratefully acknowledged. This work was partially funded by a grant from the Bureau of Flora and Fauna.

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YABBIES AT DALHOUSIE SPRINGS, NORTHERN SOUTH AUSTRALIA: MORPHOLOGICAL EVIDENCE FOR LONG TERM ISOLATION

Summary

BRIEF COMMUNICATION

YABBIES AT DALHOUSIE SPRINGS, NORTHERN SOUTH AUSTRALIA: MORPHOLOGICAL EVIDENCE FOR LONG TERM ISOLATION

This paper stems from a comprehensive morphological analysis of the taxonomy of the *destructor* group of the genus *Cherax*.[1,2] Since the specimens from Dalhousie Springs proved to be morphologically distinct from all other specimens examined, they are given special consideration here.

Dalhousie Springs are a series of over 60 active mound springs distributed throughout an area of about 60 km^2, 160 km NE of Oodnadatta in the far north of South Australia.[3] While located within the Lake Eyre Drainage division, they are isolated from the major waterways and lakes of central Australia.

Morphological analyses included both bivariate (analysis of covariance) and multivariate (principal components analysis) techniques.[1,2] On the basis of fifty metric and multistate characters, the specimens from Dalhousie Springs are closest to *C. destructor*, which is the only other species of *Cherax* to be found in central Australia.[4] Of these characters, the Dalhousie Springs specimens could be distinguished statistically from *C. destructor* by their relatively broad areola (the distance between the branchiocardiac grooves), short thorax, and short rostrum; and to a lesser extent by relatively large chelae and broad rostrum.[1] These characters are illustrated in Fig. 1.

The Dalhousie Springs specimens are separated most conspicuously from *C. destructor* by their relatively broad areola. The relationship between areola width and ocular-carapace length for the Dalhousie Springs specimens (a), *C. albidus* (b) and *C. destructor* (c) is shown in Fig. 2. The data for Dalhousie Springs specimens represent collections from several mound Springs. These data were log-transformed to linearize the allometric relationship of areola width with ocular-carapace length. Analysis of covariance indicated that the elevations of these regression lines are significantly different ($F_{2,1497} = 611.1$, $p < 0.001$). *A posteriori* comparison of the elevations using Tukey's Test[5] indicated that the differences between each pair of lines are statistically significant ($p < 0.05$), with the Dalhousie Springs specimens having the broadest areolae and *C. destructor* having the narrowest.

Dalhousie Springs are thought to have formed during the late Pliocene–early Pleistocene and the surrounding area has been substantially dry since the late Tertiary.[6,7] However, in modern times, flood waters from the creeks near the springs would have provided a connection between the springs and the Finke river system via spring run-off during particularly wet years.[7] It has been suggested that these conditions may have occurred numerous times in the past 1000 years and possibly more frequently during the Pleistocene when the springs may have been at a relatively lower elevation.[7] In the light of these suggestions, it is interesting that these populations have maintained their morphological integrity, probably in the face of repeated invasion by *C. destructor*. One explanation for this may be that the yabbies of Dalhousie Springs may have developed physiological tolerance of the high, relatively constant temperature to which they are exposed. Invading *C. destructor* may not be able to survive and reproduce under these conditions. Ecological isolation of populations between which there are no geographical barriers has been described for some species of *Gammarus* which inhabit regions with differing salinities.[8] Individuals from different populations of some "species" were so specialized that they could not survive and reproduce at any common salinity.

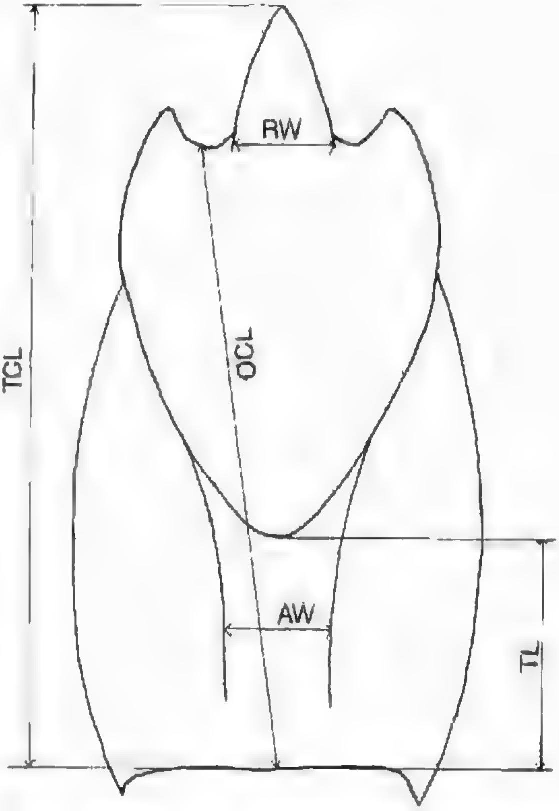

Fig. 1. Cephalothoracic measurements distinguishing the Dalhousie Springs yabbies from other specimens of *C. destructor*. TCL, total-carapace length; OCL, ocular-carapace length; TL, thorax length; RW, rostrum width; AW, areola width. Rostrum length was calculated as the difference between TCL and OCL.

On the basis of zoogeographic evidence not connected with Dalhousie Springs, I have previously postulated that *C. destructor* arose as a result of increased selection for drought tolerance during the late Tertiary–Pleistocene phase of increasing aridity and that it arose from a previously widespread "*C. albidus*-like" ancestor.[1,2] This latter species is now restricted to southwestern Victoria and the extreme southeast of South Australia. The similarity of the Dalhousie Springs specimens to *C. albidus*, with respect to relative areola width is, therefore, particularly significant. Mound springs also have been suggested as providing refuges for aquatic fauna

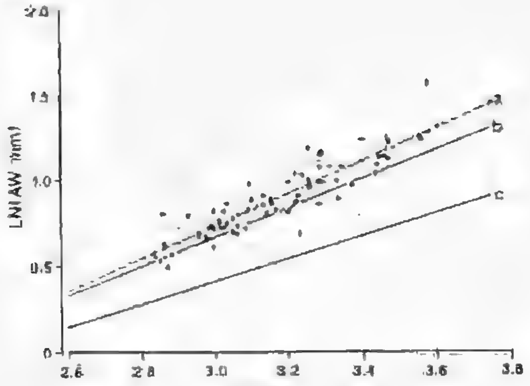

Fig. 2. Lines of best fit for the log-log regressions of areola width on ocular-carapace length. a, Dalhousie Springs (n = 75); b, *C. albidus* (n = 526); c, *C. destructor* (n = 900). All regressions are statistically significant ($p < 0.001$). The circles indicate the positions of individuals from Dalhousie Springs.

during periods of increased aridity.[9] An association between areola width and the environment has been noted for cambarid species, wide areolae being largely restricted to highly oxygenated lotic habitats and narrow areolae being more common on crayfish inhabiting waters of lower oxygen concentrations.[10,11] This association was related to the fact that a lengthening and narrowing of the areola will result in a concomitant enlargement in the gill chamber.[10] We might therefore predict that a drought-adapted species (*i.e. C. destructor*) would have a relatively narrow areola. As *C. destructor* populations inhabiting the cooler, wetter areas of central Victoria and southeastern New South Wales do not show any broadening of the areola,[1,2] this relationship (if it applies to parastacids) is not a proximal one.

Although the Spring water temperatures are high, dissolved oxygen levels are generally high to saturated in most springs, except in the immediate vicinity of the vent.[9] The permanent water of the mound springs would, therefore, buffer the crayfish from the effects of aridity and subsequent selection for drought tolerance. For further interpretation of the pattern of morphological variation, it would be interesting to know whether there has been gene flow between the Dalhousie Springs crayfish and typical *C. destructor*. Future investigation using other methods (e.g. immunological techniques) may help to clarify the relationships between the Dalhousie Springs populations, *C. destructor* and *C. albidus*.

Although these specimens are morphologically very distinct from the other *C. destructor* specimens, their taxonomic status is far from clear. The possibility that their distinctive morphology is environmentally induced must be considered. The Dalhousie mound springs represent an extreme environment. Spring water temperatures at the source vary from 29°C to 44°C, the hotter springs being in the north.[12] While summer water temperatures may reach these levels in other parts of central Australia, the spring water temperatures are constant throughout the year, at least at the source. These springs rarely flow more than 15 km from their source due to the high evaporation rate (2500 mm/annum).[12] If the unusual morphology of the Dalhousie Springs specimens is environmentally induced, some indication of morphological similarity with other central Australian populations might be expected. However, with respect to the characters which distinguish the Spring specimens, yabbies from other northern South Australian, southern Northern Territory and southwest Queensland localities are closer to southeast Australian specimens.[1,2]

A further indication of the extreme environment at Dalhousie Springs is the presence of berried females of very small carapace lengths. I have examined berried females of total carapace length (TCL) 23.4 mm (OCL 19.8 mm) and 24.3 mm (OCL 20.6 mm) from this locality. Previous field studies have recorded minimum total carapace lengths (TCLs) for berried females of 31–45 mm,[13] although berried females of total carapace length as small as 26 mm have been recorded from Lake Eucumbene in southeastern N.S.W.[14] The Dalhousie Springs specimens therefore represent the smallest berried females of "*C. destructor*" yet recorded. The size at which crustaceans reach sexual maturity in the field has been suggested to be a gauge of the influence of the environment on the performance of the population.[15]

A further complication is the possibility of recent introductions. Yabbies were first recorded from the Springs in May 1984 when they were collected using wire-mesh box traps for fish.[16] However, no *Cherax* were collected on previous visits in July/August, 1968, November, 1969, and May, 1974 using the same traps in the same area. When collecting yabbies, however, it is not unusual to have markedly different trapping success at different times. It has also been noted that locals in the mid-north of South Australia, at least as far north as Oodnadatta, have introduced yabbies into their dams.[17] Given that the morphology of the Dalhousie Springs crayfish is so distinct from all other *C. destructor* populations examined,[1,2] it is most unlikely that they are the result of recent introductions by man

While the frequency and extent of past aquatic connections between the Dalhousie Springs and surrounding drainage systems are not known, conditions favouring speciation of other taxa have existed since there are two endemic fish species, the Dalhousie catfish (*Neosilurus* sp.) and the Dalhousie hardyhead (*Craterocephalus dalhousiensis*) which cannot survive at water temperatures much less than 20°C.[18,19,20] Dalhousie Springs also contains endemic snails (family: Hydrobiidae) and amphipods.[9]

The cause of the unique morphology of the Dalhousie Springs specimens (i.e. genetic or environmental) may be solved by the rearing of young under controlled conditions. The replication of this procedure with "good" *C. destructor* would serve as a control. Without this further evidence, however, firm taxonomic conclusions are not justified.

I am indebted to Dr Sam Lake for his constructive criticism and suggestions. My thanks also go to Dr Ian Bayly and Michael Barry for their comments on this manuscript.

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MIDDLE EOCENE AGE OF THE MEGAFOSSIL FLORA AT GOLDEN GROVE, SOUTH AUSTRALIA: PRELIMINARY REPORT, AND COMPARISON WITH THE MASLIN BAY FLORA

Summary

BRIEF COMMUNICATION

MIDDLE EOCENE AGE OF THE MEGAFOSSIL FLORA AT GOLDEN GROVE, SOUTH AUSTRALIA: PRELIMINARY REPORT, AND COMPARISON WITH THE MASLIN BAY FLORA

A clay lens exposed during mining operations in a Monier Golden Grove sand pit contains abundant remains of leaves, pollen and spores. Evaluation of all the fossils continues but preliminary results of the megafossils are now available[1].

This note presents the preliminary results of a palynological examination of two samples from Golden Grove and two others from the leaf-bearing beds at Maslin Bay[2,3,4,5,6]. The latter samples were examined in order to determine whether the two sites are correlative. A more extensive treatment of the palynofloras from Golden Grove will be given following analyses of borehole samples of the clay lens obtained during a recent drilling programme in the Golden Grove area[7]. Detailed records of the palynofloras are held in the Biostratigraphy Branch, Department of Mines and Energy, South Australia.

All samples produced diverse, well preserved palynofloras in which pollen of *Nothofagidites* spp., *Haloragacidites harrisii* (Couper) Harris 1971, the gymnosperms, the Proteaceae and spores from the cryptogams are very common. No one group, however, is a very dominant part of the assemblage as is usually expected, say, of *Haloragacidites harrisii* and *Nothofagidites* spp. in Tertiary palynofloras. The samples are also rich in their diversity of triporate, tricolpate and tricolporate pollen produced by the angiosperms. One sample from Golden Grove contained an unusually high frequency of tricolporate pollen, in particular that assigned to *Rhoipites sphaerica* (Cookson) Pocknall & Crosbie 1982. In general, however, the composition of the assemblages from each site is similar.

In southern Australia two palynological zones have been erected for the Tertiary in the Gippsland and South Australian areas (Fig. 1). In the Harris zonation, palynofloras from Golden Grove and Maslin Bay can be assigned to the *P. pachypolus* Zone. This determination is made on the basis of the presence of *Nothofagidites asperus* (Cookson) Stover & Evans 1973 and *N. falcatus* (Cookson) Stover & Evans 1973, the first occurrence of which marks the base of the Zone, as well as the common occurrence of the zonal species together with frequent *Nothofagidites* spp. and *Proteacidites* spp., particularly *P. kopiensis* Harris 1972, *P. reticulatus* Cookson 1950 and *P. symphyonemoides* Cookson 1950[8]. *Trilites tuberculiformis* Cookson 1947 and *Matonisporites ornamentalis* (Cookson) Stover & Partridge 1973 are rare, and *Triorites magnificus* Cookson 1950 is absent. The first occurrence of the latter species is used to mark the top of the *P. pachypolus* Zone.

The palynofloras are also correlatives of the lower *Nothofagidites asperus* Zone in the Gippsland sequences (Fig. 1), thus supporting the conclusion drawn above. The base of the Zone is marked by the first appearance of a number of species which are present in the palynofloras including: *Foveotriletes balteus* Partridge 1973, *Gemmatricolporites gestus* Partridge 1973, *Gothanipollis bassensis* Stover 1973, *Nothofagidites asperus* (Cookson) Stover & Evans 1973, *N. falcatus* (Cookson) Stover & Evans 1973, *N. vansteenisi* (Cookson) Stover & Evans 1973, *Periporopollenites vesicus* Partridge 1973, *Rhoipites angurium* (Partridge) Pocknall & Crosbie 1982, *Rugulatisporites trophus* Partridge 1973, *Tricolpites simatus* Partridge 1973, *T. thomasii* Cookson & Pike 1954 and *Tricolporites leuros* Partridge 1973[9,10].

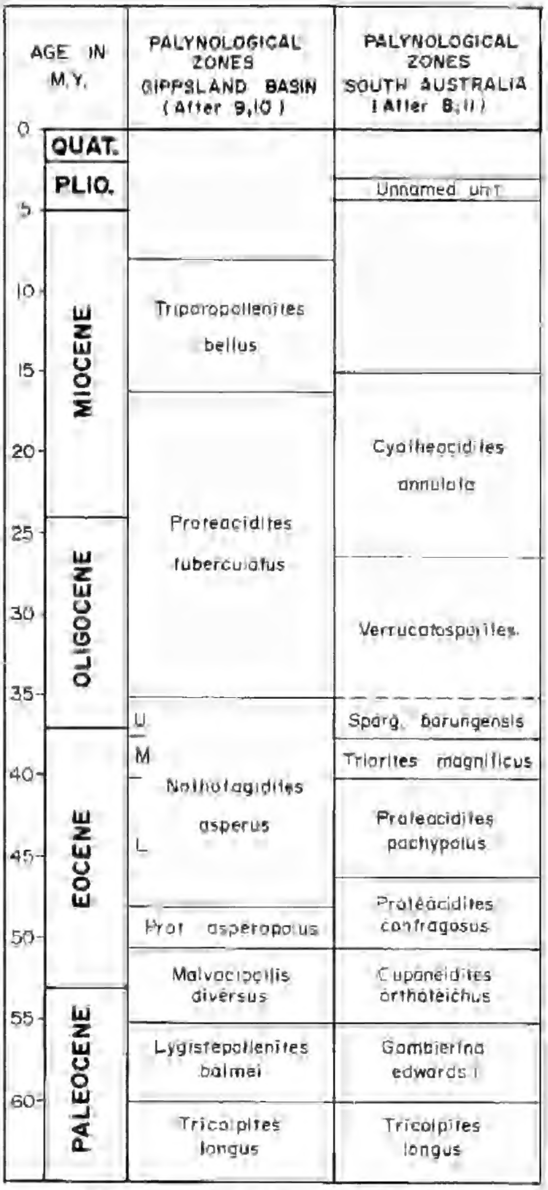

Fig. 1. Tertiary palynological zones in southern Australia.

A number of species whose upper range terminates within the lower *N. asperus* Zone are also present including

Anacolosidites acutullus Cookson & Pike 1954, *A. luteoides* Cookson & Pike 1954, *A. sectus* Partridge 1973, *Dryptopollenites semilunatus* Stover 1973, *Proteacidites alveolatus* Stover 1973, *P. asperopolus* Stover & Evans 1973, *P. incurvatus* Cookson 1950, *P. kopiensis* Harris 1972, *P. pachypolus* Cookson & Pike 1954, *P. tenuiexinus* Stover 1973, *Polycolpites reticulatus* Couper 1960, *Rhoipites sphaerica* and *Verrucosisporites cristatus* Partridge 1973.

Palynofloras previously recovered from the Maslin Bay leaf beds were believed to have been correlative with the older *Proteacidites confragosus* Zone, although in the light of later work they were reassigned to the *Proteacidites pachypolus* Zone[6,12]. The data presented in the present note not only support the latter conclusion but also show that the palynofloras from Maslin Bay and Golden Grove are correlative. Thus the Golden Grove and Maslin Bay clay lenses and plant megafossils are Middle Eocene in age, as are the fossil floras from the Maslin Bay site. The palynological zonations and the age determination indicate that the sand deposit at Golden Grove is a correlative of the North Maslin Sands.

The palynofloras found at Golden Grove appear to be more diverse than the macrofloral assemblages[1]. At least 134 taxa can be recognized in the palynoflora, of which 115 can be ascribed to established form genera or species, and a further 19 species of unknown affinity. This is to be expected, however, because the pollen and spores are representative of the regional vegetation and may have been transported considerable distances to the site. The macrofossils, on the other hand, were derived in close proximity to the site of deposition and provide evidence of the local vegetation. Moreover, the sediments in which the macrofossils occur are very finely laminated clay and silt with no current bedding to indicate that the leaves could have been brought from some distance away by streams.

Pollen and spores from a number of plant genera recorded at Golden Grove are well represented in the palynofloras. Proteaceous pollen is common and diverse, including pollen of *Banksia* Linnaeus f. and *Grevillea* R. Brown *ex* R. A. Salisbury, as is pollen from the family Podocarpaceae, including three species of *Phyllocladus* L. C. Rich, one of *Dacrydium* Solander, three of *Podocarpus* L'Herit *ex* Pers. and one *Microcachrys* F. Hooker. The Myrtaceae are common and at least four species of pollen can be recognized, including pollen with affinities to *Eucalyptus* L'Herit. Although spores of the cryptogams form only small proportion of the assemblage, they are diverse and include two species of *Lygodium* Linnaeus f. type spores and two others with probable affinities to the genus.

I thank J. M. Lindsay, W. V. Preiss, W. K. Harris and C. B. Foster for their comments on the manuscript.

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