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A LAST INTERGLACIAL EMBAYMENT FILL AT NORMANVILLE, SOUTH AUSTRALIA, AND ITS NEOTECTONIC IMPLICATIONS

BY R. P. BOURMAN, A. P. BELPERIO†, C. V. MURRAY-WALLACE‡*
*& J. H. CANN**

Summary

Bourman, R. P., Belperio, A. P., Murray-Wallace, C. V. & Cann, J. H. (1999) A last interglacial embayment fill at Normanville, South Australia and its neotectonic implications. Trans. R. Soc. S. Aust. 123(1), 1-15, 31 May, 1999.

Stratigraphic, sedimentological, amino acid racemisation, thermoluminescence (TL) and foraminiferal analyses of an embayment fill at Normanville, south of Adelaide, have established the presence of the last interglacial (Oxygen Isotope Substage 5e) subtidal sediments of the Glanville Formation at elevations of up to 12 metres AHD. Overlying aeolian deposits, dated at about 60 to 50 ka, are possible equivalents of the Fulham Sand of the Adelaide area. TL dating of the Fulham Sand from its type borehole location yielded an age of 74.9 ± 6.9 ka, considerably older than previous estimates but compatible with a recent re-evaluation of the age of the Pooraka Formation.

Key Words: Last Interglacial, embayment fill, Normanville, Glanville Formation, neotectonics, molluscs, foraminifera, amino acid racemisation, thermoluminescence dating, Fulham Sand.

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A LAST INTERGLACIAL EMBAYMENT FILL AT NORMANVILLE, SOUTH AUSTRALIA, AND ITS NEOTECTONIC IMPLICATIONS

by R. P. BOURMAN[†], A. P. BELPERIO[‡], C. V. MURRAY-WALLACE[§] & J. H. CANN[†]

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The altitude of the last interglacial shoreline at Normanville at + 12 m AHD is considerably higher than at Dry Creek (- 1.26 m AHD), Sellicks Beach (+ 4 to 5 m AHD), Victor Harbor (+ 6 m AHD) and Hindmarsh Island (+ 1 m AHD) and implies 10 m of uplift at this site relative to South Australian bench mark sites. The variation in altitude of the last interglacial Glanville Formation from Gulf St Vincent, across Fleurieu Peninsula to the Murray Basin reflects continuation of the tectonic activity revealed by dislocation of older Miocene and Earliest Pleistocene limestones.

KEY WORDS: Last Interglacial, embayment fill, Normanville, Glanville Formation, neotectonics, molluscs, foraminifera, amino acid racemisation, thermoluminescence dating, Fulham Sand.

Introduction

A sequence of last interglacial and younger sediments infills a former marine embayment in the Normanville area on the eastern shoreline of Gulf St Vincent, approximately 70 km SSW of Adelaide (Fig. 1). The extent of the former marine embayment is marked by an arcuate relict coastal cliff line cut into Cambrian and Precambrian rocks and Permian glacigenic sediments (Fig. 2). The majority of the sediment-infilled embayment occurs below the 20 m contour and the location of the former coastal cliff is clearly marked by the 30 m to 50 m contours, merging with current coastal cliffs at both the northern and southern extremities of the former embayment.

Geomorphic Setting

Three streams, Carrickalinga Creek and the Yankalilla and Bungala Rivers cross the embayment fill in the Normanville area and have contributed to its formation. The Bungala River is the largest of the streams entering the sea in the central section of the embayment and its catchment area is dominated by Permian, sandy, glacigenic deposits that have largely provided the quartzose sediments of the modern beach and dune system. Carrickalinga Creek and the Yankalilla River also pass through some areas of Permian sediments and enter the embayment at its northern and southern ends, respectively. The present rectilinear, sandy, six kilometre long shoreline is backed by modern coastal dunes up to 15 m high and contrasts markedly with the morphology of the palaeo - cliffed coastline. A combination of marine, aeolian and fluvial sediments has contributed to the infilling of the former embayment. The former cliffed coastline has a clear topographic expression, and adjoining low slopes reflect alluvial fan sedimentation at the scarp/plain junction, with aeolian sand drift contributing additional relief on the embayment fill (Figs 3, 4). Spectacular scree slopes occur along the highest parts of the last interglacial cliffline from Lady Bay to Little Gorge, where the cliff line coincides with an ancient fault zone. Fluvial, slope and aeolian sedimentation have thus somewhat obscured what was formerly a gently sloping plain of coastal progradation, with rocky shore platforms at its extremities.

Two sets of river terraces flank the three major streams, which flow across the infilled embayment. High, paired terraces are underlain by reddish, brown

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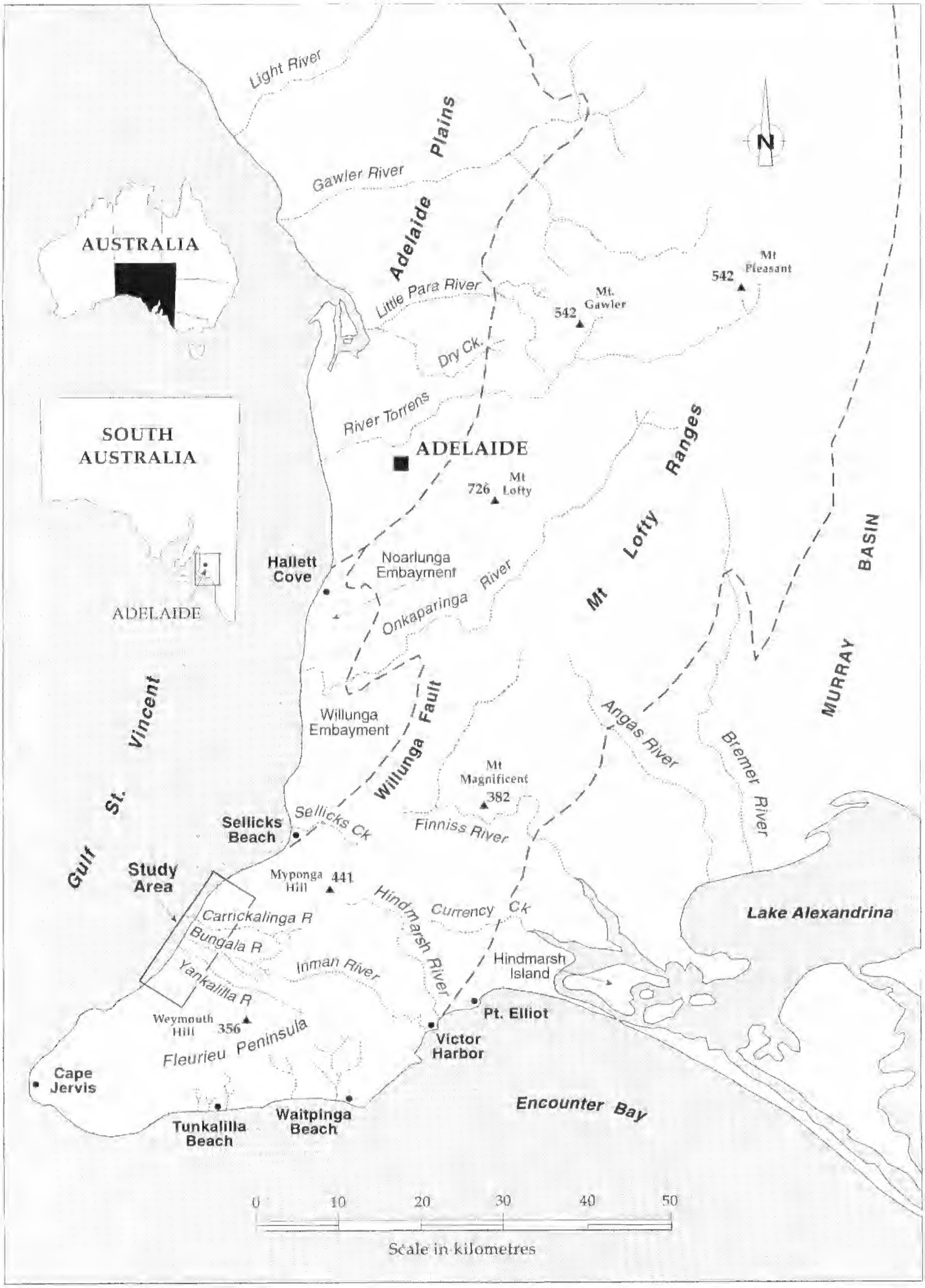
Light River
Adelaide Plains
Gawler River
N
AUSTRALIA
Little Para River
Dry Ck.
542 Mt. Gawler
542 Mt Pleasant
River Torrens
SOUTH AUSTRALIA
ADELAIDE
ADELAIDE
726 Mt Lofty
Mt Lofty Ranges
Hallett Cove
Noarlunga Embayment
Onkaparinga River
MURRAY BASIN
Willunga Embayment
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Angas River
Bremer River
Mt Magnificent 382
Sellicks Beach
Sellicks Ck
Finniss River
Study Area
Myponga Hill 441
Hindmarsh River
Currency Ck
Lake Alexandrina
Carrickalinga R
Bungala R
Inman River
Hindmarsh Island
Yankalilla R
Pt. Elliot
Weymouth Hill 356
Victor Harbor
Fleurieu Peninsula
Cape Jervis
Encounter Bay
Tunkalilla Beach
Waitpinga Beach
0 10 20 30 40 50
Scale in kilometres

Fig. 1. Location of the study area.

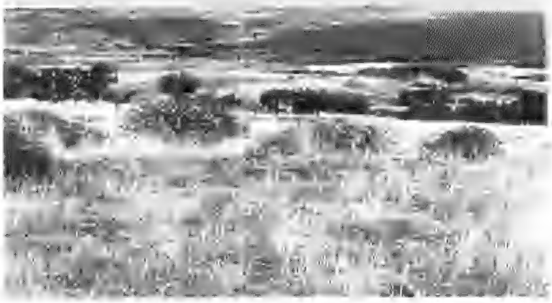

Fig. 2. General view from the north over the Normanville Embayment fill backing the modern coastal dunes marked by a line of vegetation at the shore. The present cliff line in the distance was also a coastal cliff during last interglacial times, and the relict coastal cliff inland is a continuance of this line.

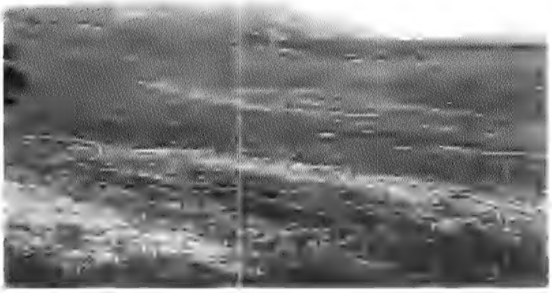

Fig. 3. View to the southwest across the Normanville Embayment fill from the relict last interglacial cliff line. Topographic irregularities on the embayment fill have resulted from alluvial fan sedimentation away from the cliff line and aeolian deposition in the right centre of the photograph.

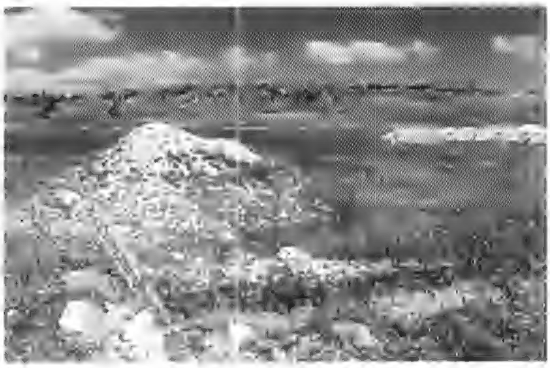

Fig. 4 View across the Normanville Embayment fill fron Hole #1 showing the relict coastal cliff in the backgrounc from which an alluvial fan extends.

coloured sediments that are regarded here as the equivalents of the Pooraka Formation, elsewhere dated as last interglacial (Bourman *et al.* 1997). Set within a valley eroded out of the Pooraka Formation sediments are grey-black coloured sediments which form lower level, paired terraces likely to be of mid-Holocene age (Bourman *et al.* 1997). A distinctive high level alluvial surface at the outlet of Little Gorge (Fig. 5) to the sea is probably related to a former higher sea level.

The extremities of the embayment are characterised by rocky cliffed shorelines developed on crystalline Archaean rocks to the south, near Little Gorge, and Cambrian metasedimentary rocks to the north near Haycock Point. These rocky shores also represent the hinge points of the embayment during the relatively higher sea level of last interglacial times.

Materials and Methods

This study was instigated by the serendipitous discovery of a series of investigative pits, up to 5 m deep (Fig. 6), excavated in the Normanville Embayment fill for a professional golf course and housing development. The locations of these holes are shown in Figure 5. The vertical walls of the pits provided complete and superlative 3-dimensional exposure of the subsurface sediment layers, which included various marine shell, gravel and sand layers beneath a near-surface calcreted horizon. Using an aluminium extension ladder for access, the sediment profiles exposed in the excavations were measured, described and sampled for dating and faunal analysis. The ground surface elevations at the pits were surveyed using an automatic level and related to Australian Height Datum (AHD) by levelling to a nearby survey bench mark.

Fossil mollusc shells were collected for species identification, habitat assessment and amino acid racemisation analysis. Amino acid racemisation analyses were undertaken on the hinge region of well-preserved, disarticulated specimens of *Mactra australis* Lamarck. Complete details of the analytical procedures followed are provided by Murray-Wallace (1993). Analyses of the N-pentafluoropropionyl D, L-amino acid 2-propyl esters were undertaken using a Hewlett Packard 5890A Series II gas chromatograph with a flame ionisation detector and a 25 m coiled, fused silica capillary column coated with the stationary phase Chirasil-L-Val. In this work, the extent of racemisation is reported for the amino acids alanine (ALA), valine (VAL), leucine (LEU), aspartic acid (ASP), glutamic acid (GLU) as well as the extent of isoleucine epimerisation (ALLO/ISO).

Sand samples from aeolian sediments were

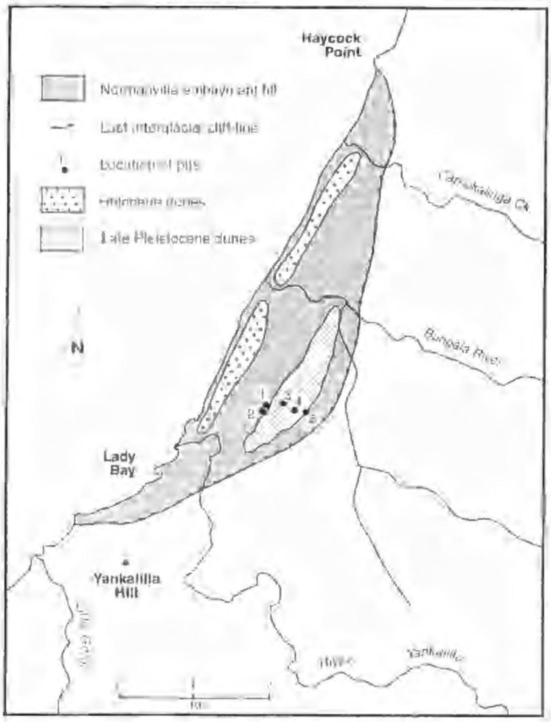

Fig. 5. Normanville Embayment - localities of excavations.

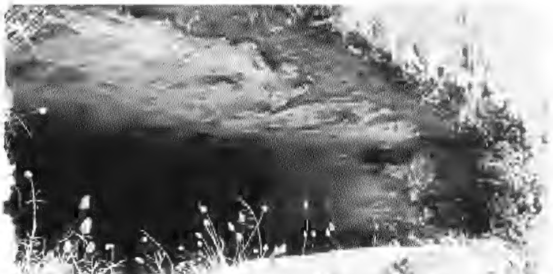

Fig. 6. Five m deep inspection pit (Hole #1) excavated into the Normanville Embayment fill sediments. Note the soil filled solution pipes which penetrate a calcrete carapace.

collected for thermoluminescence dating using appropriate techniques that prevented exposure of the sand to sunlight. Dating was carried out in the Thermoluminescence Laboratory of the University of Wollongong. One sample was collected from Hole #1 from fine, well-sorted aeolian sand overlying cross bedded gravels and sands containing disarticulated valves, to compare its age with that of the underlying shells. A second sample was collected from reddish sands that stratigraphically overlie the shells exposed in the pits and which form dunes that produce much of the current irregular relief across the surface of the Normanville Embayment fill materials. The sample was collected from a construction excavation several metres below the ground surface. These sands resemble the Fulham Sand (Firman 1966) of the Adelaide region. They are well rounded, well sorted, carry a patina of iron oxides and form dunes with a similar general distribution and setting to those of the Fulham Sand. The Fulham Sand is characterised by a low, irregular dune topography and occurs within a broad zone up to 3 km in width, subparallel to the coastline (Bowman & Sheard 1988). At Normanville similar subdued dunes are more restricted topographically, are subparallel to the coastline 1 km from the shore and are up to 0.5 km in width.

A sample of the Fulham Sand from the Adelaide Region was collected from its Type Drillhole location in a small reserve on Telford Avenue, Findon (Bowman & Sheard 1988) for thermoluminescence dating and comparison with the lithologically equivalent material at Normanville. The Telford Avenue sample was collected by sand auger from a depth below the ground surface of 2.5 m where the Fulham Sand extends to a depth of 3.3 m. This was done to avoid possible surface reworking of the original deposit.

A fourth sample was collected from aeolian material overlying an elevated shore platform and cobble beach facies of inferred last interglacial age at Sellicks Beach (May & Bourman 1984). The sand is unconsolidated but contains calcareous rhizomorphs.

Bulk samples of the Normanville Embayment fill sediments were collected for foraminiferal analysis, in particular to document the assemblages of fossil

TABLE 1. *Locations of samples collected from the Normanville Embayment fill for foraminiferal analysis.*

Hole Number	Sample Number	Depth interval below surface	AHD Elevation
#1	#1	3.56 - 4.60 m	3.5 – 4.54 m asl
#1	#2	2.60 – 2.70 m	4.54 - 5.7 m asl
#1	#3	1.80 - 2.40 m	5.70 - 6.3 m asl
#2	#4	3.00 - 3.50 m	4.60 - 5.1 m asl
#5	#5	3.00 m	11.9 m asl

foraminifera within the exposed sediments and hence to infer their age(s) and palaeoenvironments of deposition. Sediment samples for foraminiferal analysis were collected from the excavations at the following locations (Fig. 5, Table 1).

All samples were essentially disaggregated and clean and were thus dry sieved without any form of washing or other pretreatment. The grain size fractions 0.50 - 0.25 mm were retained and examined for foraminifera using standard micropalaeontological procedures (e.g. Cann *et al.* 1993). Larger grain size fractions were visually inspected, particularly for the presence of *Marginopora vertebralis*.

Results

Stratigraphy

The stratigraphy exposed in the excavations is illustrated in Figure 7 and is described in greater detail in the Appendix. In Holes #1 and #2 the base of the section is composed of fine, quartz rich, bioclastic sand up to an elevation of 4.5 m AHD (Hole #1) and 4.25 m AHD (Hole #2). This is overlain by 1.3-1.7 m (4.3-6.0 m AHD) of crossbedded gravels and sands containing numerous disarticulated whole shells, dominantly convex upward. The cross bedding is both tabular and herringboned (Fig. 8), with co-sets of beds averaging from 5-20 cm in thickness. Occasional articulated valves provide evidence that they were deposited below sea level and that the shell deposits do not represent a storm or a beach face environment of deposition. This facies association is interpreted as accumulation from an upward shoaling, tidally influenced, shallow marine sea floor.

This overlying unit comprises 0.5-0.9 m (5.8-6.9 m AHD) of fine aeolian sand containing calcareous rhizomorphs. A sample of this material was collected at an elevation of 6.2 m AHD in Hole #1 for thermoluminescence dating. An irregular, calcrete hardpan up to 0.5 m thick rests on the sand and solution pits infilled with red sandy soil extend into and through the calcrete into the underlying fine sand and gravels, in places to depths of 3 m below the surface (Fig. 9 from Hole #5). The reddish-brown *terra rossa* soil which infills the solution pipes is overlain by a grey-brown sandy loam. This generalised stratigraphy is also revealed in the other excavations but with increasing elevation in successively landward pits the lowermost units progressively fail to be exposed. The above sequence of strata is also exposed in a large excavated lake immediately to the north of Hole #1.

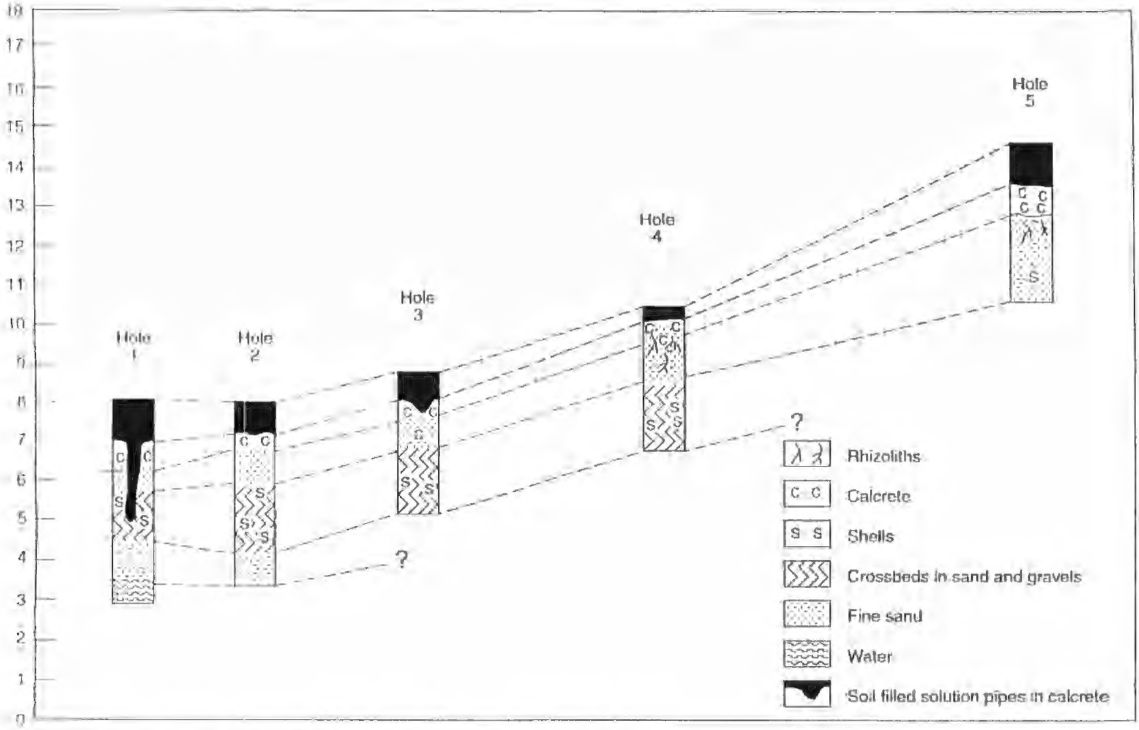

Fig. 7 Stratigraphy of Normanville Embayment fill.

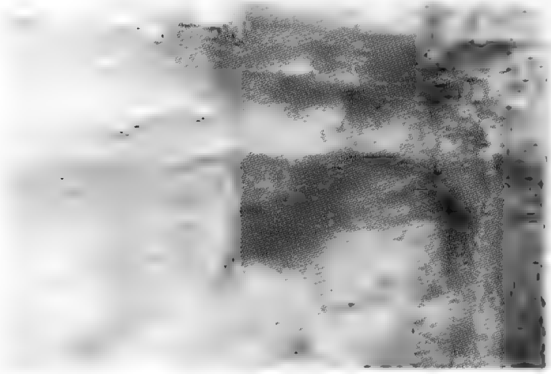

Fig. 8. Strong herringbone cross-beds exposed in Hole #1 indicating an energetic sub-tidal environment. The cross-beds are developed in sand and gravels, with occasional larger pebbles, some of which are reworked from Permian glacigenic sediments. Note occasional rhizomorphs and convex upward valves. The width of field is approximately 2 m.

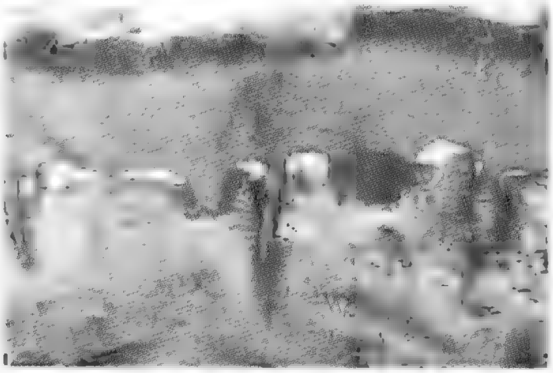

Fig. 9. Exposure as revealed in Hole #5 shows a karstified patchy calcrete with dark red brown clay-rich soil partly infilling the solution pipes, overlain by a uniform light brown sandy loam, which is in turn overlain by an organic rich A horizon. The unit underlying the calcrete is a fine quartz sand with a few calcareous rhizomorphs. At the base of the section there is stratified quartzose sand containing scattered forams and shell fragments; this unit represents a former beach deposit. Depth of section is 3 m

TABLE 2. *Fossil molluscs in the Normanville Embayment fill*

Bivalves	Gastropods
Brachidontes erosus	*Conus (Floraconus) anemone*
Brachidontes (Austromytilus) rostratus	*Diala lauta*
Chlamys (Chlamys) aktinos	*Gazameda iredalei*
Chlamys (Equichlamys) bifrons	*Haliotis* sp. (fragment)
Glycymeris (Tucetilla) radians	*Polinices incei*
Irus crenatus	*Turbo (Subninella) undulatus*
Katelysia scalarina	
Mactra australis	
Mytilus edulis planulatus	
Notospisula trigonella	
Pleuronectis subpecten (?)	
Sanguinolaria (Psammotellina) biradiata	
Tellina (Pseudarcopagia) victoriae	

Fossil mollusc assemblage

The embayment fill succession contains a relatively diverse assemblage of fossil, shallow marine molluscs (Table 2). Species identification follows that of Ludbrook (1984). The molluscs are mostly well-preserved and some show traces of their original colour (e.g. *Chlamys* sp.). Occasional articulated bivalves occur, but they are predominantly disarticulated, convex up, and show little evidence of attrition, thus indicating transportation over short distances under conditions of moderate energy. *Mactra australis* dominates the bivalve assemblage. Collectively, the assemblage reflects deposition in an intertidal to shallow subtidal setting with a sandy substrate. Some gastropods, however, such as *Turbo* sp., were evidently derived from adjacent open ocean rocky coastal settings, reflecting a thanatocoenose component of the fossil assemblage.

Amino acid racemisation results

Amino acid racemisation analyses undertaken on the hinge region of well-preserved, disarticulated specimens of *M. australis* revealed a high degree of concordance in the extent of racemisation for replicate specimens of *M. australis* from the Normanville Embayment fill (Table 3). The following coefficients of variation for inter-shell amino acid D/L ratios, for the different amino acids is noted: ALA 3.3%; VAL 4.1%; ALLO/ISO 4.2%, LEU 4.2%; ASP 1.7% and GLU 1.7%. The relative extent of racemisation of the different amino acids in each mollusc is consistent with previously established relative rates of racemisation in Quaternary molluscs such that ALA>ASP> ALLO/ISO>GLU>LEU≥VAL (Murray-Wallace *et al.* 1988) and attests to the reliability of the data reported here. Significant differences from these observed relative extents of racemisation would otherwise point to the possibility of contamination by non-indigenous amino acids.

A common age for the molluscs from the Normanville deposit is indicated by the equivalent extent of amino acid racemisation in each of these fossils. Their extent of racemisation far exceeds that for Holocene materials (Table 3; see also Murray-Wallace 1995) and a last interglacial age is indicated for the molluscs from the Normanville Embayment fill, by analogy with fossil molluscs from the reference section of the last interglacial Glanville Formation at Dry Creek in the Adelaide area (c. 125 ka; Oxygen Isotope Sub-stage 5e; Cann 1978; Belperio *et al.* 1995). Similarly, the fossil molluscs from the Normanville Embayment fill show a comparable extent of racemisation to specimens of *M. australis* from a last interglacial sand flat facies on Hindmarsh Island (Table 3). Today, the Normanville, Hindmarsh Island and Dry Creek sites are characterised by similar mean annual temperatures, and as a corollary are likely to have experienced equivalent diagenetic temperature histories. The equivalence in amino acid D/L ratios therefore indicates a common age for the fossil molluscs from these three sites.

Foraminiferal analyses

All samples yielded foraminifera and, in particular, they all contained fragments of *Marginopora vertebralis* Blainville supporting a last interglacial age for the marine deposits within the embayment fill at Normanville (Glanville Formation equivalents).

Four samples contain abundant, well preserved and easily identifiable foraminifera. The numerical distribution of species for these samples is given in Table 4 and the relative abundances of those species constituting > 1% of a population are shown in Figure 10. Three of the most common species were *Nubecularia lucifuga* Defrance, *Discorbis dimidiatus* (Parker & Jones) and *Elphidium crispum* Linne, all of which are known to be characteristic of the shallow, subtidal coastal environments of modern Gulf St Vincent (Cann & Gostin 1985; Cann *et al.* 1988, 1993). However, there are differences between the assemblages, some marked and others more subtle, the significance of which will be discussed later.

In sample #3, particle size fractions > 0.25 mm consisted predominantly of quartz grains coated wholly or in part by carbonate. Quartz grains 1.00 - 0.50 mm are polished and show a high degree of rounding and sphericity. This is consistent with aeolian reworking, sorting and polishing. Foraminifera are relatively rare and have undergone extensive carbonate diagenesis, rendering tests distinguishable only on the basis of gross shape.

TABLE 3 *Extent of amino acid racemisation and epimerisation (total acid hydrolysate) in fossil molluscs from the Normanville Embayment fill and other Late Quaternary deposits in South Australia.*

Locality	Species	Depth of burial (m)	C.M.A.T (°C)	Lab.Code or reference	AMINO	ACID D/L	RATIO			
					ALA	VAL	ALLO/ISO	LEU	ASP	GLU
Normanville	*Mactra australis*	2.6 - 2.7	16	UWGA-358	0.64±0.001	0.27±0.03	0.38±0.02	0.28±0.02	0.58±0.004	0.33±0.002
Normanville	*M. australis*	2.6 - 2.7	16	UWGA-359	0.61±0.004	0.29±0.001	0.35±0.02	0.26±0.004	0.59±0.02	0.33±0.03
Normanville	*M. australis*	3.0 - 3.5	16	UWGA-362	0.65±0.002	0.29±0.01	0.36±0.02	0.28±0.001	0.60±0.02	0.34±0.01
Hindmarsh Island	*M. australis*	1	16	UWGA-322	0.66±0.005	0.26±0.003	0.39±0.003	0.37±0.002	0.56±0.001	0.36±0.002
Dry Creek, Adelaide, Glanville Formation (125 ka BP)	*Anadara trapezia*	3	17	Murray-Wallace *et al.* (1988)	-	0.31±0.01	0.39±0.01	-	0.61±0.01	-
Sir Richard Peninsula 2660±140 BP (SUA-2881)	*Donax (Plebidonax) deltoides*	surface, exhumed midden	16	Murray-Wallace & Bourman (1990)	0.13±0.02	0.07±0.01	-		0.19±0.01	0.12±0.005

TABLE 4. *Numerical distribution of species of foraminifera constituting >1% of picked and counted samples, sediment grain size 0.50-0.25 mm.*

Species of foraminifera	Hole #1 Sample #1		Hole #1 Sample #2		Hole #2 Sample #4		Hole #5 Sample #5	
	Depth in hole 3.56-4.60 m		Depth in hole 2.60-2.70 m		Depth in hole 3.00-3.50 m		Depth in hole 2.75-3.70 m	
	No.	%	No.	%	No.	%	No.	%
Cribrobulimina mixta	3	0.9	4	1.5	5	1.6		
Nubecularia lucifuga	37	11.7	75	28.3	84	27.0	2	0.8
Quinqueloculina lamarckiana	6	1.9	6	2.3	16	5.1	7	2.7
Q. moynensis	8	2.5			4	1.3		
Q. pittensis							5	1.9
Triloculina tricarinata + T. trigonula	28	8.8	13	4.9	13	4.2		
Scutuloris parri	6	1.9	1	0.4				
Peneroplis planatus	2	0.6	1	0.4	5	1.6		
Marginopora vertebralis	2	0.6	4	1.5	2	0.6	4	1.5
Discorbis dimidiatus	97	30.6	141	53.2	147	47.3	150	56.8
Rosalina australis	5	1.6	1	0.4	2	0.6	65	24.6
Epistomaroides polystomelloides			4	1.5	2	0.6		
Elphidium crispum	113	35.6	11	4.2	23	7.4	11	4.2
E. macelliforme	3	0.9	4	1.5	2	0.6	13	4.9
Other species	7	2.2			6	1.9	7	2.7
	N = 317		*N* = 265		*N* = 311		*N* = 264	

TABLE 5. *Thermoluminescence dates.*

Laboratory No.	Specimen name	Location	TL age	Isotope Stage $\delta^{18}O$	Sea level position
W2356	Normanville 1	Hole #1 Depth 1.8 m Calcareous coastal aeolian sand	50.4 ± 4.3 ka	3.13 (4)	~-40 m[1]
W2357	Normanville 2	Reddish dune, 1 km NW of Hole #1. Depth 2.5 m Calcareous at depth	58.0 ± 6.1 ka	4.0 (4)	~-40 m[1]
W2358	Fulham Sand 1 Type Drillhole Location	Telford Ave., Findon	74.9 ± 6.9 ka	5.0 (5a)	- 80 m[1] - 14 m[1]
W2317	Sellicks Beach 1	Above cobble beach on shore platform 4-6 m asl. Calcareous	34.0 ± 2.9 ka	3.1 (3)	- 22 to - 30 m[3]

Source: $\delta^{18}O$ Isotopic events unbracketed assigned using the scheme of Martinson *et al.* (1987)
$\delta^{18}O$ Isotopic events in brackets assigned using the scheme of Aharon & Chappell (1986)
[1] Sea levels from Aharon & Chappell (1986)
[2] Sea level from Murray-Wallace *et al.* (1988)
Sea level from Hails *et al.* (1984)

When wet, some revealed other features that allowed identification, such as *E. crispum*, which showed the characteristic pattern of numerous narrow chambers with raised retral processes bridging the depressed sutures. Other species identified included *D. dimidiatus* and *M. vertebralis*. It was not possible to determine a meaningful numerical distribution of species for this sample, particularly for the particle size fraction 0.50 - 0.25 mm.

Thermoluminescence (TL) dating

The Thermoluminescence Laboratory at the University of Wollongong reported that the samples exhibited good TL characteristics with lengthy temperature plateau comparisons and regenerated TL growth curve r-square correlation coefficients approximating unity. These characteristics, together with the small age uncertainty levels associated with these determinations, further validate the depositional ages reported here (Table 5).

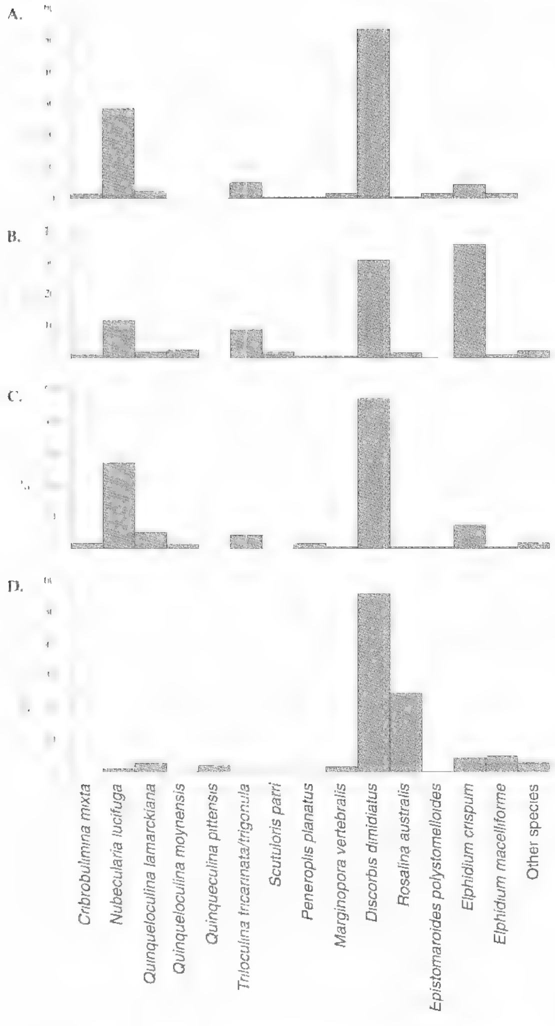

Fig. 10. Bar graph comparing percentage distributions of species of foraminifera from sediment samples; data from Table 4. A. Hole #1, sample #2, depth in hole 2.60-2.70 m. *N*=265. B. Hole #1, sample #1, depth in hole 3.56-4 .60 m. *N*=317. C. Hole #2, sample #4, depth in hole 3.00-3.50 m. *N*=311. D. Hole #5, sample #3, depth in hole 2.75-3.70 m. *N*=264.

Discussion

Foraminiferal analysis

Foraminiferal analysis has confirmed the sedimentological interpretation of a shallow marine, shoaling upward succession. It further supports the last interglacial age assignment. Fossil foraminifera within the last interglacial Glanville Formation are generally similar to those presently living within the marine environments of the South Australian gulfs, Gulf St Vincent and Spencer Gulf. However, there are distinctive elements, such as *M. vertebralis*, which signify that the waters were somewhat warmer than those of today (Cann 1978). It is now recognised that the occurrence of these organisms in the last interglacial sediments of southern Australia can be attributed to a particularly active phase of the Leeuwin current. At times of global warming this narrow current of warm tropical water flows south along the western coast of Australia before turning to the east across the Great Australian Bight (Cann & Clarke 1993; McGowran *et al.* 1997). Among the distinctive fossil foraminifera of the Glanville Formation, the most frequently recorded species has been the megascopic *M. vertebralis* although Li *et al.* (1997)[1] have referred equivalent modern specimens at Esperance, Western Australia, to the genus *Amphisorus*.

Nubicularia lucifuga is the most common species of foraminifera in the shallow subtidal *Posidonia* seagrass meadows of the modern South Australian gulfs. In the sediments exposed in Hole #1, this species increases up-sequence, from 12-28%, which suggests water shallowing, probably due to sediment aggradation and ongoing development of a seagrass environment. In the lower Sample #1 *E. crispum* is at its maximum occurrence, signifying a shallow subtidal setting of normal marine salinity but higher in the sequence this species represents < 5% of the assemblage and there is substantial development of *D. dimidiatus*. This reversal in relative abundance is a clear signal of water shallowing (Cann *et al.* 1988). Thus the sequence of sediments exposed in Hole #1 between 3.5 m and 5.5 m AHD can most easily be interpreted as one of sediment aggradation in a seagrass environment during the last interglacial sea level maximum.

The foraminiferal assemblage of Sample #4 from Hole #2 (4.6-5.1 m AHD) is remarkably similar to, and may be correlated with, that of Sample #2 of the adjacent Hole #1 (4.5-5.7 m AHD). Thus, essentially the same shallow subtidal seagrass palaeoenvironment of deposition is signified for this interval of sediment.

There are several quite marked features of the foraminiferal assemblage within sample #5, which contrast with those derived from the other samples.

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[1] Li, Quanyu, McGowran, B., Bone, Y. & James, N. P. (1997) Recent foraminifera along the southern Australian margin: palaeooceanographic significance. Third Australian Marine Geoscience Conference, Department of Geology and Geophysics, University of Adelaide. Abstracts, 38-39.

Sample #5 was derived from an inferred littoral facies at the highest elevation (11.9 m AHD) and the most landward site (Table 1). Most obviously, *N. lucifuga* comprises < 1% of the Sample #5 assemblage and this may be interpreted to indicate the absence of an adjacent subtidal *Posidonia* seagrass meadow. Despite the fact that the very high numbers of *D. dimidiatus* (57%) originated in a shallow subtidal setting, *Rosalina australis* (Parr) (25%) and *Elphidium macelliforme* McCulloch (5%) together provide convincing evidence that much of the assemblage was derived from slightly deeper inner shelf environments some distance from the coast. More subtle supporting evidence is the presence, albeit < 1%, of shelf dwelling species such as *Bolivinella folium* (Parker & Jones) and *Cibicides refulgens* de Montfort. Thus the sandy littoral sediment exposed in hole #5, with its distinctive assemblage of inner shelf foraminifera was, at least partly, derived from offshore environments and transported shorewards at the culmination of the last interglacial marine transgression. This package of sediment, revealed in the most elevated and landward of the excavations, represents the shoreward limit of the last interglacial sea level event.

Thermoluminescence dating, aeolian activity and calcretisation

The TL dates derived from aeolian sediments resting disconformably above last interglacial facies are considerably younger than the last interglacial facies at Normanville and Sellicks Beach. They suggest that there has been ongoing aeolian redistribution of former coastal and other sand bodies along the eastern shoreline of Gulf St Vincent during times when sea level was lower than at present, with continual re-setting of the TL clock. All three sites and TL dates imply an apparent youthfulness of the calcrete carapace formed on the marine/aeolian sequences. Provided that the TL age in Hole #1 is correct, these data provide a stratigraphic framework for the development of a calcreted surface and imply that calcretisation did not necessarily commence immediately upon cessation of marine sedimentation.

There has been considerable conjecture about the age of the Fulham Sand. Bowman & Sheard (1988) noted that it is not fossiliferous but that it stratigraphically overlies both the last interglacial Glanville Formation and the Pooraka Formation and is overlain by the Holocene St Kilda Formation. They regarded the age of the Pooraka Formation to be 35-20 ka BP. They concluded that the relative absence of organic and calcareous detritus in the Fulham Sand, in comparison with the St Kilda Formation, and the degree of soil development in undisturbed Fulham Sand indicated a pre-Holocene age. It was equated with aeolian landscape instability during the last glacial at some 20-16 ka, although reworking through to the present was documented.

Although based on limited data, the results presented here suggest that the Fulham Sand is considerably older than previously suggested, with potential ages ranging from 75-50 ka BP. This interpretation is not incompatible with the Fulham Sand being younger than the Pooraka Formation as it has been demonstrated, in some localities at least, that the Pooraka Formation is the terrestrial equivalent of the last interglacial (125 ka BP) marine Glanville Formation (Bourman *et al.* 1997). Consequently the Pooraka Formation is likely to be considerably older than the 35-20 ka age discussed above.

We suspect ongoing aeolian redistribution of sands exposed on the former sub-littoral zone based on the fact that the forams suggest a last interglacial age, but TL produced an age of 50 ka. Aeolian reworking even of coastal calcarenites proceeded largely unimpeded as evidenced by the TL dates at Normanville, Sellicks Beach and at the Fulham Sand Type Drillhole location.

Neotectonics

There is a long history of tectonism affecting Fleurieu Peninsula and there appears to have been variable movement along the fault zones of the region. For example, the Clarendon-Ochre Cove faultline appears to have been locked throughout the Quaternary (Ward 1966) whereas there has been considerable movement along the Willunga Fault Zone during the Pleistocene, as demonstrated by the dislocation of Middle Pleistocene beds (May & Bourman 1984).

Recurrent tectonism during the Cainozoic is illustrated by the tectonic dislocation of limestones of various ages. For example, Early Miocene limestone of the Port Willunga Formation in the Adelaide area occurs at up to 200 m below sea level (Daily *et al.* 1976); crops out at sea level at Sellicks Beach but 12 km away, across the Willunga Fault zone near Myponga, it reaches altitudes of up to 240 m, indicating a minimum amount of differential movement since this time (May & Bourman 1984). Furthermore, the earliest Pleistocene Burnham Limestone, estimated by Pillans & Bourman (1996) to be approximately 1.7 Ma old, and its equivalents vary in elevation along the shoreline of Gulf St Vincent between the extremes of - 82 m in the Port Adelaide area to + 50 m asl at Cape Jervis (Firman 1976; Ludbrook 1983; May & Bourman 1984; Belperio 1995). Ludbrook (1983) considered that the present distribution of the Burnham Limestone and its equivalents resulted from gentle warping and also by faulting as a result of Pleistocene reactivation of

Early Palaeozoic tectonism, a view which we share. The elevations of the Burnham Limestone, with additional exposures occurring at Marino (Firman 1976) (17 m asl), near Hallett Cove (30 m asl) (Ludbrook 1983), Maslins, near the Tortachilla Trig (29 m asl) (Twidale *et al.* 1967; May & Bourman 1984), Port Willunga (Firman 1976) (15 m asl) and at Sellicks Beach (8 m asl) (May & Bourman 1984), support the view of gentle tectonic tilting or warping of the landscape. However, locally, such as across the Eden Fault Zone at Marino and across the Willunga Fault Zone at Sellicks Beach, there has been significant tectonic offsetting of the Burnham Limestone, which is particularly marked since it is a typically thin unit from 1-3 m thick.

A consideration of the vertical distribution of last interglacial shoreline sediments (125 ka) further illustrates the ongoing nature of the tectonism affecting Fleurieu Peninsula. In a review of Australian occurrences of last interglacial (Oxygen Isotope Sub-stage 5e) coastal deposits, Murray-Wallace & Belperio (1991) noted that the most consistent shoreline datum for deposits of this age is from the western coast of Eyre Peninsula. Here, intertidal facies of the last interglacial shoreline occur at 2 m AHD over a distance of 500 km. The consistency of this shoreline datum has been attributed to the relative tectonic stability of the Gawler Craton. Elsewhere, variation in the altitude of last interglacial shoreline deposits has been noted and, in the case of the Coorong to the Mount Gambier Coastal Plain in the southeast of South Australia, variations in elevation have been attributed to neotectonic uplift associated with intra-plate volcanism (Murray-Wallace *et al.* 1996). From Salt Creek to near Mount Gambier the back-barrier lagoon facies (a reliable palaeo sea-level indicator) of the last interglacial Woakwine Range has been noted to rise progressively from 3-18 m AHD (Murray-Wallace *et al.* 1996).

A probable last interglacial shoreline (May & Bourman 1984) occurs at Sellicks Beach, on the upthrown side of the fault block, where an elevated shore platform at approximately 4-5 m AHD has been eroded across steeply tilted Tertiary limestone beds and on which rests a boulder beach containing shell fragments and occasional intact but abraded molluscs. Dissection of this formerly more extensive high level shore platform has produced a series of small sea stacks standing above the modern shore platform. Calcareous dune sands, several metres thick and essentially unconsolidated, but containing rhizomorphs, overlie the boulder beach. This former shoreline can be traced for several hundred metres in a southerly direction and does not appear to have been tilted. Immediately to the north of the Willunga Fault Zone, on the downthrown block, there is no evidence of this former shoreline feature, suggesting erosional removal and/or tectonic depression. The shells within the boulder beach returned a radiocarbon age exceeding 30 ka (May & Bourman 1984) while the overlying dune sand was dated at 34.0±2.9 ka by thermoluminescence techniques (Table 5). Here we interpret the elevated shore platform and boulder beach as last interglacial features, with the dune sand having been deposited or reworked during a lower interstadial sea level (oxygen isotope stage 3) when sea level may have been some 22 to 30 m lower than at present (Murray-Wallace *et al.* 1993).

At Victor Harbor on the southeastern side of Fleurieu Peninsula there is extensive geomorphological and sedimentological evidence of the last interglacial shoreline, extending up to + 6 m AHD (Bourman *et al.* 1989, 1997). However, along the coast between Sellicks Beach and Victor Harbor there are no reported occurrences of the last interglacial shoreline despite there being many occasions where high level alluvial sediments appear to grade to a shoreline considerably higher than at present. The discovery of the last interglacial shoreline at Normanville as reported in this paper helps to redress this void and provides significant data relevant to the tectonic history of Fleurieu Peninsula.

In the Normanville Embayment fill, last interglacial sediments have been identified at elevations of up to 5.8 m AHD nearest the coast to 12 m AHD at the furthest inland site. The occurrence of the littoral feather edge of the transgressive facies within the Normanville Embayment fill to 12 m AHD implies 10 m of uplift since the Last Interglacial relative to shoreline elevations in tectonically stable regions. Unfortunately palaeo sea-level indicators within this transgressive package have not been identified with any great precision. The mollusc assemblage only partly assists as some of them may potentially occur at a range of depths e.g. shallow sub-tidal. Herringbone sand and gravel cross beds, containing convex upward valves, suggest relatively strong reversing currents in a sub-littoral environment and hence provide only a minimum former sea level position. Although no articulated bivalves were recovered from the inspection pits, occasional pairs occurred in the large water hole exposure close to Hole #1. This suggests that the shells have only been transported over short distances from their original *in situ* positions.

The tectonic dislocation of the Late Pleistocene last interglacial Glanville Formation appears to mimic the earlier tectonic history of Gulf St Vincent and Fleurieu Peninsula, revealed by the dislocation of older marine units, signifying uplift of Fleurieu Peninsula and depression of the Adelaide area and

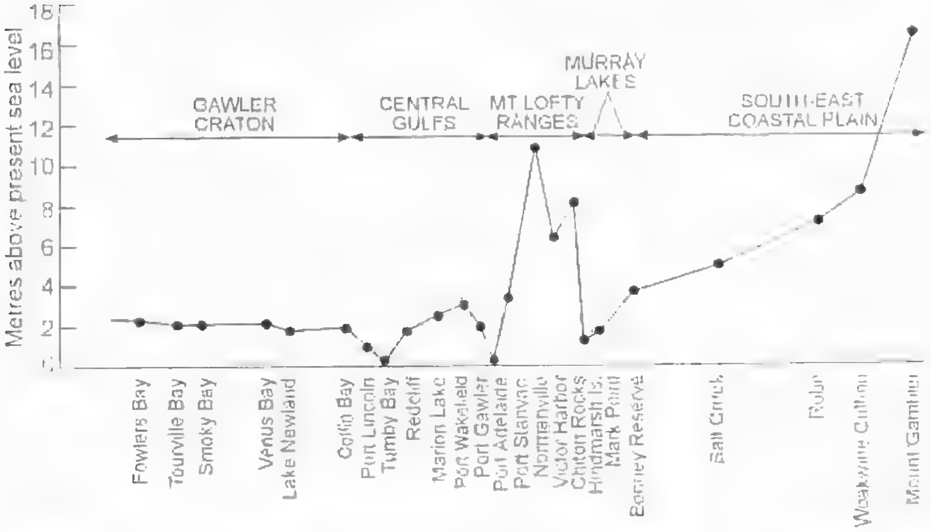

Fig. 11. Altitude of all the last interglacial intertidal facies in South Australia, modified from Murray-Wallace (1995).

the Willunga Embayment. In the area north and west of Adelaide city, the upper surface of the Glanville Formation extends to depths of 11 m below low water datum at Outer Harbor, with its known landward limit reaching low water at St Kilda and + 0.4 m at Dry Creek (Ludbrook 1976; Belperio 1985), indicating gradual submergence of the last interglacial facies in this area.

The altitudes of known last interglacial shoreline facies in South Australia, modified from Murray-Wallace (1995), are illustrated in Figure 11. The elevations suggest post-last interglacial tectonism resulting in tilting of the shoreline, with differential uplift along the Fleurieu Peninsula, with a maximum in the Normanville area, adjacent to the Little Gorge Fault, and submergence in the Adelaide and Murray Lakes areas. Ongoing uplift of the Mount Lofty Ranges throughout the Cainozoic has been demonstrated by many workers. Bourman & Lindsay (1989) reported reverse faulting on the eastern side of the Mount Lofty Ranges, which supports the view of com-pressive forces being involved in the ongoing deformation of the ranges as suggested by Wellman & Greenhalgh (1988). In addition to the demonstrated compressive forces operating, ongoing uplift may also be related to erosional unloading and associated isostatic compensation of the Adelaide Foldbelt.

Conclusions

The identification of the elevated shell beds and coastal sediments of last interglacial age in the embayment fill sediments at Normanville allows quantification of the neotectonism affecting Fleurieu Peninsula. Convincing correlation by amino acid racemisation of the last interglacial Dry Creek Glanville Formation with the shells at Normanville and those on Hindmarsh Island is supplemented by thermoluminescence and foraminiferal analysis. Comparisons of elevations of the Glanville Formation reveal the differential uplift of Fleurieu Peninsula and depression of the Adelaide area and the Murray Basin of up to 10 m over the past 125 ka. The tectonic dislocation of the last interglacial shoreline demonstrates the ongoing tectonism of the area as evidenced by the dislocation of older marine units of Miocene and earliest Pleistocene ages.

Species of foraminifera, consistent with a last interglacial age, reveal a shallow sub-tidal environment of deposition, in waters that were warmer than at present. The molluscs also reflect intertidal to subtidal settings with a sandy substrate and protection from a rocky coastline. Some of the forams and the occurrence of species of gastropods such as *Turbo* sp. in the assemblage suggest intermixing from other settings including rocky shorelines on the extremities of the embayment.

Overlying, but genetically related aeolian sands indicate ongoing aeolian activity to at least 50 ka. Thermoluminescence dating of the Fulham Sand for the first time provides a numerical age of 74.9 ± 6.9 ka, which is much older than previous estimates, but the earlier interpretations were restricted by the acceptance of too young an age for the Pooraka Formation. The formation of aeolian deposits occurred during interstadial and glacial low sea levels, by the reworking of former coastal sand bodies and sediments on the exposed sea floor. Luminescence dating has demonstrated the formation of calcrete and the development of dissolution features in the past 50 ka. On Fleurieu Peninsula, calcrete formation appears to have been retarded in its development compared to other sites around the state. This allowed the reactivation of coastal sediments and a sequence of genetically related, but significantly younger aeolian sand spreads to develop before calcretisation stabilised the sequences.

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Appendix

Detailed stratigraphy of Normanville Embayment fill exposed in excavations (Holes #1-#5). Elevations in bold refer to Australian Height datum (AHD) and those above refer to distances below the ground surface.

HOLE 1 ELEVATION 8.088 M AHD

Surface to 1.0 m **8.1-7.1 m**	Dark brown soil over variably developed relict *terra rossa* soil. In places infills sinkholes or claypots to greater depth.
1.0-1.8 m **7.1-6.3 m**	Chalky hardpan calcrete of variable thickness. Irregular upper surface with soil filled sinkholes extending to depths of 3 m.
1.8-2.4 m **6.3-5.7 m**	Dune calcarenite with soft pedogenic overprint including numerous rhizomorphs. TL sample of dune calcarenite and Sample 3 for foraminiferal analysis collected from -1.8 m. Includes the single layer of better stratified sand with rare pebbles that may represent a storm event.
2.4-3.56 m **5.7-4.54 m**	Stratified gravelly sand with tabular cross beds. Represents shallow sub-tidal to shoreline facies. Energetic tidal environment indicated by herringbone cross beds. Prominent, large convex-upward shells in middle of unit (Sample 2). Sample taken from -2.6 to -2.7 m. Gravels 0.5 to 1.0 cm diameter. Some quartz pebbles cobble sized, up to 4 cm. Gravelly sand 2.4 to 3.4 m. Sand is unconsolidated - runs readily. 5% large shells and fragments. Gravelly unit from 2.4 m to -3.4 m is an intertidal shoreline deposit. Large Permian boulders in gravel layer. Sharp top to gravelly, cross-bedded sand.
3.56-4.6 m **4.54-3.5 m**	Weakly stratified fine bioclastic sand (Sample 1). Probably a sub-tidal marine sand. Water level in bottom of hole at 4.6 m.

HOLE 2 ELEVATION 8.093 M AHD

Description

Surface to 0.8 m **8.1-7.3 m**	Red-brown soil.
0.8-1.2 m **7.3-6.9 m**	Calcrete hardpan
1.2-2.2 m **6.9-5.9 m**	Small shells, rare stones. Fine sand probably dune material.
2.2-3.9 **5.9-4.2 m**	Gravelly and shelly unit with tabular cross-beds and bi-directional herring bone pattern. Whole shells convex up. Gravels and pebbly layer clearly water laid. Most shell samples collected from 3.0 m to 3.5m below ground surface (4.6 to 5.1 m AHD) (Sample 4).
3.9 - 4.6m **4.2 - 3.5 m**	Fine bioclastic sand, weakly stratified, subtidal unit.

HOLE 3 ELEVATION 8.948 M AHD

Description

Surface to 1.0 m **8.95 - 7.95 m**	Sandy loam on top infilling pipes.
1.0 - 2.2 m **7.95 - 6.75 m**	Calcreted aeolian calcareous sand. Fine calcareous bioclastic sand. Variable basal surface 1.0-0.7 m.
2.2 - 3.7 m **6.75 - 5.25 m**	Cross-bedded gravelly and shelly sand includes coarse gravelly unit with shells (same shells as in other holes). Sharp top to gravels. Stratified, water borne sediments.

HOLE 4 ELEVATION 10.728 M AHD

Surface to 0.3 m **10.73 - 10.43 m**	Red sand. *Terra rossa* with degraded shell fragments within it. Grey-brown soil at top. Calcrete is harder here than at other sites.
0.3 - 2.0 m **10.43 – 8.73 m**	Bioclastic, fine sand with rhizomorphs and reworked calcrete. Grades up into irregular calcreted surface up to 0.3 m and down to 1.0 m.
2.0 - 3.7 m **8.73 - 7.03 m**	Well stratified gravelly sand with a few shells. Rhizomorphs extend into this unit. Pronounced top to it at depth of 2.0 m. Shells same as at other localities- possible estuarine influence- evidence of strong currents with coarse gravel moving in both directions. Possibly broad, shallow tidal channel between ocean and estuary.

HOLE 5 ELEVATION 14.870 M AHD

Surface to 1.0 m **14.87-13.87 m**	Red-brown clay-rich lower unit in places fills in solution hollows. Uniform light brown quartzose sandy loam in top metre.
1.0-1.8 m **13.87 m-13.07 m**	Poorly developed hardpan.

Appendix cont.

1.8-2.75 m **13.07-12.12 m**	Fine quartz sand with a few rhizomorphs. Increasingly patchy carbonate, probably due to low carbonate content of sediment.
2.75-3.7 m **12.12-11.17 m**	Well stratified, very quartzose sand with very low angle stratification. Contains scattered forams and shell fragments. Perhaps 5% forams and bioclastic fragments. Water deposited but not as gravelly as closer to the coast, which would have been in deeper water. Shell fragments up to 1 cm in long axis. Shells derived from hole have been excavated and dumped up on top. Represents sandy beach environment. Sample collected from 3.0 m (11.9 m AHD) with lots of forams (Sample 5). Clearly a sandy littoral unit. May extend down into a gravelly unit below as there are excavated shells at the surface.

NEW SPECIES OF CLOACINA LINSTOW, 1898, (NEMATODA: STRONGYLOIDEA) PARASITIC IN THE STOMACH OF THE QUOKKA, SETONIX BRACHYURUS (MARSUPIALIA: MACROPODIDAE), FROM WESTERN AUSTRALIA

*BY I. BEVERIDGE**

Summary

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Six new species of Cloacina Linstow, 1898 are described from the stomach of the quokka, Setonix brachyurus, from Rottnest Island, Western Australia. They are: C. ceres sp. nov., characterised by lip-like inflations of the peri-oral cuticle, oesophageal bosses extending two thirds of the way to the nerve ring, the deirid posterior to the nerve ring, absence of oesophageal denticles, a symmetrical buccal capsule, a simple straight vagina and spicules 1.56-1.97 mm in length; C. laius sp. nov., characterised by a dorsoventrally elongated buccal capsule, six leaf crown elements, a shallow buccal capsule which is arched anteriorly in lateral views, oesophageal bosses extending to the nerve ring, a single dorsal oesophageal denticle, spicules 1.50-1.97 mm in length and a recurrent vagina.

Key Words: Cloacina, new species, nematodes, Setonix, quokka, marsupials, parasites.

Transactions of the Royal Society of S. Aust. (1999), **123**(1), 17-30.

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Key Words: *Cloacina*, new species, nematodes, *Setonix*, quokka, marsupials, parasites.

Introduction

Many species of macropodid marsupials are parasitised by a suite of species of the nematode genus *Cloacina* Linstow, 1898 occurring in the sacculated forestomachs of their hosts. The number of species of *Cloacina* known from different kangaroo or wallaby hosts which have been examined in detail varies considerably, ranging from none in the case of the red-necked wallaby *Macropus rufogriseus banksianus* (Quoy & Gaimard, 1825) or two in the case of the Tasmanian pademelon, *Thylogale billardierii* (Desmarest, 1822), to 25 in the case of the wallaroo or euro, *Macropus robustus* Gould, 1841 based on a recent revision of the genus (Beveridge 1998). In other macropodid species, insufficient numbers of hosts have been examined for parasites to be able to provide reliable estimates of the diversity of species of *Cloacina* likely to be encountered in them. One such host species is the quokka, *Setonix brachyurus* (Quoy & Gaimard, 1830), which is limited in its distribution to the southwestern region of Western Australia (Kitchener 1995). A single species of *Cloacina*, *C. setonicis* was described from this host by Mawson (1961) and has subsequently been redescribed by Beveridge (1998), but since this was based on a single collection, it is possible that additional species exist. Examination of a series of quokkas has indicated that they, like most other macropodids, are parasitised by a series of species of *Cloacina*. The new species encountered are described in this paper.

Materials and Methods

A series of six quokkas was collected on Rottnest Is., WA in April 1982, using hand nets. The animals were killed with an overdose of sodium pentabarbitone and the stomach was examined for parasitic nematodes. Nematodes found were fixed in hot 70% ethanol and were subsequently stored in 70% ethanol with 5% glycerol. For examination, nematodes were cleared in lactophenol. Permanent

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preparations on slides of apical views of the mouth opening, the bursa and the spicule tips were made using polyvinyl lactophenol as the mounting medium.

Drawings were prepared using an Olympus BH2 microscope with Nomarski interference optics and a drawing tube. Measurements were made using an ocular micrometer and are presented in the text in millimetres as the range followed in parentheses by the mean. Drawings of apical views of the mouth opening are presented with the dorsal aspect uppermost; drawings of the bursa have the ventral lobes uppermost.

Holotypes have been deposited in the South Australian Museum, Adelaide (SAMA). Paratypes have been deposited in SAMA and in the British Museum (Natural History), London (BMNH).

Morphological terminology for nematodes follows that used by Beveridge (1998). The abbreviated term S-E pore is used in place of secretory-excretory pore (Bird & Bird 1991) and oesophagus is used as a synonym of the more correct term "pharynx" (Bird & Bird 1991).

Following Beveridge (1998), the new species are based on classical names since the generic name is that of a Roman goddess.

Cloacina ceres sp. nov.
(FIGS 1-14)

Types. Holotype ♂, from stomach of *Setonix brachyurus*, Rottnest Is., WA, coll. I. Beveridge, 7.iv.1982, SAMA AHC 30558; allotype ♀, SAMA AHC 30559; paratypes: 15 ♂♂, 60 ♀♀, SAMA AHC 30560; 1 ♂, 1 ♀, BMNH 1998.9.28.3-4.

Description

Small nematodes; cervical cuticle not inflated in oesophageal region; transverse cuticular annulations prominent. Sub-median papillae very small, 0.004 long, projecting anterolaterally from peri-oral cuticle, situated on elevations of peri-oral cuticle; proximal segment cylindrical, extremely short, 0.001 long, shorter than ovoid, obtuse distal segment, 0.003 long. Buccal capsule shallow, cylindrical, symmetrical in dorsoventral views, circular in apical view. Leaf crown elements 6 in number, with prominent striations, arising from full length of internal wall of buccal capsule, not recurved at tips. Peri-oral cuticle inflated into lip-like lobes attached to each leaf crown element. Dorsal tooth projecting prominently into buccal capsule; each subventral sector of oesophagus with lancet-like projection into buccal capsule. Oesophagus simple, claviform; lining ornamented with rows of sclerotised bosses from anterior end to two thirds of distance to nerve ring; denticles absent from oesophagus. Nerve ring in mid-oesophageal region; deirids in posterior oesophageal region, between nerve ring and S-E pore; S-E pore anterior to oesophago-intestinal junction.

Male (Measurements from 10 specimens, types) (Figs 9-12)

Total length 4.3-6.0 (5.4); maximum width 0.17-0.22 (0.18); dimensions of buccal capsule 0.010-0.015 (0.013) x 0.032-0.038 (0.035); length of oesophagus 0.36-0.48 (0.41); nerve ring to anterior end 0.19-0.26 (0.21); S-E pore to anterior end 0.32-0.43 (0.38); deirids to anterior end 0.32-0.40 (0.34). Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral lobes and ventral lobes joined. Dorsal lobe similar in length to lateral lobes. Dorsal ray divides at midlength; secondary subdivisions occur at ¾ length; internal branchlets directed posteriorly, not reaching margin of bursa; external branchlets shorter than internals, directed laterally, not reaching margin of bursa. Externodorsal ray arising close to lateral rays, not reaching margin of bursa. Posterolateral and ventrolateral rays fused, reaching margin of bursa; anterolateral ray divergent, shorter than other lateral rays, not reaching margin of bursa; ventrolateral and ventroventral rays fused, reaching margin of bursa. Gubernaculum broadly ovoid, 0.010-0.020 (0.013) long; genital cone with prominent anterior lip; posterior lip shorter than anterior lip, with pair of dome-shaped papillae; pair of lateral inflations of cuticle present on either side of anterior lip; spicules elongate, 1.56-1.97 (1.76) long, alate, tip simple; ala diminishing in width gradually towards tip.

Female (Measurements from 10 specimens, types) (Figs 13-14)

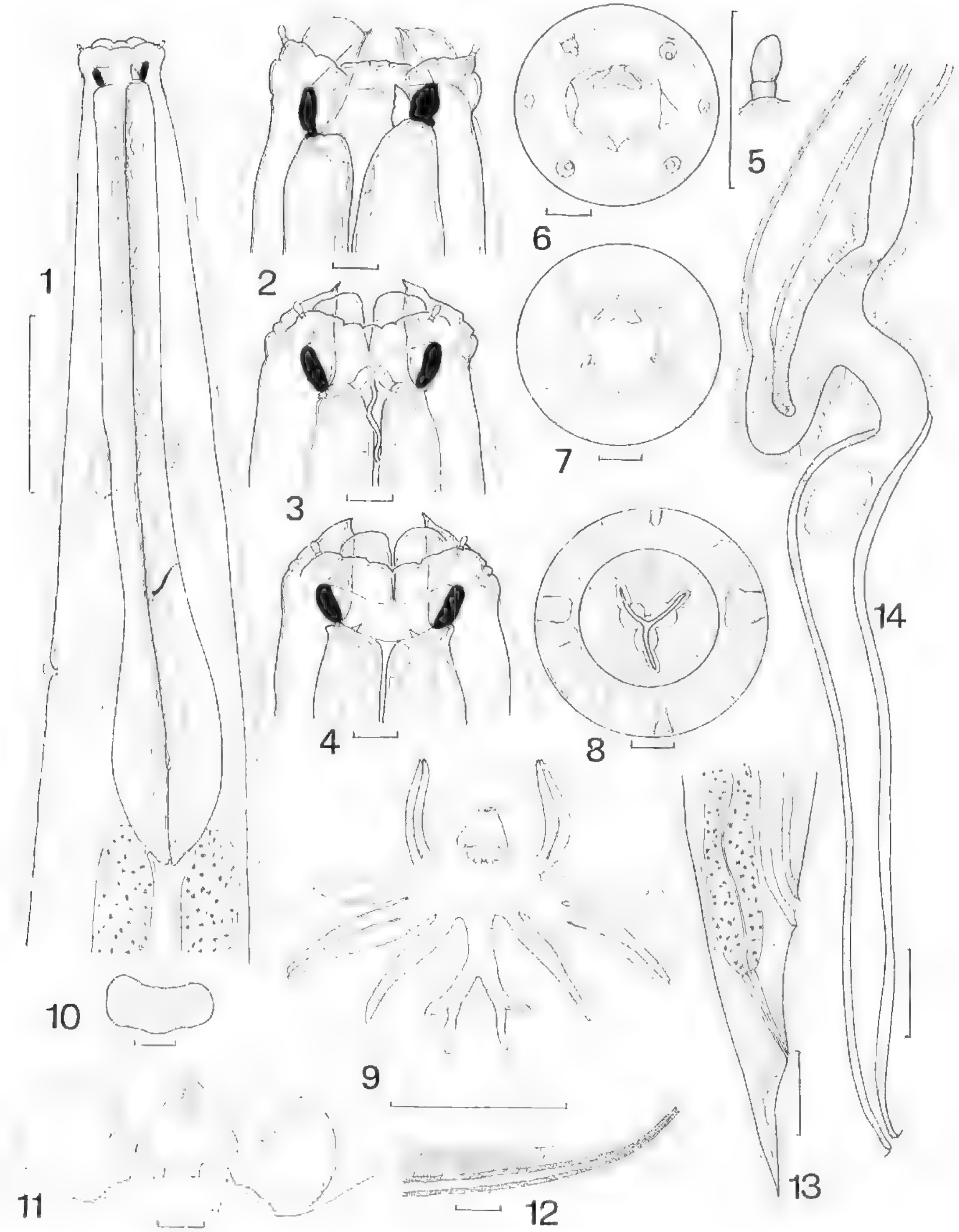
Total length 4.1-6.4 (5.7); maximum width 0.19-0.27 (0.24); dimensions of buccal capsule 0.010-0.015 (0.013) x 0.035-0.040 (0.039); length of oesophagus 0.41-0.44 (0.43); nerve ring to anterior end 0.18-0.22 (0.20); S-E pore to anterior end 0.30-0.40 (0.36); deirids to anterior end 0.25-0.35 (0.30). Tail simple, conical, 0.11-0.25 (0.16) long; vulva close to anus, 0.26-0.38 (0.33) from posterior end; vagina straight, 0.62-1.05 (0.91) long; ovejector J shaped, infundibulum longer than sphincter; egg ellipsoidal, 0.08-0.10 (0.09) x 0.04-0.06 (0.05).

Etymology

Ceres, goddess of agriculture.

Remarks

Cloacina ceres is characterised by the presence of lip-like inflations of the peri-oral cuticle, oesophageal bosses extending ⅔ of the way to the nerve ring, the deirid posterior to the nerve ring,



Figs 1-14. *Cloacina ceres* sp. nov. 1. Anterior end, lateral view. 2. Cephalic extremity, lateral view, dorsal aspect on right hand side. 3. Cephalic extremity, dorsal view. 4. Cephalic extremity, ventral view. 5. Cephalic papilla. 6. Cephalic extremity, apical view. 7. Cephalic extremity, transverse optical section through base of buccal capsule. 8. Transverse section through anterior extremity of oesophagus showing thickening of lining of oesophagus. 9. Bursa, apical view. 10. Gubernaculum, ventral view. 11. Genital cone, dorsal view. 12. Spicule tip, lateral view. 13. Female tail, lateral view. 14. Vagina and ovejector, lateral view. Scale bars = 0.1 mm, 1, 9, 13, 14; 0.01 mm, 2-8, 10-12.

absence of oesophageal denticles, a symmetrical buccal capsule, a simple straight vagina and spicules 1.56-1.97 mm in length. It is distinguishable from all congeners except *C. castor* Beveridge, 1979, *C. eos* Beveridge, 1998 and *C. papillata* Beveridge, 1979 by the possession of 6 rows of oesophageal bosses and the occurrence of the deirid posterior to the nerve ring. *Cloacina ceres* is distinguishable from all of these species by the shape of the cephalic papillae which have a very short proximal segment and a larger obtuse distal segment similar to that encountered in *C. dryope* Beveridge, 1998, *C. hebe* Beveridge, 1998, *C. hypsipyle* Beveridge, 1998, *C. linstowi* Johnston & Mawson, 1940, *C. maia* Beveridge, 1998 and *C. thetidis* Johnston & Mawson, 1939, a suite of species occurring in *Macropus dorsalis* (Gray, 1837) but lacking oesophageal bosses. *Cloacina ceres* is further distinguished from *C. castor*, *C. eos* and *C. papillata* by the presence of lip-like inflations of the circumoral cuticle and from *C. eos* and *C. papillata* in having a straight rather than a recurrent vagina.

Cloacina laius sp. nov.
(FIGS 15-28)

Types: Holotype ♂ from stomach of *Setonix brachyurus*, Rottnest Is., WA, coll. I. Beveridge, 17.iv.1982, SAMA AHC 30567, allotype ♀, SAMA AHC 30568; paratypes: 10 ♂♂, 31 ♀♀, SAMA AHC 30569, 1 ♂, 1 ♀, BMNH 1998.9.28.9-10.

Description

Small nematodes; cervical cuticle not inflated in oesophageal region; transverse cuticular annulations prominent. Sub-median papillae 0.0095 long, projecting anteriorly from peri-oral cuticle; proximal segment cylindrical, 0.006 long, longer than ovoid distal segment, 0.0035 long. Mouth opening dorsoventrally elongate. Buccal capsule shallow, symmetrical laterally, arcuate in lateral view, with apex of arch lateral; dorsal and ventral views arcuate with bases of arch dorsal and ventral. Buccal capsule walls circular in apical view. Leaf crown elements 6 in number, arise from full length of internal wall of buccal capsule, slightly incurved at tips. Peri-oral cuticle not inflated into lip-like lobes attached to each leaf crown element. Oesophagus simple, claviform, without preneural swelling; dorsal lobe of oesophagus projecting prominently into buccal capsule, bearing duct of dorsal oesophageal gland; lining of oesophagus ornamented with rows of sclerotised bosses extending from anterior end to level of nerve ring; single dorsal oesophageal denticle present immediately anterior to nerve ring. Nerve ring in mid-oesophageal region; deirids in mid oesophageal region, immediately anterior to nerve ring; S-E pore anterior to oesophago-intestinal junction.

Male (Measurements from 10 specimens, types) (Figs 23-26)

Total length 5.6-7.4 (6.4); maximum width 0.24-0.38 (0.31); buccal capsule 0.006 (0.006) x 0.055-0.068 (0.058); length of oesophagus 0.45-0.52 (0.47); nerve ring to anterior end 0.23-0.25 (0.24); S-E pore to anterior end 0.38-0.47 (0.41); deirid to anterior end 0.17-0.24 (0.20). Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral lobes and ventral lobes joined. Dorsal lobe similar in length to lateral lobes. Dorsal ray divides at $^{1}/_{3}$ length; second subdivision occurs at mid-length. Internal branchlets longer than externals, directed posterolaterally, almost reaching margin of bursa; external branchlets shorter, directed almost laterally, not reaching margin of bursa. Externodorsal ray arises close to lateral rays, not reaching margin of bursa. Posterolateral and ventrolateral rays fused, reaching margin of bursa, anterolateral ray divergent, shorter than other lateral rays; not reaching margin of bursa; ventrolateral and ventroventral rays fused, reaching margin of bursa. Gubernaculum elongate, ovoid in dorsoventral view, 0.010-0.020 (0.017) long; genital cone prominent; anterior lip conical, with single papilla at apex, posterior lip shorter than anterior lip, with pair of dome-shaped papillae; pair of lateral inflations of cuticle present on either side of anterior lip; spicules elongate, 1.50-1.97 (1.64) long, alate; alae diminishing gradually in width towards tip.

Female (Measurements from 10 specimens, types) (Figs 27-28)

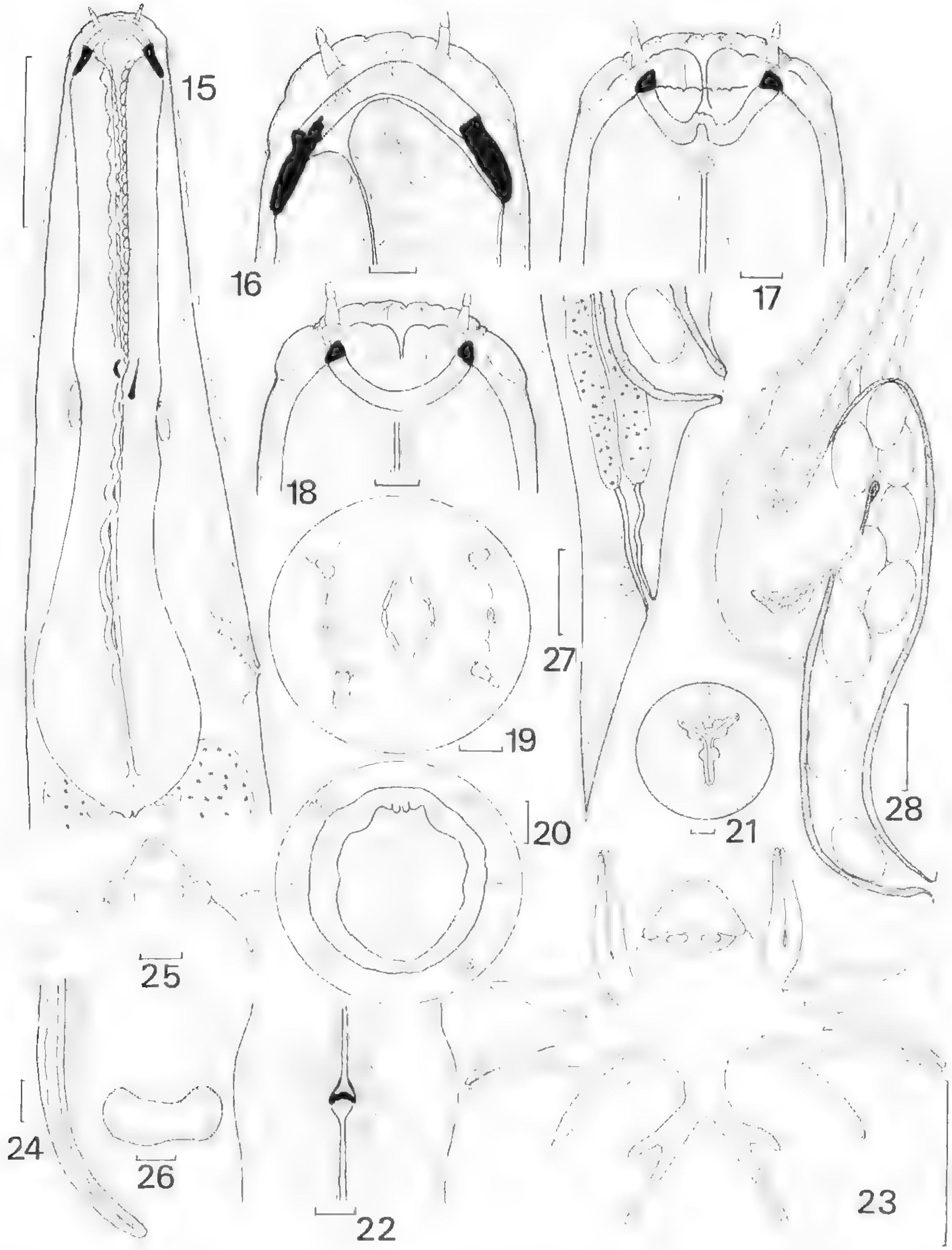
Total length 7.3-9.0 (7.9); maximum width 0.37-0.49 (0.43); buccal capsule 0.006 (0.006) x 0.060-0.070 (0.066); length of oesophagus 0.48-0.56 (0.52); nerve ring to anterior end 0.23-0.27 (0.25); S-E pore to anterior end 0.37-0.47 (0.42); deirid to anterior end 0.15-0.21 (0.18). Tail simple, conical, 0.20-0.30 (0.24) long; vulva close to anus, 0.45-0.63 (0.55) from posterior end; vagina straight, recurrent, 0.71-0.92 (0.80) long; ovejector J-shaped, sphincter and infundibulum short; egg ellipsoidal, 0.08-0.11 (0.10) x 0.06-0.07 (0.06).

Etymology

Laius, son of Labdacus, king of Thebes.

Remarks

Cloacina laius is characterised by a dorsoventrally elongated buccal capsule, six leaf crown elements, a shallow buccal capsule which is arched anteriorly in lateral views, oesophageal bosses extending to the



Figs 15-28. *Cloacina laius* sp. nov. 15. Anterior end, lateral view. 16. Cephalic extremity, lateral view, dorsal aspect on right hand side. 17. Cephalic extremity, dorsal view. 18. Cephalic extremity, ventral view. 19. Cephalic extremity, apical view. 20. Optical transverse section at level of buccal capsule. 21. Optical transverse section through anterior extremity of oesophagus showing thickening of lining. 22. Dorsal oesophageal denticle, dorsal view. 23. Bursa, apical view. 24 Spicule tip, lateral view. 25. Genital cone, dorsal view. 26. Gubernaculum, ventral view. 27. Female tail, lateral view. 28. Vagina and ovejector, lateral view. Scale bars = 0.1 mm, 15, 23, 27, 28; 0.01 mm, 16-22, 24-26.

nerve ring, a single dorsal oesophageal denticle, spicules 1.50-1.97 mm in length and a recurrent vagina. The anteriorly arched buccal capsule immediately distinguishes it from all congeners except *C. circe* sp. nov., described below. Other species with oesophageal bosses, dorsal oesophageal denticles and asymmetrical buccal capsules are *C. eileithyia* Beveridge, 1998 and *C. polyxena* Beveridge, 1998. However, in *C. eileithyia*, the buccal capsule is arched posteriorly in lateral views while in *C. polyxena*, the buccal capsule arches anteriorly only over the dorsal oesophageal tooth and the deviation is seen clearly only in dorsal views. *Cloacina circe* lacks oesophageal bosses and denticles and is therefore immediately distinguishable from *C. laius*. Thus *C. laius* is clearly distinguishable from all congeners.

Cloacina circe sp. nov.
(FIGS 29-39)

Types: Holotype ♂ from stomach of *Setonix brachyurus*, Rottnest Is., WA, coll. I. Beveridge, 17.iv.1982, SAMA AHC 30564, allotype ♀ SAMA AHC 30565; paratypes: 18 ♂♂, 44 ♀♀, SAMA AHC 30566; 1 ♂, 1 ♀, BMNH 1998.9.28.7-8.

Description

Small nematodes; cervical cuticle not inflated in oesophageal region, transverse cuticular annulations prominent. Sub-median papillae 0.014 long, projecting anteriorly from peri-oral cuticle with distal segment curved medially; proximal segment cylindrical, 0.006 long, shorter than ovoid, medially directed distal segment, 0.008 long. Buccal capsule shallow, arcuate in lateral view, with apex of arch lateral. Mouth opening dorsoventrally elongate. Buccal capsule wall thick, dorsoventrally elongated in apical view. Leaf crown elements 6 in number, incurved at tips, arise from full length of internal wall of buccal capsule. Peri-oral cuticle not inflated into lip-like lobes attached to each leaf crown element. Oesophagus simple claviform; dorsal sector of oesophagus protruding into buccal capsule with opening of dorsal oesophageal gland at apex; lining not ornamented with rows of sclerotised bosses; denticles absent in oesophagus. Nerve ring in mid-oesophageal region; deirids in posterior oesophageal region, posterior to nerve ring; S-E pore anterior to oesophago-intestinal junction.

Male (Measurements from 10 specimens, types) (Figs 34-37)

Total length 4.7-7.1 (6.0); maximum width 0.24-0.33 (0.28); buccal capsule 0.018 (0.018) x 0.065-0.090 (0.080), length of oesophagus 0.52-0.62 (0.56); nerve ring to anterior end 0.22-0.27 (0.25); S-E pore to anterior end 0.35-0.42 (0.38); deirid to anterior end 0.34-0.37 (0.36). Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral lobes and ventral lobes joined. Dorsal lobe similar in length to lateral lobes. Dorsal ray divides just before mid-length; secondary division occurs at $^{4}/_{5}$ length; internal branchlets straight, longer than externals, directed posteriorly, almost reaching margin of bursa; external branches short, directed laterally, not reaching margin of bursa. Externodorsal ray arises close to lateral rays, not reaching margin of bursa. Posterolateral and ventrolateral rays fused, reaching margin of bursa; anterolateral ray divergent, shorter than other lateral rays, not reaching margin of bursa; ventrolateral and ventroventral rays fused, reaching margin of bursa. Gubernaculum subtriangular in dorsoventral view, 0.02 (0.02) long; genital cone prominent; anterior lip conical, with single papilla at apex; posterior lip shorter than anterior lip, with pair of dome shaped papillae; pair of lateral inflations of cuticle present on either side of anterior lip; spicules elongate, 0.97-1.35 (1.25) long, alate; alae diminishing gradually in width towards spicule tip.

Female (Measurements of 10 specimens, types) (Figs 38-39)

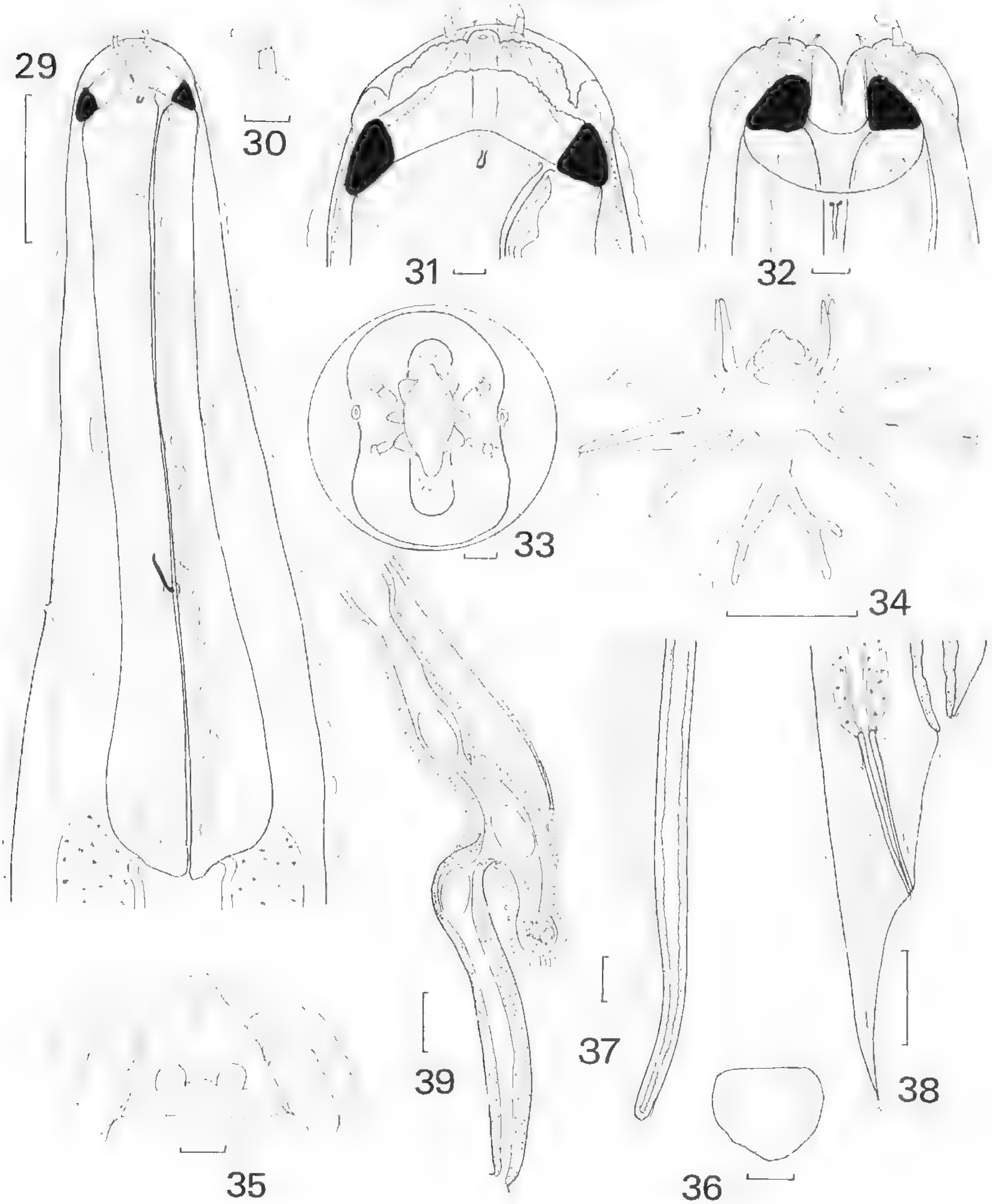
Total length 7.3-10.5 (8.8); maximum width 0.41-0.54 (0.46); buccal capsule 0.018 (0.018) x 0.090-0.098 (0.094); length of oesophagus 0.60-0.72 (0.65); nerve ring to anterior end 0.24-0.30 (0.27); S-E pore to anterior end 0.33-0.46 (0.39); deirid to anterior end 0.30-0.41 (0.34). Tail simple, conical, 0.20-0.26 (0.23) long; vulva close to anus, 0.35-0.51 (0.42) from posterior end; vagina short, straight, 0.32-0.63 (0.48) long; ovejector J-shaped; sphincter and infundibulum short; egg ellipsoidal, 0.08-0.10 (0.09) x 0.05-0.06 (0.05).

Etymology

Circe, daughter of the sun and Perse, famous for her magic.

Remarks

Cloacina circe is characterised by a dorsoventrally elongated mouth opening, six leaf crown elements, cephalic papillae which are situated close together and whose tips are deviated medially, a shallow buccal capsule arched anteriorly, an oesophagus without bosses or denticles, the deirid posterior to the nerve ring, spicules in the range 0.97-1.35 mm and a straight vagina. The anteriorly arched buccal capsule and the dorsoventrally elongate mouth opening distinguish this species from all congeners except *C. laius*. *Cloacina circe* differs from *C. laius* in lacking oesophageal bosses and denticles, in



Figs 29-39. *Cloacina circe* sp. nov. 29. Anterior end, lateral view. 30. Cephalic papilla. 31. Cephalic extremity, lateral view, dorsal aspect on right hand side. 32. Cephalic extremity, dorsal view. 33. Cephalic extremity, apical view. 34. Bursa, apical view. 35. Genital cone, dorsal view. 36. Gubernaculum, ventral view. 37. Spicule tip, lateral view. 38. Female tail, lateral view. 39. Vagina and ovejector, lateral view. Scale bars = 0.1 mm, 29, 34, 38, 39; 0.01 mm, 30-33, 35-37.

having the deirid posterior to the nerve ring rather than immediately anterior to it, in having a straight vagina and in having shorter spicules.

Cloacina chiron sp. nov.
(FIGS 40-51)

Types: Holotype ♂ from stomach of *Setonix brachyurus*, Rottnest Is., WA, coll. I. Beveridge, 17.iv.1982, SAMA AHC 30561, allotype ♀ SAMA AHC 30562; paratypes: 10 ♂♂, 12 ♀♀, SAMA AHC 30563; 1 ♂, 1 ♀, BMNH 1998.9.28.5-6.

Description

Small nematodes; cervical cuticle inflated to level of nerve ring; transverse cuticular annulations prominent. Sub-median papillae 0.016 long, projecting anteriorly from peri-oral cuticle; proximal segment cylindrical, 0.003 long, much shorter than obovoid distal segment, 0.013 long. Mouth opening dorsoventrally elongate. Buccal capsule shallow, symmetrical in lateral and dorsoventral views. Buccal capsule walls circular in apical view. Leaf crown elements 6 in number, with prominent striations, arising from full length of internal wall of buccal capsule. Peri-oral cuticle not inflated into lip-like lobes attached to each leaf crown element. Oesophagus simple claviform; lining not ornamented with rows of sclerotised bosses; denticles absent in oesophagus. Nerve ring in mid oesophageal region; deirids in anterior oesophageal region, anterior to nerve ring; S-E pore posterior to oesophago-intestinal junction

Male (Measurements from 10 specimens, types)
(Figs 46-49)

Total length 5.4-9.9 (8.5); maximum width 0.34-0.42 (0.38); buccal capsule 0.015-0.025 (0.020) x 0.065-0.085 (0.079); length of oesophagus 0.59-0.71 (0.67); nerve ring from anterior end 0.30-0.36 (0.34); S-E pore from anterior end 0.79-1.11 (0.97); deirid from anterior end 0.14-0.18 (0.17). Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral lobes and ventral lobes joined. Dorsal lobe slightly longer than lateral lobes. Dorsal ray long, dividing at mid-length; secondary subdivision near extremity; internal branchlets short, slightly longer than externals, directed posteriorly, almost reaching margin of bursa; internal branchlets very short, directed posterolaterally, not reaching margin of bursa. Externodorsal ray arises close to lateral rays, not reaching margin of bursa. Posterolateral and ventrolateral rays fused, reaching margin of bursa; anterolateral ray divergent, shorter than other lateral rays; not reaching margin of bursa; ventrolateral and ventroventral rays fused, reaching margin of bursa. Gubernaculum quadrangular in dorsoventral view, 0.03 long; genital cone prominent; anterior lip conical, with single papilla at apex; posterior lip shorter than anterior lip, with pair of dome-shaped papillae; pair of lateral inflations of cuticle present on either side of anterior lip; spicules elongate, short, 0.58-0.65 (0.62) long, alate; ala terminating anterior to spicule tip.

Female (Measurements of 10 specimens, types)
(Figs 50-51)

Total length 8.5-12.3 (10.5); maximum width 0.46 0.57 (0.50); buccal capsule 0.015-0.020 (0.020) x 0.085-0.095 (0.090); length of oesophagus 0.70-0.78 (0.75); nerve ring to anterior end 0.32-0.40 (0.37). S-E pore to anterior end 0.88-1.17 (1.00); deirid to anterior end 0.12-0.20 (0.16). Tail simple, conical 0.13-0.20 (0.17) long; vulva close to anus, 0.26-0.38 (0.34) from posterior end; vagina short, straight 0.29 0.38 (0.34); ovejector J-shaped; sphincter and infundibulum short; egg ellipsoidal, 0.10-0.13 (0.11) x 0.06-0.07 (0.07).

Etymology

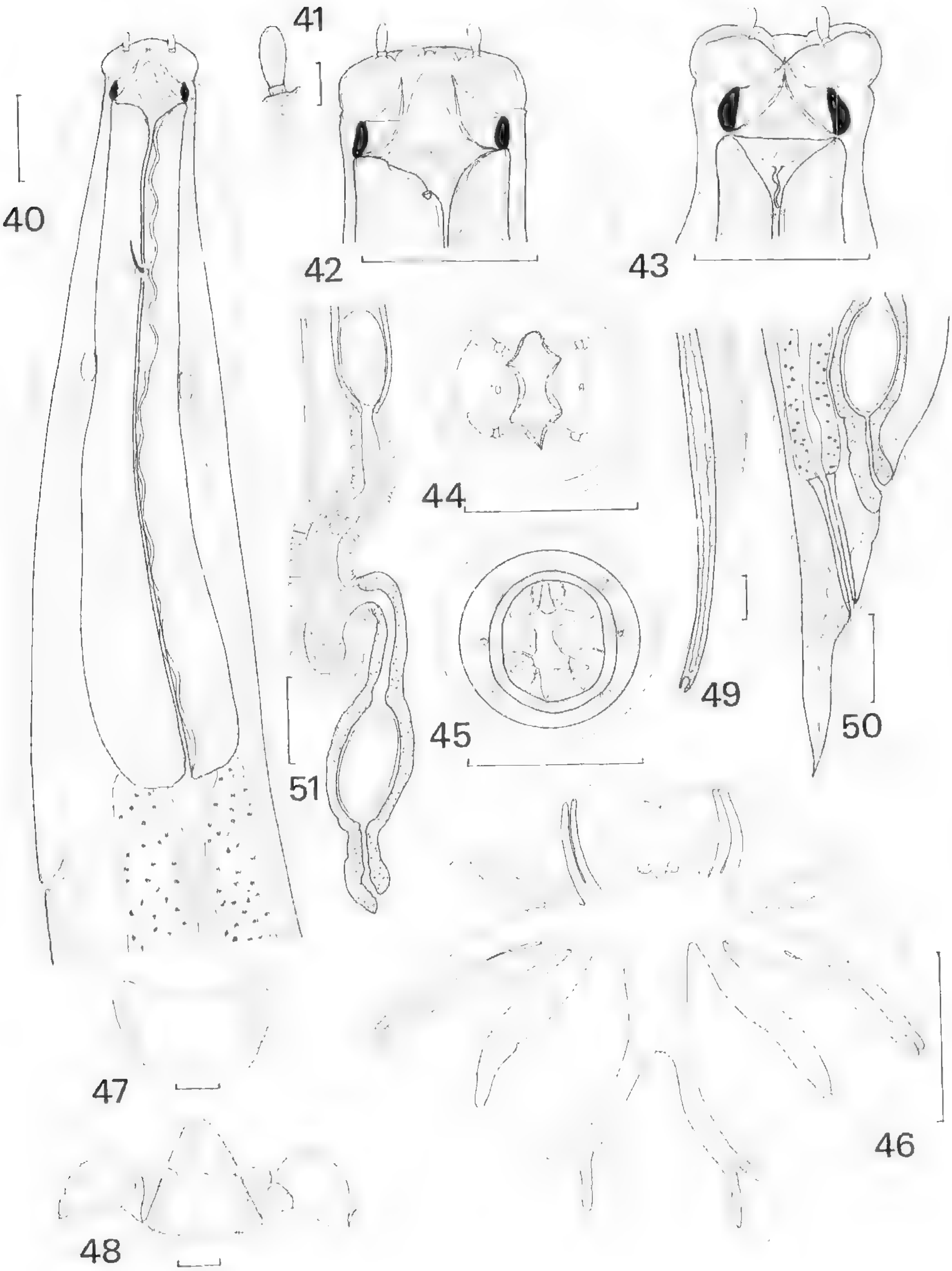
Chiron, centaur, son of Saturn.

Remarks

Cloacina chiron is characterised by a cervical cuticular inflation, cephalic papillae with a long, obtuse distal segment, six leaf crown elements, a symmetrical buccal capsule, a simple oesophagus without denticles or bosses, spicules in the range 0.58-0.65 mm and a straight vagina. The shape of the cephalic papillae and the lack of oesophageal bosses distinguish this species from all congeners except *C. dryope*, *C. hebe*, *C. hypsipyle*, *C. linstowi*, *C. maia* and *C. thetidis*. *Cloacina chiron* is distinguished from *C. dryope* in having a deeper buccal capsule, in not having the anterior region of the oesophagus distinctly broader than the posterior part and in having much shorter spicules (>1.75 mm in *C. dryope*), from *C. hebe* and *C. thetidis* in having a deeper buccal capsule in which the anterior margin does not have anterior lobes in the submedian and ventral positions and from *C. hypsipyle*, *C. linstowi* and *C. maia* in having a shallower buccal capsule without the undulating anterior margin present in the latter two species. In addition, the spicules of *C. chiron* are shorter than those in all of the species listed.

Cloacina cadmus sp. nov.
(FIGS 52-62)

Types: Holotype ♂ from stomach of *Setonix brachyurus*, Rottnest Is., WA, coll. I. Beveridge, 17.iv.1982, SAMA AHC 30555, allotype ♀ SAMA AHC 30556; paratypes: 4 ♂♂, 23 ♀♀, SAMA AHC 30557, 1 ♂, 1 ♀, BMNH 1998.9.28.1-2



Figs 40-51. *Cloacina chiron* sp. nov. 40. Anterior end, lateral view. 41. Cephalic papilla. 42. Cephalic extremity, lateral view, dorsal aspect on right hand side. 43. Cephalic extremity, dorsal view. 44. Cephalic extremity, apical view. 45. Optical transverse section through buccal capsule. 46. Bursa, apical view. 47. Gubernaculum, ventral view. 48. Genital cone, dorsal view. 49. Spicule tip, lateral view. 50. Female tail, lateral view. 51. Vagina and ovejector, lateral view. Scale bars = 0.1 mm, 40, 42-46, 50, 51; 0.01 mm, 41, 47-49.

Description

Very small nematodes: cervical cuticle not inflated in oesophageal region; transverse cuticular annulations prominent. Sub-median papillae 0.010 long, projecting anteriorly from peri-oral cuticle; proximal segment cylindrical, 0.007 long, longer than ovoid distal segment, 0.003 long. Mouth opening circular in apical view. Buccal capsule shallow, symmetrical in lateral and dorsoventral views. Buccal capsule walls hexagonal in apical view. Leaf crown elements 6 in number, incurved at tip, arising from full length of internal wall of buccal capsule. Peri-oral cuticle not inflated into lip-like lobes attached to each leaf crown element. Oesophagus simple, claviform, slender; lining not ornamented with rows of sclerotised bosses; denticles absent in oesophagus. Prominent dorsal oesophageal tooth projecting from dorsal sector of oesophagus into buccal capsule. Nerve ring in posterior oesophageal region; deirids in posterior oesophageal region, posterior to nerve ring; S-E pore in region of oesophago-intestinal junction.

Male (Measurements from 7 specimens, types)
(Figs 57-60)

Total length 3.4-4.7 (4.1); maximum width 0.15-0.19 (0.17); buccal capsule 0.005 (0.005) x 0.018-0.020 (0.019); length of oesophagus 0.32-0.38 (0.34); nerve ring to anterior end 0.15-0.18 (0.16); S-E pore to anterior end 0.26-0.31 (0.28); deirid to anterior end 0.20-0.21 (0.21). Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral lobes and ventral lobes joined. Dorsal lobe slightly longer than lateral lobes. Dorsal ray slender at origin, dividing at mid-length; secondary subdivision occurring at [illegible] length; internal branchlets longer than externals, directed posteriorly, almost reaching margin of bursa; external branchlets shorter, directed laterally, not reaching margin of bursa. Externodorsal ray arises close to lateral rays, not reaching margin of bursa. Posterolateral and ventrolateral rays fused, reaching margin of bursa; anterolateral ray divergent, shorter than other lateral rays, not reaching margin of bursa; ventrolateral and ventroventral rays fused, reaching margin of bursa. Gubernaculum ovoid in dorso-ventral view, 0.015 (0.015) long; genital cone prominent; anterior lip conical, with single papilla at apex; posterior lip shorter than anterior lip, with pair of dome shaped papillae, pair of lateral inflations of cuticle present on either side of anterior lip; spicules elongate, 1.31-1.46 (1.40) long, alate; spicule tip bifurcate, surrounded by ovoid flange; ala terminating abruptly immediately anterior to spicule tip.

Female (Measurements of 10 specimens, types)
(Figs 61-62)

Total length 3.9-5.3 (4.6); maximum width 0.15-0.26 (0.21); buccal capsule 0.005 (0.005) x 0.018-0.020 (0.019); length of oesophagus 0.34-0.41 (0.37); nerve ring to anterior end 0.15-0.18 (0.17); S-E pore to anterior end 0.25-0.37 (0.29); deirid to anterior end 0.17-0.25 (0.19). Tail simple, conical, 0.11-0.18 (0.16) long; vulva close to anus, 0.23-0.30 (0.27) from posterior end; vagina elongate, straight, 0.72-1.00 (0.79) long; ovejector J-shaped; sphincter and infundibulum short; egg ellipsoidal, 0.07-0.09 (0.08) x 0.04-0.05 (0.05).

Etymology

Cadmus, son of the Phoenician king, Agenor.

Remarks

Cloacina cadmus most closely resembles *C. burnettiana* Johnston & Mawson, 1939 in its small size, simple slender oesophagus lacking bosses or denticles, small, symmetrical buccal capsule, cephalic papillae with the proximal segment longer than the distal, six leaf crown elements, spicules in the range 1.31-1.46 mm and a straight vagina. *Cloacina cadmus* differs from *C. burnettiana* in having the deirid posterior to the nerve ring and longer spicules (0.60-0.70 mm in *C. burnettiana*). *Cloacina cadmus* also resembles *C. caballeroi* Mawson, 1977, *C. enyo* Beveridge, 1998 and *C. ips* Beveridge, 1998 but they differ in having the secondary branchlets of the dorsal ray arising at or before the primary bifurcation rather than after it as in *C. cadmus*. Other similar species are *C. nike* Beveridge, 1998 and *C. digitata* Johnston & Mawson, 1940 which differ in having the deirid anterior to the nerve ring and longer spicules (>2.5 mm). *C. cybele* Beveridge, 1998 which differs in having the deirid anterior to the nerve ring and a characteristically enlarged spicule tip, and *C. pearsoni* Mawson, 1971 which has the deirid anterior to the nerve ring and a shorter vagina.

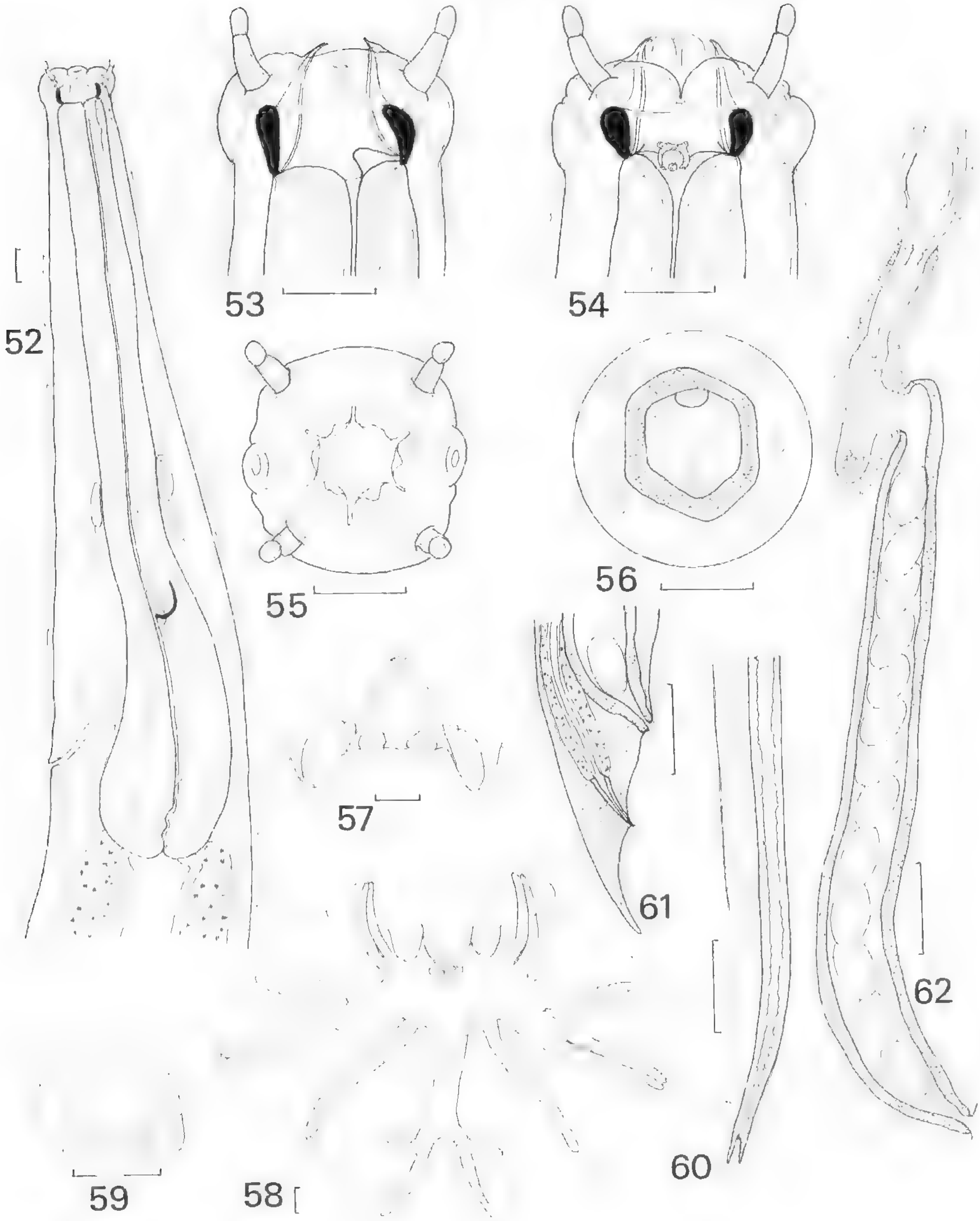
Cloacina telemachus sp. nov.

(FIGS 63-72)

Types: Holotype ♂ from stomach of *Setonix brachyurus*, Rottnest Is., WA, coll. I. Beveridge 17.iv.1982, SAMA AHC 30570, allotype ♀ SAMA AHC 30571, paratypes: 6 ♀♀, SAMA AHC 30572, 1 ♀, BMNH 1998.9.28.23.

Description

Small nematodes: cervical cuticle not inflated in oesophageal region; transverse cuticular annulations prominent. Sub-median papillae 0.015 long, projecting anteriorly from peri-oral cuticle, distal segment deviated medially; proximal segment



Figs 52-62. *Cloacina cadmus* sp. nov. 52. Anterior end, lateral view. 53. Cephalic extremity, lateral view, dorsal aspect on right hand side. 54. Cephalic extremity, dorsal view. 55. Cephalic extremity, apical view. 56. Cephalic extremity, optical transverse section through buccal capsule. 57. Genital cone, dorsal view. 58. Bursa, apical view. 59. Gubernaculum, ventral view. 60. Spicule tip, lateral view. 61. Female tail, lateral view. 62. Vagina and ovejector, lateral view. Scale bars = 0.1 mm, 52, 58, 61, 62; 0.01 mm, 53-57, 59, 60.

cylindrical, 0.006 long, shorter than obovoid, medially directed distal segment, 0.009 long. Mouth opening circular in apical view. Buccal capsule shallow, symmetrical in lateral and dorsoventral views. Buccal capsule walls striated, circular in apical view. Leaf crown elements 6 in number, only slightly incurved at tips, arise from full length of internal wall of buccal capsule. Peri-oral cuticle not inflated into lip-like lobes attached to each leaf crown element. Oesophagus simple, claviform; lining not ornamented with rows of sclerotised bosses; denticles absent in oesophagus. Nerve ring in anterior oesophageal region; deirids in mid-oesophageal region, posterior to nerve ring; S-E pore anterior to oesophago-intestinal junction, immediately posterior to deirid.

Male (Measurements of holotype) (Figs 68-70)

Total length 7.0; maximum width 0.32; buccal capsule 0.010 x 0.057; length of oesophagus 0.65; nerve ring from anterior end 0.27, S-E pore from anterior end 0.47; deirid from anterior end 0.41. Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral lobes and ventral lobes joined. Dorsal lobe similar in length to lateral lobes. Dorsal ray divides at ⅓ length; secondary subdivision occurs at ⅔ length; internal branchlets long straight, directed posterolaterally, almost reaching margin of bursa; external branchlets very short, directed posterolaterally, not reaching margin of bursa. Externodorsal ray arises close to lateral rays, not reaching margin of bursa. Posterolateral and ventrolateral rays fused, reaching margin of bursa; anterolateral ray divergent, shorter than other lateral rays, not reaching margin of bursa; ventrolateral and ventroventral rays fused, reaching margin of bursa. Gubernaculum quadrangular in shape in dorsoventral view, 0.02 long; genital cone prominent; anterior lip conical, with single papilla at apex; posterior lip shorter than anterior lip, with pair of dome-shaped papillae; spicules elongate, 2.33 long, alate.

Female (Measurements of 9 specimens, types) (Figs 71-72)

Total length 5.9-9.4 (7.1); maximum width 0.36-0.51 (0.44); buccal capsule 0.010-0.015 (0.013) x 0.053-0.060 (0.057); length of oesophagus 0.74-0.80 (0.77); nerve ring to anterior end 0.27-0.30 (0.28), S-E pore to anterior end 0.40-0.49 (0.44); deirid to anterior end 0.36-0.40 (0.38). Tail simple, conical, 0.17-0.27 (0.21) long; vulva close to anus, 0.30-0.41 (0.37) from posterior end; vagina straight, 0.45-1.12 (0.79) long, ovejector J-shaped; sphincter and infundibulum short; egg ellipsoidal, 0.08-0.10 (0.09) x 0.04-0.05 (0.05).

Etymology

Telemachus, son of Ulysess and Penelope.

Remarks

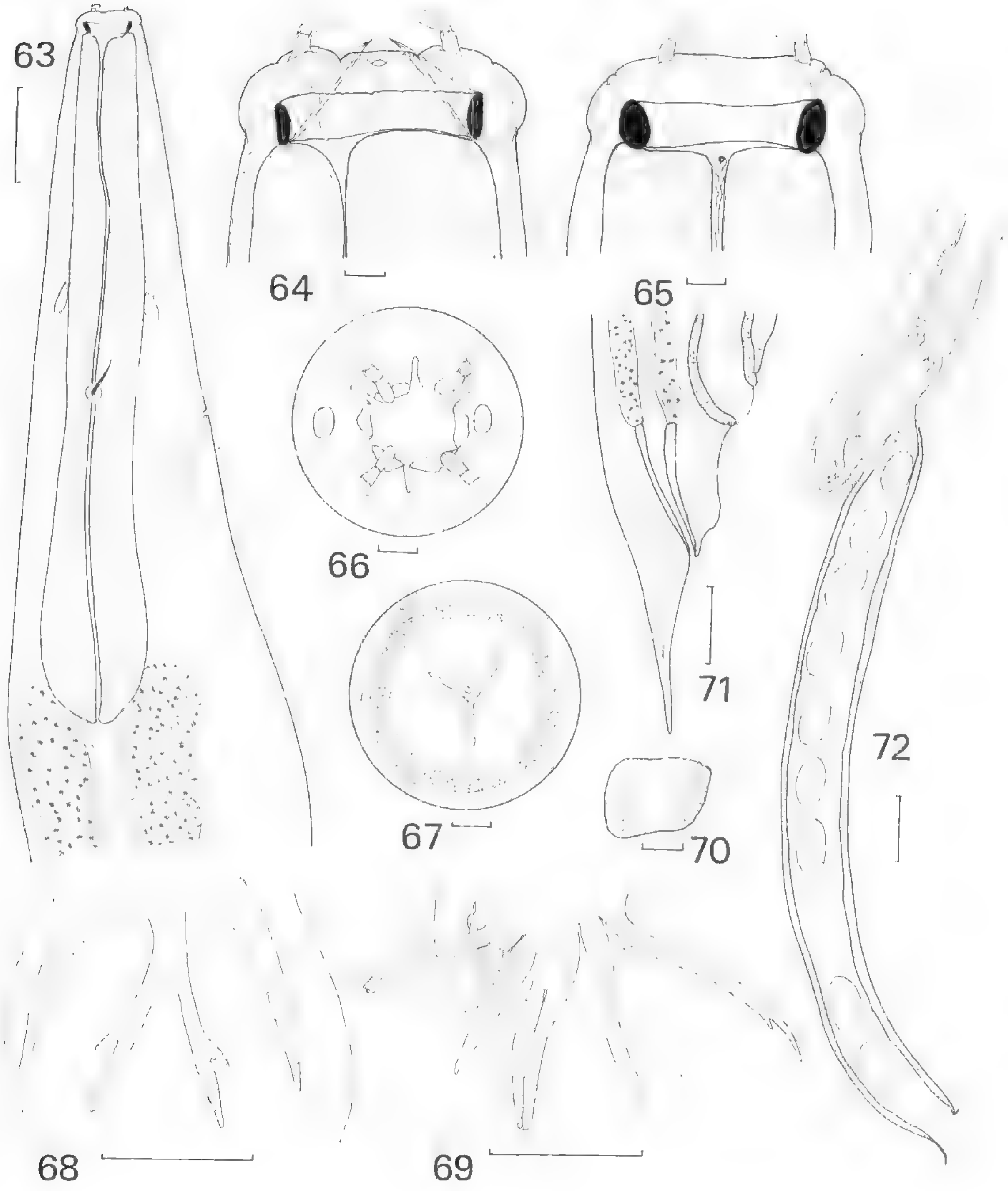
Cloacina telemachus is characterised by the cephalic papillae with the distal segment globose and directed medially, six leaf crown elements, an oesophagus without bosses or denticles, the deirid posterior to the nerve ring, spicules 2.33 mm long and a straight vagina.

Although described from a single male, *C. telemachus* is readily distinguishable from all congeners except *C. daveyi* Mawson, 1977, *C. edwardsi* Mawson, 1972, *C. epona* Beveridge, 1998, *C. ernabella* Johnston & Mawson, 1938, *C. feronia* Beveridge, 1998, *C. frequens* Johnston & Mawson, 1938 and *C. themis* Beveridge, 1998 by the shape of the cephalic papillae with a medially directed, globose distal segment. *Cloacina telemachus* is distinguished from *C. edwardsi* in that it lacks the cervical cuticular inflation and a comb-like ornamentation of the oesophageal lining. The spicules of *C. edwardsi* are shorter (0.41-0.47 mm) and the vagina is very short. *Cloacina telemachus* differs from the remaining members of this group in that it lacks oesophageal denticles. In addition, *C. telemachus* differs from *C. daveyi* which has the deirids at the level of the nerve ring, spicules > 3.6 mm and a recurrent vagina, from *C. epona* which has anterior deirids and spicules 0.96-1.05 mm long, from *C. ernabella* which has anterior deirids and spicules 1.42-1.83 mm long, from *C. feronia* which has anterior deirids and spicules 1.65-1.85 long, from *C. frequens* which has anterior deirids, spicules 1.02-1.10 long and a Y-shaped vagina and from *C. themis* which has anterior deirids and spicules 1.02-1.23 mm long.

Discussion

The current examination of gastric nematodes from a series of quokkas shows that this host, like most other kangaroo and wallaby species, harbours a range of species of *Cloacina* rather than the single species, *C. setonicis*, described to date. The new material came from a small number of quokkas collected at a single location and it is likely that more extensive examinations of this host will reveal additional species of *Cloacina*.

All species described from the quokka are currently considered to be restricted to this host. However, the parasite fauna of macropodid marsupials from Western Australia is still very poorly known and the new species of *Cloacina* described here may prove to have a wider host range when more studies are carried out in the region.



Figs 63-72. *Cloacina telemachus* sp. nov. 63. Anterior end, lateral view. 64. Cephalic extremity, lateral view, dorsal aspect on left hand side. 65. Cephalic extremity, dorsal view. 66. Cephalic extremity, apical view. 67. Cephalic extremity, transverse optical section through buccal capsule and anterior oesophagus. 68. Dorsal lobe of bursa, dorsal view. 69. Lateral lobe of bursa, lateral view. 70. Gubernaculum, ventral view. 71. Female tail, lateral view. 72. Vagina and ovejector, lateral view. Scale bars = 0.1 mm, 63, 68, 69, 71, 72; 0.01 mm, 64-67, 70.

Some of the new species closely resemble described taxa while others exhibit novel morphological features within the genus or novel combinations of morphological features. *Cloacina cadmus* closely resembles *C. burnettiana* found in *Macropus dorsalis* in Queensland (Beveridge 1998). Similarly, *C. chiron* possesses obovate cephalic papillae similar to a suite of species (*C. dryope*, *C. hebe*, *C. hypsipyle*, *C. linstowi*) found in *Macropus dorsalis* in Queensland (Beveridge 1998), but differs from all of these possible relatives in the simple shape of the buccal capsule and the oesophageal lobes projecting into the buccal capsule. *Cloacina ceres* has similarly shaped cephalic papillae but has bosses lining the oesophagus, a feature characteristic of an alternative suite of species found in a wide range of macropodid hosts (Beveridge 1998). *Cloacina telemachus* has cephalic papillae resembling *C. themis* found in *Macropus irma* (Jourdan, 1837) from Western Australia, *C. ernabella* from *Petrogale lateralis* Gould, 1842 from central Australia and *C. daveyi*, *C. frequens*, *C. epona* and *C. feronia* all from *Macropus robustus* from inland Australia, but differs from all of them in lacking oesophageal denticles. By contrast, *C. laius* and *C. circe* have an entirely novel, anteriorly arched buccal capsule which occurs in no congener. Therefore, in as far as it is possible to assess relationships within the genus, the series of species of *Cloacina* described from the quokka has possible affinities with suites of species in *M. dorsalis* and *M. robustus*, but the striking morphological originality of most of the new species makes the determination of associations difficult. It does suggest that more extensive examination of parasites from Western Australian macropodids will continue to reveal morphologically novel species of *Cloacina*.

Acknowledgments

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A NEW GENUS AND SPECIES OF GALL MIDGE (DIPTERA: CECIDOMYIIDAE) DAMAGING FLOWERS OF THE SOUTH AUSTRALIAN SWAMP PAPER-BARK, MELALEUCA HALMATURORUM (MYRTACEAE)

*By Peter Kolesik**

Summary

Kolesik, P. (1999) A new genus and species of gall midge (Diptera: Cecidomyiidae) damaging flowers of the South Australian swamp paper-bark, Melaleuca halmaturorum (Myrtaceae). Trans. R. Soc. S. Aust. 123(1), 31-36, 31 May, 1999.

A new species of gall midge, Australopesia melaleucae, is described from flower galls on Melaleuca halmaturorum F. Muell, ex Miq., a salt tolerant tree growing in temporal swamps and saline areas of southeastern Australia. No seeds are produced in infested flowers and the infestation can potentially limit the reproduction of the tree. The larva, pupa, male and female of the new species are described and illustrated. The gall midge is the first record of the tribe Lopesiini in Australia and a new genus is erected to contain it. Austrolopesia gen. nov. is compared to other genera of Lopesiini and Lophodiplosis Gagné, an Australian genus feeding on Melaleuca. The Australian species Cecidomyia frauenfeldi Schiner, 1868 from branch bud galls on Melaleuca sp. is newly combined in Dasineura.

Key Words: Diptera, Cecidomyiidae, Melaleuca halmaturorum, wetland, swamp, South Australia.

Transactions of the Royal Society of S. Aust. (1999), **123**(1), 31-36

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Kolesik, P. (1999) A new genus and species of gall midge (Diptera: Cecidomyiidae) damaging flowers of the South Australian swamp paper-bark, *Melaleuca halmaturorum* (Myrtaceae). *Trans. R. Soc. S. Aust.* **123**(1), 31-36, 31 May 1999.

A new species of gall midge, *Austrolopesia melaleucae*, is described from flower galls on *Melaleuca halmaturorum* F. Muell. ex Miq., a salt tolerant tree growing in temporal swamps and saline areas of southeastern Australia. No seeds are produced in infested flowers and the infestation can potentially limit the reproduction of the tree. The larva, pupa, male and female of the new species are described and illustrated. The gall midge is the first record of the tribe Lopesiini in Australia and a new genus is erected to contain it. *Austrolopesia* gen. nov. is compared to other genera of Lopesiini and *Lophodiplosis* Gagné, an Australian genus feeding on *Melaleuca*. The Australian species *Cecidomyia frauenfeldi* Schiner, 1868 from branch bud galls on *Melaleuca* sp. is newly combined in *Dasineura*.

Key Words: Diptera, Cecidomyiidae, *Melaleuca halmaturorum*, wetland, swamp, South Australia.

Introduction

The South Australian swamp paper-bark, *Melaleuca halmaturorum* F. Muell. ex Miq. (Myrtaceae), is a tree of 2-7 m height occurring in South Australia and Victoria (Barlow 1986). It is tolerant to salt and waterlogging and is often found in saline areas bordering permanent wetlands and temporal swamps (Mensforth & Walker 1996). Due to its dominance in these areas, *M. halmaturorum* is a major contributor to the natural groundwater discharge (Denton & Ganf 1994; Mensforth & Walker 1996). Considerable proportions of South Australian soils are degraded by, or under threat of, salinisation (Richardson & Narayan 1995). *Melaleuca halmaturorum* plays an important role in preventing the process of salinisation by keeping the groundwater level low.

The new gall midge modifies flowers of *M. halmaturorum* into hard, hairy galls (Fig. 1). The galls of the type series were collected in September, 1997 in the Coorong National Park by D. Peacock and S. Jennings during a South Australian Animal and Plant Control Commission survey of the ecological response to European rabbit population dynamics. The fact that no seeds are produced inside the galled flowers indicates that the gall midge is a potential limiting factor in the reproduction of *M. halmaturorum*

Austrolopesia melaleucae gen. et sp. nov. is not closely related to *Lophodiplosis* Gagné, an Australian genus containing species modifying leaves and buds of *Melaleuca* spp. (Gagné *et al.* 1997), nor to any other known genus and therefore a new genus has been erected. The new gall midge is the first Australian record of Lopesiini, a tribe known previously only from the Americas and Africa. *Austrolopesia* gen. nov. differs from *Lopesia* Rübsaamen, the catch-all genus of the tribe, in gynecoid male antennae, and from all other genera of the tribe in the long female postabdomen.

Cecidomyia frauenfeldi Schiner (1868) described from branch bud galls on *Melaleuca* sp. in Sydney, Australia, is placed for the first time in the genus *Dasineura* (comb. nov.). It does not belong in

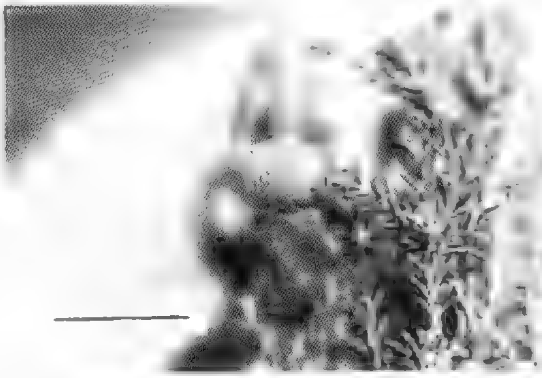

Fig. 1. Flower gall of *Austrolopesia melaleucae* sp. nov. on *Melaleuca halmaturorum*. Scale bar = 10 mm

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Cecidomyia, formerly used as a catch-all genus but now restricted to species whose larvae feed on resin in Pinaceae. The species fits *Dasineura* because it has toothed tarsal claws, an R_5 wing vein that meets C anterior to the wing apex and the female eighth tergite divided into two longitudinal sclerites.

Materials and Methods

Flower galls on *Melaleuca halmaturorum* were collected at the Coorong National Park on 2.ix.1997. The galls were processed in one of two ways. Some were cut open and the larvae preserved in 70% ethanol. Others were kept in plastic bags and the larvae reared to adults. Pupation took place within the galls. Emerged adults were preserved together with their pupal skins in 70% ethanol. Microscope mounts of the type series were prepared according to the technique outlined by Kolesik (1995). The type series and other material retained in 70% ethanol, together with dried galls, are deposited in the South Australian Museum, Adelaide [SAMA], the Australian National Insect Collection, Canberra [ANIC] and the State Herbarium of South Australia, Adelaide [SHSA]. Descriptions and measurements refer to the holotype and paratypes.

Genus *Austrolopesia* gen. nov.

Type species: *Austrolopesia melaleucae* sp. nov.

Adult

Head: Antenna: flagellomeres gynecoid in both sexes, 12 in number, first and second fused, longer than remaining ones, circumfila simple. Eye facets close together, rounded, eye bridge 6-8 facets long. Labella large, triangular in frontal view. Palpus 4-segmented.

Thorax: Wing with R_5 bent at its juncture with Rs, joining C posterior to wing apex, Rs situated closer to end of R_1 than arculus, M_{3+4} present as fold, Cu forked. First tarsomere with small ventroapical tooth. Claws toothed, bowed near basal third, empodia reaching bends in claws.

Abdomen: Sclerites entire, rectangular, with setae sparse, distributed evenly except dense posterior row and anterior pair of trichoid papillae. Male genitalia: gonocoxite elongate, cylindrical, with obtuse mesobasal lobe; gonostylus tapered distally, swollen and setulose on basal third, asetose and ridged beyond; aedeagus long, stout, tapered distally, with several large asetose papillae; hypoproct bilobed, each lobe with two setae; cerci shorter than hypoproct, with several setae on each lobe. Female genitalia: ovipositor protrusible, long; cerci large, fleshy; hypoproct small.

Pupa

Antennal horns short, angular. Frons on each side, one of two lower facial papillae setose, one of three lateral facial papillae setose. Prothoracic spiracle slightly bowed, with trachea reaching its apex. Abdominal segments II-VIII dorsally with fields of spines on anterior half.

Larva

Integument of abdominal segments covered dorsally and laterally with large spiculae, ventrally with small spiculae anteriorly, smooth elsewhere. Sternal spatula bilobed. Papillae generally as in Cecidomiidi (Gagné 1989) with ventral papillae asetose and 4 of 8 terminal papillae with corniform setae. Anus ventral.

Etymology

Austrolopesia combines the prefix "austro", referring to Australia, with *Lopesia*, the name of the type genus of the tribe Lopesiini.

Remarks

Austrolopesia gen. nov. belongs to the tribe Lopesiini (*sensu* Gagné 1994) because it has the following characters: Rs wing vein is closer to the end of R_1 than to the arculus, R_5 is bent at its juncture with Rs, claws are bent near the basal third and the female cerci are large and fleshy. Lopesiini is a tribe of Cecidomyiidae that is not well known. It contains seven genera recorded previously, with eight South American, one North American and three African species creating galls on plants from the families Boraginaceae, Chrysobalanaceae, Leguminosae, Melastomataceae, Polygonaceae and Rosaceae (Gagné & Marohasy 1993; Gagné 1994; Gagné & Hibbard 1996; Maia 1996). The gall midge described here is the first species of this tribe known to feed on Myrtaceae and is the only member of Lopesiini known from Australia. *Austrolopesia* differs from all other genera of this tribe in the prolonged ovipositor and, except for *Cordiamyia* Maia and *Ctenodactylomyia* Felt, in the gynecoid male flagellomeres. The new genus appears to be morphologically closest to *Cordiamyia*, a monospecific genus originally not assigned to tribe level but evidently belonging in Lopesiini (Maia 1996). *Cordiamyia globosa* Maia, a species forming leaf galls on *Cordia verbenaceae* DC (Boraginaceae) in South America, differs from the new species in the following characters. In *C. globosa*, the adult has a long and narrow postvertical protuberance on its head, a three-segmented palpus, the aedeagus is shorter than the hypoproct, the gonostylus barely tapers and is swollen at its basal fourth, and the ovipositor is protrusible but short; the pupa has long and bifid horns at the base of the antennae, the prothoracic spiracle is strongly bent at its distal fourth; the larva has eight terminal papillae, all with corniform setae. In *Austrolopesia melaleucae* gen. et sp. nov. the adult has a short and wide postvertical protuberance on its head, a four-segmented palpus, an aedeagus longer than the hypoproct, a tapering gonostylus which is swollen at its basal third and a long and protrusible ovipositor; the pupa has short and angular cephalic horns, the prothoracic spiracle is slightly and evenly bent; the larva has eight terminal papillae, four with pointed setae and four with corniform setae.

Austrolopesia differs from *Lophodiplosis* Gagné, an Australian genus galling *Melaleuca* spp. in Queensland (Gagné *et al.* 1997), in several characters. In *Austrolopesia*, the tarsal claws are curved near the basal third, the male flagellomeres are gynecoid and bear simple, closely appressed circumfila, all setae on the female cerci are simple, the pupa has no protuberances on the vertex and bears dorsal spines on the abdomen; the larva has a sternal spatula with a long, narrow shaft and the terminal segment bears eight robust papillae, four with corniform setae and four with strong, short, pointed setae. In *Lophodiplosis*, the tarsal claws are curved beyond the mid-length, the male flagellomeres are binodal with three looped circumfila, the female cerci bear setiform sensoria in addition to the setae; the pupa has large protuberances on the vertex and no dorsal spines on the abdomen; the larva has either a sternal spatula with a short, wide shaft or no spatula at all, and the terminal segment bears two or four minute, setose papillae.

Austrolopesia melaleucae sp. nov.
(FIGS 2-18)

Holotype: ♂, Coorong National Park, "Loop Road" South Australia [36° 11' S, 139° 41' E], 23.x.1997, reared by P. Kolesik from flower galls on *Melaleuca halmaturorum* F. Muell. ex Miq., gall collected 2.ix.1997 by D. Peacock and S. Jennings, I21410 [SAMA].

Paratypes: 3 ♀♀, 2 pupal skins [SAMA, I21411-I21415], ♂, 2 ♀♀, pupal skin [ANIC], same data but emerged 23.ix.-9.x.1997; 3 larvae [SAMA, I21416-I21418], 2 larvae [ANIC], collected with holotype.

Other material: 11 larvae, collected with holotype [SAMA].

Male (Figs 2-8)

Colour: eyes black, head dark brown, antennae grey, palpi grey with black scales, thorax and abdomen orange, genitalia light brown, legs grey with black scales. Antenna: scape and pedicel slightly longer than wide, last flagellomere with apical nipple; circumfila simple, thin; circumfilar attachment points dense; setae short, thin. Postvertical protuberance on head short, bearing 2-4 strong setae. First palpal segment short, second and third longer, equal in length, fourth longest. Frons with 3-4 setae per side. Wing 2.5 mm long, 0.8 mm wide (n=1, the second specimen with one wing missing and the second deformed in the process of mounting).

Female (Figs 9-13)

Colour as in male. Head: frons with 3-5 setae. Thorax: wing length 1.8 mm (range 1.7-1.9, n = 5), width 0.8 mm (0.8-1.0). Ovipositor 2x longer than tergite 7, with setae evenly distributed on segment 9; cerci with simple setae, setulose; hypoproct with 2 setae, setulose. Other characters as in male.

Pupa (Figs 14, 15)

Colour: antennal horns, prothoracic spiracle and dorsal spines dark brown, remaining parts pale brown. Length 1.8 mm (1.6-2.2, n=3). Cephalic papillae 46 µm (46-47) long. Frons with all setae short. Prothoracic spiracle 150 µm (134-173) long. Abdominal segments dorsally with fields of 4-15 spines on anterior half.

Larva (Figs 16-18)

Colour: orange. Length 1.8 mm (1.7-1.9, n=5). Head with antennae 2x longer than wide, posterolateral apodemes as long as head capsule. Sternal spatula 177 µm (157-211) long, with apical enlargement 46 µm (39-54) wide, depth of incision 25 µm (24-29).

Etymology

The name *melaleucae* means "of *Melaleuca*".

Gall and biology

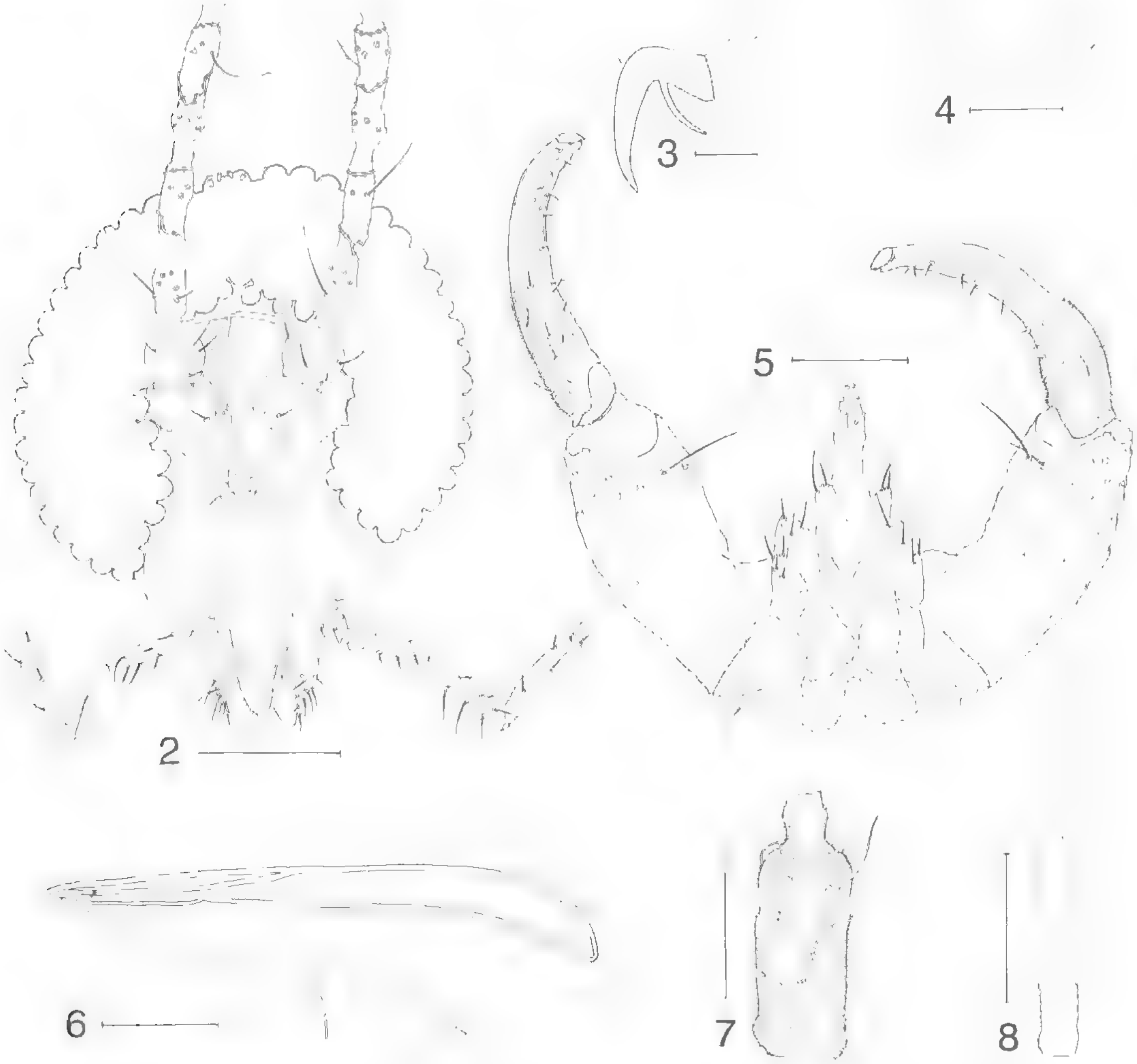
The sexual organs of the flower of *Melaleuca halmaturorum* are modified by the new gall midge into an ovoid, woody gall covered with dense, grey hairs (Fig. 1). The gall, 6-10 mm in length and 5-8 mm in width, consists of two hemispheres connected by a longitudinal suture with a small, bald nipple at the apex. Inside the gall is a small, ovoid chamber occupied by one larva. The chamber wall is 1.5-3 mm thick. The sepals and petals on the base of the gall are not modified. No seeds are produced within galled flowers. Pupation takes place within the gall. At the end of its development the pupa inserts most of its body through the suture between the hemispheres of the gall, the pupal skin splits open and the adult emerges. The empty pupal skin stays attached to the gall long after adult emergence. Some galls collected with the type series showed small, round openings, presumably created by parasitoids.

Remarks

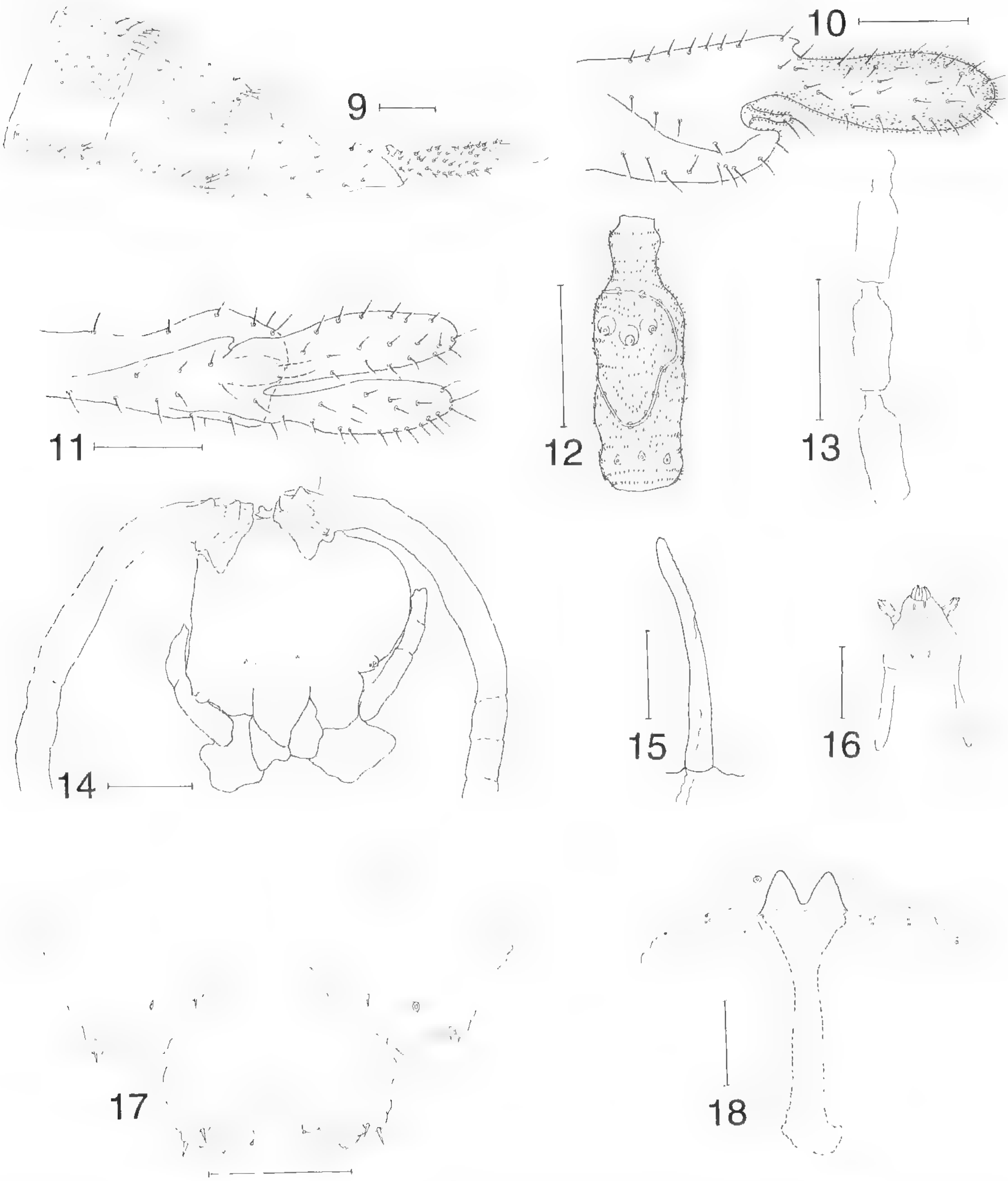
The new gall midge is different from *Dasineura frauenfeldi* (Schiner) (comb. nov.), a species described in 1868 from branch bud galls on *Melaleuca* sp. in Port Jackson, Sydney. In *D. frauenfeldi*, the R_5 meets C anterior to the wing apex, the aedeagus is sheathed by parameres, and the female eighth tergite is split into two longitudinal sclerites. In *A. melaleucae*, the R_5 meets C posterior to the wing apex, the male parameres are not present, and the female eighth tergum is not sclerotised.

Acknowledgments

I thank K. Davis for drawing my attention to the new species and D. Peacock and S. Jennings for collecting the galls and larval stages of the type specimens. M. C. O'Leary, State Herbarium of South Australia courteously identified the host plant. R. Contreras-Lichtenberg, Naturhistorisches Museum, Vienna kindly loaned the type material of *Dasineura frauenfeldi*. Special thanks go to J. D. Gray, Department of Horticulture, Viticulture and Oenology University of Adelaide and R. J. Gagné, Systematic Entomology Laboratory USDA Washington DC, for commenting on an early draft of the manuscript.



Figs 2-8. Male of *Austrolopesia melaleucae* sp. nov. Fig. 2. Head in frontal view. Fig. 3. Tarsal claw and empodium. Fig 4. First tarsomere. Fig. 5. Genitalia in dorsal view. Fig. 6. Wing. Fig. 7. Sixth flagellomere. Fig. 8. Last three flagellomeres. Scale bars = 100 µm 2, 8; 10 µm 3; 50 µm 4, 5, 7; 500 µm 6.



Figs 9-18. *Austrolopesia melaleucae* sp. nov. 9-13 female, 14, 15 pupa, 16-18 larva. Fig. 9. End of abdomen in lateral view. Fig. 10. Ovipositor in lateral view. Fig. 11. Ovipositor in dorsal view. Fig. 12. Sixth flagellomere. Fig. 13. Last three flagellomeres. Fig. 14. Anterior part in ventral view. Fig 15. Prothoracic spiracle. Fig. 16. Head in ventral view. Fig. 17. Last two abdominal segments in dorsal view. Fig. 18. Spatula with adjacent papillae. Scale bars = 100 μm 9, 13, 14, 17, 18; 50 μm 10 - 12, 15, 16.

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BAINECHINA ROSSIAE GEN. ET SP. NOV. (NEMATODA: SEURATIDAE) FROM AUSTRALIAN DASYURID MARSUPIALS

*By Lesley R. Smales**

Summary

Smales, L. R. (1999) Bainechina rossiae gen. et sp. nov. (Nematoda: Seuratidae) from Australian dasyurid marsupials. Trans. R. Soc. S. Aust. 123(1), 37-41, 31 May, 1999.

Bainechina rossiae gen. et sp. nov. (Seuratidae: Echinonematinae) is described from the stomach and small intestine of the dasyurid marsupials Planigale gilesi, P. ingrami, P. maculata and Sminthopsis macroura. It resembles Seurechina spp. most closely in body armature but can be distinguished from this genus in having a triangular not dorso-ventrally elongated mouth opening, having neither sclerotised rings between the pharynx and mouth opening, nor caudal alae into which caudal papillae extend nor peri-cloacal papillae. Bainechina rossiae is unique among the echinonematines in having papillae on the body at the level of the vulva. A key to the genera is given. Aspects of the life-cycle of B. rossiae are discussed.

Key Words: Bainechina, nematodes, Seuratidae, Echinonematinae, marsupials, Dasyuridae, Australia.

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BAINECHINA ROSSIAE GEN. ET SP. NOV. (NEMATODA : SEURATIDAE) FROM AUSTRALIAN DASYURID MARSUPIALS

by LESLEY R. SMALES[1]

Summary

SMALES, L. R. (1999) *Bainechina rossiae* gen. et sp. nov. (Nematoda : Seuratidae) from Australian dasyurid marsupials. *Trans R. Soc. S. Aust.* **123**(1), 37-41, 31 May, 1999.

Bainechina rossiae gen. et sp. nov. (Seuratidae : Echinonematinae) is described from the stomach and small intestine of the dasyurid marsupials *Planigale gilesi*, *P. ingrami*, *P. maculata* and *Sminthopsis macroura*. It resembles *Seurechina* spp. most closely in body armature but can be distinguished from this genus in having a triangular not dorso-ventrally elongated mouth opening, having neither sclerotised rings between the pharynx and mouth opening, nor caudal alae into which caudal papillae extend nor peri-cloacal papillae. *Bainechina rossiae* is unique among the echinonematines in having papillae on the body at the level of the vulva. A key to the genera is given. Aspects of the life-cycle of *B. rossiae* are discussed.

KEY WORDS: *Bainechina*, nematodes, Seuratidae, Echinonematinae, marsupials, Dasyuridae, Australia

Introduction

Nematodes of the family Seuratidae are parasites of reptiles, birds, rodents, bats and Australian marsupials (Chabaud 1978). All of the Australian species are contained within the subfamily Echinonematinae and are found in dasyurid or peramelid marsupial hosts. There are four genera, characterized by a large triangular or dorso-ventrally elongated mouth opening with no lip lobes, an anterior extremity with or without a swollen cephalic bulb bearing hooks, a short, simple pharynx, long slender spicules without alae, no pre-cloacal sucker on the male and the cloacal region covered by small cuticular granulations.

Linstowinema Smales, 1997 and *Inglechina* Chabaud, Seureau, Beveridge, Bain & Durette-Desset, 1980 contain species with a swollen cephalic bulb bearing three rows of large hooks whereas species of *Chabaudechina* (Smales in press) have five rows of hooks. These three genera all have a triangular mouth opening. *Seurechina* Chaubaud, Seureau, Beveridge, Bain & Durette-Desset, 1980 by contrast, has a dorso-ventrally elongated mouth opening and has neither a swollen cephalic bulb nor cephalic hooks.

Materials and Methods

Specimens dissected from dasyurids from the CSIRO Wildlife and Rangelands Collection (CSIRO) were fixed in hot 10% fomalin and then stored in 70% ethanol. Specimens from Blair Athol Mine, Central Queensland and Yabula near Townsville, North Queensland, dissected from dasyurids that had been fixed in 10% formalin, were stored in 70% ethanol. Specimens were examined after clearing in lactophenol. Measurements, in micrometres unless otherwise stated, were made with the aid of a drawing tube and map measurer or an ocular micrometer. Drawings were made with the aid of a drawing tube. Type specimens have been deposited in the South Australian Museum, Adelaide (SAMA). Voucher specimens are held in the Western Australian Museum, Perth (WAMP) and CSIRO, Canberra.

Systematics

Family Seuratidae (Hall, 1916) Railliet, 1916
Subfamily Echinonematinae Inglis, 1967

Bainechina gen. nov.

Anterior end without lips or lip-like structures, bearing 2 pairs of double sub-median papillae, single pair of lateral amphids. Mouth opening triangular in outline. Cephalic region without spines or hooks, remainder of body covered with numerous rows of hooks or spines. Hooks on pharyngeal region becoming smaller, grading into spines towards posterior. Armature extending over entire body of female, terminating anterior to cloaca of male. Short, simple claviform pharynx surrounded by nerve ring anterior to deirids. Deirids simple, conical. Spicules equal, similar, without alae. Vulva

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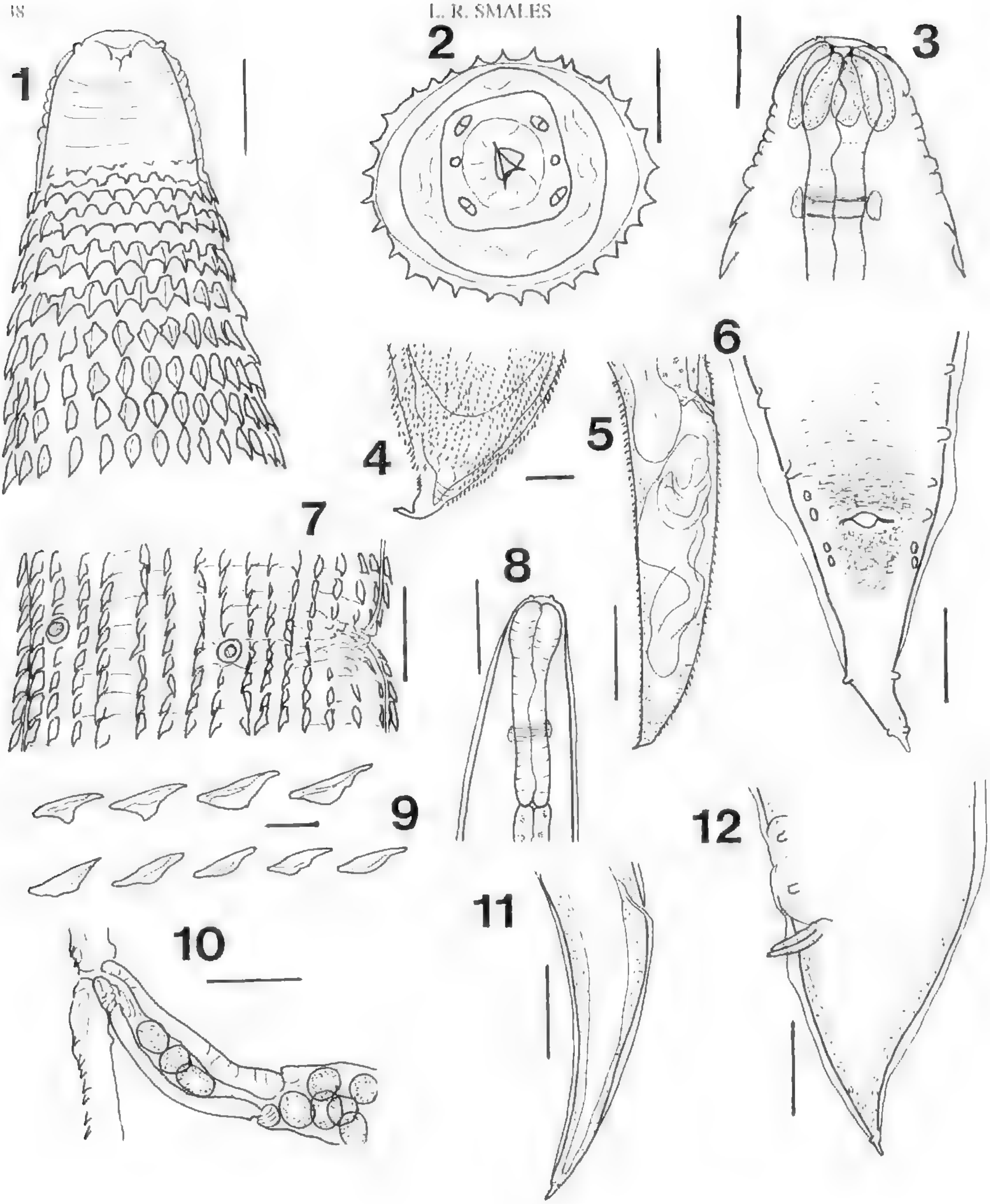

Figs 1–12. *Bainechina rossiae* gen. et sp. nov. 1. Anterior end (lateral view). 2. Anterior end (*en face* view). 3. Anterior end, optical section showing laminae (lateral view). 5. Female tail (lateral view). 6. Male posterior end (ventral view). 7. Female mid-body showing papillae and vulva (left lateral view). 8. Larva, anterior end (lateral view). 9. Body hooks (lateral view). 10. Vagina (right lateral view). 11. Larva, posterior end (lateral view). 12, Male, posterior end (lateral view). Scale bars = 100 µm 1, 10; 50 µm 2, 3, 6, 7, 8, 11, 12; 25 µm 4, 9; 200 µm 5.

at mid-region of body; monodelphic, vagina directed posteriorly. Parasites of Australian dasyurid marsupials.

Bainechina rossiae sp. nov.
(FIGS 1-12)

Holotype: ♂, from small intestine of *Planigale maculata* (Gould, 1851), Yabulu near Townsville, Queensland (19° 11' S, 146° 36' E), October 1997, coll. W. Houston, SAMA AHC 31286.

Allotype: ♀, same data, SAMA AHC 31287.

Paratypes: 5 ♀♀, same data, SAMA AHC 31288.

Other material examined: From *Planigale maculata*. Queensland: 5 ♀♀ Yabulu, AHC 31289, AHC 31290, 3 ♀♀ Blair Athol Mine site, AHC 31291, AHC 31292; Western Australia: 2 ♀♀ Mitchell Plateau, WAMP 47-98, 48-98. From *Planigale gilesi* Aitken, 1972, New South Wales: 1 ♂ Chinamans Lake, CSIRO N4409. From *Planigale ingrami* (Thomas, 1906) Northern Territory: 2 ♀♀, 4 larvae, Smithburne River, CSIRO N2116. From *Sminthopsis macroura* (Gould, 1845), Queensland: 1 ♂, 2 ♀♀ Julia Creek, SAMA AHC 31293.

Description

Small worms, with the characters of the genus. Body with fine cuticular annulations. Cephalic extremity without hooks or spines, remainder of body with rows of hooks, at each annulation, extending over entire body of female, 80% of body of male. Body hooks becoming biggest at about row 10, decreasing in size posteriorly, grading into spines. Thirty hooks in first row, 45 hooks on mid-body rows on female. Pharynx surrounded at anterior end by 4 pairs of laminae approximately 100 long. Pharynx simple, claviform, terminating at level of about 10th row of hooks, approximately $^1/_8$-$^1/_{12}$ body length. Nerve ring surrounding pharynx, deirids posterior to nerve ring, secretory-excretory pore not seen.

Male: (measurements Table 1).

Nerve ring, deirids, secretory-excretory pore not seen. Spicules equal, similar, without alae $^1/_4$ body length. Gubernaculum not seen. Eight pairs caudal papillae, 4 pairs lateral pre-cloacal, 2 pairs lateral post-cloacal, 2 pairs near tail tip. Narrow caudal alae extending from anterior caudal papillae posterior to cloaca. Cuticular embossing surrounding cloaca. Tail ending in prominent tip.

Female: (measurements Table 1).

Secretory-excretory pore not seen. Four papillae; 1 left lateral, 1 right lateral, 2 dorsal encircle body at level of vulva. Vagina directed posteriorly; monodelphic. Tail ending in prominent spike. Eggs oval 36–43 (39) by 33–36 (34).

Larvae: (measurements Table 1).

Cuticle aspinous. Tail ending in prominent spike.

TABLE 1 *Measurements of* Bainechina rossiae *sp. nov. from* Planigale *spp. Female measurements given as range, mean and standard deviation.*

	Holotype Male	Male from *P. gilesi*	Females n=10	Larvae n=4
Length	1.9 mm	2.3 mm	4.0-6.5, 5.5 ± 0.81 mm	1225
Max. width	270	235	340-410, 380 ± 48.54	87
Pharynx length	305	260	360-535, 460 ± 51.37	110
Anterior to nerve ring			80-100, 90 ± 9.80	80
Anterior to deirids			90 (n=1)	
Spicule length	460	560		
Vulva to posterior			2700-3400, 3100 ± 282.89	
Tail	94	135	48-740, 640 ± 104.00	160
Vagina			180-250, 215 ± 40.41	

Etymology

Generic name in honour of Dr O. Bain coupled with the Greek *echinos* (hedgehog, sea-urchin) following the form used by Chabaud *et al.* (1980) for other echinonematine genera; specific name after a colleague, Dr P. Rossi.

Remarks

The two females from *P. ingrami* (Thomas, 1906) were smaller (3.4–3.6 mm) compared with females from *P. maculata* (4-6.5 mm) and had shorter tails (150, 165 compared with 480-740). No mature eggs were observed in the uterus and so these differences in size might be due either to the immaturity of the worms or to differences in the fixation procedures used. Since no male specimens were available for study and the body armature of the females was the same as that for specimens from *P. maculata* they are considered, at present, to be the same species.

The females from *Sminthopsis macroura* (Gould, 1858) were larger (7.15 mm long compared with 4-6.5 mm) but the male (2 mm compared with 1.9-2.3 mm) was similar in size to specimens from *P. maculata*. All the specimens from *S. macroura* had characters consistent with *B. rossiae* and are considered to be the same species.

Inglis (1967) distinguished between pairs of papillae and a pair of phasmids on the posterior extremity of the tail of *Linstowinema*. Other echinonematine genera have three or four pairs of papillae and a pair of phasmids in this position (Chabaud *et al.* 1980; Smales 1999, in press; Smales & Rossi 1999). It is not clear whether the two pairs of papillae seen on the posterior extremity of the tail of *B. rossiae* represent a pair of papillae and a pair of phasmids or whether the phasmids were not seen.

Bainechina gen. nov. clearly belongs in the Echinonematinae because it has an anterior end with a triangular mouth opening, no lip lobes and two pairs of double cephalic papillae. It has relatively long (¹/₅ body length) simple spicules and cuticular embossing around the cloaca. In body armature it is most similar to the genus *Seurechina*, in not having a swollen cephalic bulb with large cephalic hooks but in having rows of small hooks and spines at each cuticlar annulation over the remainder of the body surface. Both genera have four pairs of laminae at the anterior end surrounding the pharynx, possibly with a role in holding the cervical spines steady when they are embedded in the intestinal mucosa (Chabaud *et al.* 1980; Smales 1998). *Bainechina* can be differentiated from *Seurechina* in having the mouth opening triangular not dorso-ventrally elongated and in not having sclerotised rings, enlarged dorsally and ventrally, capping the anterior end of the pharynx (Chabaud *et al.* 1980). *Bainechina rossiae* has eight pairs of caudal papillae, none of which extends into the caudal alae as do those of *Seurechina* spp. (Chabaud *et al.* 1980; Smales 1998). None of the caudal papillae of *B. rossiae* is peri-cloacal whereas three pairs of caudal papillae are peri-cloacal in *Seurechina* spp. (Chabaud *et al.* 1980; Smales 1998). None of the other genera within the Echinonematinae has papillae at the level of the vulva.

Of the other echinonematines, *Bainechina* differs from *Linstowinema* and *Inglechina* in not having a swollen cephalic bulb with three rows of cephalic hooks (Chabaud *et al.* 1980; Smales 1997, 1999; Smales & Rossi 1999). *Bainechina* also differs from *Chabaudechina* with five rows of cephalic hooks (Smales in press). The arrangement of caudal papillae in *Bainechina* is also unique to the genus.

Key to the genera of the Echinonematinae

1. With cephalic hooks on cephalic bulb, without laminae . . . . (2)
Without cephalic hooks on cephalic bulb, with four pairs laminae (Fig. 3) . . . . (4)
2. Three rows of hooks on cephalic bulb . . . . (3)
Five rows of hooks on cephalic bulb . . . . *Chabaudechina*
3. Rows of hooks on anterior region of body . . . . *Linstowinema*
Without body hooks . . . . *Inglechina*
4. Mouth opening oval . . . . *Seurechina*
Mouth opening triangular . . . . *Bainechina*

Discussion

The larval stages recovered from the lungs of *Planigale ingrami* (Thomas, 1906) had pharyngeal and cephalic morphology indicative of *Bainechina* (Fig. 8). Their recovery from the lungs, together with the lack of any sexual differentiation suggests that they were third or early fourth stage larvae undergoing migration to the digestive tract before moulting to fourth or fifth, sub adult stage nematodes. Spines were not observed on the body cuticle of these larvae, as has been noted on fourth stage larval *Linstowinema* and *Inglechina* (Smales 1999; Smales & Rossi 1999), possibly indicative of their being at a less advanced stage of development. *Linstowinema cinctum* (Linstow 1898), the only species in which the life cycle has been studied, develops into an infective third stage larva in experimentally infected Orthoptera (Chabaud *et al.* 1980). Dasyurids presumably become infected after eating infected arthropods. There has, however, been no record of larval migration within the definitive host, as inferred in this study, for any of the Seuratidae (Anderson 1992).

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SOURCE OF FOOD ITEMS IN AN ABORIGINAL MIDDEN AT LITTLE DIP, NEAR ROBE, SOUTHEASTERN SOUTH AUSTRALIA: IMPLICATIONS FOR COASTAL GEOMORPHIC CHANGE

By J. H. Cann & C. V. Murray-Wallace†*

Summary

Cann, J. H. & Murray-Wallace, C. V. (1999) Source of food items in an Aboriginal midden at Little Dip, near Robe, southeastern South Australia: implications for coastal geomorphic change. Trans. R. Soc. S. Aust. 123(2). 43-51, 31 May, 1999.

At Nora Creina Bay, in southeastern South Australia, fossil shell of the intertidal mollusc Katelysia scalarina from outcropping sediment yielded a radiocarbon age of 5600±140 y cal BP. The presence of intertidal sandflat sediments of this age, preserved in an open ocean coastal setting, implies that the western, mostly eroded side of Robe Range once sheltered quiet water embayments with intertidal sandflats. Radiocarbon ages for fossil mollusc from marine sediments landwards of Robe Range reveal that autochthonous deposition took place within an extensive Holocene coastal back-barrier lagoon environment from approximately 5500-4000 y BP.

Key Words: South Australia, coastal, Holocene, Pleistocene, Aboriginal midden, mollusc, foraminifera, radiocarbon, amino acid racemisation.

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by J. H. CANN[1] & C. V. MURRAY-WALLACE[2]

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At Nora Creina Bay, in southeastern South Australia, fossil shell of the intertidal mollusc *Katelysia scalarina* from outcropping sediment yielded a radiocarbon age of 5600±140 y cal BP. The presence of intertidal sandflat sediments of this age, preserved in an open ocean coastal setting, implies that the western, mostly eroded side of Robe Range once sheltered quiet water embayments with intertidal sandflats. Radiocarbon ages for fossil molluscs from marine sediments landwards of Robe Range reveal that autochthonous deposition took place within an extensive Holocene coastal back-barrier lagoon environment from approximately 5500-4000 y BP. It was originally proposed that the shells of *Katelysia* cockles, gathered by Aboriginal people and now preserved within the archaeostratigraphic Early Horizon midden at Little Dip, had originated in this back-barrier lagoon. As the *Katelysia* sp. shell from the Early Horizon midden is more than 3000 y older than *Katelysia* spp. from the nearby autochthonous lagoonal sediments (e.g. at Fresh Dip Lake), it now seems that the cockles were harvested from intertidal sandflat environments on the seaward side of Little Dip, probably before marine incursion into the low lying land behind Robe Range. These sandflats were ephemeral features, eroded as the protective outer margin of Robe Range was also reduced by the erosive force of the Southern Ocean to a linear array of small islands and sea stacks that characterise the present coastline.

KEY WORDS: South Australia, coastal, Holocene, Pleistocene, Aboriginal midden, mollusc, foraminifera, radiocarbon, amino acid racemisation.

Introduction

Coastal Aboriginal middens in the vicinity of Robe, southeastern South Australia, typically contain shell remains of marine molluscs and, in many instances, fragments of flint. The materials of the older Early Horizon sites (nomenclature of Luebbers 1978[3]) lie on the exposed surface of Robe Range within terra rossa soils. Robe Range is a composite coastal barrier, comprising carbonate-quartz dune sands, which formed during the interstadial highstand sea level of oxygen isotope substage 5c (Schwebel 1983; Huntley *et al.* 1993; Belperio *et al.* 1996). Typically the shell remains of the Early Horizon middens are dominated by species of *Katelysia* Römer, an intertidal sandflat cockle commonly found today living in protected coastal settings (Ludbrook 1984); flint fragments are not commonly present. The younger and more numerous Late Horizon middens of Robe Range consist of thin beds of shell remains and flint fragments within the modern, unconsolidated dune sands that are related to the most recent postglacial marine transgression. The shells of these deposits, which are most frequently observed as lag deposits on deflation surfaces, are mostly of *Turbo (Subninella) undulatus* Solander, a large gastropod which is currently living along the modern rocky shoreface. Early Horizon middens record an episode of Aboriginal occupation of coastal Robe Range that approximates in time to the culmination of the postglacial marine transgression in the early Holocene, while the Late Horizon sites reflect more recent occupation (Luebbers 1978[3]; Cann *et al.* 1991).

At coastal Little Dip, southeast of Robe, *Turbo* shells and flint fragments, together with finely disseminated charcoal, occur within unconsolidated dune sands and as a lag deposit across a modern deflation surface. Shell from this deposit yielded a marine reservoir corrected radiocarbon age, calibrated to sidereal years, of 470±160 y cal BP (Table 1), an age corroborated by amino acid racemisation (AAR) analysis (Cann *et al.* 1991). The dune sands and their contained archaeological remains immediately overlie scattered concen

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[3] LUEBBERS, R. A. (1978) Meals and menus: a study in prehistoric coastal settlements in South Australia. PhD thesis ANU Canberra (unpub.)

TABLE 1. *Radiocarbon dates on Holocene molluscs and charcoal from Little Dip and environs near Robe, South Australia.*

Sample locality	Dated material	Laboratory code	$\delta^{13}C$ (‰)	Conventional ^{14}C age y BP	Calibrated and marine reservoir corrected ^{14}C age y cal BP
Fresh Dip Lake	*Katelysia scalarina* and *K. rhytiphora*	SUA-3028	1.0±1.0	3760±70	3680±200
Nora Creina embayment	*K. scalarina*	SUA-3029	1.0±1.0	5250±60	5600±140
Nora Creina Late Horizon midden	*Turbo* sp	Beta-104532	1.6±0.1	1170±60	740±130
Little Dip Late Horizon midden	*Turbo* sp.	ANU-7447	0.0±2.0	840±80	470±160
Little Dip Early Horizon midden	*Katelysia* sp	SUA-2613	1.0±1.0	7480±70	7900±160
Little Dip Early Horizon midden	charcoal	ANU-7448	-24.0±2.0	9270±80	9210±230

trations of *Katelysia* shells and charcoal which are embedded within a terra rossa soil on the otherwise calcreted and karstified sediments (oxygen isotope substage 5c) of Robe Range. Radiocarbon ages of 9210±230 y cal BP (ANU-7448) for charcoal and 7900±160 y cal BP (SUA-2613) for shell confirm an early Holocene age for the materials from the lower deposit (Table 1). These results are supported by previously published (AAR) analyses of *Katelysia* shell (Cann *et al.* 1991). Both deposits are the result of human activity, and their general setting and exposed materials were proposed as an archaeostratigraphic type locality and type sections for the time-cultural Early and Late Horizons of Aboriginal occupation in southeastern South Australia (Cann *et al.* 1991, 1998).

Cann *et al.* (1991) speculated about the origin of the *Katelysia* shells as a food source in the Early Horizon midden at Little Dip. These authors noted that, although the midden is situated in close proximity to the shore, there are currently no coastal intertidal sandflat environments which could have supported this edible cockle. However, they also observed that *Katelysia* spp. are abundant in both autochthonous and allochthonous bioclastic sediments, up to several m thick, exposed in excavations and lake beds within the low lying area immediately inland (northeast) of Robe Range. These Holocene shell beds were deposited in a coastal back-barrier lagoon which supported thriving populations of *Katelysia* and other molluscs. Cann *et al.* (1991) therefore concluded that this lagoon represented the most likely source of the cockles once gathered as food by the Aboriginal people who had lived on Robe Range about 8000 years ago. This paper re-evaluates the provenance of these midden materials in the light of additional field observations and radiocarbon ages.

Observations and Methods

Field observations

Nora Creina is the name given to a coastal area about 7 km southeast of Little Dip and adjacent to Nora Creina and Stinky Bays (Fig. 1). There are three major geomorphic elements present in this area. The oldest of these is Robe Range, comprising the mostly consolidated aeolian calcarenite that is associated with the interstadial highstand of sea level, oxygen isotope substage 5c, c. 105 000 y BP (Huntley *et al.* 1993). Since the culmination of the post glacial marine transgression and stabilisation of present sea level, this complex of former coastal dunes has undergone extensive erosion by the Southern Ocean and is now represented by numerous remnant small islands and offshore sea stacks. Many of these exhibit sections of aeolian cross beds and other dune forms (Fig. 2) and their upper surfaces are calcreted, karstified and support terra rossa soils. Numerous rhizomorphs attest to the role of former vegetation as an agent in carbonate diagenesis (Fig. 3).

The modern beach at Nora Creina, which is broad and exclusively sandy, is the second geomorphic element. The sand is carbonate-quartz in composition and derived, at least in part, from the erosional reworking of the older aeolianite of Robe Range. Some of the Robe Range sea stacks appear to have been instrumental in providing anchor points for beach construction, as regional uplift of c. 70 mm per thousand years (Belperio & Cann 1990; Belperio *et al.* 1996) promoted beach progradation. The beach

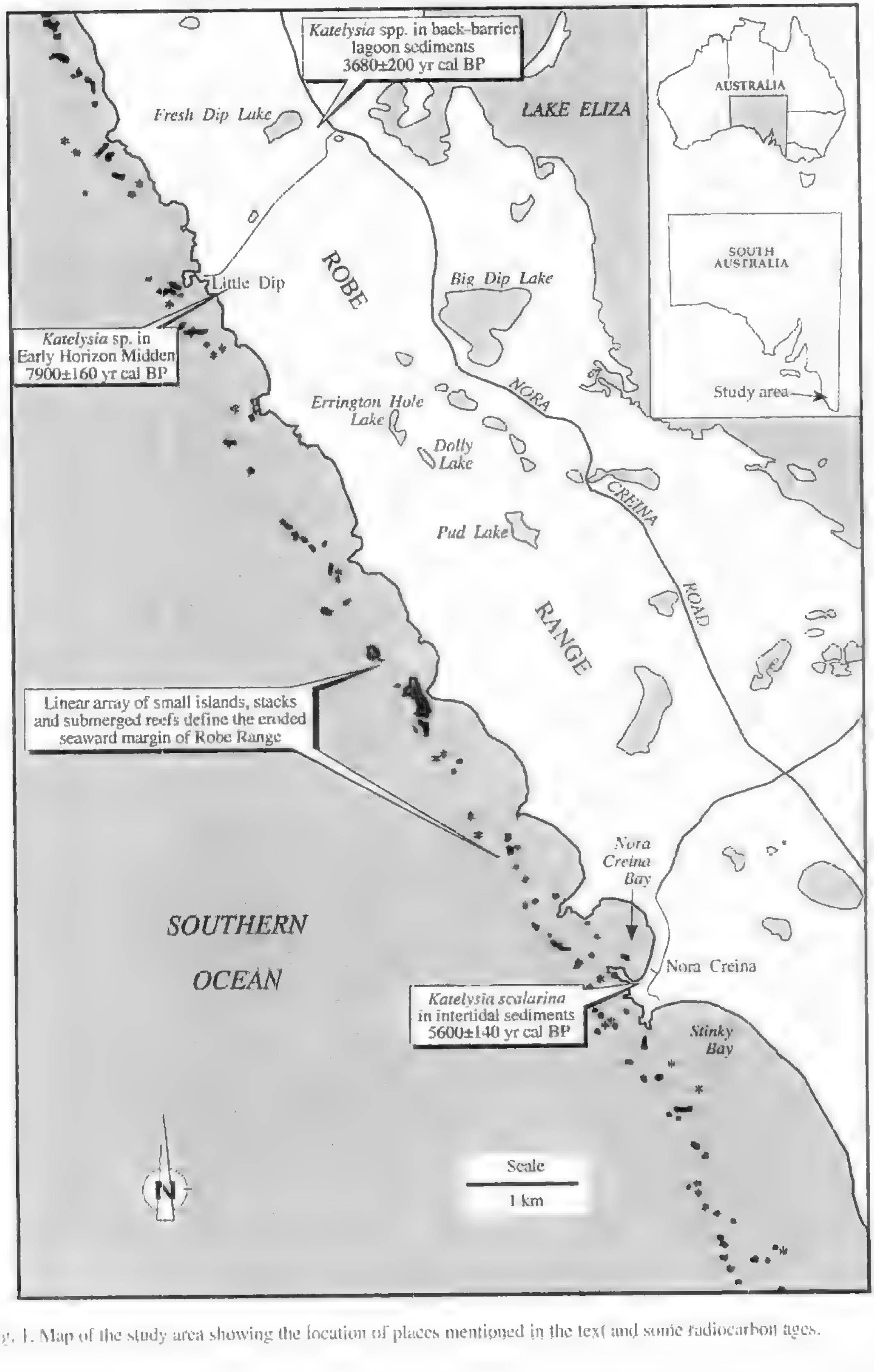
Katelysia spp. in back-barrier lagoon sediments 3680±200 yr cal BP
Fresh Dip Lake
LAKE ELIZA
AUSTRALIA
SOUTH AUSTRALIA
Study area
ROBE
Little Dip
Big Dip Lake
Katelysia sp. in Early Horizon Midden 7900±160 yr cal BP
Errington Hole Lake
NORA
Dolly Lake
CREINA
Pud Lake
ROAD
RANGE
Linear array of small islands, stacks and submerged reefs define the eroded seaward margin of Robe Range
Nora Creina Bay
SOUTHERN OCEAN
Nora Creina
Katelysia scalarina in intertidal sediments 5600±140 yr cal BP
Stinky Bay
N
Scale
1 km

Fig. 1. Map of the study area showing the location of places mentioned in the text and some radiocarbon ages.

face of Nora Creina Bay rests between headlands of the older aeolianite (Fig. 2); similar aeolianites outcrop along the Stinky Bay beach (Fig. 3).

The beaches at Nora Creina and Stinky Bays are backed by a system of modern coastal dunes which comprise the third geomorphic element. The dune sands are similar in composition to, and presumably (at least originally) in dynamic equilibrium with, those of the beach. Sections through some of these dunes have exposed typical materials of the Late Horizon middens, namely shells of *Turbo* sp. and fragments of flint.

At the southeastern extremity of Nora Creina Bay the modern high-tide beach sands abut a low wave cut exposure of poorly to moderately well cemented sediments, about 1 m in height, and extending

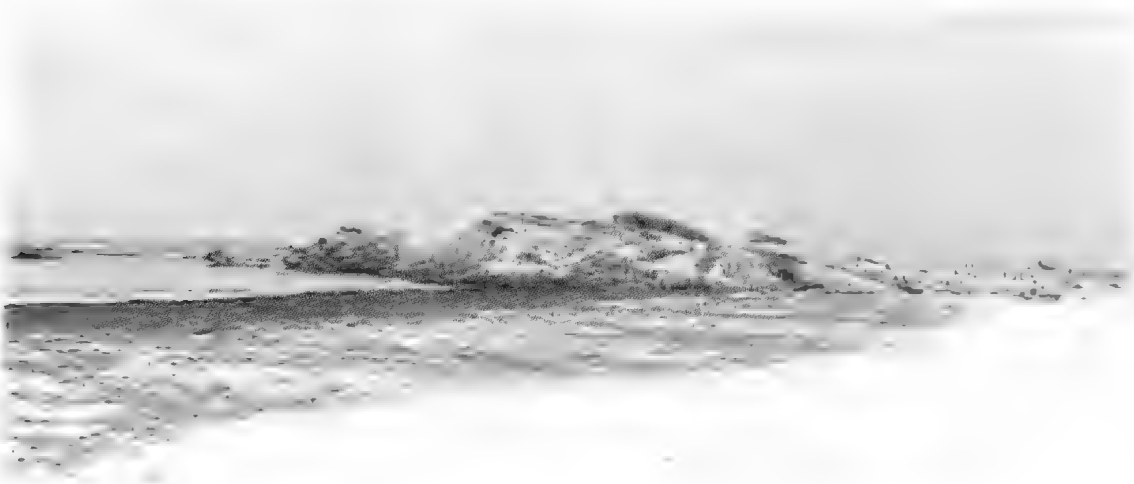

Fig. 2. The rocky outcrop of Robe Range aeolian calcarenite of age oxygen isotope substage 5e, which forms the southern headland of Nora Creina Bay. The dip slope towards the beach defines the lee side of the dune form. Motor vehicle on beach at right indicates scale.

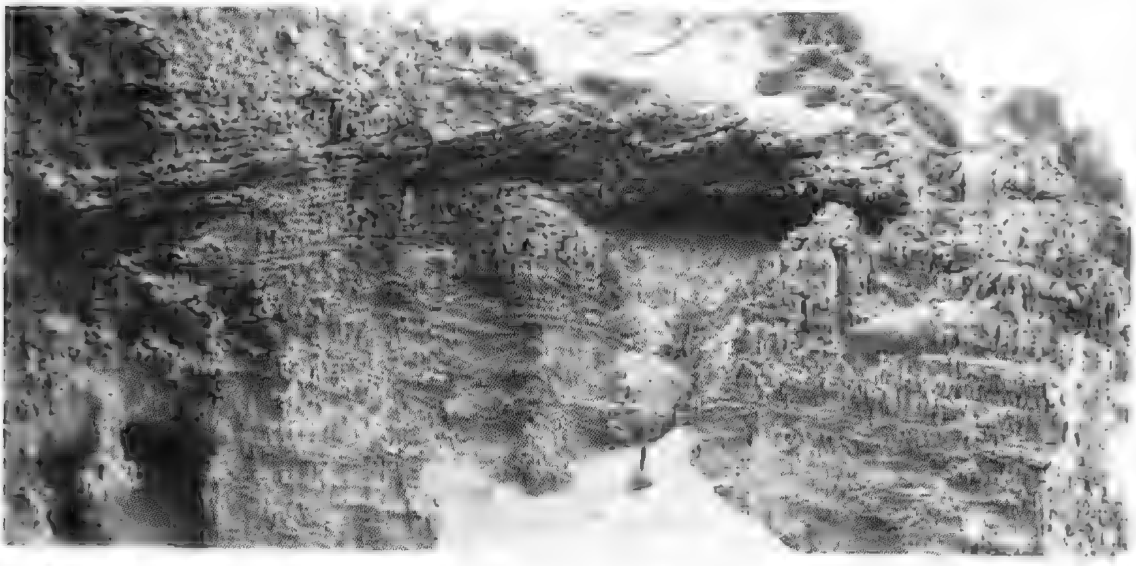

Fig. 3. Exposed section through a stranded aeolianite sea stack at the back of the beach face of Stinky Bay. This exposure reveals two sets of aeolian cross beds which are variably lithified, numerous rhizomorphs (right), a calcreted upper surface and a small solution hole (upper right). Holocene dune sand overlies the aeolianite and a garden spade for scale stands in modern beach sand.

several m back from the headland. The base of the exposure is not defined. The lowermost lithology is a breccia of calcarenite clasts, which are, at least superficially, similar in texture and composition to the locally outcropping aeolianite of the Robe Range. The angular to subrounded fragments range in size upwards to the dimensions of cobbles and are embedded in a matrix of sand of the same composition (Figs 4, 5). The texture and composition of this sediment is consistent with having been derived from the substage 5e aeolian calcarenite and deposited as storm wave beach debris.

The overlying bed, 10-25 cm thick, is sediment of quite different character, consisting of well preserved mollusc shells in a carbonate-quartz sandy matrix (Figs 4, 5). The northern part of the exposure is poorly consolidated and reveals in section both articulated and disarticulated bivalve shells in a grey, carbonate-quartz, slightly muddy sand. The unpaired shells are oriented both convex up and down with several having an imbricated fabric (Fig. 6). The southern part of the outcrop reveals the fossil shells in both vertical and horizontal exposures within essentially clean, slightly better cemented, carbonate-quartz sand (Fig. 7). Bivalves include species of *Anapella* Dall, *Brachidontes* Swainson, *Mactra* Linnaeus and *Katelysia*, and among the gastropods *Batillaria (Batillariella) estuarina* (Tate) is most common. From this sediment a specimen of *Katelysia scalarina* (Lamarck) was taken for radiocarbon dating and bulk sediment was also taken for foraminiferal analysis. The palaeoenvironment

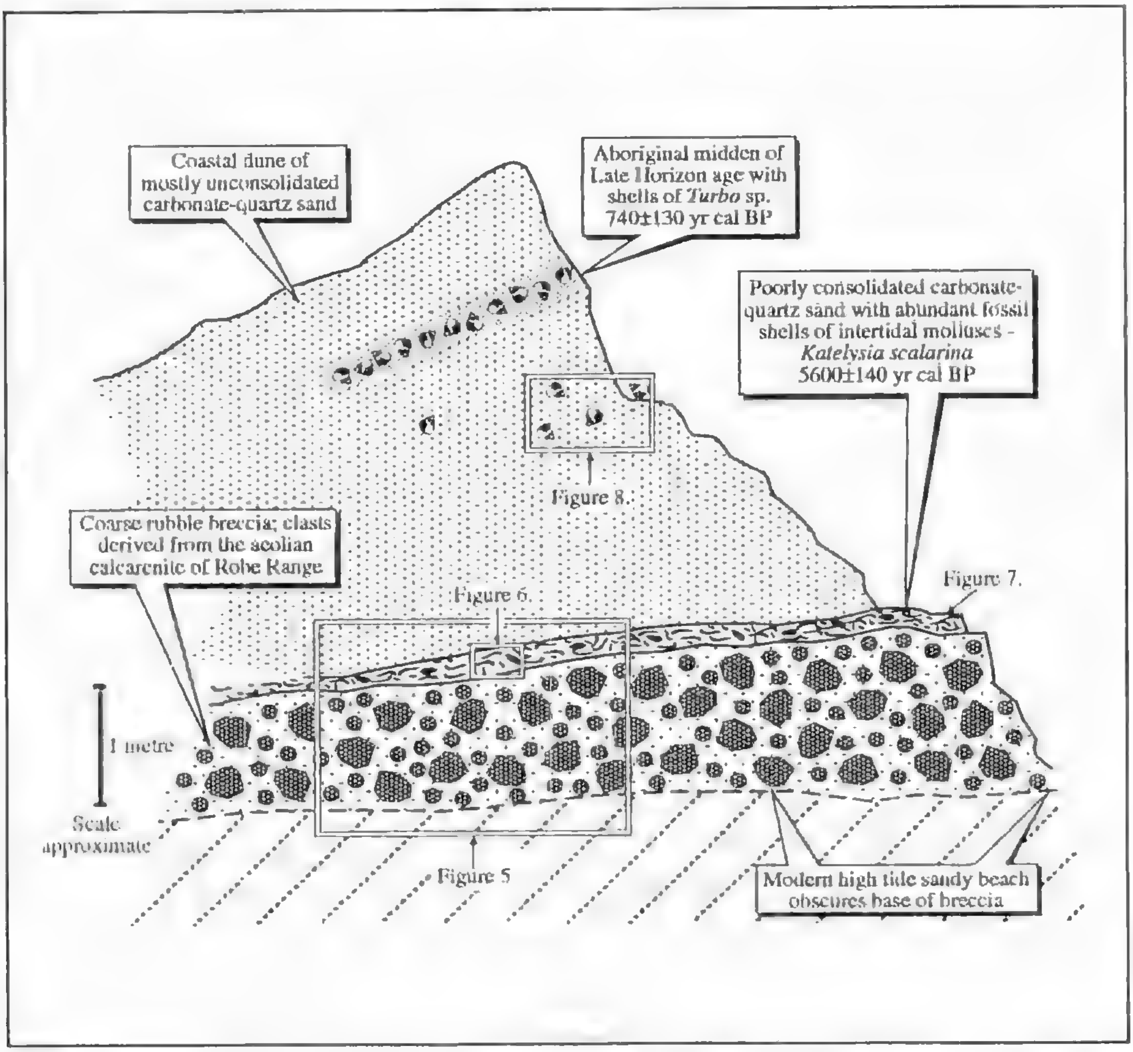
Coastal dune of mostly unconsolidated carbonate-quartz sand
Aboriginal midden of Late Horizon age with shells of *Turbo* sp. 740±130 yr cal BP
Poorly consolidated carbonate-quartz sand with abundant fossil shells of intertidal molluscs - *Katelysia scalarina* 5600±140 yr cal BP
Figure 8.
Coarse rubble breccia; clasts derived from the aeolian calcarenite of Robe Range
Figure 6.
Figure 7.
1 metre
Scale approximate
Figure 5
Modern high tide sandy beach obscures base of breccia

Fig. 4. Diagrammatic section of the exposure at the southern end of the beach at Nora Creina Bay. Also shown are the locations of features mentioned in the text and included as additional Figs 6-8.

that is signified by these fossil molluscs was at least closely similar to a modern intertidal sandflat and it is significant that such an environment once prevailed in a coastal setting which faced the Southern Ocean.

The shelly sandflat facies at Nora Creina Bay occurs up to 1 m above the modern high-tide sandy beach, and approximately 1.5 m above present mean sea level. Emergence of the shell bed may be attributed to the regional tectonic uplift, 490 mm in 7 ka (Belperio & Cann 1990), with superimposed hydroisostatic adjustments. The degree of hydroisostatic deformation for this setting is likely to be similar to that registered elsewhere at sites close to the continental shelf edge in southern Australia, such as at Port Lincoln, which records about 500 mm of emergence since the culmination of the post glacial marine transgression (Belperio 1995).

Overlying these beds of the shelly sandflat facies is a dune, 5-6 m high, of vegetated, but otherwise essentially unconsolidated carbonate-quartz sand. Included within the dune is an horizon of numerous

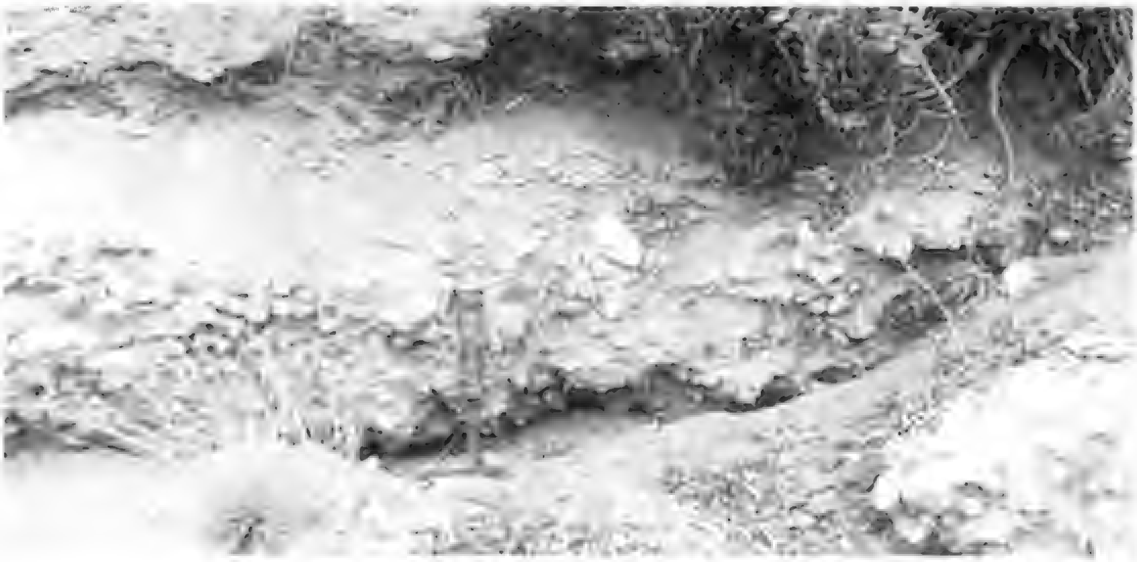

Fig. 5. Basal rubble breccia bed with cobble size clasts of reworked aeolian calcarenite, believed to represent storm wave beach debris. A sandy bed with preserved mollusc shells overlies the breccia. Geological hammer for scale.

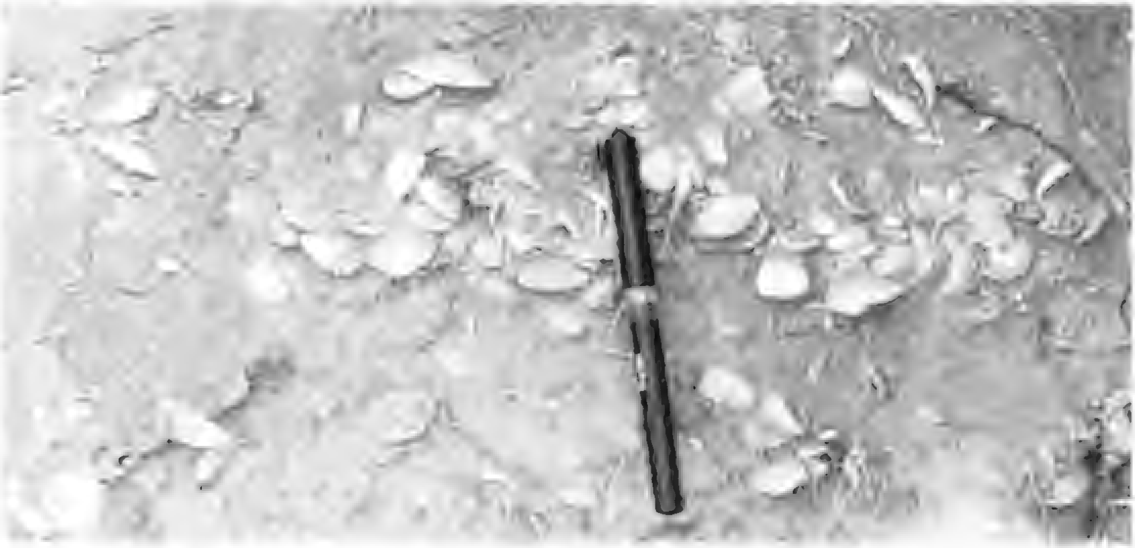

Fig. 6. Detail of fossil mollusc shells, which are here mostly disarticulated, convex upwards and partly imbricated, signifying some degree of transportation. The pen indicates scale.

large shells of *Turbo* sp., together with an associated lag of shells on an erosion surface, which is here interpreted as a Late Horizon Aboriginal midden (Figs 4, 8). A specimen of shell was taken from this deposit for radiocarbon dating.

Radiocarbon dating

Radiocarbon dating of the fossil molluscs, involving liquid scintillation counting of residual radiocarbon, followed the conventional methods as documented by Gupta & Polach (1985). As pretreatment, before sample preparation, the fossil shells were rigorously etched in c. 4 M hydrochloric acid. The conventional radiocarbon ages were calibrated to sidereal years using the program of Stuiver & Reimer (1993), which included a correction for the marine reservoir effect for southern Australian ocean surface waters (–450±35 y) (Gillespie & Polach 1979). With the exception of the *Turbo* sp. from Nora Creina (Beta-104522), all the radiocarbon ages were calculated using estimated δ13C values. Results are reported in Table 1.

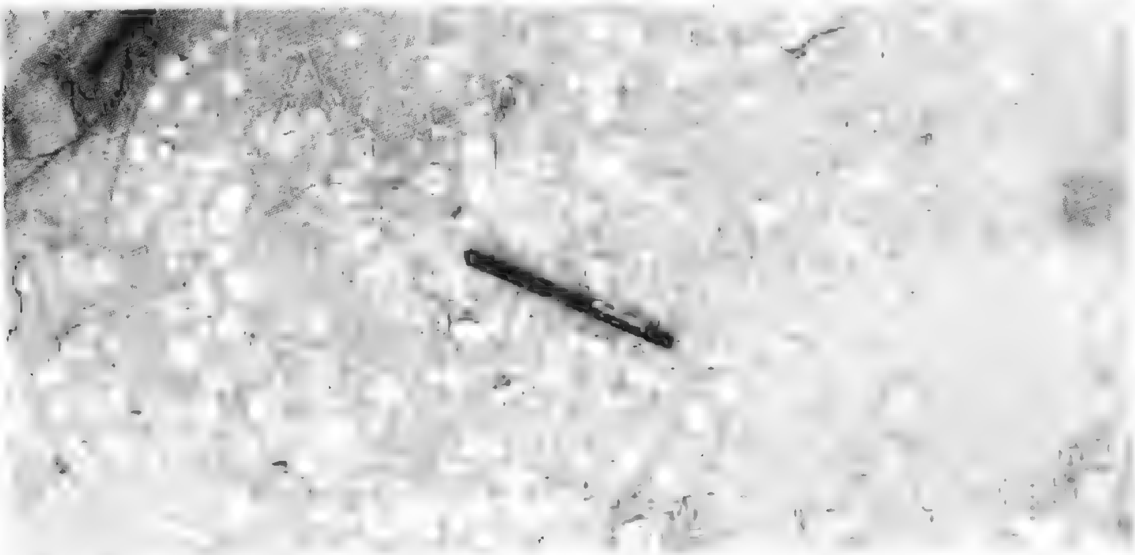

Fig. 7. Exposed upper surface of the shell bed. The pen indicates scale.

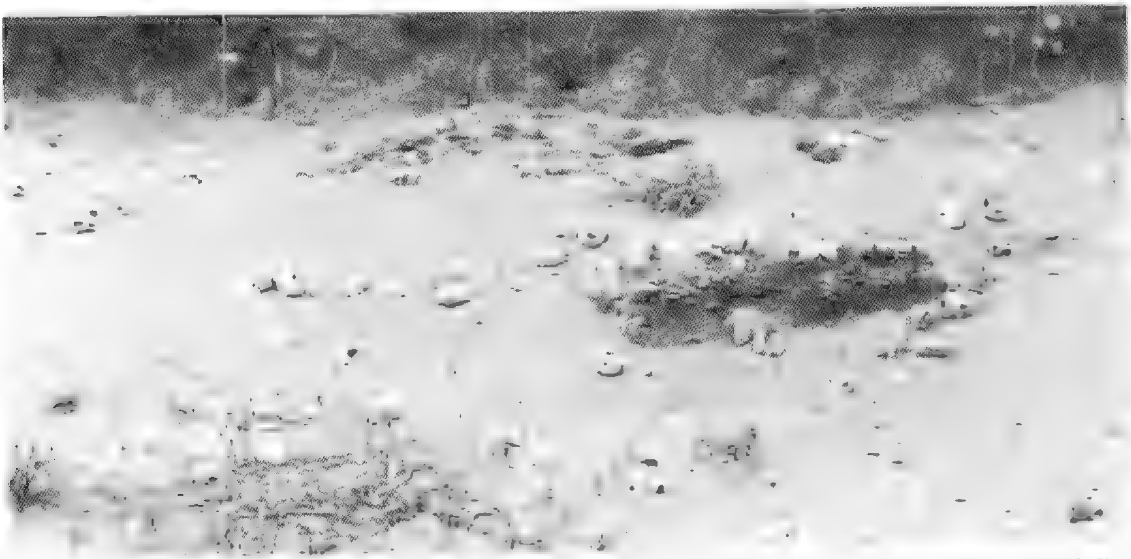

Fig. 8. Shells of *Turbo* sp. as a lag deposit derived from a Late Horizon Aboriginal midden in the dune. The larger shells are about 10 cm in diameter.

Micropalaeontology

The sediment sample collected from the shell bed cropping out at Nora Creina Bay was soaked in tap water to facilitate disaggregation and wet sieved to remove sediment grains <0.125 mm. The retained material was air dried and sieved to obtain the grain size fraction 0.50-0.25 mm for microscopic examination. Grains from this fraction were randomly sprinkled on to a picking tray, and the observed tests of foraminifera were identified and removed to a standard microfossil slide. However, polished or abraded tests, or those of yellow-brown colouration and infilled with authigenic cement, were excluded as these were all presumed to be relict. More than 300 individuals were extracted and identified, and the numerical abundance of species was evaluated as an indication of the palaeoenvironment.

Results and Discussion

Radiocarbon ages

The radiocarbon age determined for shell of *Katelysia scalarina* at Nora Creina Bay, calibrated to sidereal years, is 5600±140 y cal BP and that for *Turbo* sp. in the overlying dune sand is 740±130 y cal BP (Table 1). Cann *et al.* (1998) reported radiocarbon ages which indicate that the postglacial marine transgression into the coastal lagoon behind Robe Range was initiated c. 7500 y BP. Otherwise, fossil shells collected from autochthonous deposits of oysters and cockles within this lagoon consistently yielded dates around 5500-4000 y BP and shells from coquinoid deposits were as young as c. 2000 y BP. Thus the age for the shelly sediments at Nora Creina is consistent with sedimentation within the earlier part of the postglacial marine transgression and points to the formerly more extensive intertidal shelly sandflat environment on the seaward side of Robe Range.

Foraminifera

Microscopic examination of the sediment grain size fraction 0.50-0.25 mm, from the shelly sediment at Nora Creina Bay, revealed that three groups of foraminifera constitute almost three quarters of the assemblage. *Triloculina inflata* d'Orbigny + *T. oblonga* (Montagu) 16%, *Discorbis dimidiatus* (Parker & Jones) 30% and *Elphidium crispum* (Linné) 26%. Lesser species, each making up 3-5%, were *Nubecularia lucifuga* Defrance, *Spiroloculina antillarum* d'Orbigny, *Quinqueloculina subpolygona* Parr and *Triloculina tricarinata* (d'Orbigny). Such a distribution of species is consistent with a sand flat environment, as inferred from the molluscs. Species such as *Rosalina australis* (Parr), *Cibicides* sp. de Montfort and *Planulinoides biconcavus* (Jones & Parker), that might otherwise have signified more pronounced influence of the open ocean, are each represented by only a single specimen.

Coastal sandflats

During the early to mid Holocene, c. 5600 years ago, in the Nora Creina Bay area, the coastal marine setting hosted populations of marine molluscs and foraminifera which together imply the existence of an intertidal sandflat environment. It appears that, at the culmination of the postglacial marine transgression, such environments were initially created in sheltered areas, such as eroded embayments, and were adjacent to clusters of sea stacks and small islands (erosional remnants of the Late Pleistocene component of Robe Range). The aeolian calcarenites which comprise Robe Range are variably lithified and the fragmented nature of the present landscape attests to extensive erosion of the less consolidated sediments by the forces of the Southern Ocean. The eroded remnants of Robe Range can be traced for up to 1 km offshore and their presence implies an average rate of coastal recession of 143 mm y^{-1} since the culmination of the postglacial marine transgression some 7000 years ago. This local rate of cliff retreat is up to three times greater than that reported by Twidale (1997) for various sites on Eyre Peninsula. The large quantities of relict carbonate bioclasts, that impart the distinctive yellow-brown colour to the sands of the present day beach and the Holocene coastal dunes of the Robe Range complex, attest to the degree of erosion of the older aeolianite succession. With continued erosion of the protective stacks and islands at the seaward edge of Robe Range, the sandflats that had formerly hosted the intertidal fauna, as in the Nora Creina embayment became exposed to unabated marine erosion. The sands were redistributed, partly as a transgressive blanket of parabolic dunes, constituting the most recent phase of construction of Robe Range and also partly along the coast to be deposited in the protected environments that were to become Guichen and Rivoli Bays. These latter sediments are now represented as a series of relict foredunes (Sprigg 1952; Cann *et al.* 1991, 1998).

Katelysia shells in the Early Horizon midden at Little Dip

Cann *et al.* (1991) originally proposed that the shells of *Katelysia* cockles, gathered as a food source by Aboriginal people, and now preserved within the archaeostratigraphic Early Horizon midden at Little Dip, had originated in the Holocene back-barrier coastal lagoon behind Robe Range. Large populations of molluscs, especially *Katelysia* spp., became established within this lagoon and their shelly remains accumulated forming extensive bioclastic sediments. As the radiocarbon age from

Katelysia sp. shell in the Early Horizon midden is more than 3000 y older than the ages from *Katelysia* spp. in the nearby autochthonous back-barrier lagoon sediments, it now appears unlikely that the shells in the midden had their origin in the lagoonal waterway. The radiocarbon dated fossil *K. scalarina* from Nora Creina confirms that, in sheltered settings along the Holocene coast, hospitable environments prevailed for this mollusc. It would seem that, in the early Holocene, Aboriginal people harvested the cockles from intertidal sandflat environments on the seaward side of Little Dip. As may be inferred from the available radiocarbon data (Cann *et al.* 1998), this was probably several hundred years before the postglacial marine transgression flooded the low lying land behind Robe Range.

Conclusions

At the culmination of the postglacial marine transgression, the seaward side of Robe Range, near Nora Creina and Little Dip, provided sheltered back-barrier settings in which sands were deposited and intertidal molluscs, especially *Katelysia* spp., were able to thrive. Aboriginal people gathered these cockles as a food source, as evidenced by the abundant shell remains in the Early Horizon midden at Little Dip. The less consolidated parts of the beach/dune barrier succumbed to the erosive forces of the Southern Ocean, thus reducing this feature over time to the linear array of sea stacks and small islands that characterise the seaward edge of Robe Range today. The unprotected sandflats were thus exposed to the open ocean and their sediments were redistributed. Much sand was blown onshore as a blanket of transgressive coastal dunes. Sand was also transported along the coast and deposited in the sheltered areas that became Guichen and Rivoli Bays. Radiocarbon ages for the Early Horizon midden shells at Little Dip, and for the *Katelysia scalarina* from the sandflat facies at Nora Creina, constrain this environmental change to the time interval c. 8000-5600 y BP.

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THREE NEW SPECIES OF STRONGYLOID NEMATODES FROM THYLOGALE STIGMATICA (GOULD, 1860) AND THYLOGALE THETIS (LESSON, 1828) (MARSUPIALIA: MACROPODIDAE)

*BY J. E. GRIFFITH**

Summary

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Thylonema woodalli sp. nov. is described from the stomach of pademelons Thylogale stigmatica and T. thetis from Queensland. Thylonema woodalli differs from congeners in the shape of the buccal capsule. Thylonema clelandae sp. nov. is described from the stomach of the pademelon, Thylogale stigmatica. Thylonema clelandae differs from congeners in the shape of the buccal capsule, the sclerotised folds in the oesophageal bulb, lip-like structures in the buccal capsule and lack of an annulus in the wall of the buccal capsule.

Key Words: Thylogale stigmatica, Thylogale thetis, Thylonema woodalli sp. nov., Thylonema clelandae sp. nov., Thylostrongylus franklinae sp. nov., nematodes, new species, Macropodidae.

Transactions of the Royal Society of S. Aust. (1999), **123**(2), 53-60.

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KEY WORDS: *Thylogale stigmatica*, *Thylogale thetis*, *Thylonema woodalli* sp. nov., *Thylonema clelandae* sp. nov., *Thylostrongylus franklinae* sp. nov., nematodes, new species, Macropodidae.

Introduction

The nematode parasites of the red-legged pademelon, *Thylogale stigmatica* Gould, 1860, from Queensland, include a highly distinctive series of species or genera either restricted to this host or occurring in closely related species (Beveridge *et al.* 1992; Spratt *et al.* 1991). However, although the helminth communities of *Thylogale stigmatica stigmatica*, Gould, 1860 have been investigated in areas north of Townsville (Beveridge *et al.* 1992), only a limited number of pademelons belonging to other species or subspecies has been examined in southern Queensland and northern New South Wales (Johnston & Mawson 1939; Beveridge 1982, 1983). During an investigation of the helminth communities of *Thylogale stigmatica wilcoxi* M'Coy, 1866 and *T. thetis* Lesson, 1828 collected from southern Queensland and northern New South Wales, several undescribed nematodes were encountered. This paper presents the description of two new species of *Thylonema* Beveridge, 1981 and one new species of *Thylostrongylus* Beveridge, 1982.

Materials and Methods

Pademelons were collected opportunistically as road kills and stored at -20° C. Carcases were thawed and a sample of stomach content was collected from various regions of the stomach and fixed in 10% formalin. Nematodes were removed from stomach content, washed in water, cleared in lactophenol, and examined using an Olympus BH2 microscope. Drawings were made with the aid of a drawing tube. Measurements are given in micrometers, unless otherwise stated, as the range followed by the mean in parentheses. Type specimens have been deposited in the South Australian Museum, Adelaide (SAMA).

Thylonema woodalli sp. nov.
(FIGS 1-8)

Holotype: ♂, from the stomach of *Thylogale stigmatica wilcoxi* (M'Coy, 1866), Mount Glorious Queensland, 1994, coll. P. Woodall, SAMA AHC 31299.

Allotype: ♀ SAMA AHC 31300.

Paratypes: 3 ♂♂, 7 ♀♀, SAMA AHC 31301, 31302.

Other material examined: from *Thylogale stigmatica*: Queensland: 4 ♂♂, 2 ♀♀, Green Mountain, Lamington National Park, SAMA AHC 31305; 1 ♂, Palmerston, SAMA AHC 31325; from *Thylogale thetis*: Queensland: 1 ♂, 1 ♀, Lamington National Park, SAMA AHC 31306.

Description

Small, whitish nematodes; body covered with numerous fine annulations; cephalic collar absent; mouth opening slit-like to oval, laterally elongated; two small amphids present on lateral extremities of mouth opening; dorsal and ventral lips each with two bilobed cephalic papillae; papillae not projecting above lips, bilobed medially, rounded laterally; single seta protruding between lobes; buccal capsule wider in dorsal than in lateral view, anterior and posterior extremities of wall poorly sclerotised; central region forming heavily sclerotised annulus; wall of buccal capsule thickened anteriorly on dorsoventral and lateral aspects, terminating anteriorly, posterior to mouth opening in medially-directed expansions; buccal capsule wall tapering posteriorly; oesophagus elongate, corpus cylindrical, widening slightly posteriorly; isthmus short; bulb elongate, clavate, as wide as corpus; nerve ring encircling oesophagus at isthmus; deirids slightly anterior to nerve ring; secretory-excretory pore at oesophago-intestinal junction.

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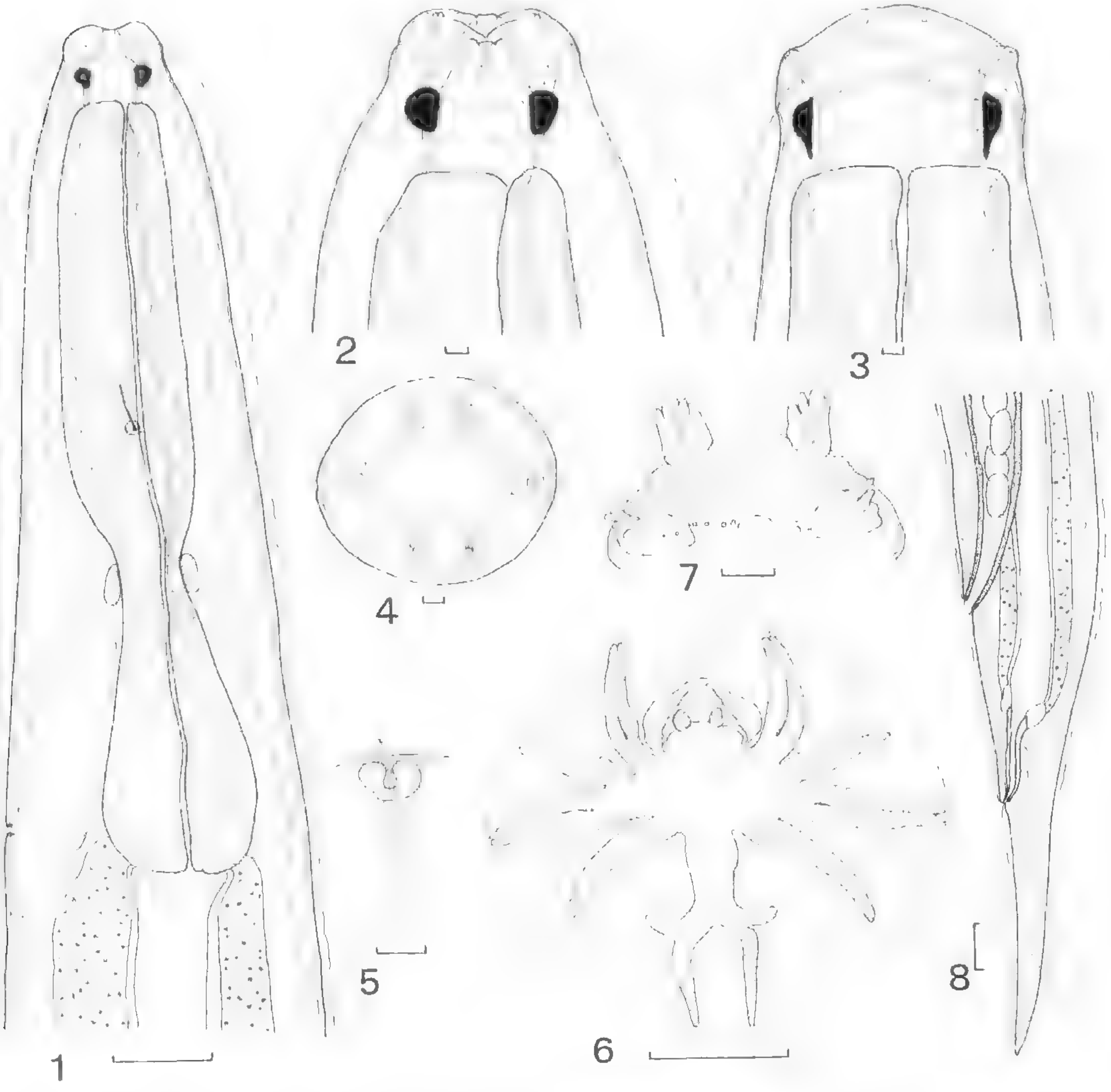
Male (Measurements of 8 specimens) (Figs 1-7)



Figs 1-8. *Thylonema woodalli* sp. nov. from the pademelons, *Thylogale stigmatica* and *T. thetis*. 1. Anterior end, lateral view. 2. Anterior extremity lateral view. 3. Anterior extremity dorsal view. 4. *En face* view of anterior extremity. 5. Submedian cephalic papilla, lateral view. 6. Bursa, apical view. 7. Genital cone, dorsal view. 8. Female tail, lateral view. Scale bars = 0.01 mm, 2-5; 0.1 mm, 1, 6-8.

Length 5.04-7.90 (6.72) mm, maximum width 280-480 (388); buccal capsule 35-45 (40) x 45-110 (84) in lateral view; oesophagus 600-840 (736); nerve ring to anterior end 420-580 (505); secretory-excretory pore to anterior end 690-840 (795); deirids to anterior end 370-410 (390). Bursal lobes not separated; ventral and lateral lobes joined, lateral lobes distinct from slightly longer dorsal lobe; ventral lobes joined ventrally; ventroventral and ventrolateral rays apposed, reaching margin of bursa; externolateral ray divergent from lateral trunk, almost reaching margin of bursa, mediolateral and posterolateral rays apposed, reaching margin of bursa; externodorsal ray arising close to lateral trunk, not reaching margin of bursa; dorsal ray dividing at mid-length into two slender arcuate branchlets, almost reaching margin of bursa; two small, lateral branches arising soon after level of major bifurcation; spicules narrow, elongate, alate, 1.7-2.2 (2.0) mm long; alae with fine transverse striations; anterior extremities of spicules irregularly knobbed; tips pointed; anterior lip of genital cone prominent, conical; posterior lip with two bulbous papillae and array of irregular projections dorsal to them; gubernaculum absent.

Female (Measurements of 10 specimens) (Fig 8)

Length 8.08-9.70 (8.48) mm, maximum width 390-550 (473); buccal capsule 35-50 (45) x 70-105 (80) in lateral view; oesophagus 700-860 (786); nerve ring to anterior end 490-570 (520); secretory-excretory pore to anterior end 770-950 (860); deirids to anterior end 430 (430); tail short, conical, 450-580 (505) long; vulva immediately anterior to anus, 820-1000 (899) from posterior end; ovejector longitudinally disposed; eggs thin-shelled, ellipsoidal, 70-110 (95) x 40-60 (51).

Site of infection

Stomach.

Etymology

Named in honour of Dr P. Woodall, Department of Anatomy, University of Queensland.

Remarks

The species falls within the strongyloid subfamily Cloacininae Stossich, 1899, based on the cylindrical buccal capsule, the longitudinally disposed ovejector, the origin of the externodorsal ray with the lateral rays and the two pairs of branches to the dorsal ray (Lichtenfels 1980). It also has a poorly sclerotised buccal capsule with prominent annulus and lacks a leaf crown placing it within the tribe Coronostrongylinea Beveridge, 1986.

The species is placed within the genus *Thylonema* because of the laterally elongated mouth opening the annular thickenings of the mid-region of the buccal capsule and the characteristic morphology of the cephalic papillae, which are bilobed medially with a seta arising between the lobes of each papilla. Other genera of the Coronostrongylinea (*Coronostrongylus* Johnston & Mawson 1939, *Popovastrongylus*, Mawson 1977 and *Papillostrongylus* Johnston & Mawson, 1939) have conical cephalic papillae with one or two setae arising from the apex and are not bilobed.

The new species is distinguished from congeners by the morphology of the buccal capsule and the shape of its dorsal and ventral thickenings, features that distinguish other congeners (Beveridge 1981). The thickening of the buccal capsule in *Th. woodalli* appears to be a prominent ring of material encircling the mid-region of the buccal annulus as in *Th. thylonema*. *Thylonema arundeli* has a V-shaped buccal capsule in lateral view, which is widest anteriorly and tapers posteriorly, while the buccal annulus of *Th. barkeri* lies at the base of the capsule (Beveridge 1981). Spicules of the new species are 1.70-2.22 mm long compared with 1.22-1.48 mm in *Th. arundeli*, 1.91-2.02 mm in *Th. thylonema*, and 1.48-1.70 mm in *Th. barkeri* (Beveridge 1981). *Thylonema woodalli* is distinguished from *Th. thylonema* by the shape of the buccal capsule, spicule lengths and the lack of prominent lateral lips bearing amphids in the new species.

Beveridge (1981) observed that the genus *Thylonema*, common in *T. stigmatica*, had not been found in *Thylogale thetis*. The present study documents *T. thetis* as a host for *Thylonema woodalli*. However, *Th. woodalli* was found in only one *T. thetis* of ten examined, compared with four of five *T. stigmatica wilcoxi* from the same region. It is possible, therefore, that *Th. woodalli* is an example of host-switching from *T. stigmatica* to *T. thetis* since both species are sympatric at the collection sites. It is interesting that the other three species within the genus have not been reported from *T. thetis* despite high prevalences of infection in sympatric populations of *T. stigmatica wilcoxi* (unpub.).

Thylonema woodalli was prevalent in *T. s. wilcoxi* in southeastern Queensland but was not reported by Beveridge *et al.* (1992) from *T. s. stigmatica* in northern Queensland. The current records include the occurrence of one male in *T. s. stigmatica* from the Atherton region, indicating that it is present in northern Queensland, though at a very low prevalence.

Thylonema clelandae sp. nov.
(FIGS 9-14)

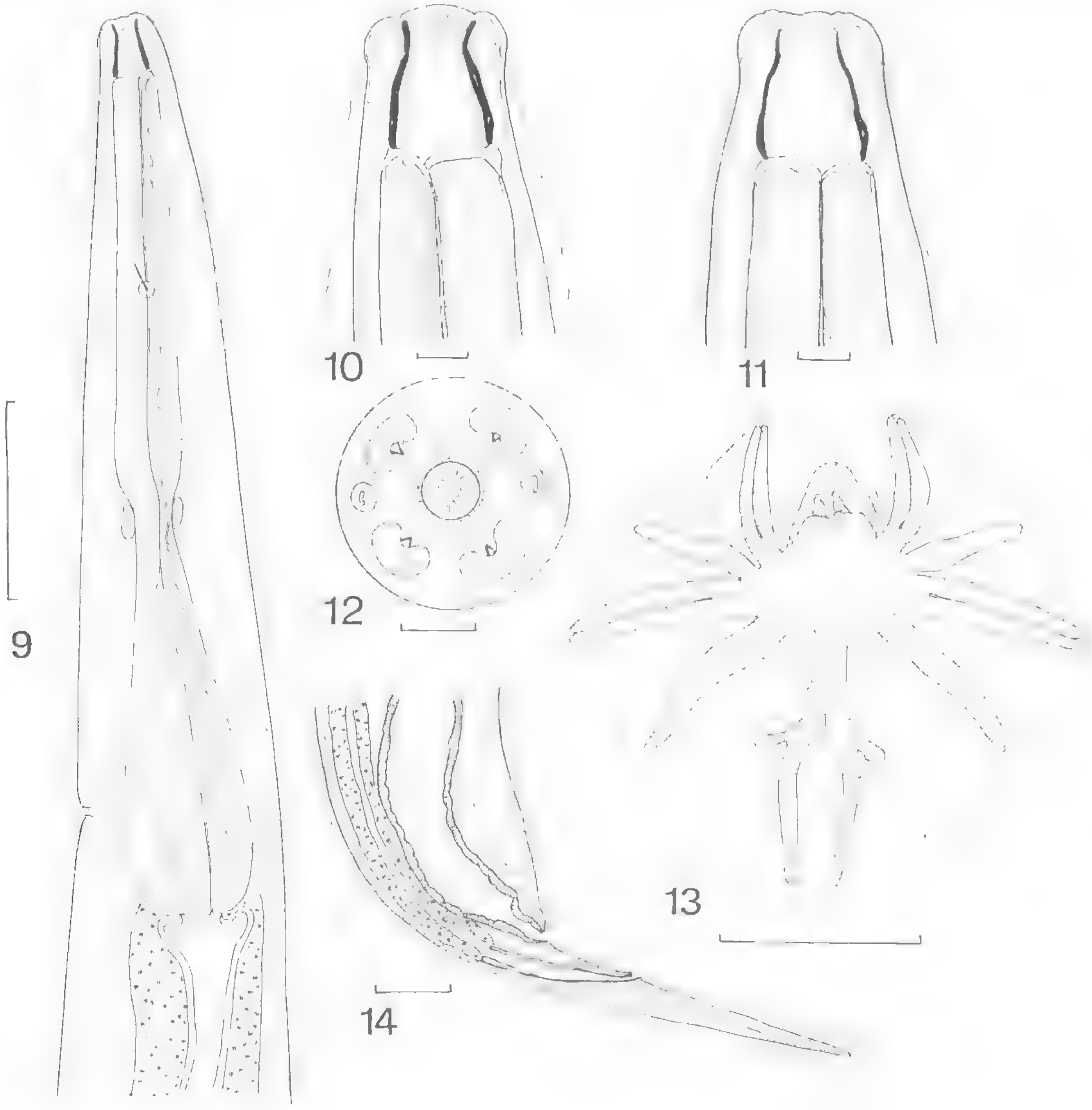
Holotype: ♂, from stomach of *Thylogale stigmatica* *wilcoxi* (M'Coy, 1866), Green Mountain, Lamington National Park Queensland, 1994, coll. P. Woodall, SAMA AHC 31296.

Allotype: ♀, SAMA AHC 31297.

Paratypes: 6 ♂♂, 3 ♀♀ AHC SAMA 31298.

Description

Small, white nematodes; body covered with numerous fine annulations; mouth opening circular in apical view, with numerous lip-like structures projecting internally from anterior extremity of buccal capsule; two small amphids present; submedian cephalic papillae bilobed medially, rounded laterally; single short seta protruding medially between lobes; buccal capsule cylindrical; lumen of buccal capsule narrowing anteriorly; inner margin of buccal capsule sclerotised to level of cephalic collar, continuing to mouth opening;



Figs 9-14. *Thylonema clelandae* sp. nov. from the pademelon, *Thylogale stigmatica*. 9. Anterior end, lateral view. 10 Anterior extremity, lateral view. 11. Anterior extremity, dorsal view. 12. *En face* view of anterior extremity. 13. Bursa, apical view. 14. Female tail, lateral view. Scale bars = 0.1 mm, 9, 13-14; 0.01 mm, 10-12.

oesophagus elongate: corpus cylindrical, widening slightly posteriorly: isthmus short; bulb elongate, clavate, wider than corpus with distinctive oblique thickenings of the lining; nerve ring encircling oesophagus at isthmus; deirids slightly anterior to nerve ring; secretory-excretory pore anterior to oesophago-intestinal junction.

Male (Measurements of 8 specimens) (Figs 9-13)

Length 4.5-4.8 (4.6) mm, maximum width 200-340 (248); buccal capsule 17-20 (20) x 20-35 (28) in lateral view; oesophagus 425-465 (439); nerve ring to anterior end 245-260 (253): secretory-excretory pore to anterior end 370-590 (418): deirids to anterior end 235-285 (269): bursal lobes not well separated; ventral and lateral lobes joined, lateral lobes distinct from slightly longer dorsal lobe; ventral lobes joined ventrally: ventroventral and ventrolateral rays apposed, reaching margin of bursa: externolateral ray divergent from lateral trunk, almost reaching margin of bursa; mediolateral and posterolateral rays apposed, reaching margin of bursa: externodorsal ray arising close to the lateral trunk, not reaching margin of bursa; dorsal ray dividing at mid-length into two slender arcuate branches, almost reaching margin of bursa, two small, lateral branches arising soon after level of major bifurcation; spicules narrow, elongate, alate, 1,530-1,680 (1,576) mm; alae with fine transverse striations: anterior extremities of spicules irregularly knobbed: tips pointed: anterior lip of genital cone prominent, conical; posterior lip with two bulbous papillae; gubernaculum absent.

Female (Measurements of 4 specimens) (Fig. 14)

Length 5.05-5.39 (5.22) mm, maximum width 240-310 (268); buccal capsule 18-20 (19) x 25-28 (26) in lateral view; oesophagus 430-500 (456); nerve ring to anterior end 255-320 (275): secretory-excretory pore to anterior end 405-425 (410); deirids to anterior end 285 (285); tail short, conical, 300-335 (323) long: vulva immediately anterior to anus, 435-450 (444) from posterior end; ovejector longitudinally disposed; eggs thin-shelled, ellipsoidal, 70-90 (81) x 40-48 (43).

Site of infection

Stomach.

Etymology

Named in honour of Mrs B. La Nauze (née Cleland).

Remarks

The new species is allocated to *Thylonema* for the same reasons as those presented above for *Th. woodalli*. *Thylonema clelandae* is distinguished from all congeners by the shape of the buccal capsule, which diminishes in diameter anteriorly and lacks a prominent annulus or thickening. The circular mouth opening in cross section, the lip-like projections of the buccal capsule into the mouth opening and the sclerotised folds within the oesophageal bulb also enable this species to be distinguished from congeners.

The buccal capsule of *Th. clelandae* is most similar to that of *Th. barkeri*. However, *Th. clelandae* lacks the characteristic annulus present at the base of the buccal capsule of *Th. barkeri*. The annulus occurs in the mid region of the buccal capsule of *Th. thylonema*, *Th. arundeli* and *Th. woodalli*. Spicules of the new species are 1.53-1.68 (1.58) mm long compared with 1.70-2.22 mm in *Th. woodalli*, 1.22-1.48 mm in *Th. arundeli*, 1.91-2.02 mm in *Th. thylonema* and 1.48-1.70 mm in *Th. barkeri* (Beveridge 1981).

The mouth opening of *Th. barkeri* is more rounded than in congeners and is sometimes folded to give the appearance of tiny lips or leaf crown elements and therefore it is similar to that of *Th. clelandae*. However, true lip-like appendages are present only in the buccal capsule of *Th. clelandae*.

In *Th. clelandae*, the genital cone is complex, as in other species of *Thylonema*, with a prominent conical anterior lip and bulbous papillae on the posterior lip.

The genus *Thylonema* has until now been characterised both by distinctively shaped submedian papillae and the presence of a sclerotised annulus surrounding the buccal capsule. *Thylonema clelandae* lacks the annulus, though in some specimens the posterior part of the buccal capsule wall is slightly thicker than the anterior part. However, *Th. clelandae* possesses the characteristic cephalic papillae of the genus thereby confirming this character as its key distinguishing feature. The labial crown of numerous fine elements is a novel morphological character for the genus.

Thylostrongylus franklinae sp. nov.
(FIGS 15-23)

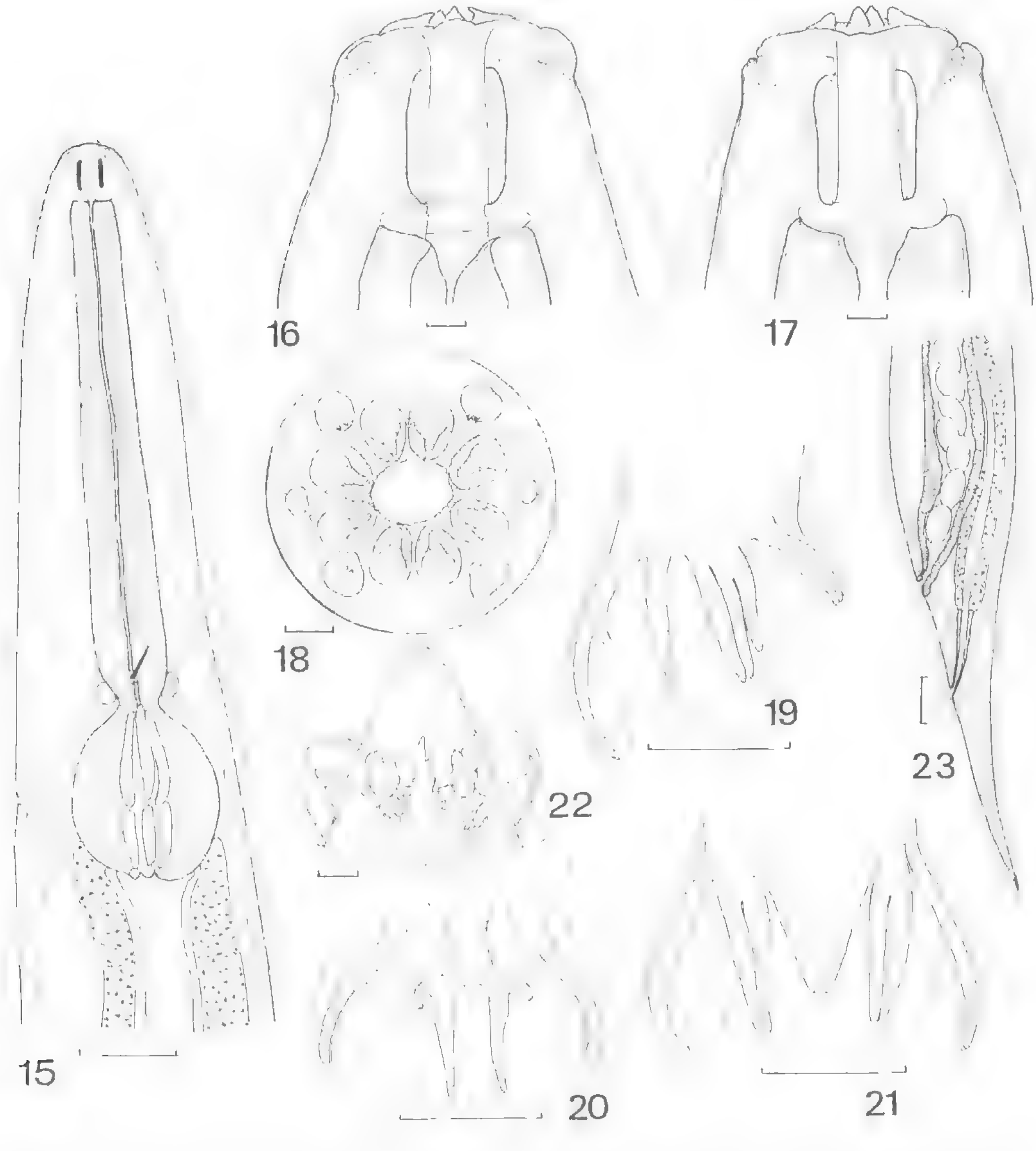
Holotype: ♂ from stomach of *Thylogale stigmatica wilcoxi*, Green Mountain, Lamington National Park Queensland, July 1994, coll. P. Woodall, SAMA AHC 31307.

Allotype: ♀, SAMA AHC 31308.

Paratypes: 2 ♂♂, 8 ♀♀, SAMA, AHC 31309.

Description

Small nematodes without alae or longitudinal body striations; body covered, with numerous, fine transverse annulations; cephalic collar distinct, demarcated on anterior and posterior borders by transverse sutures; collar pierced by two amphids and four larger submedian papillae each bearing two stout setae; external labial crown with eight blunt-tipped sculptured petaloid elements, arising internally to cephalic collar; mouth circular in cross section; buccal capsule cylindrical, subdivided longitudinally, slightly longer than wide, heavily sclerotised with numerous fine transverse striations; small cavity containing granular material surrounding anterior end of buccal capsule; oesophagus short, corpus cylindrical; isthmus short; bulb ovoid; lumen of bulb with elongate sclerotised plates; nerve ring encircling oesophagus at isthmus,



Figs 15-23. *Thylostrongylus franklinae* sp. nov. from the pademelon, *Thylogale stigmatica*. 15. Anterior end, lateral view. 16. Anterior extremity, lateral view. 17. Anterior extremity, ventral view. 18. *En face* view of anterior extremity. 19. Bursa, lateral view. 20. Dorsal and externodorsal rays of bursa, dorsal view. 21. Bursa, ventral view. 22. Genital cone, dorsal view. 23. Female tail, lateral view. Scale bars = 0.1 mm, 15, 19-21, 23; 0.01 mm, 16-18, 22.

secretory-excretory pore at level of nerve ring; deirids just anterior to pharyngo-intestinal junction; anterior projections of intestinal wall absent.

Male (Measurements of 3 specimens) (Figs 15-22)

Length 6.4-6.6 (6.5) mm, maximum width 290-320 (307); buccal capsule 35-40 (37) x 25 (25) in lateral view, oesophagus 640-690 (673); nerve ring to anterior end 510-560 (540); secretory-exretory pore to anterior end 660-680 (667); deirids to anterior end 580-590 (582); bursa short; lobes not separated from one another; no bosses or striations present on bursa; ventroventral and ventrolateral rays slender, apposed, reaching margin of bursa; mediolateral and posterolateral rays long, thin, apposed reaching margin of bursa; externolateral ray divergent, shorter than other lateral rays, joining lateral trunk near origin, not reaching margin of bursa; externodorsal ray arising close to lateral trunk, reaching margin of bursa; dorsal ray stout in origin; dividing at ⅔ length into two long, narrow branches; two short lateral branchlets leaving main branches at one half the total length; genital cone prominent; anterior lip conical, large with two large lateral appendages; 2 trilobed ventral appendages on dorsal aspect of cloaca; pair of large additional lateral appendages present; numerous projections decreasing in length from ventral to dorsal aspect around posterior lip, arranged radially around posterior lip; spicules slender, elongate, alate, 1.82-1.94 (1.88) mm; alae with numerous transverse striations, anterior extremities of spicules irregularly knobbed; distal tips pointed; alae tapering towards spicule tips; gubernaculum absent; cordate thickening present at junction of spicule sheaths; elongate thickenings present in ventral wall of spicule sheath, posterior to cordate thickening.

Female (Measurements of 9 specimens) (Fig. 23)

Length 6.3-7.5 (7.1) mm, maximum width 35-41(37); buccal capsule 25-30 (28.9) x 35-45 (39) in lateral view, oesophagus 680-740 (710); nerve ring to anterior end 540-680 (587); secretory-excretory pore to anterior end 620-740 (677); deirids to anterior end 560-620 (580); tail long, gradually tapering to point, 370-500 (444), vulva immediately anterior to anus, 580-740 (651) from posterior end; vagina long, straight thick walled, 800-1150 (903), leading to longitudinally placed ovejector; eggs ellipsoidal, thin shelled, 70-110 (88) x 40-50 (46).

Site of infection

Stomach.

Etymology

Named in honour of Dr R. Franklin.

Remarks

This species belongs to the strongyloid subfamily Cloacininae Stossich, 1899, because it possesses a cylindrical buccal capsule, and a longitudinally disposed ovejector, the origin of the externodorsal ray is close to the lateral rays and there are two pairs of branches on the dorsal ray (Lichtenfels 1980). The species belongs to the genus *Thylostrongylus* Beveridge, 1982, because it has a distinct cephalic collar pierced by two amphids and four submedian papillae, an external labial crown of eight elements surrounding the mouth opening, a circular mouth opening and buccal capsule in cross section and elongate sclerotised plates lining the ovoid oesophageal bulb (Beveridge 1982).

Thylostrongylus franklinae differs from *Ts. parvus* in the proportions of the buccal capsule, which resemble more closely those of *Ts. tasmaniensis* (see Beveridge 1982). It differs from *Ts. tasmaniensis* in having prominent striations on the buccal capsule, in spicule length, in the origin of the dorsal ray and in overall size (Beveridge 1982). It differs from *Ts. parvus* and *Ts. tasmaniensis* in total length, maximum width, length from the nerve ring to anterior end, length from the secretory-excretory pore to the anterior end, length from the deirids to the anterior end, length of the spicules, length from the vulva to the posterior end, length of the tail and the size of the egg (Beveridge 1982). All measurements in *Th. franklinae* are substantially greater than those of *Ts. parvus* and *Ts. tasmaniensis* (Beveridge 1982). The cephalic papillae have two setae in *Ts. franklinae* as do those of *Ts. parvus*, whereas *Ts. tasmaniensis* has only one seta on each submedian papilla (Beveridge 1982). However, the setae are extremely difficult to see clearly.

Discussion

Species of the macropodid genus *Thylogale* have been reported to harbour a relatively diverse community of strongyloid nematodes (Beveridge *et al.* 1992). The helminth community includes a number of distinctive genera, which are found only within pademelons, for example *Thylonema* Beveridge 1981, *Trigonostonema* Beveridge 1981, *Cassunema* Beveridge & Johnson 1981, *Thylostrongylus* Beveridge 1982, *Ichthostrongylus* Beveridge 1983, or occur primarily within pademelons with one or more exceptions occurring in other macropodid hosts, such as *Monilonema* Beveridge & Johnson 1981, *Thallostonema* Beveridge 1983 and *Wallabinema* Beveridge 1983. The three species described in this paper conform to genera which are found only as parasites of pademelons.

The addition of three new species to the spectrum of helminth parasites described from pademelons supports the hypothesis that the pademelons harbour a distinctive nematode parasite fauna in comparison with other macropodid marsupials (Beveridge *et al.* 1992). The reasons for the relative diversity and distinctive parasitic community found within species of *Thylogale* are not clear.

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A REDESCRIPTION OF THE AUSTRALIAN EOCENE FOSSIL, MONOCOTYLEDON PETERMANNIOPSIS (LILIANAE: AFF. PETERMANNIACEAE)

By John G. Conran & David C. Christophel**

Summary

Conran, J. G. & Christophel, D. C. (1999) A redescription of the Australian Eocene fossil monocotyledon Petermanniopsis (Lilianae: aff. Petermanniaceae). Trans. R. Soc. S. Aust. 123(2), 61-67, 31 May, 1999.

The fossil monocotyledon Petermanniopsis angleseaënsis Conran et al. was known previously only from a single incomplete mummified leaf from the Site II Lens B of the Anglesea Coal Mine fossil deposit, Victoria. The recognition of three additional leaf impressions with cuticles from the Site I Mesophyll and Site II Lens B lenses at Anglesea allows for the amendment of the original description to include the leaf apex and estimates of size and cuticular variability. The leaves are confirmed as acrodromous, with acuminate apices and a short drip tip. The usefulness of the unusual marginal venation in Petermanniopsis as an identifying feature is also discussed. In addition, the stomata are brachyparacytic and amphibrachyparacytic, rather than anomocytic, as reported previously.

Key Words: Petermanniopsis, angleseaënsis, monocotyledon, macrofossil, Eocene, Anglesea, Victoria. Australia.

Transactions of the Royal Society of S. Aust. (1999), **123**(2), 61-67.

A REDESCRIPTION OF THE AUSTRALIAN EOCENE FOSSIL MONOCOTYLEDON *PETERMANNIOPSIS* (LILIANAE: *AFF.* PETERMANNIACEAE)

by JOHN G. CONRAN[*] & DAVID C. CHRISTOPHEL

Summary

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The fossil monocotyledon *Petermanniopsis anglesеaënsis* Conran *et al.* was known previously only from a single incomplete mummified leaf from the Site II Lens B of the Anglesea Coal Mine fossil deposit, Victoria. The recognition of three additional leaf impressions with cuticles from the Site I Mesophyll and Site II Lens B lenses at Anglesea allows for the amendment of the original description to include the leaf apex and estimates of size and cuticular variability. The leaves are confirmed as acrodromous, with acuminate apices and a short drip tip. The usefulness of the unusual marginal venation in *Petermanniopsis* as an identifying feature is also discussed. In addition, the stomata are brachyparacytic and amphibrachyparacytic, rather than anomocytic, as reported previously.

KEY WORDS: *Petermanniopsis anglesеaënsis*, monocotyledon, macrofossil, Eocene, Anglesea, Victoria, Australia.

Introduction

The fossil net-veined monocotyledon *Petermanniopsis anglesеaënsis* Conran *et al.* is known from a partial mummified leaf recovered from Site II Lens B at the Alcoa Anglesea locality in Victoria (38° 25' S, 138° 28' E; Fig. 1) in a Late Middle Eocene fossiliferous clay lens (Conran *et al.* 1994). The geology of this deposit has been described by Christophel *et al.* (1987). Subsequent examination of the collections of fossilised leaf compressions held at the University of Adelaide Botany Department palaeobotany collection (ADU) revealed the presence of an additional three specimens referable to this taxon; two from the Site II Lens B and one from the Site I Mesophyll Lens. All of these specimens showed cuticular preservation, and two were more or less complete leaves. This enables the amendment of the description for *P. anglesеaënsis* to include information about the leaf apex and to verify and/or expand the range of variation seen in the architectural and cuticular features used to define the taxon. As the specimens were from a number of different lenses from the original, it also allows for further comment on the nature of the communities in which *P. anglesеaënsis* occurred.

Materials and Methods

Fossil lamina fragments were removed from the

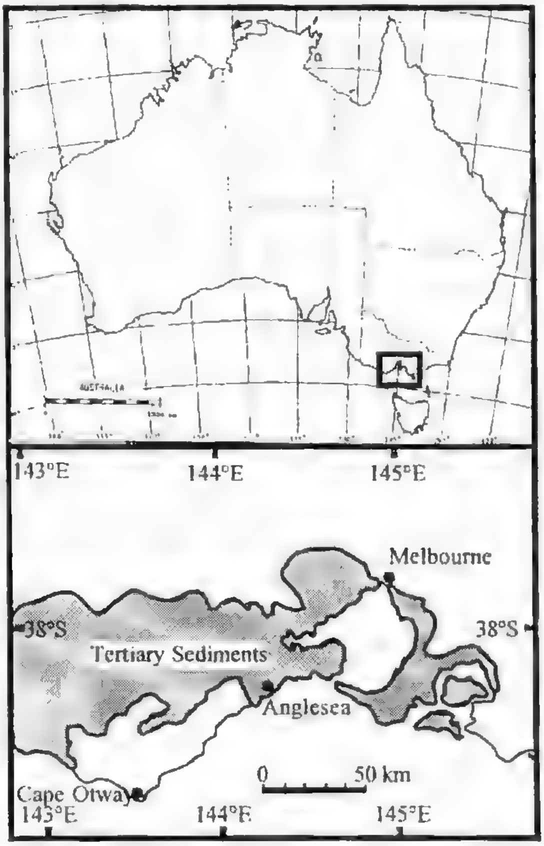

Fig. 1. Map showing the locality of the Angelsea deposit derived from Christophel *et al.* (1987).

Department of Botany, The University of Adelaide Australia 5005.

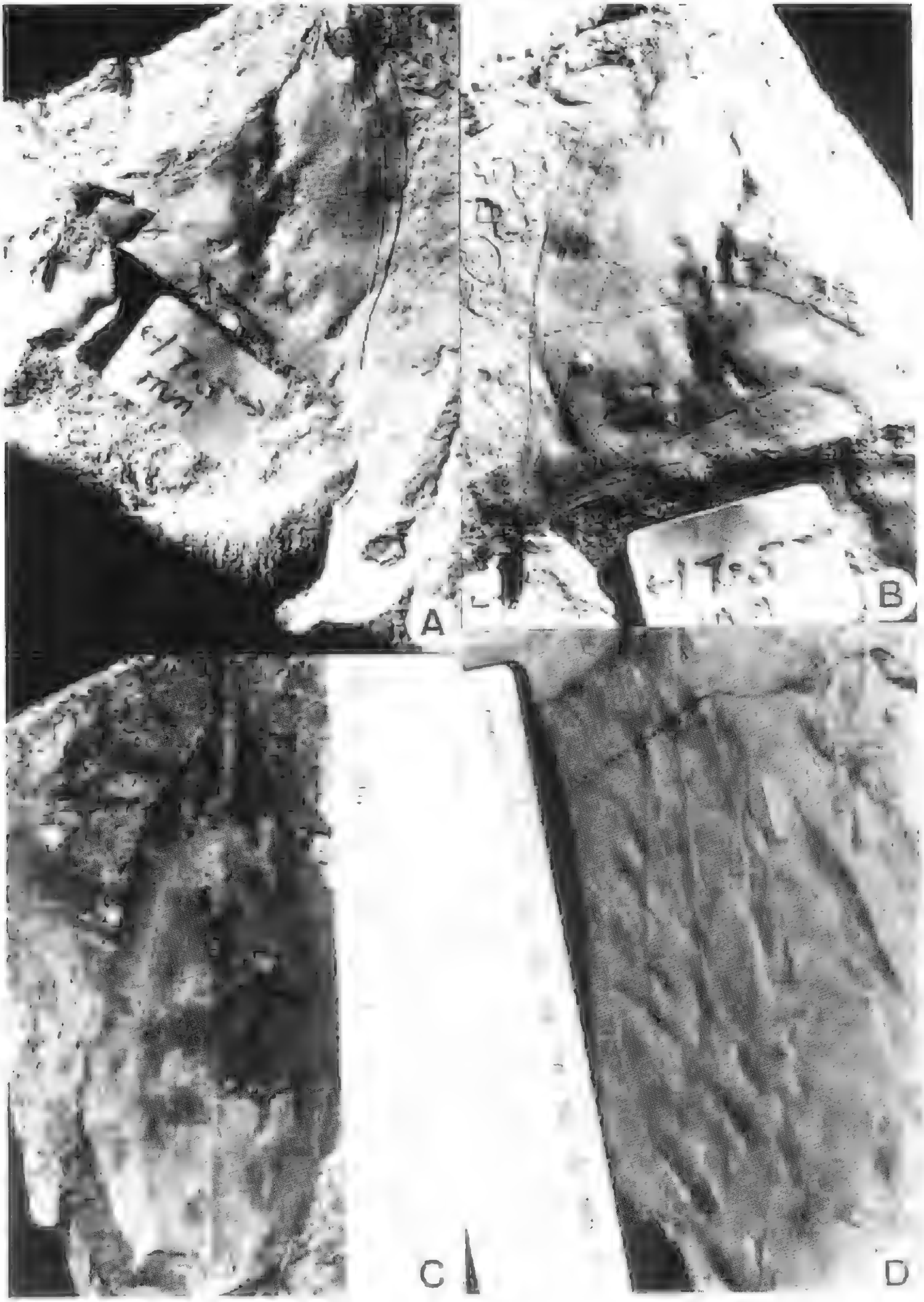

Fig. 2. *Petermanniopsis anglesaensis* specimens. A, Site II Lens B, 4087. B, Site II Lens B, 4088. C, Site I Mesophyll Lens, Mono 1. D, Ebenaceae Lens, 4122. All to indicated scales

compressions, macerated in hot 2% w/v H_2O_2 to remove any mesophyll, and the remaining cuticular material cleaned and prepared by the methods of Christophel & Lys (1986). Leaf compression and cuticle vouchers of the taxa were deposited at ADU. Mounted cuticles were examined and photographed under Nomarski differential interference contrast optics microscopy using a Zeiss photomicroscope. Leaf morphology, venation architecture and epidermal cells and cuticles were described following the criteria outlined by Dilcher (1974), Wilkinson (1979), Conover (1983, 1991), and Baranova (1992). Leaf size class and rainforest classification follows that of Webb (1959).

Systematics

The description format follows that of Conran *et al.* (1994). Specimen numbers refer to the ADU palaeobotanical collection.

Superorder: Order Lilianae: Liliales

Family *incertae sedis aff.* Petermanniaceae Hutch. *et* Smilacaceae Vent.

Genus *Petermanniopsis* Conran *et al*

Type species: *Petermanniopsis angleseaënsis* Conran *et al.*

Petermanniopsis Conran *et al*

Revised description

Leaf simple, entire, symmetrical; shape ovate-elliptical; size notophyll-mesophyll; apex tapering, acuminate-attenuate with short drip-tip, base acute, tapering into a petiole. Venation acrodromous with seven primary veins (midrib plus 3 sets of paired first order laterals), the inner three noticeably stronger, all veins weakening markedly towards leaf apex. Midrib straight. Secondary veins solitary, curved, more or less regularly spaced between primaries, unbranched, emerging basally from primary veins at a low angle (15-20°) above petiole. Intersecondaries few, simple. Tertiary veins random reticulate-branched percurrent with external looping from marginal primaries and secondaries. Sub-marginal fimbrial vein present, with small dicraeoid (Y-shaped) veinlets along its length extending outwards towards margin (Fig. 3). Areoles indistinct with free-

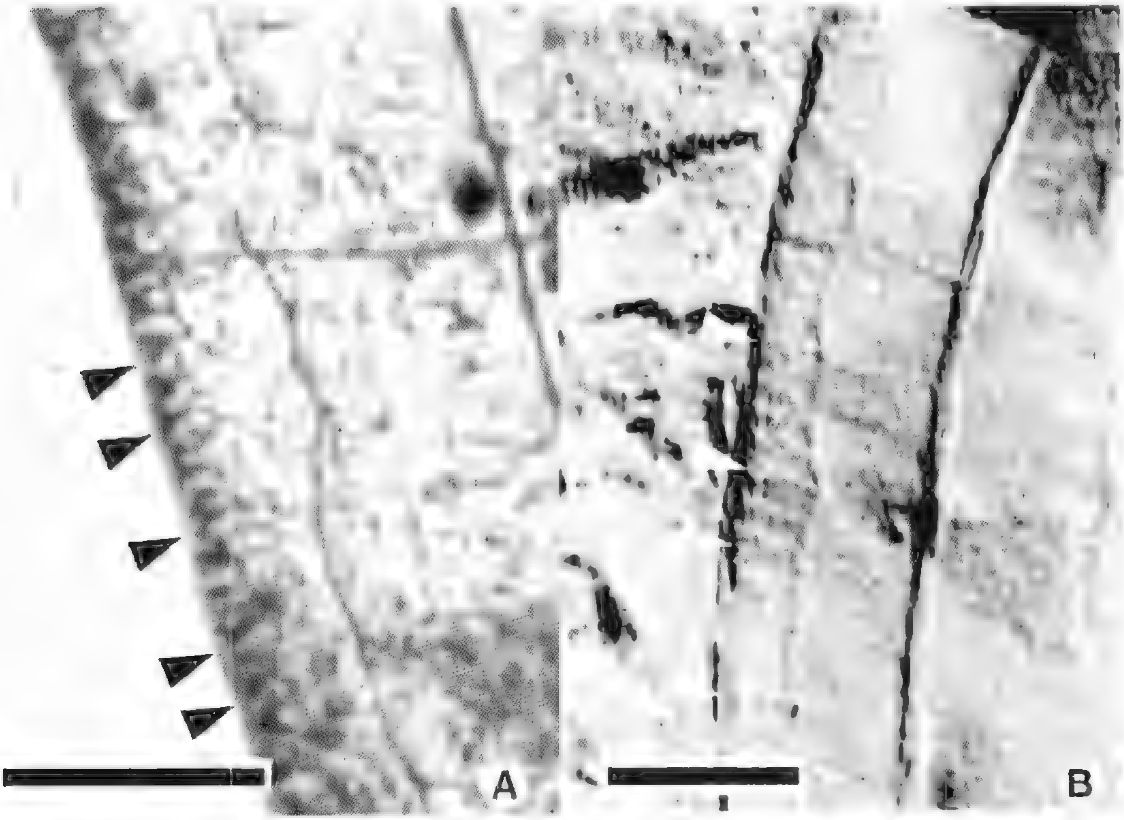

Fig. 3. Venation detail showing dicraeoid marginal branching. A. Site II Lens B 2600 (holotype). B. Site II Lens B 4087 upper. Scale bars = 2 mm.

branched vein endings. Leaves hypostomatic, stomata scattered, level with epidermis, orientation random; stomatal complex brachyparacytic, sometimes amphibrachyparacytic (e.g. Fig. 4F). Abaxial non-stomatal cells with straight to strongly curved anticlinal walls; adaxial cells slightly smaller with straight to moderately curved anticlinal walls; all non-stomatal periclinal walls without ornamentation. Trichomes, trichome bases and hydathodes absent

Petermanniopsis angleseaënsis Conran *et al.*
(FIGS 2-4)

1994. *Petermanniopsis angleseaënsis* Conran *et al.*, *Int. J. Pl. Sci.* **155**, 816-827 (1994).

Material

Holotype: ADU 2600A (Fig. 3A), Site II Lens B, Alcoa open cut coal mine, Anglesea, Vic., *D. C. Christophel s.n.*, Nov. 1987.

Isotypes: (cuticle specimens) ADU 2600B & 2600C (Figs 4A, B), Site II Lens B, Alcoa open cut coal mine, Anglesea, Vic., *D. C. Christophel s.n.*, Nov. 1987.

Other material examined: ADU Mono 1 (Figs 2C, 4E, F), Site I Mesophyll Lens, Alcoa open cut coal mine, Anglesea, Vic., *D. C. Christophel s.n.*, Nov. 1987; ADU 4087 (Figs 2A, 3B, 4C, D), Site II Lens B, Alcoa open cut coal mine, Anglesea, Vic., *D. C. Christophel s.n.*, Nov. 1987; ADU 4088 (Fig. 2B), Site II Lens B, Alcoa open cut coal mine, Anglesea, Vic., *D. C. Christophel s.n.*, Nov. 1987; ADU 4122 (Figs 2D, 4G, H), Ebenaceae Lens, Alcoa open cut coal mine, Anglesea, Vic., *D. C. Christophel s.n.*, Nov. 1987.

Revised description

Leaf ovate-elliptic, at least 12-13.5 cm long and 3.5-5.5 cm wide. Apex acuminate-attenuate with a short drip-tip; apical angle 22-24°. Base acute, basal angle 55-70°, tapering into a petiole. Epidermal cell walls of both surfaces curved to straight, although the abaxial cells are generally larger and more strongly curved. Abaxial epidermal cells (15-40 x 13-25 µm; mean 25 x 21 µm); adaxial cells 13-25 x 13-22 µm (mean 20 x 15 µm). Guard cells 32-38 x 7-10 µm (mean 34 x 9 µm), stomatal apertures 15-18 x 7-10 µm (mean 17 x 8 µm).

Discussion

Given the present state of flux in monocotyledon classification due to realignments stemming from molecular sequencing, the placement of the Petermanniaceae and its alleged allies is questionable beyond its allocation to the Lilianae: Liliales, possibly near the Smilacaceae (Chase *et al.* 1995a,b). The new fossils both support the recognition of *P. angleseaënsis* as a taxon distinct from *Petermannia* and confirm the observation by Conran *et al.* (1994) that the leaves were probably acrodromous. The precise nature of the venation seen in these net-veined monocots is also under review, with Pole (1991, 1993) referring to the acrodromous multiple primary veins described by Conover (1983) as representing, at least in *Ripogonum scandens* J. R. & G. Forst., a true brochidodromous first order venation pattern. Nevertheless, the presence in all of the *Petermanniopsis* fossils of clear acrodromous second order venation supports the acrodromous classification of the primary venation by Conran *et al.* (1994). The marginal venation seen in the fossils is both a general feature and one apparently unique amongst the net-veined monocots. The dicracoid free veinlets extending out from the sub marginal fimbrial vein are also not found in any other members of this group, and could be a useful character for the identification of fragmentary *Petermanniopsis* remains.

There is similar variation in the stomatal classification of these net-veined Lilianae. Although Tomlinson & Ayensu (1969), Dahlgren & Clifford (1982), Dahlgren *et al.* (1985), Conover (1991) and Conran *et al.* (1994) variously describe the cuticles of most net-veined taxa as anomocytic (including *Smilax*, *Petermannia* and *Petermanniopsis*), Gopal & Raza (1992) considered *Smilax* to be predominantly paracytic and "tricytic". Stebbins & Khush (1961) regarded the stomatal complex in the monocots to be a stable, taxonomically useful feature, although Tomlinson (1974) argued that it should only be used in conjunction with other morphological characteristics. Dilcher (1974) observed that the stomatal complex was generally unaffected by the environment, although several different types could sometimes be found on the same leaf. This condition, although rare (Baranova 1992), is known for the net-veined monocot *Dioscorea wattii* Pr. & Burk. which has paracytic, anisocytic and staurocytic stomata in addition to the more common anomocytic pattern (Upadhyay 1987). As it is not possible to study the ontogeny of the stomata in *Petermanniopsis*, cells associated with the stomatal complex can only be classified predominantly into patterns corresponding to Dilcher's (1974) brachyparacytic and amphibrachyparacytic types (Fig. 4F). This is a correction to the previous report by Conran *et al.* (1994) that the stomata were anomocytic. Unfortunately, these features do not in themselves help to relate *Petermanniopsis* more

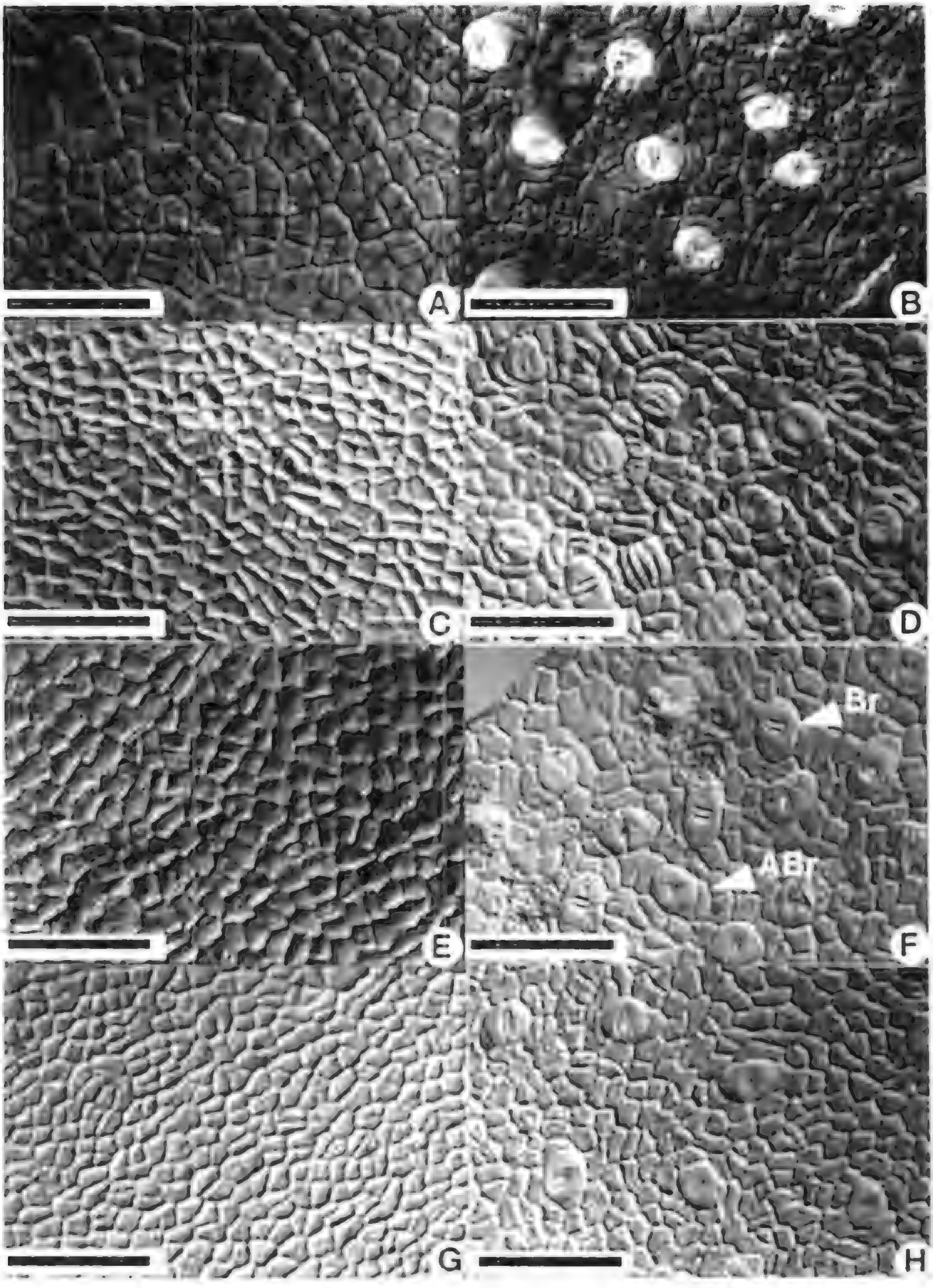

Fig. 4 *Petermanniopsis angleseaënsis* cuticles showing brachyparacytic (Br) and amphibrachyparacytic (ABr) stomata A, Site II Lens B 2600b (isotype) upper. B. lower. C. Site II Lens B, 4087 upper. D. lower. E. Site I Mesophyll Lens, Mono 1 upper. F, lower. G, Ebenaceae Lens, 4122 upper. H, lower. Scale bars = 40 µm.

closely to other members of the net-veined Lilianae, as no other taxa have been recorded with these stomatal types.

The additional specimens from the Ebenaceae and Mesophyll lens *sensu* Christophel *et al.* (1987) are important, as their presence implies a wider habitat range for *Petermanniopsis*. This is based on the low parataxon overlap between the Site I and Site II lenses; the Mesophyll Lens dominated by mesophyll leaf parataxa (as its name suggests); the Ebenaceae Lens by entire-leaved notophyll leaf parataxa (*sensu* Christophel *et al.* 1987). In contrast, the Site II lenses contain abundant Myrtaceae and various other undescribed taxa which were either very rare or absent from the Site I lenses. The differences between the lenses were discussed by Christophel *et al.* (1987) by way of comparison with the extant rainforest community at Noah Creek in far north Queensland (16° 07' S, 145° 26' E), where the patchiness of the forest was reflected in the localised bias of the litter samples. If the habitat preferences for *Petermannia cirrosa* F. Muell. at Warrie National Park, Springbrook Plateau in southeast Queensland (26° 14' S, 153° 17' E) are examined, not only is the vegetation similarly patchy, with *Nothofagus* Microphyll Mossy Forest, Notophyll Vine Forest (NVF) and *Eucalyptus acmenoides* Schau. forest with or without NVF understorey, all within a 1 km radius of each other, but *Petermannia* is a relatively common understorey component in all of these environments (Conran 1988, 1991).

The presence of *Petermanniopsis* in several lenses suggests that it was similarly a relatively common understorey plant in the Anglesea rainforests, and one with a fair tolerance of variation in local conditions. Other present day common understorey net-veined Australian rainforest monocots such as *Smilax*, *Ripogonum* and *Dioscorea* (all of which co-occur with *Petermannia*), have not been recorded amongst the Anglesea megafossil taxa, but, given that *Smilax australis* R. Br., for example, can occur everywhere from dense rainforest to dry open eucalypt forest, the absence of these other net-veined monocots from the Anglesea fossil deposit may reflect taphonomic and preservational biases and cannot be taken as proof that they were absent from the original forests.

Now that several specimens of *P. angleseaënsis* Conran *et al.* are at hand, it may be concluded that the general leaf morphology suggested in the original description was correct and that the stomatal patterns exhibited by the taxon are variable, which is consistent with other net-veined monocot taxa. The presence of this taxon in several discrete clay lenses at the Anglesea locality, whose floristic signatures suggest a mosaic patterned rainforest structure (Christophel *et al.* 1987), also allows us to conclude that the environmental tolerances of the fossil plant were equally broad as *Petermannia* - its nearest surviving relative.

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A COMPARISON OF SOME SOIL MICROINVERTEBRATE ASSEMBLAGES IN SOUTHERN AUSTRALIA

*BY ALAN F. BIRD**

Summary

Bird, A. F. (1999) A comparison of some soil microinvertebrate assemblages in southern Australia. Trans. R. Soc. S. Aust. 123(2), 69-75, 31 May, 1999.

Microinvertebrates from five widely diverse environments have been isolated and living specimens examined. A total of 24,237 organisms was counted. They consisted of annelids, archiannelids, crustaceans, insects, molluscs, nematodes, tardigrades and turbellarians. In all instances nematodes predominated as follows: edge of lake numbers (n) 86%, taxa (t) 79%, ocean beach n 53%, t 76%, river bank n 87%, t 71%, river estuary n 93%, t 84% and wheat field n 91%, t 87%. The mean percentage of nematodes as numbers (n) and taxa (t) in these soils was n=82 and t=79.

Key Words: Microinvertebrates, nematodes, diverse environments, abundance, biodiversity, meiofauna.

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BIRD, A.F. (1999) A comparison of some soil microinvertebrate assemblages in southern Australia. *Trans. R. Soc. S. Aust.* **123**(2), 69-75, 31 May, 1999.

Microinvertebrates from five widely diverse environments have been isolated and living specimens examined. A total of 24,237 organisms was counted. They consisted of annelids, archiannelids, crustaceans, insects, molluscs, nematodes, tardigrades and turbellarians. In all instances nematodes predominated as follows: edge of lake numbers (n) 86%, taxa (t) 79%, ocean beach n 53%, t 76%, river bank n 87%, t 71%, river estuary n 93%, t 84% and wheat field n 91%, t 87%. The mean percentage of nematodes as numbers (n) and taxa (t) in these soils was n=82 and t=79.

The numbers of nematodes per litre of soil at each site ranged from 80-17,300 and the numbers of taxa from 11-21, although some were classified only to class or phylum. These results clearly indicate the abundance, richness and dominance of nematodes compared with other soil microinvertebrates in these widely diverse habitats. Reasons for the relatively low overall counts are discussed.

KEY WORDS: Microinvertebrates, nematodes, diverse environments, abundance, biodiversity, meiofauna.

Introduction

Earlier research into the microinvertebrates of South Australian soils has indicated that nematodes predominate in all soil environments studied (Nicholas *et al.* 1992; Yeates & Bird 1994). However, no quantitative comparisons with other micrometazoans over a range of habitats have previously been made. Where quantitative comparisons between groups of animals have been made, such as on the macroinvertebrates at Goyder Lagoon (Sheldon & Puckridge 1998), it is possible to establish the degree of dominance. In this study, insects dominated making up 63% of individuals and 76% of taxa. These organisms were collected at the soil surface by sweeping with a fine mesh net. However, separation of microinvertebrates from the soil is more complex and typically involves either sieving through a range of sieves or utilizing movement in response to gravity in a misting apparatus (Yeates & Bird 1994).

Within the soil, microscopic nematodes are known to be as biodiverse as the macroinvertebrates above it (Lawton *et al.* 1998) and are considered to be the most abundant metazoans (Bernard 1992).

The principle objective of the work reported here was to quantify the abundance and diversity of the main taxonomic groups of soil-inhabiting microinvertebrates in a range of environments.

Materials and Methods

Soil samples were collected from five different environments. All of these soils are classified under the US soil classification (Soil Survey Staff 1998) as Entisols or young sandy soils. One of these was terrestrial (a wheat field) and is subclassified as an orthent with the texture of a dry sandy loam. The remaining four were semi-aquatic from the shore of a lake, the edge of a river, the shore of an estuary and an ocean beach. All of these were wet sands and were classified as aquents

Terrestrial environment (1)

(1) Samples were collected on 20 April 1998 from sandy loam soil at a site (34° 14' S, 138° 19' E) near Avon, SA. This site had been direct drilled and had a wheat/wheat rotation. The soil was moist after rain which had fallen the previous week and which had broken the summer drought. Soil was sampled to a depth of 11.5 cm using a 4.7 cm diameter corer thus giving a sample volume of approximately 200 ml. Ten samples were collected at regular intervals giving a final soil volume of 2 l which was mixed in a plastic bag and stored in a polystyrene box for transport back to the laboratory.

Within several hours of its collection the soil sample was sieved through a 2 mm sieve, weighed into 50 g aliquots and placed in a misting machine for four days as described previously (Yeates & Bird 1994). The misting process both aerates the soil and stimulates movement of the micrometazoa which

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TABLE 1. *List of sites, their localities and environmental characteristics.*

No. (see Fig. 1)	Sites: Name	Sites: GPS Reading	Soil classification (US)	% Clay	% Silt	% Sand: Fine	% Sand: Coarse	Texture	Salinity: Total Soluble Salts mg l^{-1}
1	Wheat field (Avon)	lat 34° 14' S long 138° 19' E	Entisol - orthent	12	2	7	79	Sandy loam	[#] nd
2	Lake Alexandrina	lat 35° 23' S long 139° 03' E	Entisol - aquent	<1	<1	<1	99	Sandy	300
3	Glenelg River (Dartmoor)	lat 37° 55' S long 141° 17' E	Entisol - aquent	nd	nd	nd	nd	Sandy	1800
4	River Murray estuary (Goolwa)	lat 35° 32' S long 138° 50' E	Entisol - aquent	<1	<1	32	67	Sandy	23 500
5	Ocean beach (Guichen Bay)	lat 37° 10' S long 139° 45' E	Entisol - aquent	0	0	1	99	Sandy	34 200

[#] nd = not determined

gravitate through the soil and into the collecting tubes. At the completion of the extraction and after sedimentation and supernatant removal, the living micrometazoa were counted following the method of Bird (1996) and classified into major groups.

Aquatic environments (2-5)

The remaining four environments were considered to be aquatic since all the soils were water-logged and merging with the water's edge. They were all sandy soils and the micrometazoa were extracted by sieving. In sequence of increasing salinity the soils were:

(2) Lake Alexandrina at the mouth of the Bremer River (35° 23' S, 139° 03' E). Collected 26 August 1998. The lake was choppy and almost covered the sandy beach where the collection was made. The Bremer River had partly flooded the area of rushes and reeds adjacent to the lake.

(3) Glenelg River at Dartmoor (Vic.) near Fort O'Hare and just before the junction with the Crawford River (37° 55' S, 141° 17' E). Collected 29 July 1998 after heavy rain.

(4) River Murray estuary between the sea and the seaward side of the Goolwa barrage (35° 32' S, 138° 50' E). Collected 2 June 1998.

(5) Ocean beach at Guichen Bay at Robe (37° 10' S, 139° 45' E). Collected 16 September 1998 in the intertidal zone with the tide receding. The ocean was calm.

In each case five samples were collected using the 4.7 cm corer giving a total volume of approximately 1 l. The soil was mixed in a bucket with water from the environment being studied. The water was free of microinvertebrates as determined initially by eye and later by microscopic examination. The soil was sieved through 2 mm, 800 µm and 750 µm sieves and then material was collected on 500 µm, 300 µm, 125 µm, 75 µm and 53 µm sieves. The material was washed from these sieves into a beaker and decanted into 200 ml tissue culture flasks. The contents of the flasks were tipped into counting chambers and allowed to gravitate. The living micrometazoa were then examined and counted under a dissecting microscope and classified into major groups using bright field and differential interference contrast optics.

Soil sections

Soil samples were taken by the method described by Brewer & Sleeman (1988) and were transported to the laboratory in an ice box. They were freeze dried in the laboratory and impregnated with araldite *in vacuo* (Cent & Brewer 1971). After polymerization, thin sections, ranging in thickness from 20-40 µm, were cut using a diamond tipped saw blade and were then ground on a rotary diamond lap.

These sections were examined and photographed under polarized light with an Olympus Vanox photomicroscope using Ilford Delta 400 film.

Results

The environments

The environmental characteristics and locations for the five sites are given (Table 1, Fig. 1). The sites are widely separated, ranging from a wheat field with a sandy loam textured soil to wet sandy soils from fresh water habitats situated on the banks of Lake Alexandrina and the Glenelg River, respectively, to saline habitats at a river estuary and a sandy beach. The salinities of these environments range from 300 mg l^{-1} for the shore of Lake Alexandrina to 34,200 mg l^{-1} for the ocean beach at Guichen Bay.

Microinvertebrate assemblages

A total of 24,237 individuals from approximately 93 taxa was counted from the five samples. Some

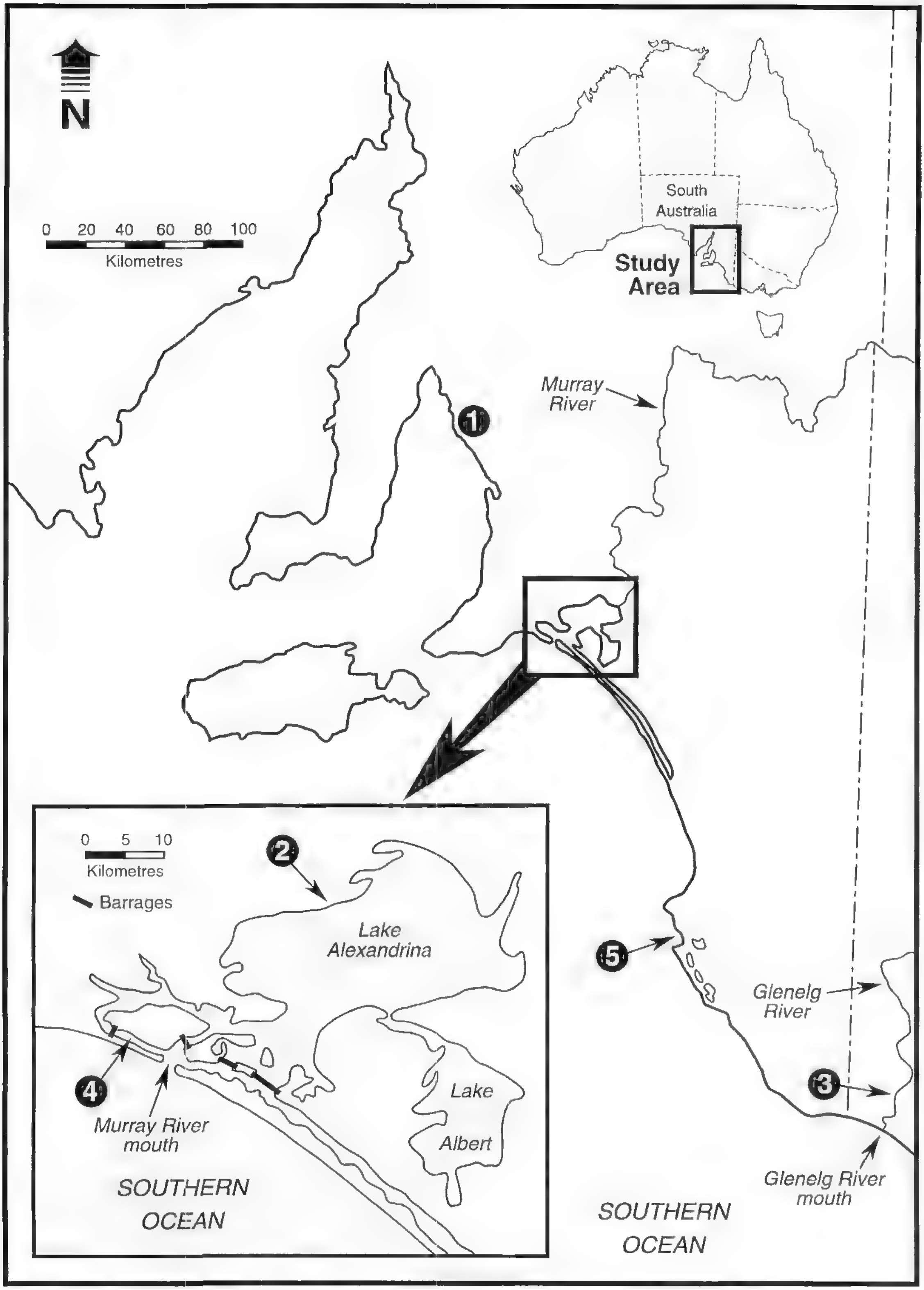
N
0 20 40 60 80 100
Kilometres
South Australia
Study Area
Murray River
1
2
3
4
5
0 5 10
Kilometres
Barrages
Lake Alexandrina
Lake Albert
Murray River mouth
SOUTHERN OCEAN
Glenelg River
Glenelg River mouth
SOUTHERN OCEAN

Fig. 1. Maps showing collecting sites.

TABLE 2. *Microinvertebrate numbers (n) and major taxonomic groups (t) extracted from soil sample cores taken to a depth of 11.5 cm in five widely dispersed geographic localities in southern Australia.*

Zoological groups	Localities (1) Wheat field (Avon)	 (2) Lake Alexandrina	 (3) Glenelg River (Dartmoor)	 (4) River Murray estuary (Goolwa)	 (5) Ocean beach (Guichen Bay)
Nematodes					
n (nos l^{-1} soil)	1400	690	17300	1800	80
as % fauna	91	86	87	93	53
t (taxonomic groups)	13	11	17	21	13
as % taxa	87	79	71	84	76
Archiannelids					
n (nos l^{-1} soil)	-	-			33
as % fauna	-	-	-		22
t (taxonomic groups)	-	-	-	-	1
as % taxa	-	-			6
Other Annelids					
n (nos l^{-1} soil)	12	50	1900	48	12
as % fauna	0.6	6	10	2.5	8
t (taxonomic groups)	1	1	3	1	1
as % taxa	6.5	7	13	4	6
Turbellarians					
n (nos l^{-1} soil)	-		170	66	
as % fauna	-		1	3	
t (taxonomic groups)	-		1	1	
as % taxa	-	-	4	4	
Tardigrades					
n (nos l^{-1} soil)	130	30	40		
as % fauna	8.3	4	0.2	-	
t (taxonomic groups)	1	1	1	-	
as % taxa	6.5	7	4		
Insects					
n (nos l^{-1} soil)	-	30	390		
as % fauna	-	4	2	-	
t (taxonomic groups)	-	1	2		
as % taxa	-	7	8		
Crustaceans					
n (nos l^{-1} soil)	-	-	-	29	25
as % fauna	-	-		1.5	16
t (taxonomic groups)	-			2	1
as % taxa	-	-		8	6
Molluscs					
n (nos l^{-1} soil)	-		-		2
as % fauna	-	-	-		1
t (taxonomic groups)	-	-	-		1
as % taxa	-	-		-	6

specimens were identified to species and some of these occurred in more than one of the five environments. Other specimens could only be placed in families or orders. Nematodes were the dominant group comprising 82% of individuals and 79% of taxa (Table 2). The numbers of nematodes per litre of soil at each site ranged from 80 at the ocean beach site to 17,300 at the Glenelg River bank and the number of taxa from 11 on the bank of Lake Alexandrina to 21 for the River Murray estuary. It must be emphasized that figures for these taxa are only approximate due to a combination of limited taxonomic knowledge, rapidity of assessment and some replication of taxa. These limitations are discussed below.

In the wheat field 91% of the numbers of animals counted were nematodes and they comprised 87% of the taxa. Tardigrades made up most of the remainder representing just over 8% of the animals. They consisted entirely of *Macrobiotus* cf. *pseudohufelandi* Iharos 1966 (Bird 1996; Bird & McClure 1997). Tardigrades were also found to a lesser extent in the wet sandy soils of the Glenelg River and Lake Alexandrina shores and belonged to a different family. Nematodes comprised 87% and 86% of the numbers and 71% and 79% of the taxa, respectively, in these environments (Table 2). Annelids made up 10% of the numbers of the microinvertebrates of the Glenelg River bank, the remaining organisms comprising insect dipteran larvae (2%) and an unidentified species of turbellarian (1%). A thrip insect, identified as *Frankliniella schultzei* (Trybom) (A. Wells pers. comm. 1998) made up 4% of the Lake Alexandrina assemblage together with a species of annelid (6%) and a species of tardigrade (4%). In addition, a large number of copepod and cladoceran Crustacea was found swimming in the water above the soil but these were not considered to be part of the soil environment.

In the more saline wet soils of the River Murray estuary below the Goolwa barrages and at Guichen Bay, nematodes constituted 93% of the numbers and 84% of the taxa for the former and 53% of the numbers and 76% of the taxa in the latter. Both of these environments contained small annelids and those from the river estuary were identified as genera belonging to the family Naididae (K. Lee pers. comm. 1998). These were the only environments with Crustacea in the soil samples rather than in the water. The ocean beach sample was the only one to contain molluscs (1% of the numbers and 6% of the taxa) and an archiannelid (22% of the numbers and 6% of the taxa). The archiannelids resemble the genus *Polygordius* and lack setae or parapodia. Because of their enigmatic appearance, they are listed separately here from the other annelids (Table 2).

Soil sections

It is difficult to recognize and classify organisms in soil sections although soil sections do give some idea of the environment in which these micro-invertebrates have to move and feed. Thus, a 20 µm vertical section through the saline wet sandy soil (aquent) of the Murray River estuary and photographed under bright field optics (Fig. 2) shows part of a nematode that is 40 µm wide and is surrounded by sand grains ranging from about 50 µm to 300 µm in diameter and which exhibit birefringence under polarized light, interspersed with some darker coloured organic material. This soil contains about 180 nematodes 100 ml^{-1} (Table 2) so that the chance of obtaining easily identifiable microinvertebrates from tangential soil sections is remote.

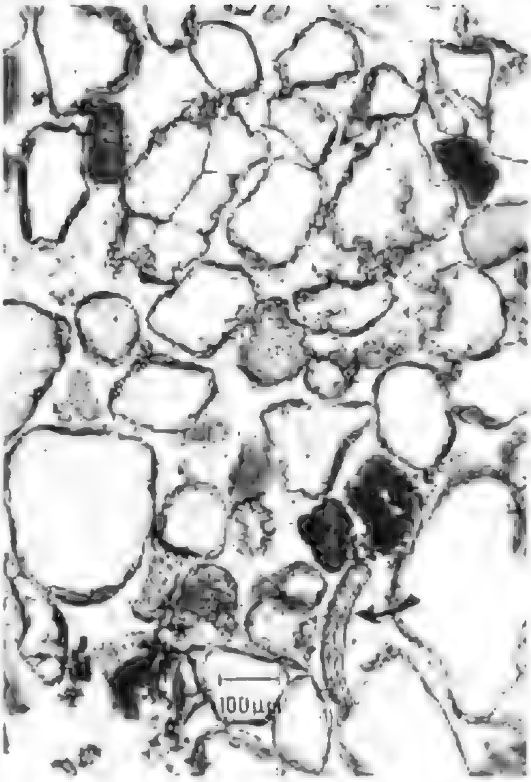

Fig. 2. A 20 µm thick vertical section cut through the top 0.5-2.5 cm of soil at the River Murray estuary, collected at site 4, see Fig. 1. Photographed under bright field optics and showing part of a nematode (arrow).

Discussion

It is clear from these results that nematodes predominate both in numbers and diversity among the micrometazoa in a wide range of soil environments. Just as insects can predominate among the macroinvertebrates at the soil surface (Sheldon & Puckridge 1998) nematodes predominate among the microinvertebrates within the soil. Their numbers vary depending on the time of the year that they are collected and the weather conditions on the day of collection. Thus, in the wheat field soil at Avon, there are many more nematodes present when the wheat and weeds are growing during winter (Yeates & Bird 1994), as indicated by the presence of plant parasitic forms, than at the end of summer when there is only dry stubble on the ground and few, if any, plant parasitic forms. Similarly, it has been shown (Nicholas *et al.* 1992) that nematode numbers on the shore of Lake Alexandrina vary markedly from month to month throughout the year. When the lake is rough or during the hottest months of January, February and March, there is considerable mortality of nematodes and other microinvertebrates as judged by the presence of dead specimens during counting (pers obs). Also, there was an increase in nematode mortality when the salinity in the River Murray estuary dropped following the opening of the barrage gates and the discharge of River Murray water (Nicholas *et al.* 1992).

It seems that climatic and seasonal variations as well as human interference can cause measurable changes in nematode population numbers. However, these changes seem to influence all the micrometazoa since the percentage of nematodes in these populations remains constant. Thus the percentage of nematodes present in the micrometazoan population of a Lake Alexandrina sample collected on 3.ii.1998 was 87 compared with 86 for a sample collected six months later on 26.viii.1998, although there was a three-fold difference in nematode numbers (pers. obs.).

The proportion of nematodes to other micro-invertebrates in the five different environments examined was uniformly high, ranging from 53-93% with a mean of 82%. Furthermore, nematodes were the only microinvertebrate group, apart from annelids, to occur in all the environments studied and had much greater diversity than any other group (Table 2). Because of their relatively low numbers in the environments studied, other micrometazoa may have been present but not detected. For example, tardigrades were present in one collection (26.viii.1998) from the shores of Lake Alexandrina but not in another (2.ii.1996). Similarly, some forms may occur in large numbers in the water over the soil but not in the soil as was the case with Crustacea (copepods and cladocerans) on one occasion (26.viii.1998) at the Lake Alexandrina site.

The archiannelids recovered from the ocean beach at Robe were small (0.35-1.95 mm long), were covered with cilia and had a pair of anterior lateral tentacles (or cirri). They appeared to exude a sticky mucus. Differences in size might have been due to damage caused by sieving since the anterior parts of all specimens examined seemed to have similar dimensions e.g. the tentacles in all samples measured were about 150 µm long and 10 µm wide. Thus the shorter specimens might have been broken during collection.

Nematodes have been recognized as the most abundant metazoans in the soil (Bernard 1992) but, although there is general agreement on this point, quantitative comparisons with other groups of micrometazoa in various different environments are rare. Raffaelli (1982) compared the numbers of six microinvertebrate groups namely nematodes, copepods, turbellarians, archiannelids, enchytraeids and gastrotrichs from 17 sandy marine beaches around Great Britain. Calculations from his Table 2 show that nematodes averaged 75% of organisms in all these sites. Similarly, McLachlan's (1985) work on the fauna of sandy beaches in Western Australia showed that nematodes are the most abundant of the meiofauna. Calculation of the means from the eight sites given in his Table 4 show that nematodes made up 56% of the microinvertebrates, crustaceans 24%, annelids 10%, turbellarians 7% and other groups 3%. It is interesting to note that although nematodes and crustaceans (harpacticoids) were present in all the beach sites examined by McLachlan (1985), annelids (oligochaetes) were absent from four of the eight sites and turbellarians from two of them. However, if comparisons between different investigations are to be made, accurate and uniform sampling methods need to be adopted. As Lawton *et al.* (1998) point out, in their work on biodiversity in a tropical forest, a vast amount of effort is required in compiling an inventory of the organisms present and this applies particularly to microscopic organisms.

It is agreed by some (Ladd *et al.* 1981) that the biomass of an organism in the soil is more important than its numbers, particularly when determining the labile nitrogen and carbon content of the soil. A factor that is sometimes not taken into account, although it is particularly important, is the reproductive capability of the organism in question. Because some soil nematodes can complete their life cycles in three days and each female can lay several hundred eggs within a couple of weeks, the number can grow to millions (Bird & Bird 1991) with a greater biomass than much larger and more slowly reproducing forms. In nature these huge increases in number are kept in check by a range of factors such as competition, predation and limited food resources. Thus, huge numbers of nematodes are rarely, if ever, found in nature, with the above-mentioned factors being responsible, at least in part, for the variations in actual numbers that can occur at different times at the one site. For example, Nicholas & Hodda (in press) found that the numbers of nematodes at a given sandy beach site can vary considerably, being lowest in winter and highest during the summer. However, the proportions of nematodes to the other microinvertebrate phyla in the soil appear to remain remarkably constant.

It seems reasonable to ask ourselves what factors the Insecta and Nematoda share that give them the competitive edge in attaining dominance in their respective environments. A major factor may be their ability to moult which provides a mechanism for their transition into or out of a resistant abiotic stage in which their metabolism almost comes to a standstill.

Four of the six major groups mentioned above, namely, the Insecta, Crustacea, Tardigrada and Nematoda are thought to be phylogenetically related and, together with some less abundant groups, the onycophorans, nematomorphans, kinorhynchs and priapulids, have been grouped into a clade called Ecdyozoa which emphasizes their common ability to undergo ecdysis or moult (Aguinaldo *et al.* 1997). The concept that moulting arose only once is put forward for further testing (Aguinaldo *et al.* 1997). It remains to be seen whether or not this monophyly of moulting animals is confirmed by later investigators.

In conclusion, this paper is an attempt to draw attention to the numbers of free living nematodes in a range of soil environments. The numbers counted are lower than those that actually occur because of the limitations of the techniques employed in their isolation and detection, particularly as only living and moving material was considered. Furthermore, the number of taxa counted was limited by the author's knowledge of nematode taxonomy. However, all material was fixed and preserved for subsequent identification.

These preliminary studies emphasize the need to examine the microinvertebrates of the soil in more detail and to understand further the ecology of the nematodes that dominate in these environments. This is a largely unexplored area of research that has been overlooked by those involved in research on soil microbiology.

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SEASONAL VARIATION IN SALINITY IN THE WATERVALLEY WETLANDS IN THE SOUTH EAST OF SOUTH AUSTRALIA

BRIEF COMMUNICATION

Summary

The Watervalley Wetlands in the south east of South Australia are a group of shallow seasonal, ephemeral and permanent lakes and swamps which have been restored or rehabilitated between 1984 and 1995 (Fig. 1). They comprise a series of 15 wetland complexes totalling some 12,000 ha and are managed primarily for the conservation of waterbirds by a private conservation organisation, Wetlands and Wildlife, or by T. K. and P. A. Brinkworth.

Transactions of the Royal Society of S. Aust. (1999), **123**(2), 77-80.

BRIEF COMMUNICATION

SEASONAL VARIATION IN SALINITY IN THE WATERVALLEY WETLANDS IN THE SOUTH EAST OF SOUTH AUSTRALIA

The Watervalley Wetlands in the south east of South Australia are a group of shallow seasonal, ephemeral and permanent lakes and swamps which have been restored or rehabilitated between 1984 and 1995 (Fig. 1). They comprise a series of 15 wetland complexes totalling some 12,000 ha and are managed primarily for the conservation

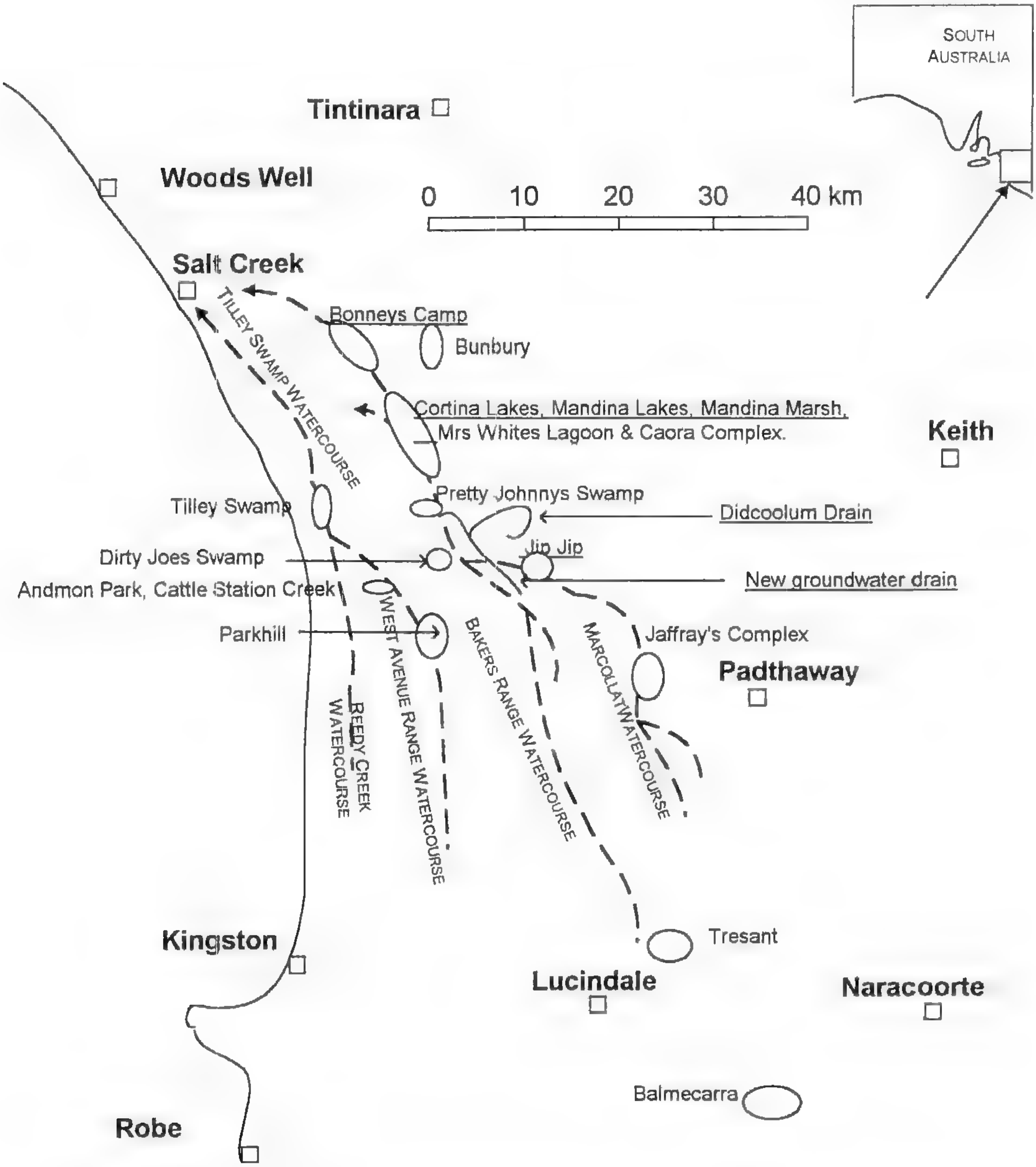
SOUTH AUSTRALIA
Tintinara
Woods Well
0
10
20
30
40 km
Salt Creek
TILLEY SWAMP WATERCOURSE
Bonneys Camp
Bunbury
Cortina Lakes, Mandina Lakes, Mandina Marsh,
Mrs Whites Lagoon & Caora Complex.
Keith
Pretty Johnnys Swamp
Didcoolum Drain
Tilley Swamp
Jip Jip
Dirty Joes Swamp
New groundwater drain
Andmon Park, Cattle Station Creek
Jaffray's Complex
Parkhill
WEST AVENUE RANGE WATERCOURSE
BAKERS RANGE WATERCOURSE
MARCOLLATWATERCOURSE
Padthaway
REEDY CREEK WATERCOURSE
Tresant
Kingston
Lucindale
Naracoorte
Balmecarra
Robe

Fig. 1. The Watervalley Wetlands. Note: Sites mentioned in the text are underlined. Wetlands are not drawn to scale.

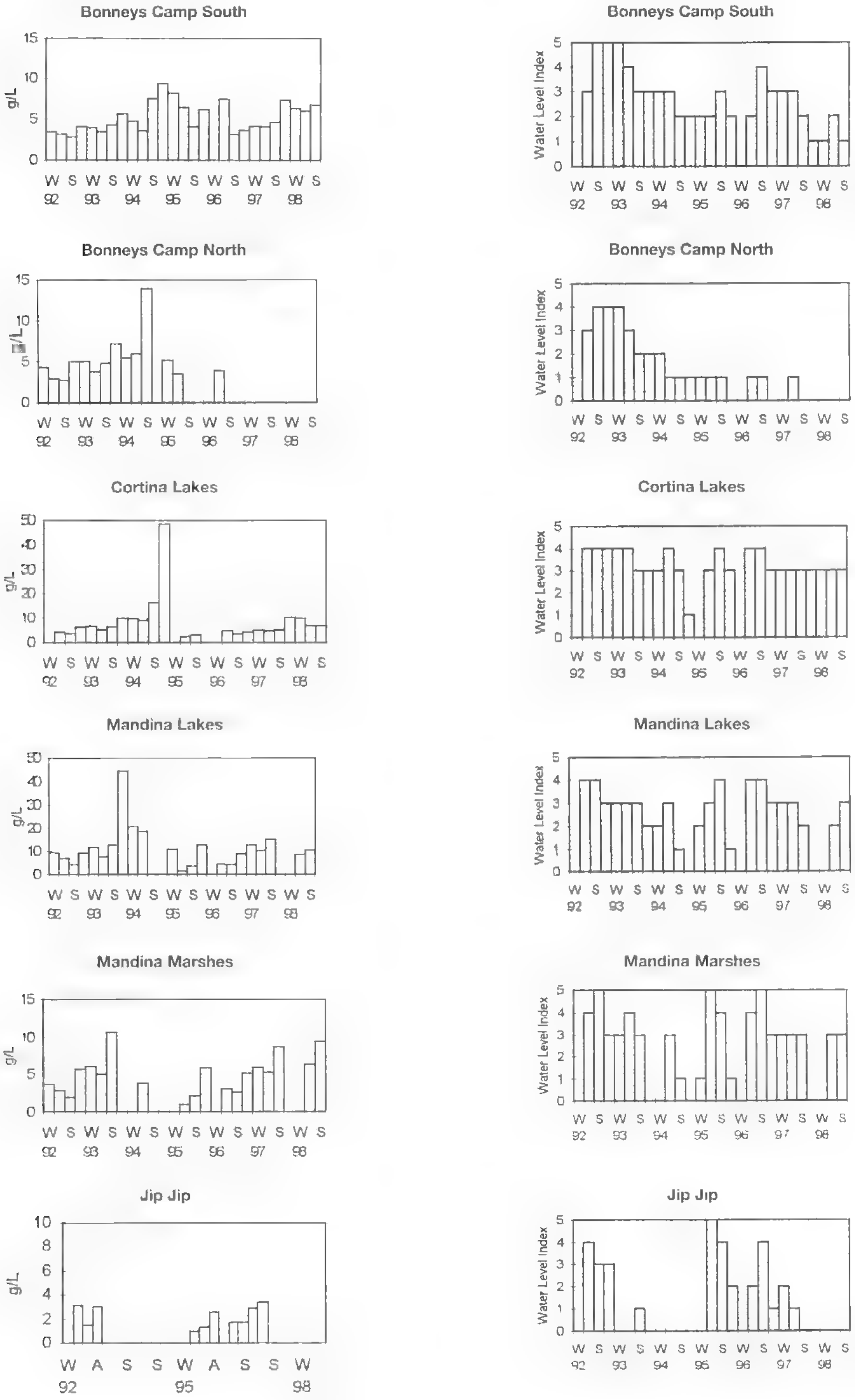

Fig. 2. Seasonal fluctuations of salinity and the concurrent Water Level Index in six of the Watervalley Wetlands. W = winter; S = summer. Note different scales for salinity of Cortina Lakes and Mandina Lakes. Except for winter 1996, no reading indicates that the sampling site was dry.

of waterbirds by a private conservation organisation, Wetlands and Wildlife, or by T. K. and P. A. Brinkworth. The majority of these wetlands fulfil the criteria for listing as Wetlands of International Importance under the Ramsar Convention and are a key component of the projected Wetlands Waterlink which will form a network of conserved wetlands from Bool Lagoon to the Coorong. The major land use in the region is grazing by sheep and cattle. Much of the grazing land became available for agriculture only through the drainage of the original wetlands (92 % of which have been destroyed) and now much of that land is threatened by soil salination. The waters of the remaining wetlands vary from fresh to saline but all wetlands that have been studied are subject to seasonal fluctuations in salinity.

White & Brake described the ecological attributes, history and water chemistry of six of the Watervalley Wetlands. All six wetlands described (Jip Jip, Mandina Marshes, Mandina Lakes, Cortina Lakes and the south and north lagoons of Bonneys Camp) are fed largely by fresh to mildly saline water which flows along a system of man-made drains from catchments to the south east. The water reaches the northern wetlands only in years of above average rainfall in the catchment and flows through the wetlands in the listed order, terminating in the northern lagoon at Bonneys Camp. Salinity is highest in late autumn or early winter and lowest in spring (Fig. 2) whether or not fresh water enters the system from the south and, apparently, independently of run off from local rainfall. There is no significant correlation between local rainfall in the three months preceding sampling and salinity (at Bonneys Camp r=0.1089 and at Cortina r=0.1763). This supports the opinion that run off was a minor contributor to the water in the wetlands because of the porosity of the soils in the region. The relationship between the wetlands and underlying groundwater has not been determined so the factor causing this winter depression in salinity is still a matter for conjecture. Between August 1992 and August 1994 there was a general upward trend in the levels of salinity and concern was expressed that this upward trend in salinity might continue. The present paper reports on the salinity of the wetlands since August 1994 and comments on some previously discussed points.

Salinity was measured indirectly as conductivity (mS/cm) with an ACTIVON™ conductivity probe (which corrects readings to 25°C) on-site as described and discussed earlier, in autumn, winter, spring and summer (except for the winter of 1996) from 1992 to the present at each of the six sites listed above. Conductivity was converted to salinity in g/L by multiplying conductivity by 0.640. Water levels were scored using the Water Level Index (WLI) of Tamasier and Grillas. The index scores water levels on a scale of 0 (empty) to 5 (overflowing). Seasonal fluctuations in salinity, together with the water level indices, are shown in Figure 2.

Salinity has also been recorded in the recently opened Didicoolum Drain on Petherick Rd from the time it was completed in March 1996 and in another drain which was completed in 1998 and which taps the local groundwater unlike the majority of drains in the region which carry surface water only. Water from both of these drains enters the system just south of Mandina Marshes. Mean readings for the Didicoolum Drain and the six previously mentioned sites as well as the two readings available from the new drain are given in Table 1. Rainfall figures are those for Tintinara, the nearest long-term official gauging station to the study sites, and Naracoorte, near the centre of the catchment area, and were obtained from the Bureau of Meteorology in Adelaide.

1993, 1994 and 1997 were years of lower than average rainfall in the study area (94, 79 and 72% respectively of the average of 470 mm at Tintinara) and in its catchment (83, 71 and 82% of the average 580 mm at Naracoorte) as was 1998 (80% at Naracoorte). In 1994-95 all of the sampling sites except the south lagoon at Bonneys Camp dried for periods of up to ten months and Jip Jip, Mandina Marshes, Mandina Lakes and the north lagoon of Bonneys Camp dried completely. All but Cortina Lakes and the south lagoon of Bonneys Camp dried again in 1998. Only the sampling site in the south lagoon of Bonneys Camp retained water throughout the study but the water level dropped about a metre during the summer of 1994-95 and autumn 1995 and again over the corresponding period of 1997-98 reducing what is normally a continuous shallow lake to a series of isolated basins. Although the sampling site at Cortina Lakes dried in the late autumn and winter of 1995 water remained in other basins of the lake. Jip Jip was drained for maintenance of the outlet control in the summer of 1992 and again in the autumn of 1993 so the lengthy dry period in that wetland was abnormal.

Fresh water flowed from the drainage system into all of the wetlands except the north lagoon of Bonneys Camp during the late winter and spring of 1995 and again in 1996 but the new water did not reach the south lagoon of Bonneys Camp until after the spring readings were taken. Rainfall at Naracoorte in 1995 was 590 mm (long-term average = 580 mm) and a little below average at 555 mm in 1996 but this was still not sufficient to fill all of the wetlands after they had dried in the drought. With the return to below average rainfall in 1997 and 1998 all wetlands are currently well below capacity or dry.

When the flow of fresh water reached the wetlands in the spring of 1995 the salinity of the water quickly dropped to levels near, or below, those measured in the earlier part of the study in 1992, a year of above average rainfall (122% and 139% of the long-term mean for Tintinara and Naracoorte, respectively). The seasonal variation reported has continued but the general upward trend in salinity apparently has not, although at the time of writing conditions are again dry (1998 rainfall at Naracoorte was 486 mm) and salinities are increasing once more (Fig. 2). At the two sites with near permanent water, there is a significant negative correlation of salinity with Water Level Index (r=-0.6586, p < 0.01 at Bonneys Camp South and r=-0.8558, p < 0.01 at Cortina Lakes). White & Brake predicted that Mandina and Cortina Lakes, wetlands which could not be drained but dried only by evaporation, were in danger of becoming increasingly saline each time they dried. This does not appear to be the case, at least in the short term. The patterns in salinity are similar in all systems.

The length of time needed to fill the system after it dries was not previously apparent. There has been insufficient water to reach the north lagoon of Bonneys Camp since water stopped flowing into it in January 1993. The wetlands in the south east region of Australia have long been recognised as crucial to the conservation of the nomadic water

TABLE 1. *Salinity of selected sites at Watervalley Wetlands 1992-1998.*

	Bonneys Camp S g/L	Bonneys Camp N g/L	Cortina Lakes g/L	Mandina Lakes g/L	Mandina Marsh g/L	Jip Jip g/L	Didi Drain g/L	New Drain g/L
Mean	5.15	5.26	8.02	11.39	5.01	2.23	4.92	
SD	1.79	2.77	8.34	8.75	2.61	0.89	0.40	
Max.	9.31	13.95	44.35	44.35	10.75	3.41	5.50	7.48
Min.	2.82	2.75	2.31	1.52	1.00	0.93	4.04	6.28
No.	26	14	24	22	19	10	12	2

Didi Drain = Dideoolum Drain at Petherick Rd.

birds of Australia[5,6]. Fifty per cent of the fresh water potentially available to these wetlands is currently drained out to sea[7] and further drains are planned; a proportion of this new drainage water can be diverted to the wetlands and some has already begun to flow into the system. Evidence so far (Table 1 and unpublished data supplied by the South East Water Conservation and Drainage Board) indicates that some of the planned drains will be carrying groundwater of greater salinity than that which has previously entered the wetlands[1] but the measured salinity of those waters is within the limits of known salinities of the wetlands, particularly those in the northern part of the watercourses. Given these circumstances it is important to the long term viability of the Watervalley Wetlands, as well as to others in the region, that fresh water from the current and any future drains be made available to the wetlands wherever feasible. The Watervalley Wetlands are managed with the aim of maximising the diversity of species present. This requires a diversity of habitat and the varied salinity of the Watervalley Wetlands, which currently ranges from fresh (Jip Jip) to permanently saline (Mandina Lakes), provides such diversity. Saline lakes are generally more productive than freshwater systems[8] but a long-term increase in salinity in either the freshwater wetlands or the saline ones will inevitably lead to a state of constant hypersalinity and this in turn will lead to the exclusion of some species of waterbirds and plants which currently inhabit the wetlands[9,10]. Long-term monitoring of the consequences of the addition of more saline water to the wetlands is essential and this paper provides baseline information for future studies.

This study is supported by the Wildlife Conservation Fund of South Australia, the University of South Australia and Wetlands and Wildlife. I thank the Brinkworth family for their hospitality and freedom of access to their property. My thanks also go to T. C. R. White for invaluable field assistance and for comments on drafts of this paper.

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THE OCCURRENCE OF PACHPYGUS GIBBER (THORELL, 1859) (COPEPODA: NOTODELPHYIDAE) IN AUSTRALIAN WATERS

BRIEF COMMUNICATION

Summary

The ascidicolid copepod, Pachypygus gibber (Thorell, 1859) was reported to occur in Australian waters by Schellenberg[1]. That observation has been questioned by subsequent authors. However, the finding of P. gibber in the branchial basket of the ascidian Ciona intestinalis (Linnaeus, 1767) in South Australia now confirms a southern hemisphere record for P. gibber. Since the host ascidian has been introduced into Australian waters, the commensal copepod may also have been introduced.

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The ascidicolid copepod, *Pachypygus gibber* (Thorell, 1859), was reported to occur in Australian waters by Schellenberg . That observation has been questioned by subsequent authors. However, the finding of *P. gibber* in the branchial basket of the ascidian *Ciona intestinalis* (Linnaeus, 1767) in South Australia now confirms a southern hemisphere record for *P. gibber.* Since the host ascidian has been introduced into Australian waters, the commensal copepod may also have been introduced.

The genus can be separated into two groupings based on the morphology of the fourth leg exopodite.

Very little is known of the ascidicolous copepod fauna of

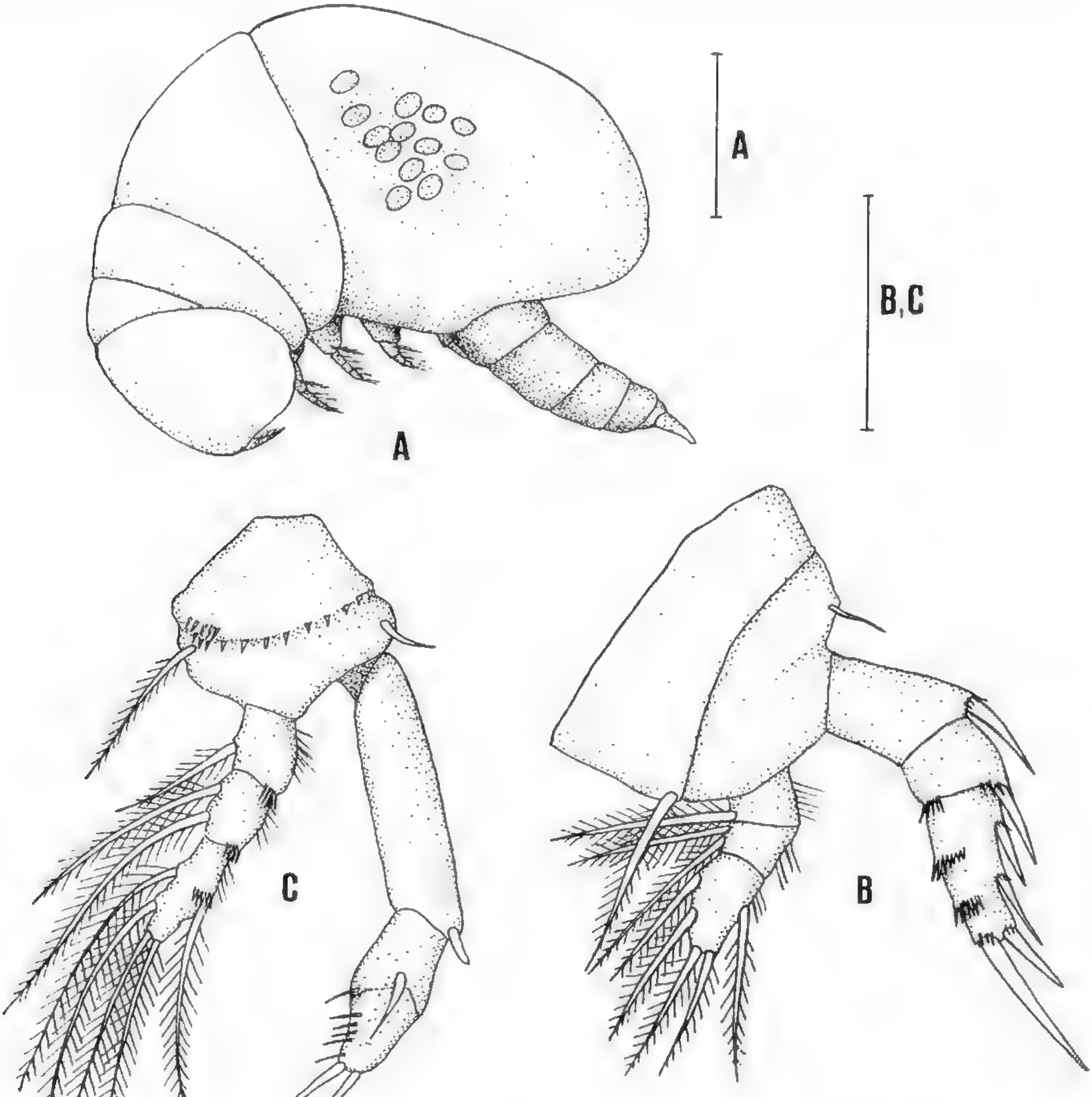

Fig. 1. *Pachypygus gibber* (Thorell, 1859), female. A. Lateral view. B. Exopodite leg 4. *Pachypygus australis* Gotto, 1975, female. C. Exopodite leg 4 (redrawn from Gotto 1975). Scale bars = 1 mm A; 0.25 mm B,C.

Australia. The first and still most extensive collection was that of Schellenberg[1]. He recorded nine species of copepod from Australian ascidians, including *Pachypygus gibber* (as *Notopterophorus gibber*), from *Ascidia glabra* Hartmeyer, 1922. Unfortunately, his collection was apparently lost during the Second World War. His identification of *P. gibber* was queried by Illg[2] who noted, in a major review of the family, that *P. gibber* had a predominantly Western Atlantic and Mediterranean distribution, while the allopatric species, *P. macer* Illg, 1958, occurred in the Carribean and West Indies. In a series of papers, Ooishi[3-6] documented the occurrence of *P. gibber* in Japanese waters and described *P. curvatus* Ooishi, 1961 and *P. globosus* Ooishi, 1963. The subsequent description from Australia of an apparently closely related species to *P. curvatus* (*P. australis* Gotto, 1975), led Gotto[7] to speculate that *P. gibber* might also occur in Australian waters, as reported by Schellenberg[1]. This note confirms that *P. gibber* does occur in Australian waters.

Seven female ascidicolous copepods were collected by one of us (WZ) from Angas Inlet near Port Adelaide, South Australia. One was dissected in lactophenol[8]. The dissected female and the six intact specimens are housed in the South Australian museum collection (C5846).

Systematics

Family Notodelphyidae
Genus *Pachypygus*
Pachypygus gibber (Thorell, 1859)
Synonym: *Notopterophorus gibber* Thorell, 1859

Collected 11 Feb 1998 from *Ciona intestinalis* (Linnaeus, 1767) collected in Angas Inlet, east of the Garden Island public boat ramp, Port Adelaide, South Australia.

Total length of body, from rostrum to caudal ramus, average of 7 specimens 4.0 mm. Range 3.5 – 4.4 mm (Fig. 1A). There were no significant differences between the females from Australia and the detailed description of *P. gibber* collected from *Ciona intestinalis* in the Bay of Naples (Mediterranean Sea)[9].

Comments: Based on the morphology of the exopodite of the fourth leg, there appear to be two groupings within *Pachypygus*. The first group, typified by *P. gibber*, has the exopodite of leg 4 as follows: three-segmented, first segment short. Segments lacking all medial setae, second segment with medial setules, medial margin of third segment with rows of spinules at approximate thirds. Lateral margin of segments one and two with lateral spine, third segment with three lateral, one terminal spine (Fig. 1B). This pattern is followed by *P. macer* and *P. globosus* (but the latter has two terminal spines).

The second group, consisting of *P. curvatus* and *P. australis*, has a fourth leg exopodite which is three-segmented with a very long sparsely setose first segment. In *P. australis*, segments two and three are partially fused (Fig. 1C), described as "tongue-shaped", second segment bearing two unequal setae, third segment carrying five delicate setae, two blunt terminal spines and many small irregularly arranged tubercles.

This is the first confirmed record of *Pachypygus gibber* in southern hemisphere waters. However, the host ascidian *Ciona intestinalis* was introduced into Australia prior to 1899[10] and therefore the commensal copepod may also be an introduction from the northern hemisphere.

We are very grateful to P. Mather, c/- Queensland Museum for confirming the identification of *Ciona intestinalis*

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SPECIES OF GNATHOSTOMA (NEMATODA: SPIRUROIDEA) FROM BANDICOOTS AND DASYURIDS (MARSUPIALIA) FROM AUSTRALIA

BRIEF COMMUNICATION

Summary

First discovered in a gastric tumor of a tiger in the Regent's Park Zoological Gardens, London Gnathostoma spinigerum Owen, 1836 occurs in a range of felid and canid hosts, including feral and domestic cats (Felis catus) and dogs (Canis sp.) from Asia, Oceania and South America[1]. In Australia G. spinigerum has previously been known as an uncommon parasite of cats[2]. Up to 1978 nine occurrences of this parasite, all from Townsville, Queensland, had been reported[2].

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BRIEF COMMUNICATION

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First discovered in a gastric tumor of a tiger in the Regent's Park Zoological Gardens, London *Gnathostoma spinigerum* Owen, 1836 occurs in a range of felid and canid hosts, including feral and domestic cats (*Felis catus*) and dogs (*Canis* sp.) from Asia, Oceania and South America. In Australia *G. spinigerum* has previously been known as an uncommon parasite of cats. Up to 1978 nine occurrences of this parasite, all from Townsville, Queensland, had been reported. Subsequently one occurrence was reported from a feral cat from Kinchega National Park New South Wales, two were reported from 104 cats from Brisbane, one from 17 cats from central Australia, one from 188 cats from the Northern Territory and one from 327 cats from Victoria and New South Wales. This latter record was also from Kinchega National Park. No infections by the parasite were reported from surveys for cat parasites in Sydney NSW, Tasmania or Perth Western Australia. *Gnathostoma spinigerum* has been found in dogs on one occasion, a single male worm in a sub-cutaneous cyst.

First discovered in the Philippines, *Gnathostoma doloresi* Tubangui, 1925, reported as *G. hispidum* Fedtschenko, 1872, normally parasitic in the stomach of the pig (*Sus scrofa*), has been found only once in Australia. Two specimens were recovered from a pig from Northern Queensland. It has been suggested that the pig may have been landed illegally from Papua New Guinea, where the parasite is common.

A northern quoll, *Dasyurus hallucatus* Gould, collected at Cannallie Creek, Northern Territory (13° 03' S, 131° 12' E) by P. Haycock, on 31. vii. 1995 had seven specimens of a gnathostome in the diaphragm and liver. An anterior end apparently of the same species of gnathostome had previously been collected from a brush-tailed phascogale, *Phascogale tapoatafa* (Meyer), from Wongabel State Forest, Atherton Queensland (17° 20' S, 145° 30' E) by R. Krauss & D. M. Spratt on 13. iv. 1984. These nematodes, 3.5-4.5 mm long had the typical morphology of advanced third-stage larvae of *G. spinigerum*, namely a cephalic bulb with 4 rows of hooks, 4 ballonet-cervical sac systems and rows of single, toothed spines over the entire body. The number of cervical hooks per row, 40 in the first row and 47 in the third row, of one specimen, and the form of the hooks, like rose-thorns, was also typical of *G. spinigerum*.

A second gnathostome, a single specimen 21 mm long, was found in a northern brown bandicoot, *Isoodon macrourus* (Gould) collected by R. Norman at Ravenshoe, Queensland (17° 36' S, 145° 29' E) on 1. ix. 1991. This specimen had a cephalic bulb with 10 rows of hooks and the 4 ballonet-cervical sac systems typical of the genus. The entire body surface was covered with rows of spines, the anterior one third with multi-pronged spines, the posterior two thirds with single, toothed spines. Of the anterior spines those in the region immediately posterior to the neck had 4-5 prongs; the remainder were tri-pronged. Although features of a reproductive system could not be distinguished the details of cephalic and body spination were sufficient to identify this worm as an adult or maturing adult *G. doloresi*. *Gnathostoma doloresi* is most similar to *G. hispidum*, which is also found in pigs. Miyazaki in his review of gnathostomiasis noted that he had previously re-examined specimens of *G. hispidum* and *G. doloresi* and determined that material from pigs from New Guinea previously identified as *G. hispidum* was, in fact, *G. doloresi*. This determination was confirmed by Talbot. Accordingly *G. hispidum* is considered to be limited in geographical distribution to Asia and Europe while *G. doloresi* is found in Asia and Oceania, supporting the identification of the specimen from the northern brown bandicoot as *G. doloresi*.

The life cycle of a gnathostome includes an active, free living, sheathed second stage larva which swims in water until it is ingested by a copepod whereupon it develops into a third stage larva. These third stage larvae mature to advanced third stage after infected copepods are consumed by a vertebrate host and usually occur in the muscle or other tissue sites of the vertebrate. When animals infected by advanced third stage larvae are themselves eaten, the new host may either be unsuitable for further larval development, becoming a paratenic host in which the larvae re-encyst, or a suitable final host in which larvae mature to adults in lesions in the oesophagus, stomach or kidneys.

In the case of the advanced third stage larvae of *G. spinigerum* found in *D. hallucatus* and *P. tapoatafa*, these dasyurids appear to be acting as paratenic hosts. The worms would develop into adults only after the dasyurid had been eaten by a suitable predator, probably a feral cat. In the case of the adult worm found in the northern brown bandicoot it is not clear how this infection could have occurred. Although bandicoots are largely insectivorous and it has been suggested that they might be opportunistic feeders on infant rodents, it is unlikely that they would have accidentally ingested an adult gnathostome when scavenging a dead pig.

In all cases, an infection of the normal definitive host, a feral cat with *G. spinigerum*, or a domestic pig with *G. doloresi* has been reported for the same region, although not the specific localities of the new records. Since *G. spinigerum* is uncommon in cats in Australia it is likely to be also uncommon in other hosts which participate in its life cycle. Similarly with the record of *G. doloresi* in pigs. This may, however, be an under representation of actual incidence of infection in feral pigs in Northern Queensland given the potential for importation of infected pigs into the region, which is sparsely populated. Two other spiruroid nematode parasites of the gastric mucosa of pigs, *Physocephalus sexalatus* and *Simondsia paradoxa* were found in four of 51 feral pigs examined in Cape Tribulation National Park between April and June 1992, but no species of *Gnathostoma* were reported.

The specimens are deposited in the CSIRO Wildlife and Ecology collection, Canberra, registration numbers N4411 and N4632, recorded as N2179 in Spratt *et al.*, and the South Australian Museum, Adelaide, registration number AHC 30212.

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VOL. 123, PART 3

NEW SPECIES OF PARASITIC NEMATODES FROM DORCOPSULUS VANHEURNI (MARSUPIALIA: MACROPODIDAE) FROM PAPUA NEW GUINEA

By I. Beveridge & R. Speare†*

Summary

Beveridge, I. & Speare, R. (1999) New species of parasitic nematodes from Dorcopsulus vanheurni (Marsupialia: Macropodidae) from Papua New Guinea. Trans. R. Soc. S. Aust. 123(3), 85-100, 30 November, 1999.

Seven new species of Cloacina are described from the stomach of the lesser forest wallaby, Dorcopsulus vanheurni, from a single locality, Doido, in Papua New Guinea. Cloacina syphax sp. nov. differs from all congeners by the undulating anterior margin of its buccal capsule, lack of lips and acutely pointed tips to the submedian cephalic papillae.

Key Words: Dorcopsulus vanheurni, nematodes, new species, Cloacina.

Transactions of the Royal Society of S. Aust. (1999), **123**(3), 85-100.

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Summary

BEVERIDGE, I. & SPEARE, R. (1999) New species of parasitic nematodes from *Dorcopsulus vanheurni* (Marsupialia: Macropodidae) from Papua New Guinea. *Trans. R. Soc. S. Aust.* **123** (3), 85-100, 30 November, 1999.

Seven new species of *Cloacina* are described from the stomach of the lesser forest wallaby, *Dorcopsulus vanheurni*, from a single locality, Doido, in Papua New Guinea. *Cloacina syphax* sp. nov. differs from all congeners by the undulating anterior margin of its buccal capsule, lack of lips and acutely pointed tips to the submedian cephalic papillae. *Cloacina sinon* sp. nov. is distinguished by the shape of its buccal capsule which is sinuous in apical view, quadrangular in shape and has eight medially directed lobes. *Cloacina solon* sp. nov. is differentiated by its cervical cuticular inflation, submedian cephalic papillae with obtuse distal segments, a sinuous anterior margin to the buccal capsule and an unornamented oesophagus. *Cloacina sappho* sp. nov. can be separated from congeners by the long, acute submedian cephalic papillae and the presence of the amphids on elevations of the cuticle while *C. sciron* sp. nov. is distinguished by its cervical inflation, single oesophageal denticle, deirid at the level of the nerve ring and eight leaf crown elements. *Cloacina sterope* sp. nov. can be differentiated from congeners by the asymmetry of the buccal capsule in lateral view, the presence of oesophageal bosses and a denticle, the deirid posterior to the nerve ring and a straight vagina. *Cloacina solymus* sp. nov. is distinguishable by the tiny submedian cephalic papillae, sinuous anterior margin of the buccal capsule and sub-cylindrical oesophagus. Additional undescribed species were found but insufficient material was available to permit description.

KEY WORDS: *Dorcopsulus vanheurni*, nematodes, new species, *Cloacina*.

Introduction

Most species of kangaroos and wallabies which have been examined for the presence of internal parasites have been found to harbour a diverse array of parasitic nematodes, the majority belonging to the superfamily Strongyloidea Weinland, 1863 (Spratt *et al.* 1991). However, a number of species of wallabies has apparently never been examined for helminth parasites and prominent among them are the forest wallabies of the related genera *Dorcopsis* Schlegel & Mueller, 1842 and *Dorcopsulus* Matschie, 1916 from Papua New Guinea. During 1984, one of us (RS) had the opportunity to collect parasites from four specimens of the lesser forest wallaby, *Dorcopsulus vanheurni* (Thomas, 1922), at Doido in the Chimbu Province of Papua New Guinea (6° 33'S, 144° 50' E). New species of the nematode genus *Cloacina* von Linstow, 1898 found in the stomachs of the animals examined are described in this paper.

Materials and Methods

Stomach contents of wallabies were preserved in 10% formalin. In the laboratory, the contents were washed to remove the formalin, nematodes were extracted, washed in water and stored in 70% ethanol prior to examination. For identification, nematodes were cleared in lactophenol. Permanent preparations, on slides, of apical views of the mouth opening, bursa and spicule tips were made using polyvinyl lactophenol as the mounting medium. Measurements were made using an ocular micrometer and are presented in millimetres as the range followed by the mean in parentheses. In instances where all individual measurements were the same, a single figure appears before the mean in parentheses. If only two measurements were available, the individual measurements are given. Drawings were made with the aid of a drawing tube attached to an Olympus BH2 microscope using Nomarski interference optics. Drawings of apical views of the mouth opening are presented with the dorsal aspect uppermost; drawings of the bursa have the ventral lobes uppermost.

Terminology for morphological features of the genus *Cloacina* follows Beveridge (1998), except

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that the term secretory-excretory (S-E) pore is used following Bird & Bird (1991). Holotype specimens have been deposited in the South Australian Museum, Adelaide (SAMA) while paratype material has been distributed between SAMA and the British Museum (Natural History), London (BMNH). Host nomenclature utilised is that of Flannery (1995). Following Beveridge (1998), the names of the new species are of classical origin.

Cloacina syphax sp. nov.
(FIGS 1-10)

Types. Holotype ♂ from stomach of *Dorcopsulus vanheurni*, Doido, Papua New Guinea, 17. v. 1984, coll. R. Speare, SAMA AHC 31199; allotype ♀, SAMA AHC 31200; paratypes: 20 ♂♂, 9 ♀♀, SAMA AHC 31201-2; 1 ♂, 1 ♀, BMNH 1998.9.28.21-22.

Description

Small nematodes; cervical cuticle slightly inflated in oesophageal region; transverse cuticular annulations prominent. Sub-median papillae elongate, 0.015 long, projecting anteriorly from peri-oral cuticle; proximal segment cylindrical, short, 0.005 long, shorter than ovoid, acute distal segment, 0.010 long. Buccal capsule shallow, cylindrical, symmetrical in dorsoventral views, circular in apical view. Dorsal margin of buccal capsule prominently lobed, with bifid lobes posterior to each submedian papilla. Eight leaf crown elements, with faint striations, arising from full length of internal wall of buccal capsule, recurved at tips. Peri-oral cuticle not inflated into lip-like lobes attached to each leaf crown element. Dorsal oesophageal gland not projecting into buccal capsule. Oesophagus simple, elongate, claviform; lining unornamented; denticles absent. Nerve ring in mid-oesophageal region; deirids in anterior oesophageal region, immediately anterior to nerve ring; S-E pore anterior to oesophago-intestinal junction.

Male (Measurements from 10 specimens, types) (Figs 5-8)

Total length 3.75-5.45 (4.63); maximum width 0.22-0.38 (0.31); dimensions of buccal capsule 0.018-0.020 (0.019) x 0.05-0.06 (0.055); oesophagus 0.47-0.60 (0.55); nerve ring to anterior end 0.22-0.26 (0.24); S-E pore to anterior end 0.39-0.50 (0.45); deirids to anterior end 0.18-0.26 (0.21). Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral and ventral lobes joined. Dorsal lobe slightly longer than lateral lobes. Dorsal ray slender at origin; primary branchlets arise at $^{1}/_{3}$ length, before major bifurcation; secondary branchlets at $^{2}/_{3}$ length; internal branchlets directed posteriorly, reaching margin of bursa; external branchlets similar in length to internals, directed posterolaterally, not reaching margin of bursa. Externodorsal ray arising close to lateral rays, not reaching margin of bursa. Posterolateral and ventrolateral rays apposed, reaching margin of bursa; anterolateral ray divergent, shorter than other lateral rays, not reaching margin of bursa; ventrolateral and ventroventral rays apposed, reaching margin of bursa. Gubernaculum broadly triangular, 0.025, 0.030 long; central cordate and paired lateral thickenings of spicule sheaths present; genital cone with prominent anterior lip; posterior lip shorter than anterior, with pair of dome shaped papillae; pair of lateral inflations of cuticle present on either side of anterior lip; spicules elongate, 2.50-2.93 (2.73) long, alate, tip simple; ala diminishing in width gradually towards tip.

Female (Measurements from 5 specimens, types) (Figs 9, 10)

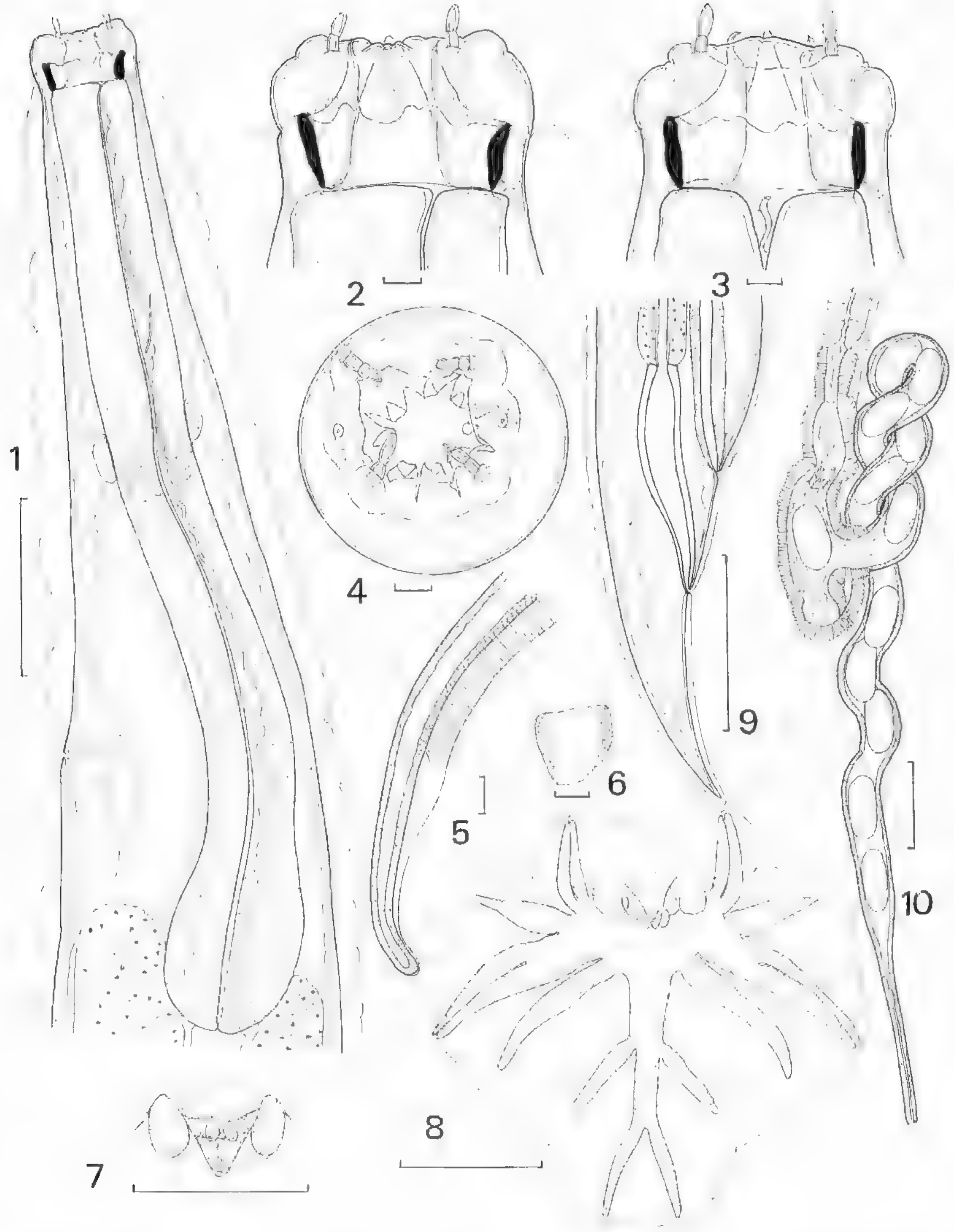
Total length 4.14-5.13 (4.59); maximum width 0.28-0.39 (0.33), dimensions of buccal capsule 0.020 (0.020) x 0.055-0.065 (0.060); oesophagus 0.58-0.61 (0.59); nerve ring to anterior end 0.25-0.27 (0.26); S-E pore to anterior end 0.37-0.46 (0.43); deirids to anterior end 0.18-0.23 (0.20). Tail simple, conical, 0.13-0.19 (0.14) long; vulva close to anus, 0.20-0.31 (0.23) from posterior end; vagina straight posteriorly, anterior region twisted, recurrent, 1.00-1.22 (1.13) long; ovejector J- shaped, infundibulum shorter than sphincter; egg ellipsoidal, 0.07-0.08 (0.07) x 0.04 (0.04).

Etymology

Syphax, king of Numidia at the time of the second Punic war.

Remarks

Cloacina syphax is distinguished from all congeners by the shape of the anterior margin of the buccal capsule which is undulate and has a roughly bifid, anteriorly directed lobe immediately posterior to each submedian papilla. Congeners with symmetrical buccal capsules bearing prominent anterior lobes are *C. artemis* Beveridge, 1998, *C. hebe* Beveridge, 1998, *C. hypsipyle* Beveridge 1998, *C. linstowi* Johnston & Mawson, 1940, *C. thetidis* Johnston & Mawson, 1939 and *C. wallabiae* Johnston & Mawson, 1939. The distal segments of the cephalic papillae in *C. hebe*, *C. hypsipyle*, *C. linstowi* and *C. thetidis* are obtuse at their tips rather than acute as in *C. syphax*; *C. artemis* and *C. wallabiae* have lip-like expansions of the cephalic cuticle attached to each leaf crown element which are lacking in *C. syphax*. For these



Figs 1-10. *Cloacina syphax* sp. nov. 1. Anterior end, lateral view of ♂. 2. Cephalic extremity, lateral view, dorsal aspect on right hand side. 3. Cephalic extremity, dorsal view. 4. Cephalic extremity, apical view. 5. Spicule tip, lateral view. 6. Gubernaculum, ventral view. 7. Genital cone, dorsal view. 8. Bursa, apical view. 9. Female tail, lateral view. 10. Ovejector and vagina, lateral view. Scale bars = 0.1 mm, 1, 7-10; 0.01 mm, 2-6.

reasons, *C. syphax* is considered distinct from all congeners.

Cloacina sancus sp. nov.
(FIGS 11-23)

Types: Holotype ♂ from stomach of *Dorcopsulus vanheurni*, Doido, Papua New Guinea, 17.v.1984, coll. R. Speare, SAMA AHC 31194; allotype ♀, same data, SAMA AHC 31195; paratypes, same data: 6 ♂♂, 2 ♀♀, SAMA AHC 31196; 1 ♂, BMNH 1998.9.28.15.

Description

Small nematodes; cervical cuticle not inflated in oesophageal region; transverse cuticular annulations prominent. Sub-median papillae small, 0.010 long, projecting anteriorly from peri-oral cuticle; proximal segment cylindrical, short, 0.005 long, as long as ovoid, obtuse distal segment, 0.005 long. Buccal capsule shallow, cylindrical, symmetrical in dorsoventral views, not sinuous or lobed in dorsoventral views but sinuous in apical view, with medially directed indentations posterior to each amphid and submedian papilla as well as one dorsal and one ventral indentation. Eight leaf crown elements, with faint striations, arising from full length of internal wall of buccal capsule, not recurved at tips. Peri-oral cuticle striated, not inflated into lip-like lobes attached to each leaf crown element. Dorsal and subventral oesophageal teeth absent. Oesophagus simple, claviform, slightly constricted at level of nerve ring, lining not ornamented; denticles absent. Nerve ring in mid oesophageal region; deirids in anterior oesophageal region, anterior to nerve ring; S-E pore anterior to oesophago-intestinal junction.

Male (Measurements from 9 specimens, types) (Figs 18-21)

Total length 4.82-6.62 (5.84); maximum width 0.40-0.52 (0.45); dimensions of buccal capsule 0.020-0.025 (0.022) x 0.065-0.080 (0.075); oesophagus 0.68-0.75 (0.71); nerve ring to anterior end 0.34-0.38 (0.36); S-E pore to anterior end 0.55-0.64 (0.60); deirids to anterior end 0.22-0.27 (0.25). Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral and ventral lobes joined. Dorsal lobe similar in length to lateral lobes. Dorsal ray divides at midlength; secondary subdivisions at 3/4 length; internal branchlets directed posteriorly, not reaching margin of bursa; external branchlets shorter than internals, directed posterolaterally, not reaching margin of bursa. Externodorsal ray arising close to lateral rays, not reaching margin of bursa. Posterolateral and ventrolateral rays apposed, reaching margin of bursa; anterolateral ray divergent, shorter than other lateral rays, not reaching margin of bursa; ventrolateral and ventroventral rays apposed, reaching margin of bursa. Gubernaculum broadly quadrangular, 0.025-0.040 (0.032) long; central cordate and paired lateral thickenings of spicule sheaths present; genital cone with prominent anterior lip; posterior lip shorter than anterior lip, with pair of dome shaped papillae; pair of lateral inflations of cuticle present on either side of anterior lip; spicules elongate, 1.73-2.67 (2.25) long, alate, tip simple; ala diminishing in width gradually then terminating abruptly immediately anterior to tip.

Female (Measurements from 3 specimens, types) (Figs 22, 23)

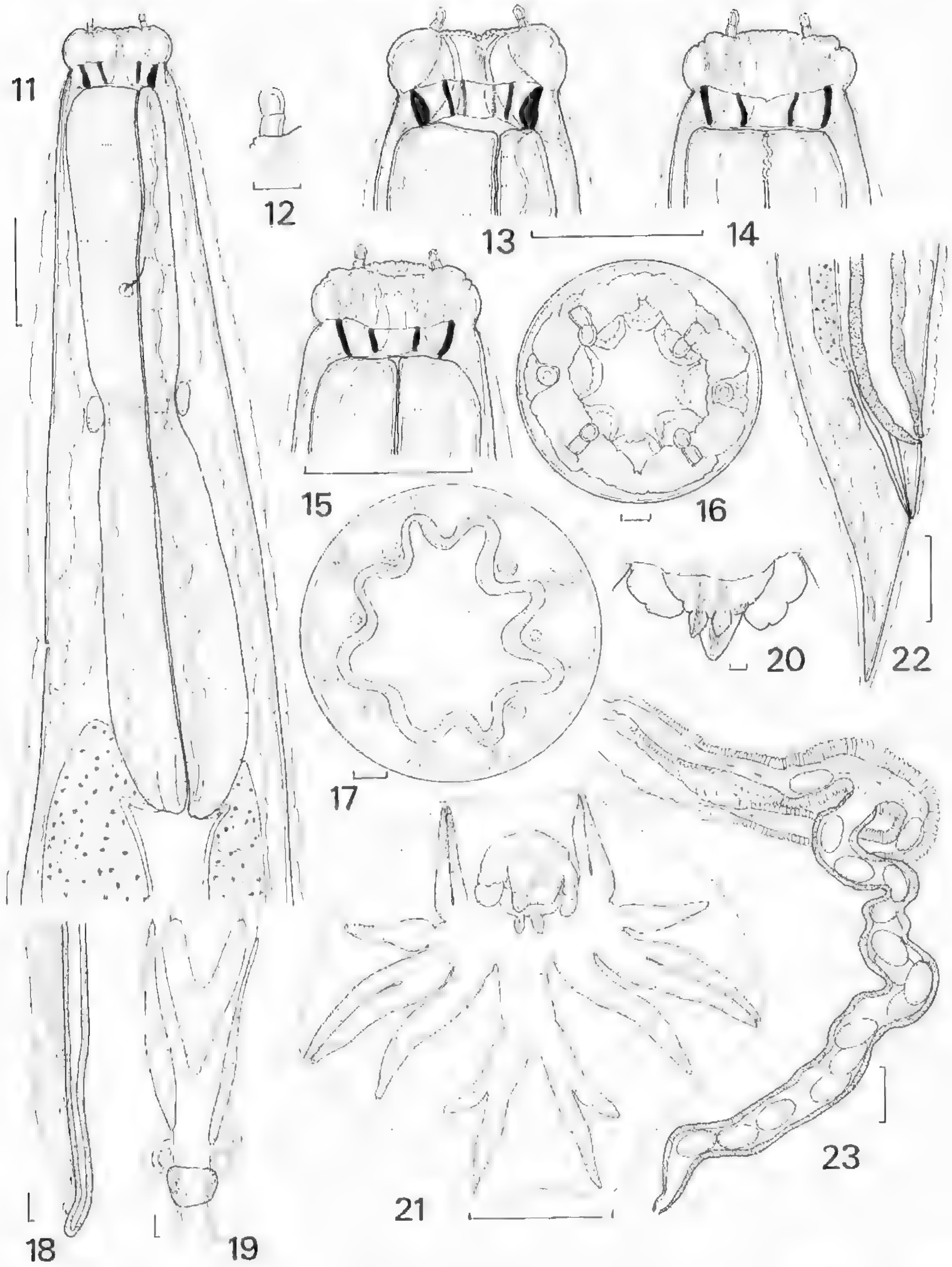
Total length 5.5-11.2 (7.8); maximum width 0.41-0.74 (0.60); dimensions of buccal capsule 0.020-0.025 (0.022) x 0.080-0.105 (0.090); oesophagus 0.79-0.88 (0.84); nerve ring to anterior end 0.38-0.40 (0.39); S-E pore to anterior end 0.50-0.74 (0.62); deirids to anterior end 0.21. Tail simple, conical, 0.19, 0.21 long; vulva close to anus, 0.30, 0.32 from posterior end; vagina sinuous, 0.67, 0.86 long; ovejector J- shaped, infundibulum as long as sphincter; egg ellipsoidal, 0.07, 0.08 x 0.04, 0.04.

Etymology

Sancus, a deity of the Sabines.

Remarks

Cloacina sancus is distinguished from all congeners except *C. bancroftorum* Johnston & Mawson, 1939 and *C. thetidis* by the shape of the buccal capsule, which is sinuous in apical views. The sinuosity is distinguishable in lateral views (Fig. 13) by the presence of two vertical thickenings of the buccal capsule wall. Similar thickenings of the wall are visible in dorsal and ventral views (Figs 14, 15). In both *C. bancroftorum* and *C. thetidis*, the shape of the buccal capsule in apical view is approximately triangular with six indentations of the margin. In *C. sancus*, the buccal capsule is roughly quadrangular in apical view and has eight indentations of its margin, six associated with amphids and submedian papillae as well as a dorsal and a ventral indentation. The wall of the buccal capsule is straight in lateral views in *C. sancus* and *C. thetidis* but is undulating in *C. bancroftorum*. The submedian papillae of *C. sancus* resemble those of *C. bancroftorum*, with a short, rounded distal segment, while those of *C. thetidis* have an elongate, obtuse distal segment. In the female, the ovejector of *C. thetidis* is Y-shaped compared with J-shaped ovejectors in *C. sancus* and *C. bancroftorum*, while the vagina is recurrent in *C. bancroftorum* but not in *C. sancus*.



Figs 11-23. *Cloacina sancus* sp. nov. 11. Anterior end, lateral view of ♂. 12. Submedian cephalic papilla. 13. Cephalic extremity, lateral view, dorsal aspect on right hand side. 14. Cephalic extremity, dorsal view. 15. Cephalic extremity, ventral view. 16. Cephalic extremity, apical view. 17. Optical transverse section through buccal capsule. 18. Spicule tip, lateral view. 19. Gubernaculum and thickenings of spicule sheaths, ventral view. 20. Genital cone, dorsal view. 21. Bursa, apical view. 22. Female tail, lateral view. 23. Ovejector and vagina, lateral view. Scale bars = 0.1 mm, 11, 13-15, 21-23; 0.01 mm, 12, 16-20.

Cloacina solon sp. nov.

(FIGS 24-34)

Types: Holotype ♂ from stomach of *Dorcopsulus vanheurni*, Doido, Papua New Guinea, 17.v.1984 coll. R. Speare, SAMA AHC 31203; allotype ♀, same data, SAMA AHC 31204; paratypes: 2 ♂♂, 3 ♀♀, SAMA AHC 31205; 1 ♂, 1 ♀, BMNH 1998.9.28.18-19.

Description

Small nematodes; cervical cuticle prominently inflated in oesophageal region; transverse cuticular annulations faint on cervical inflation, prominent posterior to it. Sub-median papillae elongate, 0.018 long, projecting anteriorly from peri-oral cuticle; proximal segment cylindrical, short, 0.006 long, shorter than ovoid, obtuse distal segment, 0.012 long. Buccal capsule shallow, cylindrical, symmetrical in dorsoventral views, circular in apical view; anterior margin of buccal capsule sinuous in lateral, dorsal and ventral views. Eight leaf crown elements, with faint striations, arising from full length of internal wall of buccal capsule, recurved at tips. Peri-oral cuticle not inflated into lip-like lobes attached to each leaf crown element. Dorsal oesophageal tooth absent; each sub-ventral sector of oesophagus with single, lancet-like projection into buccal capsule. Oesophagus simple, elongate, claviform; lining unornamented; denticles absent. Nerve ring in mid-oesophageal region; deirids in anterior oesophageal region, just anterior to nerve ring; S-E pore anterior to oesophago-intestinal junction.

Male (Measurements from 10 specimens, types) (Figs 29-32)

Total length 4.8-7.6 (5.5); maximum width 0.32-0.47 (0.41); dimensions of buccal capsule 0.015-0.018 (0.017) x 0.070-0.080 (0.075); oesophagus 0.70-0.83 (0.75); nerve ring to anterior end 0.27-0.32 (0.29); S-E pore to anterior end 0.52-0.63 (0.59); deirids to anterior end 0.19-0.26 (0.22). Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral and ventral lobes joined. Dorsal lobe similar in length to lateral lobes. Dorsal ray divides at 1/3 length; secondary subdivisions at 2/3 length; internal branchlets directed posteriorly, almost reaching margin of bursa; external branchlets shorter than internals, directed posterolaterally, not reaching margin of bursa. Externodorsal ray arising close to lateral rays, not reaching margin of bursa. Posterolateral and ventrolateral rays apposed, reaching margin of bursa; anterolateral ray divergent, shorter than other lateral rays, not reaching margin of bursa; ventrolateral and ventroventral rays apposed, reaching margin of bursa. Gubernaculum broadly quadrangular, 0.025-0.030 (0.029) long; central cordate and paired lateral thickenings of spicule sheaths present; genital cone with prominent anterior lip; posterior lip shorter than anterior, with pair of dome shaped papillae; pair of lateral inflations of cuticle present on either side of anterior lip; spicules elongate, 2.60-2.94 (2.81) long, alate, tip simple; ala diminishing in width gradually, terminating near tip.

Female (Measurements from 10 specimens, types) (Figs 33, 34)

Total length 4.7-6.8 (6.0); maximum width 0.34-0.55 (0.46); dimensions of buccal capsule 0.015-0.020 (0.018) x 0.080-0.090 (0.085); oesophagus 0.71-0.86 (0.78); nerve ring to anterior end 0.22-0.30 (0.27); S-E pore to anterior end 0.53-0.67 (0.61); deirids to anterior end 0.20-0.23 (0.21). Tail simple, conical, 0.17-0.22 (0.19) long; vulva close to anus, 0.27-0.39 (0.32) from posterior end; vagina long, distal region straight, proximal region recurrent, 1.09-1.41 (1.21) long; ovejector J shaped, infundibulum longer than sphincter; egg not seen.

Etymology

Solon, a famous legislator of Athens, one of the seven sages of Greece.

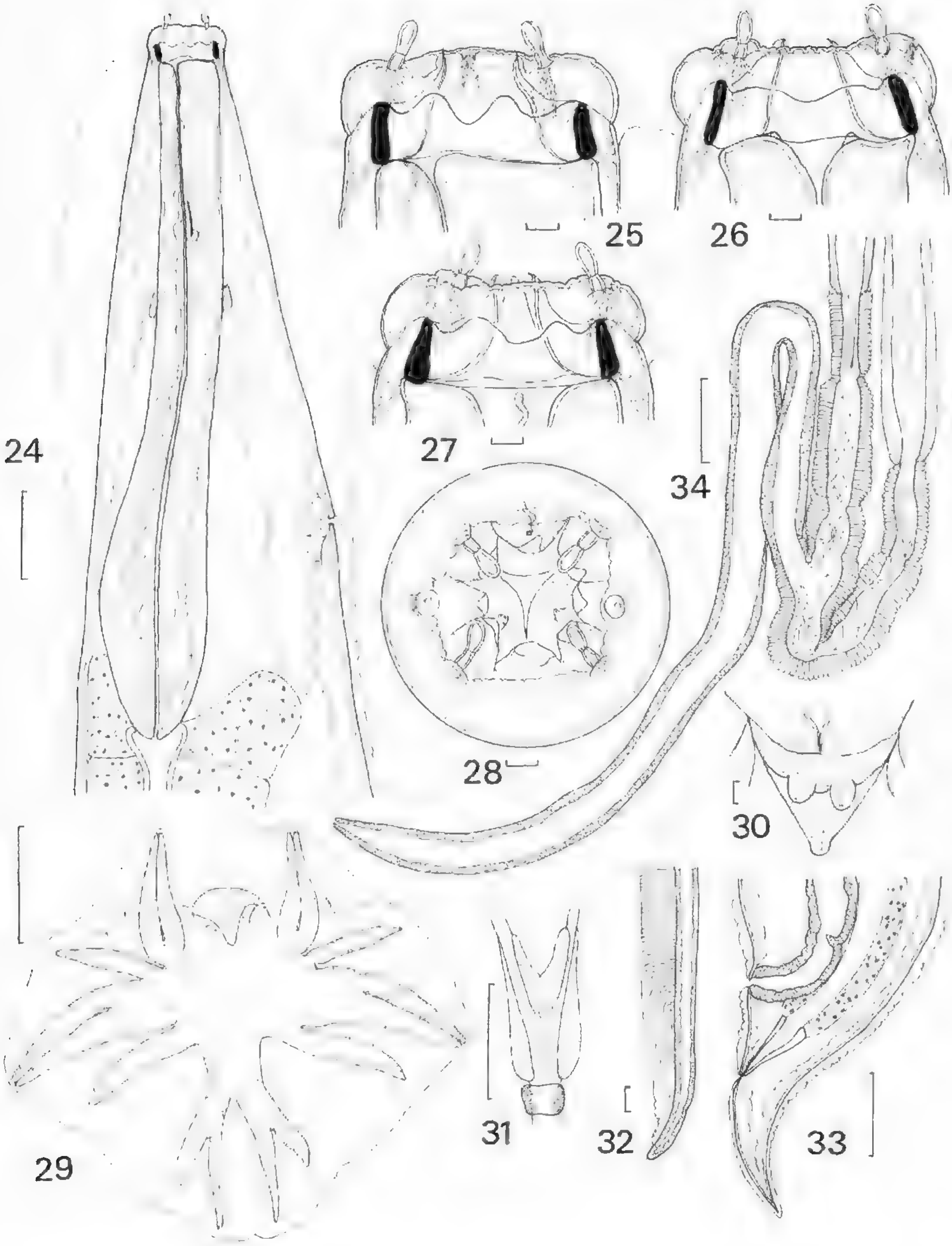
Remarks

Cloacina solon is characterised by a simple, claviform, unornamented oesophagus, submedian cephalic papillae in which the proximal segment is short and the distal segment large and obtuse and by a buccal capsule which has a regularly sinuous anterior margin. These features distinguish it from all congeners except *C. dryope* Beveridge, 1998, *C. hebe*, *C. hypsipyle*, *C. linstowi*, *C. maia* Beveridge, 1998 and *C. thetidis*. *Cloacina dryope*, *C. hebe* and *C. thetidis* have extremely shallow buccal capsules which distinguish them immediately from *C. solon*, while *C. linstowi* and *C. maia* lack a cervical inflation of the cuticle and have Y-shaped ovejectors rather than the J-shaped ovejector found in *C. solon*. *Cloacina hypsipyle* possesses a buccal capsule which is triangular in apical view rather than circular as in *C. solon* and has six leaf crown elements rather than the eight in *C. solon*. In addition, the spicules of *C. hypsipyle* are 1.04-1.15 mm long compared with 2.60-2.94 mm in *C. solon* and the vagina of *C. hypsipyle* is straight while that of *C. solon* is recurrent.

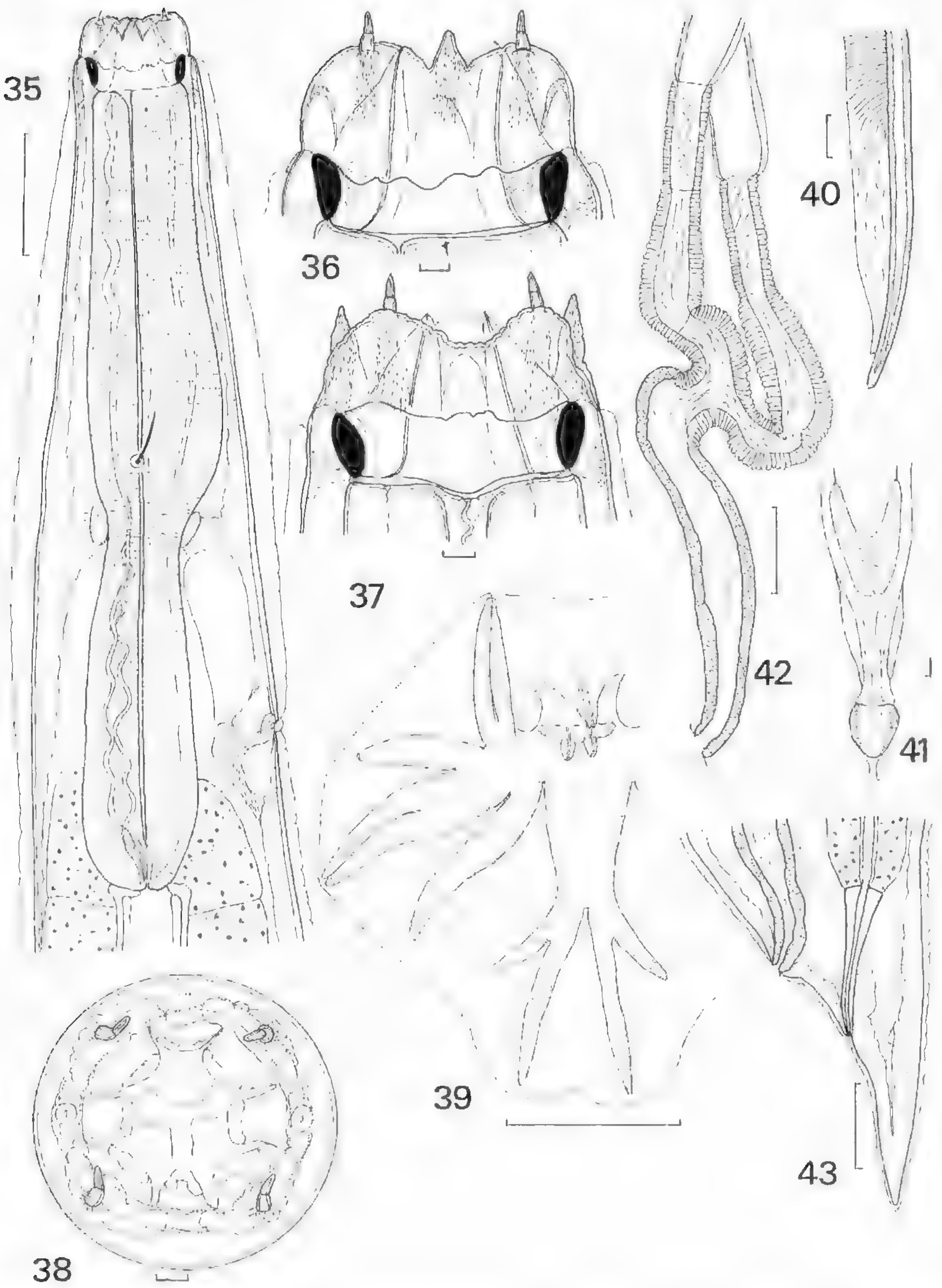
Cloacina sappho sp. nov.

(FIGS 35 - 43)

Types: Holotype ♂ from stomach of *Dorcopsulus vanheurni*, Doido, Papua New Guinea, 17.v.1984,



Figs 24-34. *Cloacina solon* sp. nov. 24. Anterior end, lateral view of ♂. 25. Cephalic extremity, lateral view, dorsal aspect on left hand side. 26. Cephalic extremity, ventral view. 27. Cephalic extremity, dorsal view. 28. Cephalic extremity, apical view. 29. Bursa, apical view. 30. Genital cone, dorsal view. 31. Gubernaculum and thickenings of spicule sheaths, ventral view. 32. Spicule tip, lateral view. 33. Female tail, lateral view. 34. Ovejector and vagina, lateral view. Scale bars = 0.1 mm, 24, 29, 31, 33-34; 0.01 mm, 25-28, 30, 32.



Figs 35-43. *Cloacina sappho* sp. nov. 35. Anterior end, lateral view of ♂. 36. Cephalic extremity, lateral view, dorsal aspect on left hand side. 37. Cephalic extremity, dorsal view. 38. Cephalic extremity, apical view. 39. Bursa, apical view. 40 Spicule tip, lateral view. 41. Gubernaculum and thickenings of spicule sheaths, ventral view. 42. Ovejector and vagina, lateral view; 43. Female tail, lateral view. Scale bars = 0.1 mm, 35, 39, 42, 43; 0.01 mm 36-38, 40, 41.

coll. R. Speare, SAMA AHC 31188, allotype ♀, same data, SAMA AHC 31189; paratypes: 1 ♂, 1 ♀, SAMA AHC 31190.

Description

Small nematodes; cervical cuticle not inflated in oesophageal region; transverse cuticular annulations prominent. Sub-median papillae 0.013 long, projecting anteriorly from peri-oral cuticle, situated on elevations of peri-oral cuticle; proximal segment cylindrical, short, 0.005 long, shorter than acute, subtriangular distal segment, 0.009 long; amphids on prominent conical projections from peri-oral cuticle. Buccal capsule shallow, cylindrical, symmetrical in lateral views, circular in apical view; anterior margin of buccal capsule irregularly undulate. Eight leaf crown elements, with faint striations, arising from full length of internal wall of buccal capsule, not recurved at tips. Peri-oral cuticle not inflated into lip-like lobes attached to each leaf crown element. Dorsal oesophageal tooth absent. Oesophagus simple, claviform, region anterior to nerve ring broader than that posterior to nerve ring; lining unornamented; denticles absent. Nerve ring in posterior oesophageal region; deirids immediately anterior to nerve ring; S-E pore anterior to oesophago-intestinal junction.

Male (Measurements from 3 specimens, types) (Figs 39-41)

Total length 5.0-6.3 (5.7); maximum width 0.29-0.40 (0.35); dimensions of buccal capsule 0.018-0.020 (0.019) x 0.080-0.090 (0.085); oesophagus 0.65-0.71 (0.68); nerve ring to anterior end 0.40-0.43 (0.42); S-E pore to anterior end 0.58-0.60 (0.59); deirids to anterior end 0.26-0.36 (0.32). Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral and ventral lobes joined. Dorsal lobe similar in length to lateral lobes. Dorsal ray divides at midlength; secondary subdivisions immediately posterior to primary division; internal branchlets elongate, directed posteriorly, almost reaching margin of bursa; external branchlets shorter than internals, directed posterolaterally, not reaching margin of bursa. Externodorsal ray arising close to lateral rays, not reaching margin of bursa. Posterolateral and ventrolateral rays apposed, reaching margin of bursa; anterolateral ray divergent, shorter than other lateral rays, not reaching margin of bursa; ventrolateral and ventroventral rays apposed, reaching margin of bursa. Gubernaculum subtriangular, 0.030-0.040 (0.037) long; central cordate and paired lateral thickenings of spicule sheaths present; genital cone with prominent anterior lip; posterior lip shorter than anterior, with pair of dome shaped papillae; pair of lateral inflations of cuticle present on either side of anterior lip; spicules elongate, 1.30-1.50 (1.38) long, alate.

Female (Measurements from 2 specimens, types) (Figs 42, 43)

Total length 5.9, 8.1; maximum width 0.46, 0.54; dimensions of buccal capsule 0.020, 0.020 x 0.100, 0.170 ; oesophagus 0.80, 0.87; nerve ring to anterior end 0.47, 0.53; S-E pore to anterior end 0.68, 0.77; deirids to anterior end 0.26, 0.29. Tail simple, conical, 0.21, 0.25 long; vulva close to anus, 0.33, 0.36 from posterior end; vagina straight, 0.44, 0.59 long; ovejector J-shaped, infundibulum longer than sphincter; egg not seen.

Etymology

Sappho, a Greek lyric poetess.

Remarks

Although described from a very limited series of specimens, *C. sappho* is immediately distinguishable from all congeners by the irregularly undulating anterior margin of the buccal capsule and by the presence of prominent conical projections from the peri oral cuticle, bearing the amphids. In addition, the shape of the oesophagus, with the anterior region broader than the posterior region, distinguishes the new species from all congeners except *C. dryope*, from which it differs in having a relatively deeper buccal capsule, a buccal capsule that is circular in apical view rather than dorsoventrally elongate as in *C. dryope*, in having eight rather than six leaf crown elements and in the shape of the cephalic papillae which in *C. dryope* terminate with an elongate, obtuse segment.

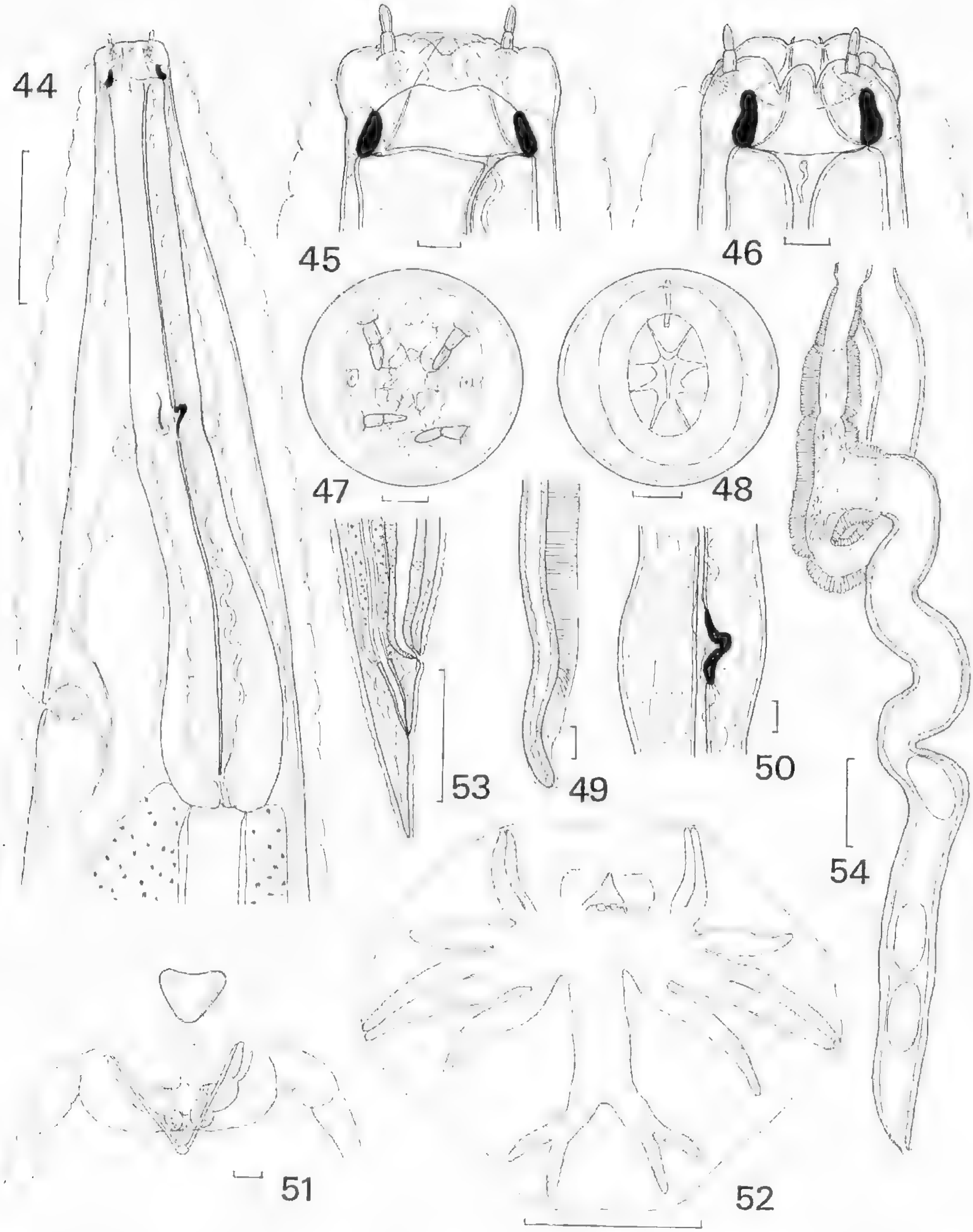
Cloacina sciron sp. nov.

(FIGS 44-54)

Types: Holotype ♂ from stomach of *Dorcopsulus vanheurni*, Doido, Papua New Guinea, 17.v.1984, coll. R. Speare, SAMA AHC 31207; allotype ♀, same data SAMA AHC 31208; paratypes: 18 ♂♂, 24 ♀♀, SAMA AHC 31209, 31210; 1 ♂, 1 ♀, BMNH 1998.9.28.16-17.

Description

Small nematodes; cervical cuticle inflated in oesophageal region, inflation originating at level of peri-oral cuticle; transverse cuticular annulations prominent. Sub-median papillae elongate, 0.011 long, projecting anteriorly from peri-oral cuticle; proximal segment cylindrical, 0.005 long, almost as long as ovoid, distal segment, 0.006 long. Buccal capsule shallow, cylindrical, symmetrical in dorsoventral views, dorsoventrally elongate in apical



Figs 44-54. *Cloacina sciron* sp. nov. 44. Anterior end, lateral view of ♂. 45. Cephalic extremity, lateral view, dorsal aspect on right hand side. 46. Cephalic extremity, dorsal view. 47. Cephalic extremity, apical view. 48. Optical transverse section through buccal capsule. 49. Spicule tip, lateral view. 50. Oesophageal denticle, lateral view. 51. Gubernaculum and genital cone, ventral view. 52. Bursa, apical view. 53. Female tail, lateral view. 54. Ovejector and vagina, lateral view. Scale bars = 0.1 mm, 44, 52-54; 0.01 mm 45-51.

view; anterior margin of buccal capsule arched anteriorly in lateral views. Eight leaf crown elements, with faint striations, arising from full length of internal wall of buccal capsule, not recurved at tips. Peri-oral cuticle not inflated into lip like lobes attached to each leaf crown element. Dorsal oesophageal tooth absent. Oesophagus simple, elongate, claviform; lining unornamented; single dorsal denticle present in mid-region of oesophagus. Nerve ring in mid-oesophageal region; deirids at level of nerve ring; S-E pore anterior to oesophago-intestinal junction.

Male (Measurements from 10 specimens, types) (Figs 49, 51, 52)

Total length 4.0-6.1 (4.5); maximum width 0.26-0.36 (0.32); dimensions of buccal capsule 0.008-0.010 (0.009) x 0.040-0.045 (0.043); oesophagus 0.45-0.51 (0.48); nerve ring to anterior end 0.24-0.27 (0.25); S-E pore to anterior end 0.37-0.50 (0.45); deirids to anterior end 0.27-0.35 (0.30). Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral and ventral lobes joined. Dorsal lobe similar in length to lateral lobes. Dorsal ray stout at origin, trunk long, divides at ⅔ length; secondary subdivisions arise after primary division; internal branchlets directed posteriorly, almost reaching margin of bursa; external branchlets as long as internals, directed posterolaterally, not reaching margin of bursa. Externodorsal ray arising close to lateral rays, not reaching margin of bursa. Posterolateral and ventrolateral rays apposed, reaching margin of bursa; anterolateral ray divergent, shorter than other lateral rays, not reaching margin of bursa; ventrolateral and ventroventral rays apposed, reaching margin of bursa. Gubernaculum subtriangular, 0.02 (0.02) long; central cordate and paired lateral thickenings of spicule sheaths present; genital cone with prominent anterior lip; posterior lip shorter than anterior, with pair of dome shaped papillae; pair of lateral inflations of cuticle present on either side of anterior lip; spicules elongate, 2.83-3.30 (3.00) long, alate, tip simple, recurved; ala diminishing in width gradually towards tip.

Female (Measurements from 10 specimens, types) (Figs 53, 54)

Total length 3.7-6.8 (4.8); maximum width 0.17-0.36 (0.31); dimensions of buccal capsule 0.010-0.013 (0.012) x 0.040-0.045 (0.044); oesophagus 0.44-0.55 (0.49); nerve ring to anterior end 0.24-0.27 (0.26); S-E pore to anterior end 0.38-0.57 (0.45); deirids to anterior end 0.25-0.38 (0.29). Tail simple, conical, 0.14-0.22 (0.18) long; vulva close to anus, 0.20-0.39 (0.29) from posterior end; vagina slightly sinuous, 0.78-1.10 (0.88) long; ovejector J-shaped, infundibulum as long as sphincter; egg ellipsoidal, 0.075-0.080 (0.079) x 0.040-0.045 (0.044).

Etymology

Sciron, an Epicurean philosopher.

Remarks

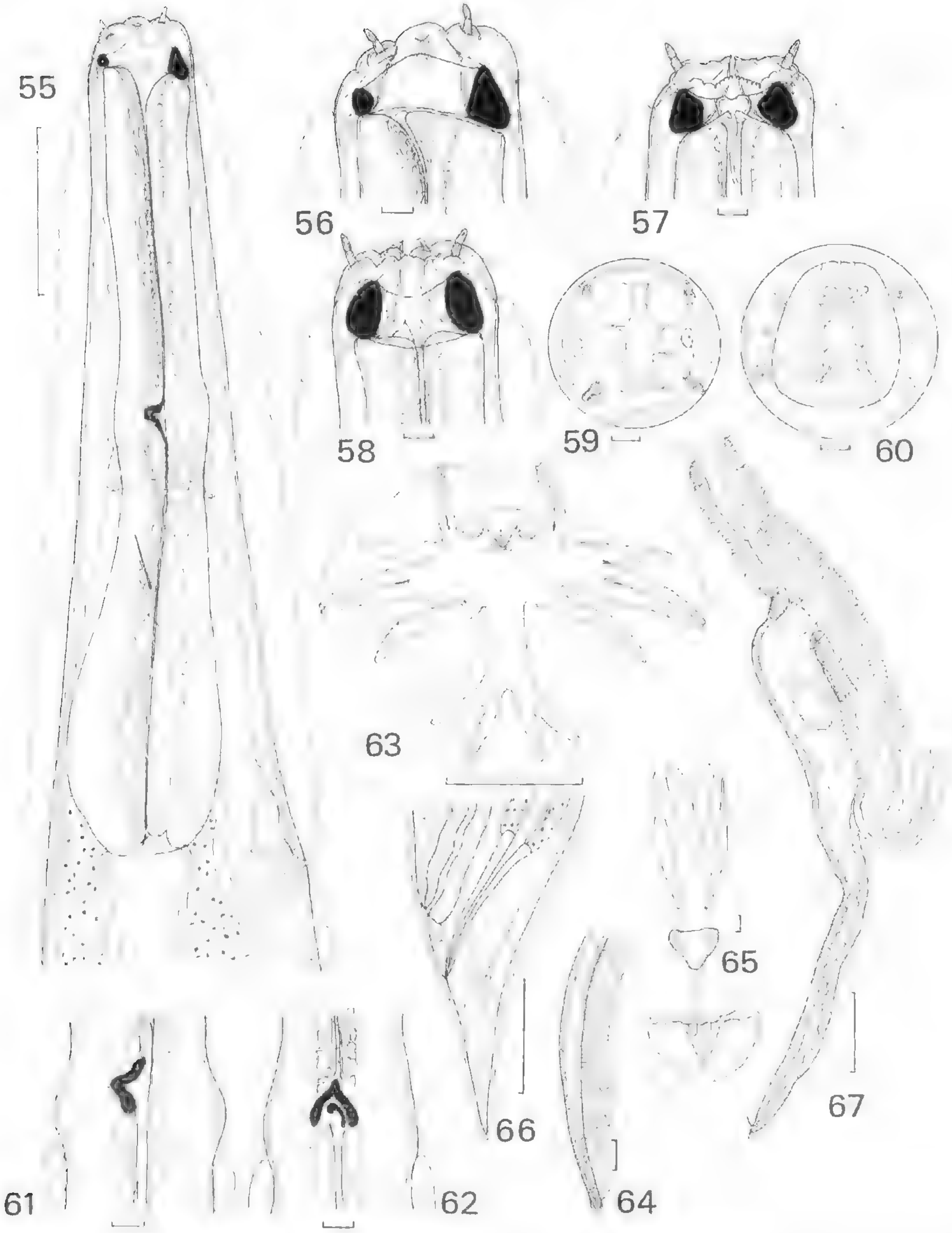
Cloacina sciron is characterised by a simple, clavate oesophagus with a dorsal denticle at the level of the nerve ring, the deirid at the level of the nerve ring, a cervical cuticular inflation and eight leaf crown elements. Species which most closely resemble *C. sciron* in possessing an unornamented oesophagus and a single dorsal oesophageal denticle are: *C. cornuta* (Davey & Wood, 1938), *C. dindymene* Beveridge, 1998, *C. dirce* Beveridge, 1998 and *C. longispiculata* Johnston & Mawson, 1939. *Cloacina cornuta* differs from *C. sciron* in having a prominent dorsal oesophageal tooth, *C. dindymene* and *C. dirce* have eight leaf crown elements, the deirid is in the anterior region of the oesophagus and, in addition, *C. dirce* has lips. *Cloacina longispiculata* has a cervical cuticular inflation which terminates posterior to the level seen in *C. sciron*, has an anteriorly placed deirid, the S-E pore lies posterior to the oesophago-intestinal junction and the female tail is blunt with a distinctive sinuous and slightly recurrent vagina.

Cloacina sterope sp. nov
(FIGS 55-67)

Types: Holotype ♂ from stomach of *Dorcopsulus vanheurni*, Doido, Papua New Guinea, 17.v.1984, coll. R. Speare, SAMA AHC 31191; allotype ♀, same data, SAMA AHC 31192; paratypes: 8 ♂♂, 4 ♀♀, SAMA AHC 31193; 1 ♂, BMNH 1998.9.28.20

Description

Small nematodes; cervical cuticle slightly inflated in oesophageal region; transverse cuticular annulations prominent. Sub-median papillae small, 0.010 long, projecting anteriorly from peri-oral cuticle; proximal segment cylindrical, 0.005 long, as long as ovoid, acute distal segment, 0.005 long. Buccal capsule shallow, cylindrical, asymmetrical in lateral views, with ventral wall of buccal capsule much thicker than dorsal wall; buccal capsule dorsoventrally elongate in apical view; anterior margin of buccal capsule bowed anteriorly in lateral view, concave in dorsal and ventral view. Eight leaf crown elements, arising from full length of internal wall of buccal capsule, not recurved at tips. Peri-oral cuticle not inflated into lip-like lobes attached to each leaf crown element. Dorsal oesophageal tooth projecting prominently into buccal capsule; each sub-ventral sector of oesophagus with lancet-like tooth projecting into buccal capsule. Oesophagus



Figs 55-67. *Cloacina sterope* sp. nov. 55. Anterior end, lateral view of ♂. 56. Cephalic extremity, lateral view, dorsal aspect on left hand side. 57. Cephalic extremity, dorsal view. 58. Cephalic extremity, ventral view. 59. Cephalic extremity, apical view. 60. Optical transverse section through buccal capsule. 61. Oesophageal denticle, lateral view, dorsal aspect on left hand side. 62. Oesophageal denticle, dorsal view. 63. Bursa, apical view. 64. Spicule tip, lateral view. 65. Gubernaculum, genital cone and thickenings of spicule sheaths, ventral view. 66. Female tail, lateral view. 67. Ovejector and vagina, lateral view. Scale bars = 0.1 mm 55, 63, 66, 67; 0.01 mm, 56-62, 64, 65.

simple, claviform, with slight preneural swelling; lining ornamented with rows of sclerotised bosses extending from anterior end to nerve ring; single dorsal oesophageal denticle immediately anterior to nerve ring. Nerve ring in mid-oesophageal region; deirids immediately posterior to nerve ring. S-E pore at level of oesophago-intestinal junction.

Male (Measurements from 10 specimens, types) (Figs 63-65)

Total length 3.5-6.0 (4.8); maximum width 0.16-0.37 (0.29); dimensions of buccal capsule 0.015-0.023 (0.020) x 0.048-0.055 (0.053); oesophagus 0.39-0.49 (0.45); nerve ring to anterior end 0.23-0.27 (0.25), S-E pore to anterior end 0.42-0.52 (0.46); deirids to anterior end 0.28-0.37 (0.31). Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral and ventral lobes joined. Dorsal lobe similar in length to lateral lobes. Dorsal ray divides just after midlength; secondary subdivisions immediately after primary division; internal branchlets directed posteriorly, not reaching margin of bursa; external branchlets as long as internals, directed posterolaterally, not reaching margin of bursa. Externodorsal ray arising close to lateral rays, not reaching margin of bursa. Posterolateral and ventrolateral rays apposed, reaching margin of bursa; anterolateral ray divergent, shorter than other lateral rays, not reaching margin of bursa; ventrolateral and ventroventral rays apposed, reaching margin of bursa. Gubernaculum broadly triangular, 0.020-0.030 (0.026) long; central cordate and paired lateral thickenings of spicule sheaths present; genital cone with prominent anterior lip; posterior lip shorter than anterior, with pair of dome shaped papillae; pair of lateral inflations of cuticle present on either side of anterior lip; spicules elongate, 1.67-2.07 (1.96) long, alate, tip simple; ala diminishing in width gradually then ending abruptly at tip

Female (Measurements from 5 specimens, types) (Figs 66, 67)

Total length 4.2-5.5 (4.4); maximum width 0.32-0.43 (0.38), dimensions of buccal capsule 0.015-0.020 (0.018) x 0.053-0.065 (0.062); oesophagus 0.46-0.52 (0.50); nerve ring to anterior end 0.23-0.26 (0.25); S-E pore to anterior end 0.35-0.46 (0.42); deirids to anterior end 0.28-0.30 (0.29). Tail simple, conical, 0.15-0.20 (0.19) long; vulva close to anus, 0.20-0.34 (0.30) from posterior end; vagina straight, 0.69-0.88 (0.72) long; ovejector J-shaped, infundibulum longer than sphincter; egg ellipsoidal, 0.06-0.09 (0.08) x 0.03-0.04 (0.04).

Etymology

Sterope, one of the Pleiades.

Remarks

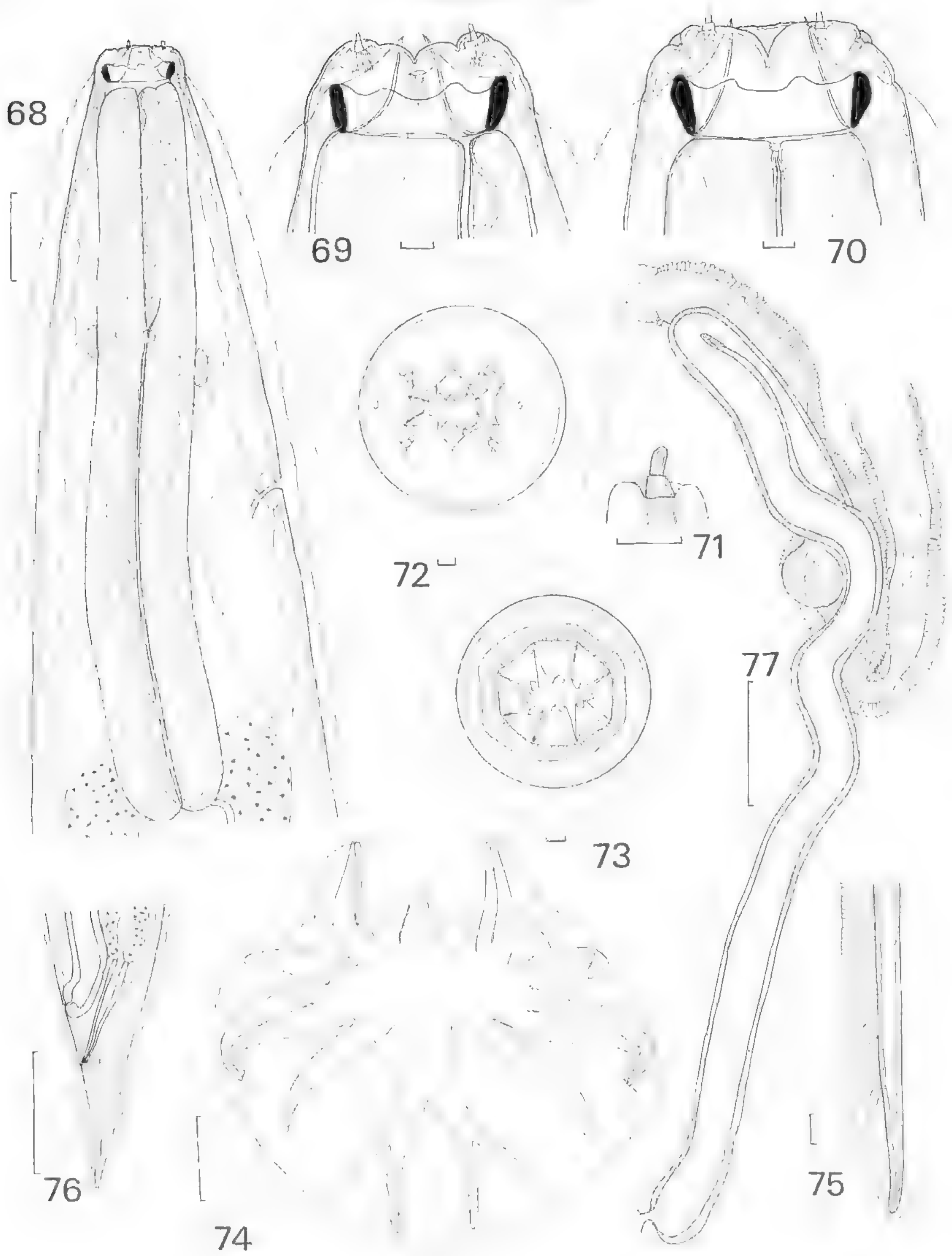
Cloacina sterope is characterised by a buccal capsule which is asymmetrical in lateral view, bosses lining the anterior half of the oesophageal lumen, a single dorsal oesophageal denticle, eight leaf crown elements and the deirids immediately posterior to the nerve ring. Of the species related to *C. sterope*, *C. antigone* Beveridge, 1998 differs in possessing an anteriorly placed deirid, a sinuous vagina and a cervical cuticular inflation. *C. australis* (Yorke & Maplestone, 1926) differs in possessing an anteriorly placed deirid, a sinuous vagina and large bosses at the anterior extremity of the oesophagus. *C. dis* Beveridge, 1998 differs in its anteriorly placed deirid, a spirally arranged vagina and submedian papillae with a very short distal segment. *C. eileithyia* Beveridge, 1998 differs in the shape of the buccal capsule wall and in number of leaf crown elements. *C. hecuba* Beveridge, 1998 differs in the anterior position of the deirid and the convoluted vagina, *C. io* Beveridge, 1998 in the anterior position of the deirids and the slender distal segment to the submedian papilla, *C. leto* Beveridge, 1998 in the anterior deirids, the shape of the dorsal oesophageal tooth and the elongate, convoluted vagina, *C. minor* (Davey & Wood, 1938) in the anterior deirid and the shape of the dorsal ray, *C. papillata* Beveridge, 1979 in the presence of six leaf crown elements, cephalic papillae with a short distal segment and a recurrent vagina, *C. polyxena* Beveridge, 1998 in the anterior position of the deirid, the shape of the buccal capsule in dorsal view with its anterior loop over the dorsal oesophageal tooth and the extremely short vagina and *C. tyro* Beveridge, 1998 in the anterior deirid, the lack of sub-ventral oesophageal teeth and the sinuous vagina

Cloacina solymus sp. nov.
(FIGS 68-77)

Types: Holotype ♂ from stomach of *Dorcopsulus vanheurni*, Dodo, Papua New Guinea, 17.v.1981, coll. R. Speare, SAMA AHC 31197; allotype ♀, same data, SAMA AHC 31198.

Description

Small nematodes; cervical cuticle not inflated in oesophageal region; transverse cuticular annulations prominent. Sub-median papillae very small, 0.009 long, projecting anteriorly from slight depressions in the peri-oral cuticle; proximal segment cylindrical, short, 0.004 long, slightly shorter but wider than ovoid, distal segment, 0.005 long. Buccal capsule shallow, cylindrical, symmetrical in lateral and dorsal views, roughly octagonal in apical view; anterior margin of buccal capsule regularly sinuous



Figs 68-77. *Cloacina solymus* sp. nov. 68. Anterior end, lateral view of ♂. 69. Cephalic extremity, lateral view, dorsal aspect on right hand side. 70. Cephalic extremity, dorsal view. 71. Submedian cephalic papilla. 72. Cephalic extremity, apical view. 73. Optical transverse section through buccal capsule. 74. Bursa, apical view. 75. Spicule tip, lateral view. 76. Female tail, lateral view. 77. Ovejector and vagina, lateral view. Scale bars = 0.1 mm, 68, 74, 76, 77; 0.01 mm, 69-73, 75.

with anterior projection immediately posterior to each submedian papilla. Eight leaf crown elements, arising from full length of internal wall of buccal capsule, not recurved at tips. Peri-oral cuticle not inflated into lip-like lobes attached to each leaf crown element. Oesophagus simple, of almost uniform width; lining unornamented; denticles absent. Nerve ring in mid-oesophageal region; deirids at level of nerve ring; S-E pore anterior to oesophago-intestinal junction.

Male (Measurements from 2 specimens, types) (Figs 74, 75)

Total length 7.8, 8.6; maximum width 0.54, 0.55; dimensions of buccal capsule 0.020, 0.023 x 0.085, 0.085; oesophagus 0.85, 0.89; nerve ring to anterior end 0.34, 0.37; S-E pore to anterior end 0.55, 0.62; deirids to anterior end 0.34, 0.43. Bursa without prominent divisions between lobes. Ventral lobes joined ventrally; lateral and ventral lobes joined. Dorsal lobe similar in length to lateral lobes. Dorsal ray divides at midlength; secondary subdivisions at ¾ length; internal branchlets directed posteriorly, not reaching margin of bursa; external branchlets shorter than internals, directed posterolaterally, not reaching margin of bursa. Externodorsal ray arising close to lateral rays, not reaching margin of bursa. Posterolateral and ventrolateral rays apposed, reaching margin of bursa; anterolateral ray divergent, shorter than other lateral rays, not reaching margin of bursa; ventrolateral and ventroventral rays apposed, reaching margin of bursa. Genital cone with prominent anterior lip; pair of lateral inflations of cuticle present on either side of anterior lip; spicules elongate, 3.76, 3.79 long, alate, tip simple; ala diminishing in width gradually towards tip.

Female (Measurements from allotype) (Figs 76, 77)

Total length 5.0; maximum width 0.32; dimensions of buccal capsule 0.023 x 0.080; oesophagus 0.80; nerve ring to anterior end 0.30; S-E pore to anterior end 0.46; deirids to anterior end 0.28. Tail simple, conical, 0.20 long; vulva close to anus, 0.29 from posterior end; vagina recurrent, 1.08 long; ovejector J- shaped, infundibulum longer than sphincter; egg not seen.

Etymology

Solymus, a Trojan, the mythical founder of Solmo.

Remarks

Although only a small series of specimens was available for examination, *C. solymus* is a distinctive new species. It is characterised by a simple, unornamented oesophagus, symmetrical buccal capsule with a sinuous anterior margin, small cephalic papillae, deirid at the level of the nerve ring and a recurrent vagina. Congeners with symmetrical buccal capsules and prominent anterior lobes are *C. artemis*, *C. hebe*, *C. hypsipyle*, *C. linstowi*, *C. thetidis* and *C. wallabiae*. The distal segments of the cephalic papillae in *C. hebe*, *C. hypsipyle*, *C. linstowi* and *C. thetidis* are much larger than the proximal segments and are obtuse at their tips rather than being small and narrower than the proximal segment as occurs in *C. solymus*, while *C. artemis* and *C. wallabiae* have lip-like expansions of the cephalic cuticle attached to each leaf crown element which are lacking in *C. solymus*.

Cloacina solymus also resembles *C. syphax*, *C. solon* and *C. sappho*, which occur in the same host, in the shape of the buccal capsule, but differs from these species in having very small submedian cephalic papillae.

Cloacina spp.

Additional undescribed species of *Cloacina* were present in the stomachs of the wallabies examined but were represented by single specimens only. Description of these species will have to await the collection of new material. The specimens have been deposited in SAMA (AHC 31182-5).

Discussion

The descriptions of new species presented here indicate that *Dorcopsulus vanheurni* habours a diverse array of species of *Cloacina*. Only four animals were available for examination but the above findings suggest that collection of additional wallabies will reveal an even greater variety of nematodes. The helminths of macropodid marsupials from Papua New Guinea are poorly known with most available records (Spratt *et al*. 1991; Flannery *et al*. 1996) being based on the examination of a limited series of helminths collected from one or two host specimens.

The entire series of *Cloacina* spp. found in *D. vanheurni* is new and demonstrates a mixture of affinities with subgroupings within the genus. *Cloacina sterope*, characterised by an asymmetrical buccal capsule and an oesophagus lined with bosses, has affinities with a series of other species (*C. antigone*, *C. australis*, *C. dis*, *C. eileithyia*, *C. hecuba*, *C. io*, *C. leto*, *C. minor*, *C. papillata*, *C. polyxena* and *C. tyro*) which occur in a range of species of macropodids (*Macropus agilis* (Gould, 1842), *M. dorsalis* (Gray, 1837), *M. giganteus* Shaw, 1790), *M. robustus* Gould, 1841), *Wallabia bicolor* (Desmarest, 1804)) in Australia (Beveridge 1998).

Cloacina sciron, by contrast, is characterised by a simple, unornamented oesophagus and a single dorsal denticle. It therefore resembles a different series of species (*C. cornuta, C. dindymene, C. dirce* and *C. longispiculata*) again parasitic in macropodids (*Macropus agilis, M. robustus, M. antilopinus* (Gould, 1842)) in northern Australia (Beveridge 1998) while *C. sancus* has affinities with *C. bancroftorum* occurring in *M. dorsalis* in northeastern Australia.

The series of new species, *C. syphax, C. solon, C. sappho* and *C. solymus*, is characterised by a simple, unornamented oesophagus, lack of lips and a symmetrical buccal capsule with a sinuous anterior margin. While a parallel series of species (*C. hebe, C. hypsipyle, C. linstowi, C. thetidis*) occurs in *M. dorsalis* in Australia with similarly sinuous buccal capsule margins, the new species from Papua New Guinea are distinct in possessing eight leaf crown elements rather than six and in having the deirid either at the level of the nerve ring or just anterior to it rather than in the anterior oesophageal region. In spite of these similarities, *C. syphax, C. solon, C. sappho* and *C. solymus* differ markedly in the shape of their cephalic papillae and the branching pattern of their dorsal rays. By contrast, *C. hebe, C. hypsipyle, C. linstowi*, and *C. thetidis* all have similar, distally obtuse cephalic papillae. The evidence available therefore suggests that the series of species *C. syphax, C. solon, C. sappho* and *C. solymus*, described here, may represent a unique subgrouping within the genus restricted to a single host species. This hypothesis remains to be tested both by more detailed anatomical comparisons of the as yet undescibed species of *Cloacina* present in *D. vanheurni* and by more extensive collecting from related host species in Papua New Guinea.

Acknowledgments

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FOSSIL TURTLES FROM THE EARLY PLIOCENE BLUFF DOWNS LOCAL FAUNA, WITH A DESCRIPTION OF A NEW SPECIES OF ELSEYA

By Scott A. Thomson & Brian S. Mackness†*

Summary

Thomson, S. A. & Mackness, B. S. (1999) Fossil turtles from the Early Pliocene Bluff Downs Local Fauna, with a description of a new species of Elseya. Trans. R. Soc. S. Aust. 123(3), 101-105, 30 November, 1999.

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Key Words: Pliocene, Bluff Downs Local Fauna, chelids, Emydura, Chelodina, Elseya, turtles.

Transactions of the Royal Society of S. Aust. (1999), **123**(3), 101-105.

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by SCOTT A. THOMSON[*] & BRIAN S. MACKNESS[†]

Summary

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KEY WORDS: Pliocene, Bluff Downs Local Fauna, chelids, *Emydura*, *Chelodina*, *Elseya*, turtles.

Introduction

Australian chelid turtle taxonomy is poorly known and much in need of review (Cogger *et al.* 1983; Thomson *et al.* 1997). Electrophoretic surveys have revealed that in some instances, currently accepted species boundaries are difficult to justify and what are currently regarded as single species are in fact two or more species (Georges & Adams 1992, 1996).

The detailed morphological analysis required to verify these findings has not been completed (Thomson & Georges, 1996; Thomson *et al.* 1997), and until recently it was not possible to distinguish even between extant short-necked genera on the basis of osteological characters (Gaffney 1977). The poor knowledge of osteological characters suitable for distinguishing the genera of extant forms makes the identification of fossils, many incomplete, difficult (Thomson *et al.* 1997). In many instances, chelid fossils have been assigned to either *Chelodina* or *Emydura*, with little or no evidence presented to eliminate the possibility that the short-necked forms among them may be *Elseya*, *Rheodytes* or *Elusor*.

Materials and Methods

Specimens of the chelid turtle species identified using electrophoresis by Georges & Adams (1996) were obtained from museums, the Conservation Commission of the Northern Territory and the University of Canberra. Where possible, the voucher specimens of Georges & Adams (1992, 1996) were utilized to avoid incorrect identification. The specimen collection was supplemented by limited field sampling. All specimens were skeletonised and assessed by methods outlined in Thomson *et al.* (1997).

The fossil specimens from Bluff Downs were collected as part of an on-going study of the palaeoecology of the Bluff Downs Local Fauna by one of the authors (BM). Specimens will be deposited in the Queensland Museum. Each was examined to determine the presence of character states for the characters identified as being diagnostic at the level of genus for extant taxa. The fossil specimens were then assigned to genus. Throughout this paper, names of the bony elements of the shell and the overlying scutes follow those of Zangerl (1969) except that we follow Pritchard & Trebbau (1984) and recognize the term pleural as referring to the bones of the carapace rather than the scutes. Additional terminology referring to the anterior bridge struts of the plastron and the bridge strut suture of the carapace follows Thomson *et al.* (1997).

Five characters were identified as diagnostic at generic level. Where polarity is indicated, it was determined by comparison with South American chelids and African pelomedusids in a cladistic analysis to be presented elsewhere (Thomson & Georges unpub.). Only those characters relevant to the identification of the fossil specimen are presented.

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Anterior bridge struts

Character A. Contact with pleural 1

A0: In the primitive state, the posterior edge of the bridge-carapace suture runs parallel and adjacent to the rib/gomphosis of pleural 1.

A1: In the derived state, the posterior edge of this suture contacts the rib/gomphosis at its anterior end but is set at a forward divergent angle of between 15° and 50°. This angle is most pronounced in *Emydura*, least in *Rheodytes*.

Character B. Bridge suture shape.

B1: The anterior and posterior edges of the bridge-carapace suture diverge from their point of congruence closest to the vertebral column. The widest extent of the suture is distal to the vertebral column and there is no medial constriction.

B2: The anterior and posterior edges of the bridge-carapace suture are parallel or closely so with a prominent suture surface between them. There is no medial constriction.

B3: The bridge-carapace suture is expanded for its full length but more so at extremes, there being an obvious medial constriction.

B4: The bridge-carapace suture narrows from its widest point proximal to the vertebral column and constricts completely to form a ridge confluent with the edge formed by the ventral suture of the peripheral bones.

Rib/gomphosis of pleural 1

Character C. Rotation of the rib/gomphosis.

C0: The ventral surface of the distal extent of the rib/gomphosis is rotated obliquely, to face ventrally but with posterior inflection.

C1: The rib/gomphosis shows no such torsion distally.

Dorsal characters

Character D. Relative width of Vertebral 1

D1: First three vertebral scutes equal or sub-equal in width.

D2: First vertebral scute wider than second and third.

Character E. Cervical Scute

E0: Cervical scute typically present.

E1: Cervical scute typically absent.

Posterior internal carapace characters

Character F. Carapace Pelvis Suture

F0: Ilium sutures to the seventh and eighth pleurals and the pygal.

F1: Ilium sutures to the eighth pleural and pygal only but is directly adjacent to the suture between the seventh and eighth pleurals.

F2: Ilium sutures to the eighth pleural and pygal only but is widely separated from the suture between the seventh and eighth pleural.

Comparative material

All names used for undescribed species are from Georges & Adams (1992, 1996) with modifications from Thomson *et al.* (1997). Abbreviations used: AM, Australian Museum; NTM, Museum and Art Galleries of the Northern Territory; QM, Queensland Museum; WAM, Western Australian Museum; UC University of Canberra; UM, University of Michigan Field Series; UU, University of Utah.

Elusor macrurus: UC 0184-93, 0225-29 UU 19488, 19508; *Elseya dentata*: NTM 13319, 13521, 16330, QM 59265, 59277-80, UC 0307-18; *Elseya georgesi*: AM 138387-88, UM 02016-17; *Elseya irwini*: ANWC 0520; *Elseya lavarackorum*: QM F24121, QMJ 31939, 31942, 31944, 31946-47, 31949-50 31952, 46284, 47908, 47911, 48544, 48547, 60255, UC0201; *Elseya latisternum*: AM 123037, 123039, 125474-75, QM 48054-55; *Elseya novaeguineae*: AM 42662, 125038; *Elseya purvisi*: AM 123040, 123042, QM 59289-90; *Emydura macquarii*: QM 48016, 48034, 48050-51, 59275-76, UC 0175-76, 0303; *Emydura subglobosa*: NTM 5028, 8206, 13428, 13433, 16332, UC 0171-72, 0177; *Emydura tanybaraga*: AM 125470-71, 125491, NTM 8211 8213, 17339, *Emydura victoriae* NTM 13513-14, 32917, 32976, UC 0165; *Elseya* sp. aff. *E. dentata* (South Alligator): AM 128002, 128004, QM 59285-89, NTM 5097, 13512, 13985, UC 0304; *Elseya* sp. aff *E. latisternum* (Gwyder): *Elseya* sp. aff. *E. lavarackorum* (Burnett) UC 0305-6, QM 2966, 28449, 36036, 36039, 36041-42, 36044-47, 37933, 38533, 59269-71; *Elseya* sp. aff. *E. lavarackorum* (Johnstone): QM 22694, 23175, 23299, 23300, 23322, 24938, 28449, 48060, 48068, AM 123028-29, QM 48028, 48038; *Pseudemydura umbrina*: UC 0178 WAM 29337; *Rheodytes leukops*: UC 0173.

Systematics

Order Testudines Linnaeus, 1758
Suborder Pleurodira Cope, 1864
Family Chelidae Ogilby, 1905

Elseya nadibajagu sp. nov.
(FIG. 1)

Holotype: QM F30576, a partially articulated carapace and associated plastron collected by H. Godthelp during the 1992 Field Season, Upper Andrews Quarry.

Referred specimens: QM F30577 also collected at the same site.

Type Locality

Upper Andrews Quarry (19° 43′ S, 145° 36′ E) Allingham Formation, Bluff Downs, Bluff Downs

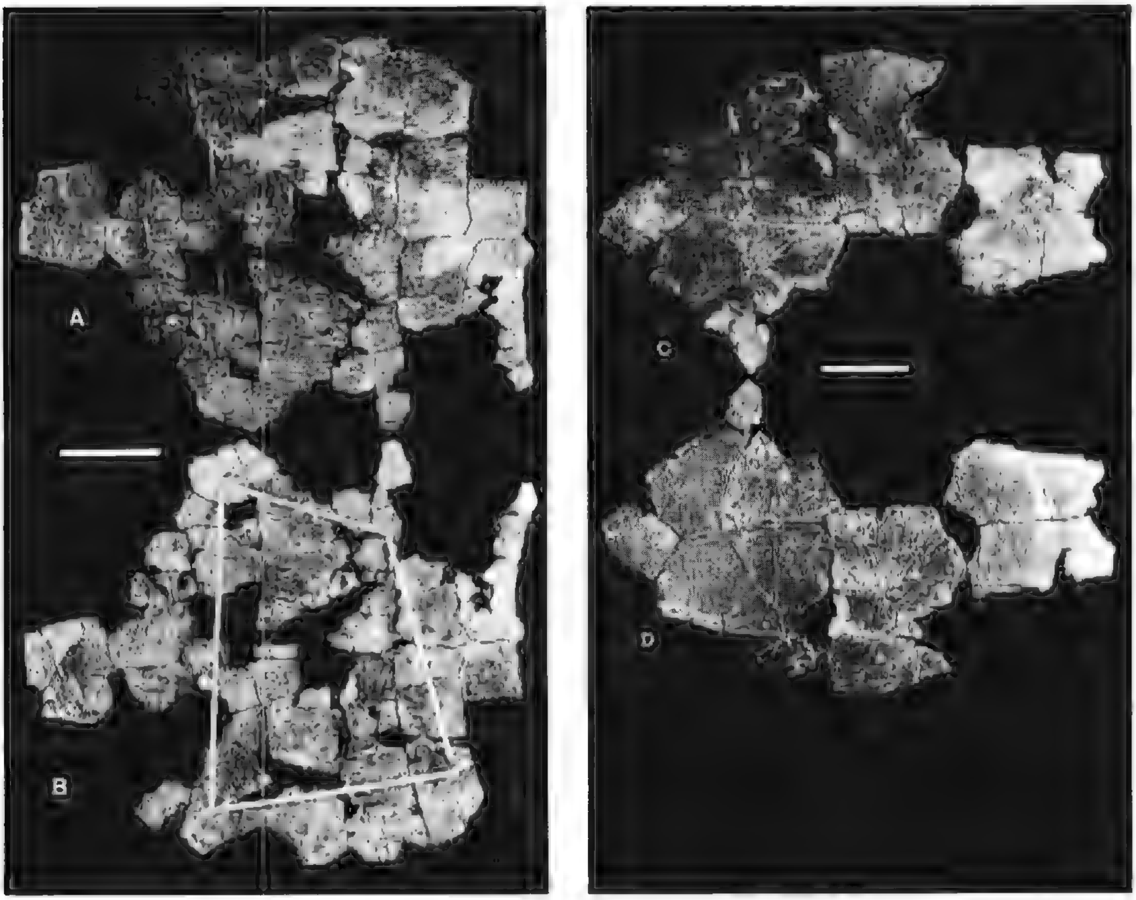

Fig. 1. Holotype of *Elseya nadibajagu* sp. nov. (A). External view of carapace. (B). Internal view of carapace. (C). Internal view of plastron. (D). External view of plastron. Scale bars = 5 cm.

Station, north-eastern Queensland. The Allingham Formation was named by Archer & Wade (1976) for a sequence of terrigenous clays, silts, sands and calcareous sands that outcrop on Bluff Downs Station, along the banks of the Allingham Creek, a tributary of the Burdekin River. Several different quarries have been established to exploit these outcrops, all showing a similar and contiguous stratigraphy (BM unpub.). The sediments recovered are fluviatile and lacustrine in nature and represent a number of depositional events.

Age

Early Pliocene, based on the radiometrically dated age of the overlying basalts (Archer & Wade 1976; Mackness *et al*. in press)

Diagnosis

The fossil is identified as an *Elseya* by the presence of steeply angled bridge struts, features diagnostic of *Elseya* sensu stricto. (Thomson *et al*. 1997; Thomson in press) and *Emydura*. The carapacial sutures for these struts are wide throughout their length, which is diagnostic of the *Elseya lavarackorum* group within this genus (Thomson *et al*. 1997). Other diagnostic features include the first vertebral scute being wider than the second and third and the absence of a cervical scute (Thomson *et al*. 1997; Thomson in press).

Within *Elseya*, this species is most similar to *E. irwini* (Cann, 1998) from the Burdekin River but can be distinguished from it by the close encroachment of the ilium suture to the seventh pleural. In *E. irwini* the suture is widely spaced as is typical of *Elseya* but in *E. nadibajagu* they are extremely close, almost approaching the *Emydura* condition in this character.

Description

Carapace consists of a complete nuchal bone with no cervical scute present. The left pleural one is more complete than the right and the anterior bridge strut has a wide sutural surface between parallel anterior and posterior edges of the suture throughout its length, which is preserved. The suture is deeply inserted into the carapace and angled sharply away from the rib/gomphosis. The sulci preserved in this region indicate that the first vertebral scute was wider than the second and third.

Pleurals two to six are partially preserved on either side but without their peripheral contacts. Also preserved as an unarticulated unit is the left eighth peripheral. The anterior sutural surface for the ilium is clearly constrained to this unit and does not extend on to, or make sutural contact with, the seventh pleural. It does however, continue on to the pygal in the posterior, the typical condition of the Chelidae.

All the units are represented in the plastron except the epiplastra, which are either both missing or not identifiable among the fragments. Included here also are both bridge struts. The bridge struts are wide throughout the length at the sutural surface where they contact the carapace. The plastral elements, both in sulci and bony elements, are similar in form to any extant member of the *Elseya lavarackorum* group.

Etymology

The specific epithet is from the Gugu-Yalanji dialect phrase *nadi bajagu*, meaning 'very long time ago' (Oates *et al.* 1964) and is used to denote the significant age of the fossil. The name is of neuter gender.

Chelodina sp.

Material examined: QM F30578, an isolated nuchal bone from a long-necked turtle of the *Chelodina longicollis* group.

Remarks

This specimen can be diagnosed by the extreme widening of the posterior half of the nuchal bone as well as the wide, square cervical scute. There is also a large series of muscle attachments for the muscles at the base of the neck which, by necessity, are enlarged in the long-necked turtles (Thomson & Georges 1996). The placement within the *C. longicollis* group is based on the sculptured surface of the shell, a feature more prevalent in species such as *C. longicollis* and *C. novaeguineae* than in members of the *C. expansa* group. This is, however, a highly variable character and probably of poor taxonomic value (Gaffney 1981; Thomson in press).

Emydura macquarii

Material examined: QM F 30579, a series of pleurals all diagnostic of the genus *Emydura* using the bridge strut characters of Thomson *et al.* (1997).

Remarks

None of the pleurals is distinguishable from those of extant species in the area, *Emydura macquarii* (= *E. krefftii*, Georges & Adams 1996) and we therefore take the most parsimonious view and assign the fossil to the living species which is found in Allingham Creek today.

Discussion

The living species that most closely resembles *Elseya nadibajagu* sp. nov. is *E. irwini* described by Cann (1998) on the basis of its head colour. Georges & Adams (1996) have confirmed the validity of *E. irwini* on the basis of electrophoretic studies. Both of these taxonomic indicators (head colour and biochemistry) have not been preserved in the fossil material. The use of osteological characters, such as the position of the ilium/carapace suture, has enabled the separation of *E. nadibajagu* from other members of the genus *Elseya*. There is a possibility, however, that this character may be subject to a lot more variation than can be seen in the limited sample of both *E. irwini* and *E. nadibajagu*, although analyses of variation present in other members of the genus makes this unlikely. Reptiles have a lower rate of species turnover than their mammalian counterparts with many extant species having fossil records stretching back millions of years (La Duke 1991).

White & Archer (1994) described the fossil chelid *Emydura lavarackorum* from the Pleistocene deposits of Riversleigh and living examples were described just three years later (Thomson *et al.* 1977).

The occurrence of three different chelid taxa from Bluff Downs is not unusual with tropical river systems having four or more different genera in the one region (Legler & Georges 1993). There have been five different turtles recorded for the Burdekin (Cann 1998) including three short-necked and two long-necked taxa.

The palaeoenvironment of the Bluff Downs local fauna has been interpreted as being similar to that in present day Kakadu (Boles & Mackness 1994) with avian species such as darters and pygmy-geese indicating permanent water bodies (Mackness 1995). There may have also been riparian rainforest or vine thickets (Mackness unpub.). Fossils of short-necked chelids dominate the Bluff Downs fauna at the time of preservation, indicating a Pliocene palaeoenvironment with well developed rivers, creeks and lagoons and abundant aquatic fauna (Cann 1978; Legler 1985). The long-necked tortoises indicate that at the same time, there may have been shallow turbid lagoons (White 1997).

Acknowledgments

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THE SWELL CLIMATE OF THE SOUTH AUSTRALIAN SEA

By M. A. Hemer & J. A. T. Bye**

Summary

Hemer, M. A. & Bye, J. A. T. (1999) The Swell Climate of the South Australian Sea. Trans. R. Soc. S. Aust. 123(3), 107-113, 30 November, 1999.

The Southern Ocean swell continually impinges on South Australian coastal waters. In this study we present simple formulae which predict the swell height at several locations in the South Australian Sea from swell height data in the open sea south of Eyre Peninsula, which are available in real time from the Bureau of Meteorology. The predictions are based on the state of the art wave model SWAN, and indicate that the major factor which determines the coastal swell climate is the direction of approach of the open ocean swell. From these predictions, bottom orbital currents can be computed, which are a fundamental factor in the marine ecology of the South Australian Sea. The formulae can also be used (at own risk) on a routine basis by mariners and surfers.

Key Words: Swell, marine ecology, South Australia.

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Introduction

The swell generated in the Southern Ocean south west of Australia has been recorded to be the largest of any in the world's oceans (Chelton *et al.* 1981). However, the swell in the semi-enclosed waters of South Australia is generally considered insignificant. This transition between the open ocean and coastal waters controls many aspects of the South Australian marine environment. The seasonal rhythm for the swells is a reliable signal on which the marine ecology of the surf zone depends. Southern Ocean storms also from time to time produce exceptional swell events which ventilate the interior of the coastal seas by the intensity of the bottom orbital currents that they generate. This study shows that the effects of swell can be reliably estimated, and provides a simple predictive formula which can be used by ecologists to classify marine environments and also by mariners and surfers to make real time forecasts for a specified coastal location. Specifically, we investigate the swell energy band as it propagates from the open ocean south of South Australia (Fig. 1(a)) into the South Australian Sea (Fig. 1(b)), which comprises (Bye 1976) the semi-enclosed waters of Spencer Gulf, Gulf St Vincent, Investigator Strait, Backstairs Passage and Encounter Bay, extending out over the continental shelf to the 200 m contour, bounded to the west by Cape Carnot and on the east by Cape Jaffa (Fig. 2).

Fig. 1(a). Example of open ocean swell observed in the Southern Ocean, from RV Southern Surveyor (photograph: CSIRO Marine Laboratories, Hobart)

Fig. 1(b). Example of swell approaching the beach, West Bay, Kangaroo Island in February 1998.

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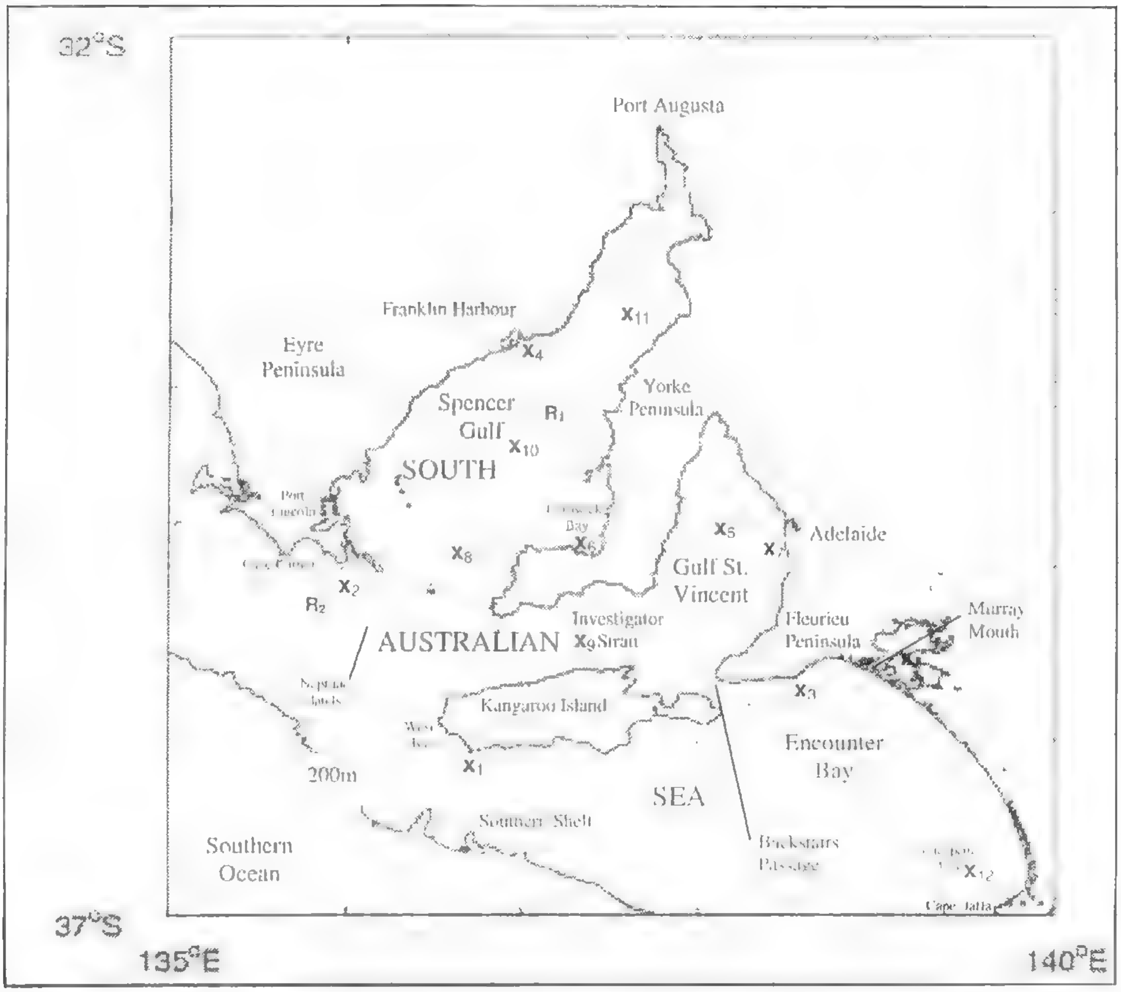
32°S
37°S
135°E
140°E
Port Augusta
Franklin Harbour
Eyre
Peninsula
x_{11}
x_4
Spencer
Gulf
R_1
x_{10}
Yorke
Peninsula
SOUTH
Port
Lincoln
Bay
x_6
x_5
x_7
Adelaide
x_8
Gulf St.
Vincent
x_2
R_2
Investigator
x_9 Strait
AUSTRALIAN
Fleurieu
Peninsula
Murray
Mouth
Kangaroo Island
x_3
Encounter
Bay
200m
x_1
SEA
Southern Shelf
Southern
Ocean
Backstairs
Passage
x_{12}
Cape Jaffa

Fig. 2. The South Australian Sea with points of interest as mentioned in the text. x_i - indicate the positions of forecast formulae listed in Table 1. R_i show wave observation sites.

Wave Data

The only extended series of measurements of the Southern Ocean swell along the South Australian coastline was conducted by Steedman Science and Engineering of Perth, Western Australia, between May and October 1984 at seven measurement sites in the Great Australian Bight. These data have been analysed by Provis & Steedman (1985)[1], who noted a reduction in significant wave height by a factor of about two as the waves moved from the deepwater wave recorder in 1150 m of water, across the shelf towards the coast to the shallowest wave recorder in 26 m of water. Significant wave heights in excess of 5 m were recorded on several occasions, and waves of over 10 m were recorded during a July storm as far inshore as the 75 m depth contour. The significant wave period remained almost constant at about 15 s at all seven measurement sites. This period is very similar to the dominant swell period (16 s) in the classical experiment of Munk *et al.* (1963) in which swell was observed to travel across the Pacific Ocean to Alaska from Southern Ocean winter storms, almost without loss of energy.

An interesting feature of the measured open ocean wave spectra is that they are unimodal, i.e. there are no distinct wind sea and swell peaks. Only at times of very low incident swell were separate peaks observed. Young & Gorman (1995) suggest that the proximity of the site to the Southern Ocean storm belt does not provide sufficient time for the wavefield to disperse and a bimodal (wind wave and swell) wave spectrum to develop.

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[1] Provis, D. G. & Steedman, R. K. (1985) Wave measurements in the Great Australian Bight. Paper presented at Australasian Conference on Coastal and Ocean Engineering. IEAust., Christchurch, NZ 1985. (unpub.)

No open sea wave measurements appear to be available for the summer season, but in April 1998, a new series of wind wave and swell measurements was initiated in the South Australian Sea and the adjacent Southern Ocean using electric field measurements (Heinson *et al.* 1998; Hemer 1998[2]; Hemer *et al.* 1999). The details of this program are reported elsewhere, but for our purposes an important feature was the near simultaneous observation of wave spectra on the Southern Shelf and in Spencer Gulf with which the predictions of the wave model can be compared. Apart from these measurements, wave studies in the South Australian Sea (Bye *et al.* 1975[3]; Culver & Walker 1981[4]; Walker 1989[5]) have usually neglected the swell signal.

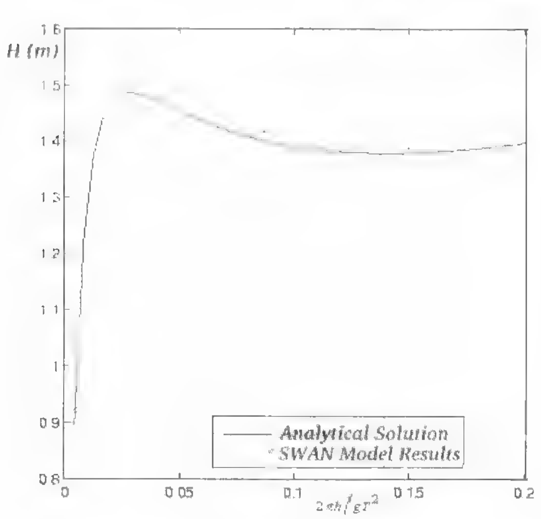

Fig. 3. Comparison of SWAN wave heights with the analytic solution of Nielsen (1983) for an incoming swell of period (T = 12 s) and height (H_o = 1.4 m) running up a plane of slope 1.125 x 10^{-3} with a quadratic bottom friction coefficient, C_f = 0.015. The abscissa is the ratio of the water depth (*h*) to incoming wavelength ($gT^2/2\pi$) where g is the acceleration of gravity and the ordinate is the wave height (H). The SWAN results (x) are computed on a 4 km grid.

The SWAN Wave Model

The SWAN wave model (**S**imulating **WA**ves **N**earshore) is a directional spectral wave model written by the Coastal Engineering group of the Delft University of Technology, Netherlands (Ris *et al.* 1997) especially for coastal seas. In the formulation of the model, many wave propagation processes are implemented. These include wave propagation, wave refraction due to bottom shoaling and refraction and reflection by currents. Along with these effects, the model also includes generation of wave energy by wind, dissipation of wave energy by whitecapping and depth induced wave breaking, frictional dissipation due to bottom drag and redistribution of energy over the wave spectrum by non-linear wave-wave interactions (SWAN 1998[6]). Limitations of SWAN are that it does not account for diffraction or reflections, and hence it is unsuitable for regions where wave height variations are large within a horizontal scale of a few wavelengths (Ris *et al.* 1997) and regions of 'steep beaches' (i.e. cliffs, harbours etc.) SWAN is therefore a 'state of the art' model for the present study of the propagation of swell into the South Australian Sea. It is important however to carry out two basic checks on the model.

Firstly, the analytic model of Nielsen (1983) was compared with the results of the SWAN model over a plane sloping bed under variable conditions in which a plane wave was propagated into the domain at the deepest end (Hemer 1998[2]). Figure 3 shows that, for a typical swell period of 12 s, and a quadratic bottom friction coefficient (C_f) of 0.015,

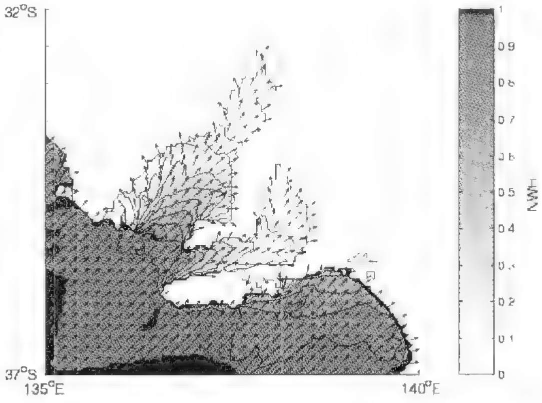

Fig. 4. The swell wavefield in the South Australian Sea predicted by the SWAN model for C_f = 0.015 and D_o = 230°. The contours show normalised wave height (NWH): contour interval 0.1, and the arrows indicate the direction of swell propagation.

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[2] Hemer, M. (1998) A Wave Study of the South Australian Sea: Prediction, Observation using Electric Field Measurements, and Application to Sediment Resuspension Processes. BSc (Hons) Thesis, The Flinders University of South Australia (unpub.).

[3] Bye, J. A. T., Gunn, B. W. & Nikpalj, C. V. (1975) The Wave Climate off Cape Jervis, South Australia between June and November, 1974. Flinders Institute for Atmospheric and Marine Science Research Report, No. 17. (unpub.).

[4] Culver, R. & Walker, D. (1981) Redcliff Wave Atlas. The University of Adelaide Department of Civil Engineering report. (unpub.).

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[6] SWAN (1998) SWAN web page. http://swan.ct.tudelft.nl

such as would occur over sandy beaches (Jonsson 1966), the analytical solution and the numerical solution are in very good agreement for the grid interval 4 km. The SWAN model simulations presented below are run on a uniform 100 x 100 rectangular grid of grid interval, 4.5 km on which the bathymetry was taken from the Australian Geological Surveying Organisation (AGSO) 30 arc second digital file. Secondly, we compare the predictions of SWAN for swell propagation into Spencer Gulf, with the April 1998 wave observations and the predictions of the Bureau of Meteorology Southern Ocean wave model (WAM) which is run in operational mode with wave fields issued at 0000, 0600, 1200 and 1800 UTC, and is available from the Bureau of Meteorology (Bureau of Meteorology, 1999[7]). It is convenient to present the results of the comparison at the end of the next section after the SWAN model outputs have been described.

Results

Figure 4 shows the normalised wave height[8]

$$NWH = {}^{H}\!/_{H_o} \tag{1}$$

where H is the swell wave height, and H_o is the open ocean input swell height, and also the wave direction (D) for swell of period 15 s and H_o = 3.5 m propagating from the direction, D_o = 230°. It is observed that the swell begins to lose its energy as soon as it enters the region. More energy is lost when the wave front reaches Kangaroo Island (KI) with the coast absorbing the energy of some directional components of the wave. Large wave heights occur at the coast of KI, (NWH ~ 0.9) close to the coast. These results agree with anecdotal observations of large wave heights on the southern and western coasts of KI.

Kangaroo Island provides a significant blockage to wave energy influx into Gulf St Vincent (GStV), and the wave energy that enters GStV is due to refraction as the water depth decreases and the waves "wrap" into Investigator Strait, becoming quite perpendicular to the depth contours. Significant loss of wave energy is observed with waves propagating eastward through Backstairs Passage, so that almost all the wave energy due to swell in GStV originates from waves propagating through Investigator Strait. Waves at the head of GStV, the western end of Backstairs Passage and the metropolitan coast of Adelaide all show wave heights less than 10% of the input height (NWH < 0.1). In Investigator Strait refraction is seen to have an effect with the waves becoming more and more perpendicular to the coast and the northern coast of KI shows regions where waves have refracted more than 180° from the input wave direction. Within the gulf, a northward dominance of wave propagation still exists, but a significant spreading towards the coast at all locations is observed. Wave height is observed to increase markedly along the southern side of Fleurieu Peninsula, with almost no waves at the western end (NWH < 0.1) to significant wave energy at the Murray Mouth (NWH ~ 0.6). Propagation into Encounter Bay shows very little refraction, due to the waves initially travelling almost normal to the depth contours.

The propagation of swell into Spencer Gulf (SG) shows a continual loss of wave energy (or wave height) with decreasing water depth towards the head of the gulf. Large loss of wave energy is observed in the various "shadow zones" of SG such as Hardwicke Bay. Again clear evidence of refraction is observed with wave direction becoming nearly perpendicular to the coast in all regions. Within Hardwicke Bay, waves are observed to be propagating in directions rotated more than 90° from the input swell direction. In the vicinity of Port Lincoln, waves are observed to have refracted by 180° with waves travelling in the opposite direction to the input swell. The general pattern of wave energy in SG shows a spreading and loss of wave energy towards the sides of the gulf. The south western coast of Eyre Peninsula shows very little loss of energy before reaching the coast. On the west coast of Eyre Peninsula, however, the observations of Provis & Steedman (1985)[9] show a halving of wave height from deep water to the coast. Boundary effects preclude a comparison between simulation and observations in this region but a similar reduction factor occurs in the model in Encounter Bay. Islands in the opening to SG such as the Neptune Islands are seen to block some wave energy from propagating into the gulf.

The wave period of the swell remains at a constant 15 s throughout the model domain. This result is expected given that no further wind forcing within the region is present. A reduction of wavelength of ~30% occurs within the gulf, due to the decrease in wave speed with decreasing water depth (see eqn (5)). From the model results, the maximum bottom orbital velocity, U_* can also be derived (Hemer 1998[10]), (see eqn (4)). It is found that a balance exists between the decreasing wave heights and wavelength and the decreasing water depth. The

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[7] BUREAU OF METEOROLOGY (1999) Bureau of Meteorology http://www.bom.gov.au

[8] Wave H [illegible] the [illegible] the relation $H = 4\sqrt{E}$ in which E is the wave energy (Phillips 1977).

[9] PROVIS, D. G. & STEEDMAN, R. K. (1985) Wave Measurements in the Great Australian Bight. Paper Presented at Australasian Conference on Coastal and Ocean Engineering, [illegible] Christchurch, New Zealand, 1985 (unpubl.)

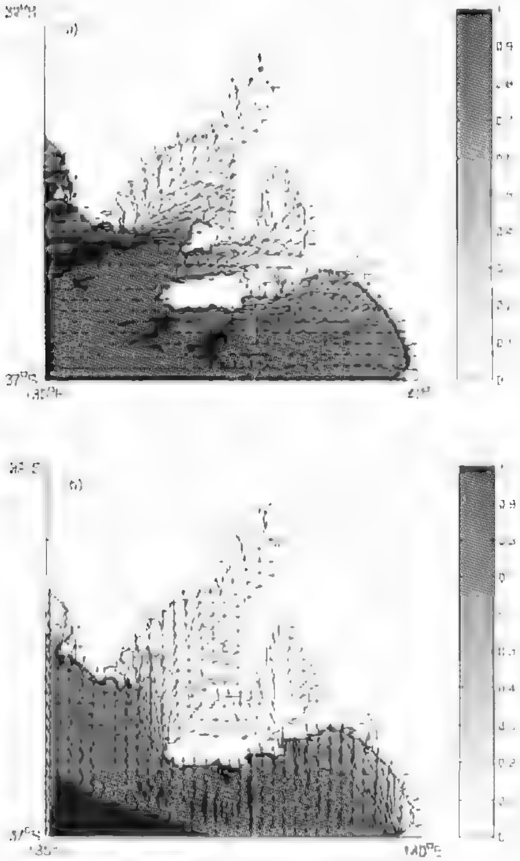

Fig. 5. As for Figure 4. (a). A westerly swell $D_o = 260°$. (b). A south-easterly swell: $D_o = 160°$.

largest U values (for $H_o = 3.5$ m) of ~0.5 ms⁻¹ (1 knot) were observed in the shallow water of the south coast of Kangaroo Island. Within the gulfs, water depths were much less, but wave energy had dissipated such that U values, 0.15 ms⁻¹ (0.3 knot), were less than half of the magnitude on the south coast of Kangaroo Island.

A number of sensitivity studies (Hemer 1998²) have been carried out by varying input model wave heights, directions, periods, bottom friction and wave breaking parameters, and model runs were also carried out with a uniform depth South Australian Sea. Variation of input swell wave heights (H_o) was found to cause minimal changes in the NWH throughout the South Australian Sea with slightly lower NWH (greater dissipation) for a larger input wave height. Changing the input wave period also only had small effects on the wave heights and directions within the South Australian Sea for typical swell periods.

The swell propagation is also insensitive to the variation of bottom friction, such as might be caused over seagrass beds. In the coastal zone however, bottom friction is found to cause significant decreases in predicted wave heights, e.g. wave heights in the surf zone are approximately 25% greater if frictionless conditions are assumed for coastal zone depths less than 10 m. Finally, specifying the South Australian Sea to have a uniform depth of 50 m gave almost the same reduction in wave height with progression into Spencer Gulf and Gulf St Vincent, as for the depth varying topography. These results suggest that the dominant source of energy loss in the South Australian Sea is absorption of wave energy at the coast by frictional loss in the shallows and wave breaking on coastal beaches in depths less than 10 m, rather than any form of depth induced effect in the interior of the sea.

We conclude from these sensitivity studies that the major source of swell height variability in the South Australian Sea is the direction of approach of the deep sea swell. Figure 5 illustrates the effect of a rotation of the direction of approach of the deep sea swell, either towards a westerly or a south-easterly direction. A westerly swell penetrates into Investigator Strait, and is refracted into Spencer Gulf along the western coast of Yorke Peninsula (Fig. 5(a)). On the other hand, Investigator Strait is well protected from the south easterly swells, more typical of Summer weather conditions, which are refracted into Spencer Gulf on the eastern coast of Eyre Peninsula (Fig 5(b)). This pattern occurred on April 20 1998 when wave observations were made in mid Spencer Gulf (R_1 in Fig. 2). The observed swell height and direction were respectively, H = 0.13 m, and D = 230°, whereas south of Eyre Peninsula the WAM model predicted the swell height and direction, $H_o = 1.8$ m and $D_o = 160°$, from which NWH = 0.08. The SWAN model prediction shown in Fig. 5(b) yields NWH = 0.08, and direction D = 223°, in good agreement with the observations. The accuracy of the WAM model was also assessed by comparison with observed wave data obtained south of Eyre Peninsula on April 16 1998 (R_3 in Fig. 2). The predicted swell parameters, $H_o = 1.5$ m and $D_o = 220°$ were in good agreement with the observations of $H_o = 1.3$ m and $D_o = 225°$ (Hemer 1998²).

We conclude that the predictions of the WAM and SWAN models can be successfully linked to provide reliable swell prediction formulae for the South Australian Sea, which are presented in the next section.

Swell Prediction Formulae

The isolation of wave direction as the dominant influence on normalised wave heights (NWH) within

TABLE 1. *The coefficients of the swell forecasting formula (eqn (2)) and swell heights (H) and maximum bottom orbital velocities (U) for swell propagating from the directions 230°, 260° and 160° for various locations in the South Australian Sea.*

Position	h(m)	a_4 (x10^{-9})	a_3 (x10^{-6})	a_2 (x10^{-3})	a_1 (x10^{-1})	a_0
1. Cape du Couedic	47	-6.8842	6.3809	-2.2079	3.3862	-18.512
2. Cape Catastrophe	50	-68.622	58.499	-18.517	25.781	-132.24
3. Fleurieu Peninsula	27	34.150	-27.419	8.0454	-10.190	47.388
4. Franklin Harbour	11	12.867	-10.714	3.2704	-4.3259	20.988
5. Mid Gulf St Vincent	33	-2.2965	1.8031	-0.51453	0.63910	-2.9210
6. Hardwicke Bay	10	2.0027	-1.7867	0.58009	-0.80486	4.0597
7. Adelaide	10	5.8435	-4.8575	1.4918	-1.9994	9.9339
8. Lower Spencer Gulf	46	32.394	-26.892	8.1539	-10.644	50.701
9. Investigator Strait	36	-7.7955	5.9928	-1.6607	1.9985	-8.8503
10. Mid Spencer Gulf	28	28.793	-23.973	7.3154	-9.6709	46.871
11. Upper Spencer Gulf	12	4.2561	-3.5376	1.0781	-1.4241	6.9002
12. Lacapede Bay	39	8.2295	-6.6782	1.9008	-2.1954	9.0546

	H^S_{230}	H^S_{260}	H^S_{160}	U^S_{230}	U^S_{260}	U^S_{160}
Position		(m)			(ms^{-1})	
1. Cape du Couedic	4.73	4.84	3.85	0.77	0.78	0.62
2. Cape Catastrophe	4.47	4.52	4.29	0.65	0.66	0.63
3. Fleurieu Peninsula	2.91	2.31	1.93	1.10	0.87	0.73
4. Franklin Harbour	0.73	0.42	0.22	0.98	0.56	0.29
5. Mid Gulf St Vincent	0.36	0.55	0.07	0.10	0.16	0.02
6. Hardwicke Bay	0.50	0.48	0.13	0.77	0.74	0.20
7. Adelaide	0.59	0.63	0.34	0.91	0.97	0.52
8. Lower Spencer Gulf	3.44	2.69	1.09	0.58	0.45	0.18
9. Investigator Strait	1.81	2.76	0.24	0.45	0.68	0.06
10. Mid Spencer Gulf	1.63	0.92	0.45	0.58	0.33	0.16
11. Upper Spencer Gulf	0.24	0.14	0.07	0.28	0.17	0.09
12. Lacapede Bay	4.46	3.51	3.15	0.86	0.67	0.61

the South Australian Sea suggested that swell prediction formulae could be obtained. The set (150°, 160°, 175°, 190°, 200°, 215°, 222°, 230°, 237°, 245°, 253° and 260°) was chosen from SWAN runs as representative of the swell energy window from which waves propagate, and the NWH was determined at selected grid points. Using the twelve runs, a polynomial of order 4 was fitted at each grid point to interpolate NWH over the range of propagation directions, D_0 = 150° - 260°.

$$NWH = a_4 D_o^4 + a_3 D_o^3 + a_2 D_o^2 + a_1 D_o + a_o \quad (2)$$

The coefficients are shown in Table 1 for the positions in the South Australian Sea illustrated in Fig. 2. It is emphasised that, for the coastal sites, eqn (2) predicts the incoming swell heights outside the surf zone at a depth of 10 m. Table 1 allows a simple calculation of swell heights to be made using the deep sea swell height and direction from the WAM model output, over the range of directions for which significant swell energy propagates into the South Australian Sea.

The travel time, τ in h, for swell over a distance, *d* in km, assuming deep water wave conditions, is

$$\tau = 0.18 \, {}^{d}\!/_{T} \quad (3)$$

in which *T* is the swell period. For a representative travel distance of 350 km, and a swell period of 13 s, τ ~ 5 h, and hence real time forecasts for swell conditions can be obtained from the six hourly wavefields available from the Bureau of

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[i] The authors accept no liability on the use of information given in this paper.

[ii] HARRISON, P. (1997) Protecting Gulf St. Vincent: A Statement on its Health and Future. Department of Environment and Natural Resources, Adelaide, 1997. (unpub.).

Meteorology (Bureau of Meteorology, 1999[7]). It is suggested that input parameters be taken from the WAM output at the 37°S and 135°E grid point[10].

The corresponding maximum bottom orbital velocities, U, due to the swell can be calculated from eqn (2) using the formula

$$U = {}^{\pi H}\!/_{T \sinh(kh)} \qquad (4)$$

in which h is the water depth and k is the wavenumber of the swell, which can be determined from the approximate formula (Fenton 1990)

$$k = \frac{4\pi^2}{gT^2}\left(\coth\left(\frac{2\pi}{T}\sqrt{\frac{h}{g}}\right)^{3/2}\right)^{2/3} \qquad (5)$$

in which g is the acceleration due to gravity. The swell heights ($H^s_{D_o}$) and maximum bottom orbital velocities ($U^s_{D_o}$) for an open ocean swell of 5 m propagating from the directions (D_o) discussed in the previous section are representative of the most severe swell conditions likely to be encountered in the South Australian Sea (Table 1).

Conclusion

This study uses state of the art wave modelling to show the propagation of swell into the South Australian Sea. An obvious application is real time swell forecasting for mariners and surfers. The SWAN model can be also run to forecast the wind wave spectrum generated by local winds but this is beyond the present scope.

The intrinsic interest of swell is its role in sediment transport processes at the sea bottom. The example of Table 1 illustrates that a severe swell event generates very significant bottom orbital motion which resuspends sediment particles into the water column which may then be transported by tidal and wind driven currents. In order to describe the sediment transport process in coastal areas, it is essential to determine the swell climate accurately. The results of this wave study, along with developed sediment resuspension tools, will help significantly to advance the understanding of sediment and particulate transport processes in regions of concern within the South Australian Sea, for example, the Adelaide metropolitan coastline (Wynne 1984) and the mouth of the River Murray (Harvey 1996), and provide a framework for its future management (Harbison 1997[11]).

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A NEW SPECIES OF GALL MIDGE (DIPTERA: CECIDOMYIIDAE) DAMAGING BRANCH SHOOTS OF THE DRYLAND TEA-TREE, MELALEUCA LANCEOLATA (MYRTACEAE)

By Peter Kolesik & David E. Peacock†*

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Transactions of the Royal Society of S. Aust. (1999), **123**(3), 115-119

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Introduction

The dryland tea-tree, *Melaleuca lanceolata* Otto (Myrtaceae), also known as Moonah or black tea-tree, is a shrub or a small tree of up to 10 m in height occurring in Western Australia, South Australia, Victoria, New South Wales and Queensland (Barlow 1986). It grows in various habitats, in South Australia commonly in saline heavy clays that are subject to periodic waterlogging. The durable wood is occasionally used in the timber industry and the flowering trees are valued by beekeepers (Cunningham *et al.* 1981).

The gall midge modifies branch shoots of *M. lanceolata* subsp. *lanceolata* into galls that resemble pine cones (Fig. 1). The galls were collected by one of us (DEP) in October, 1998 in the Coorong National Park during a South Australian Animal and Plant Control Commission ecological survey. Although the galls were found in low abundance the gall midge can potentially have a severe impact on tree development because it prevents the growth of new branches.

The new gall midge, to be attributed to Kolesik, is placed in the genus *Lopesia* and becomes the second known Australian species of the tribe Lopesiini, along with *Australopesia melaleucae* Kolesik (1999) that forms flower galls on *Melaleuca halmaturorum* F. Muell. ex Miq. in South Australia.

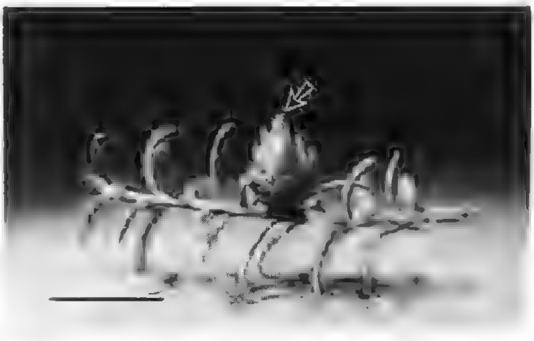

Fig. 1. Branch shoot gall of *Lopesia quadrata* sp. nov. on *Melaleuca lanceolata*. Arrow marks pupal skin. Scale bar = 10 mm.

Materials and Methods

Branch galls on *Melaleuca lanceolata* were collected at the Coorong National Park on 5.x.1998. The galls were processed in one of two ways. Some were peeled open and the larvae preserved in 70% ethanol. Those remaining were kept in plastic bags and the larvae were reared to adults. Pupation took place within the galls. Emerged adults were preserved together with their pupal skins in 70% ethanol. Microscope mounts of the type series were prepared according to the technique outlined by Kolesik (1995). The type series and other material retained in 70% ethanol, together with dried galls, are deposited in the South Australian Museum, Adelaide (SAMA), the Australian National Insect Collection, Canberra (ANIC) and the State Herbarium of South Australia, Adelaide (AD). Descriptions and measurements refer to the holotype and paratypes.

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Genus *Lopesia* Rübsaamen, 1908

Lopesia Rübsaamen, 1908: 29

Type species, *Lopesia brasiliensis* Rübsaamen, 1908: 30, figs 11, 12

Lopesia is a genus of the supertribe Cecidomyiidi originally characterised by the bend in the R_5 wing vein at its juncture with R_s. R_s situated beyond the midlength of R_1, toothed tarsal claws, empodia shorter than claws, short female postabdomen with large cerci, and four-segmented palpi. It is currently used as a catch-all genus within the tribe Lopesiini and now also includes species with simple tarsal claws and a reduced number of palpal segments (Gagné & Marohasy 1993; Gagné & Hibbard 1996). The new species fits *Lopesia* s.s. in all characters except the two-segmented palpi, a reduction that appears independently in many genera and does not preclude placing the species within the wider concept of the genus.

Lopesia quadrata sp. nov.
(FIGS 1 - 16)

Holotype: ♂, Coorong National Park, "Loop Road", South Australia (36° 11' S, 139° 41' E), 8.x.1998, reared by P. Kolesik from branch shoot galls on *Melaleuca lanceolata* Otto subsp. *lanceolata*, gall collected 5.x.1998 by D. E. Peacock, 121427 (SAMA).

Paratypes: 1 ♂, 2 ♀♀, 3 pupal skins (SAMA, 121428-121432), 2 ♂♂, 2 ♀♀, 3 pupal skins (ANIC), same data but emerged 8.x.-23.x.1998, 1 larva (SAMA, 121433), 1 larva (ANIC), collected with holotype.

Other material: 20 ♀♀, 3 pupal skins, same data as paratypes (SAMA), galls, same data (AD99926213).

Male (Figs 2 - 8)

Colour: eyes black, head dark-brown, antennae and palpi brown, thorax black dorsally and red elsewhere, abdomen with sclerotised parts brown and unsclerotised parts red, genitalia brown, legs brown and yellow.

Head: Antenna: scape slightly longer than wide; pedicel spheroid; flagellomeres 12 in number, binodal, with one circumfila on basal node, two on distal, circumfilar loops not reaching the next distal circumfilum, nodes with sparse, short setulae, last flagellomere with small, apical nipple. Eye facets closely adjacent except at vertex where sparser, eye bridge 3 facets long. No postvertical protuberance. Palpi two-segmented, segmentation weak. Frons with 5 - 9 setae per side. Labella hemispherical, each with 6 - 9 short setae.

Thorax: Wing length 2.3 mm (range 2.2 - 2.4, n = 4), width 0.9 mm (0.8 - 0.9), R_s varies between barely visible to full strength vein. Tarsal claws curved beyond midlength, with short, wide tooth, empodia less than half claw length.

Abdomen: Sternum I not sclerotised, asetose, sternites II - VIII with anterior pair of trichoid sensilla, posterior setal row and sparse setae scattered elsewhere. Tergites I - VII with anterior pair of trichoid sensilla, posterior setal row and sporadic setae elsewhere, tergum VIII not sclerotised, asetose. Genitalia: gonocoxite cylindrical, with large, rounded, setulose mesobasal lobe; gonostylus slightly tapered distally, bent at distal third, slightly swollen and setulose on basal third, asetose and ridged beyond; aedeagus with several asetose papillae, longer than gonocoxites, robust, tapered distally; hypoproct bilobed, each lobe with several setae, setulose; cerci bilobed, shorter than hypoproct, each lobe with several setae, setulose.

Female (Figs 9 - 12)

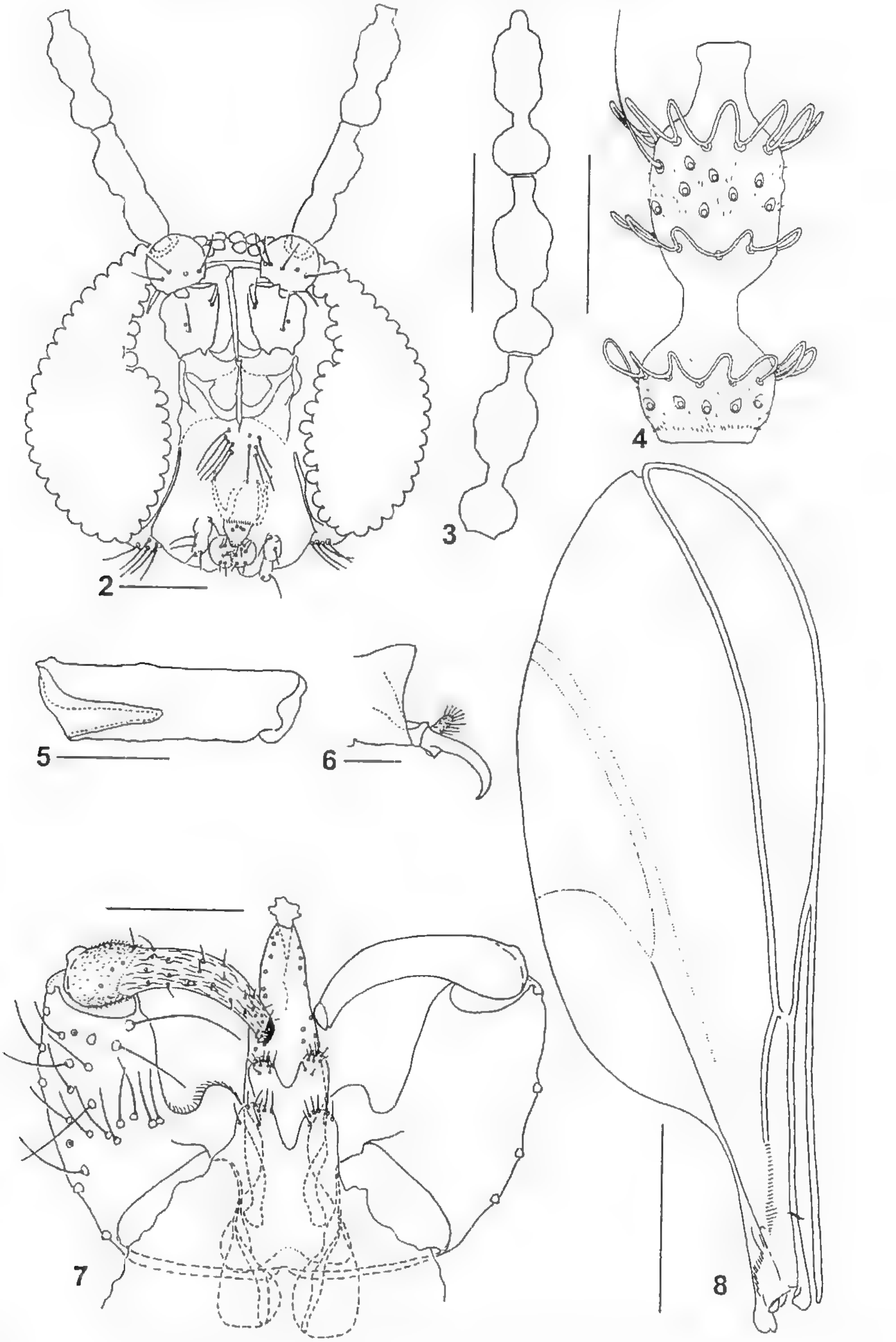
Colour as in male. Head: frons with 7 - 8 setae, labella each with 3 - 7 setae; flagellomeres cylindrical, with slight restriction at midlength in basal ones, circumfila simple around midlength, with several small, interconnected arches distally, setulae short and spare basally, unusually long and dense distally. Wing length 2.6 mm (2.3 - 2.8, n = 4), width 1.0 mm (0.9 - 1.0). Abdomen: sternum VIII and IX not sclerotised, setose; tergite VIII consisting of two small areas, one on each side of centre, tergum IX sclerotised, both setose. Ovipositor short, barely protrusible; cerci ovoid, completely setulose and setose, several setae on posteroventral surface thick; hypoproct short, robust, with several setae, setulose. Other characters as in male.

Pupa (Figs 13, 14)

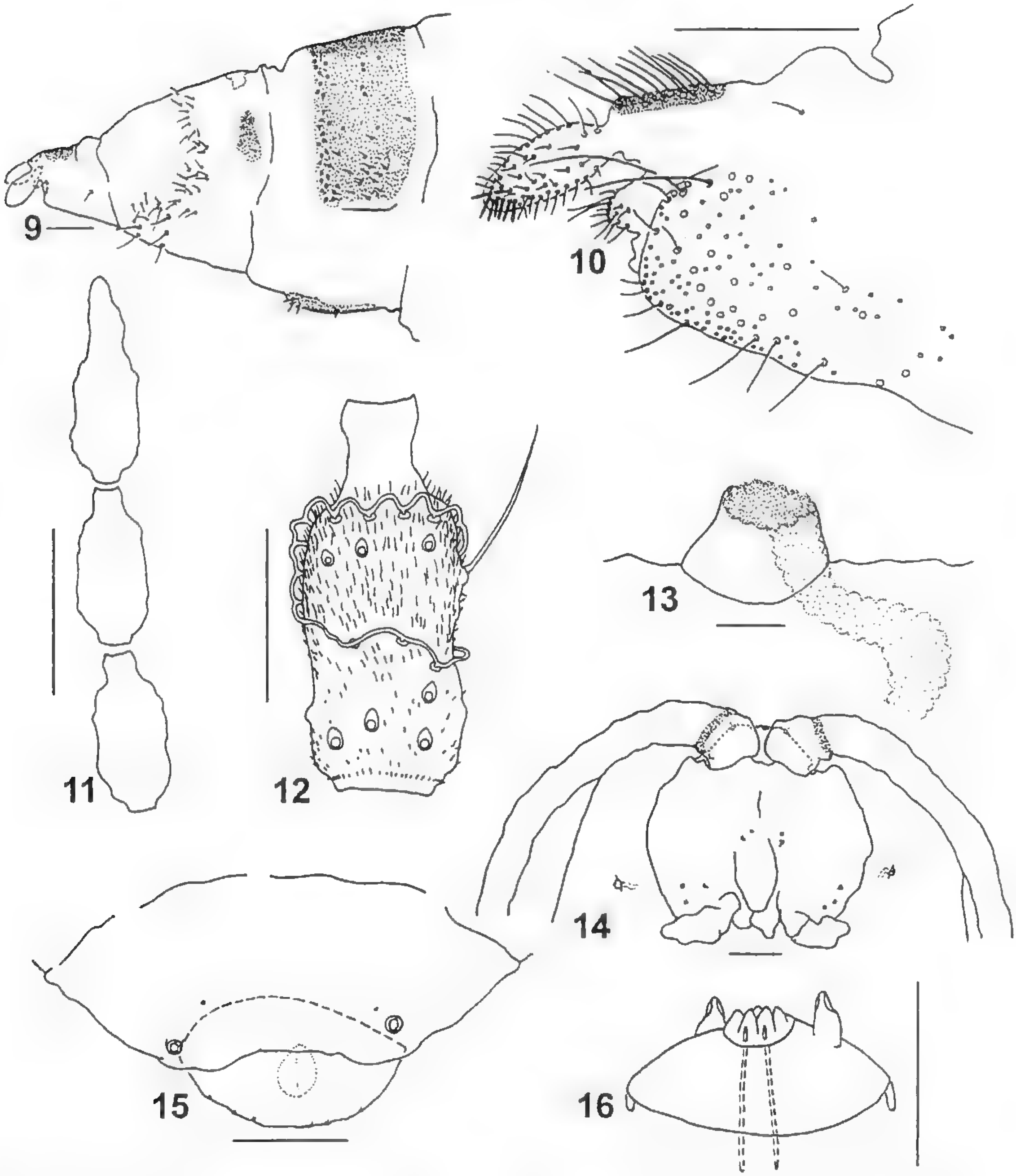
Colour: narrow ring on anterior part of antenna pale brown, remaining parts grey. Length 2.6 mm (2.3 - 2.8, n = 6). Cephalic papillae 5 µm (4 - 5) long. Frons on each side, one of two facial papillae setose, one of three lateral papillae setose, all setae minute. Prothoracic spiracle very short, as long as wide. No dorsal abdominal spines.

Larva (Figs 15, 16)

Colour: orange-red. Length 1.5 - 1.9 mm (n = 2). Head: antennae unusually broadened basally, posterolateral apodemes very short. No sternal spatula. Terminal segment with several small, asetose papillae.



Figs 2 - 8. Male of ***Lopesia quadrata*** sp. nov. Fig. 2. Head in frontal view. Fig. 3. Last three flagellomeres. Fig. 4. Sixth flagellomere. Fig. 5. First tarsomere. Fig. 6. Tarsal claw and empodium. Fig. 7. Genitalia in dorsal view. Fig. 8. Wing. Scale bars = 100 µm 2, 3, 7; 50 µm 4 -6; 500 µm 8.



Figs 9 - 16. *Lopesia quadrata* sp. nov. 9 - 12 female, 13, 14 pupa, 15, 16 larva. Fig. 9. End of abdomen in lateral view (setation on segment IX and ovipositor omitted). Fig. 10. Ovipositor in lateral view. Fig. 11. Last three flagellomeres. Fig. 12. Sixth flagellomere. Fig. 13. Prothoracic spiracle. Fig. 14. Anterior part in ventral view. Fig. 15. Last two abdominal segments in dorsal view. Fig. 16. Head in ventral view. Scale bars = 100 µm 9 - 11, 14, 15; 50 µm 12, 16; 10 µm 13.

Egg

Elongate-ovoid, red in colour.

Etymology

The name *quadrata* is a Latin adjective for "square", referring to the shape of the gall in the top side view.

Gall and biology

The midge transforms a branch shoot into a pine cone-like gall (Fig. 1), 3 - 9 mm long and 4 - 6 mm wide, square in the side top view; outer leaflets hard and brown in colour, inner ones soft and yellow-green, all sparsely covered with short, silvery hairs. Each gall contains one larva dwelling between two closely appressed leaflets. Pupation takes place inside the gall. At the end of its development the pupa lifts 2/3 of its body outside the gall. Shortly afterwards the pupal skin splits open at the dorsal part of the thorax and the adult emerges. At the beginning of October 1998, at the Coorong National Park, the gall midge population consisted mainly of pupae with only a small proportion of larvae. Of 11 examined *Melaleuca lanceolata* trees, six had galls of the new species. The tree with the highest infestation was 5 m high with a canopy of 4 m and bore about 200 galls.

Remarks

Previously, five cecidomyiids have been known to induce galls on *Melaleuca* spp. Gagné *et al.* (1997) described four species: *Lophodiplosis bidentata* Gagné from rosette bud galls on *M. quinquenervia* (Cav.) S. T. Blake, *L. cornuata* Gagné from trumpet-shaped leaf galls on *M. nervosa* (Lindley) Cheel, and *M. viridiflora* Sol. ex Gaertner, *L. indentata* Gagné from blister galls on leaves of *M. quinquenervia*, *M. dealbata* S. T. Blake, *M. viridiflora*, *M. arcana* S. T. Blake, *M.* "*fluviatilis*" Barlow and *M. saligna* Schauer and *L. denticulata* Gagné from *M. quinquenervia* and *M. viridiflora*. The fifth species, *Austrolopesia melaleucae* Kolesik (1999), transforms flowers of *M. halmaturorum* F. Muell. ex Miq. into hard, spherical, hairy galls.

The main character that distinguishes the new species from the otherwise rather diverse species of *Lophodiplosis* Gagné is the conspicuous protuberance on the pupal vertex which is present in the other species but absent in *Lopesia quadrata* sp. nov. The new species differs from *Austrolopesia melaleucae*, a species with which it shares the type locality, in all developmental stages. In *L. quadrata*, the palpi are two-segmented, the tarsal claw has a broad, short tooth, the male flagellomeres are binodal, the ovipositor is short and barely protrusible, the pupal prothoracic spiracle is as long as wide and the larva has no sternal spatula. In *A. melaleucae*, the palpi are four-segmented, the tarsal claw has a thin, long tooth, the male flagellomeres are gynecoid, the ovipositor is long and protrusible, the pupal prothoracic spiracle is several times longer than wide and the larva has a well developed sternal spatula.

Some specimens of the new species had the aedeagus widely opened at its terminal end, a transformation possibly caused by mating.

Acknowledgments

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OBSERVATIONS OF SOME NEMATODES FROM KANGAROO ISLAND, SOUTH AUSTRALIA, INCLUDING THE DESCRIPTION OF A NEW SPECIES, HEMICYCLIOPHORA FLUVIALIS (TYLENCHIDA: HEMICYCLIOPHORIDAE), FROM ROCKY RIVER

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The morphology of the new species, *Hemicycliophora fluvialis*, is compared with that of four mainland South Australian species of this genus. It resembles *H. charlestoni* Reay, 1984 more closely than the other South Australian species. A population of *Eutobrilus heptapapillatus* (Jaubert & Heyns, 1979) Tsalolikhin, 1981 is also described from Rocky River and is compared with populations of this species from mainland Australia and South Africa. A population of *Hemicriconemoides minor* Brzeski & Reay, 1982 collected from soil adjacent to Rocky River is compared with specimens from Kuitpo Forest, 30 km south of Adelaide. Relationships between these Kangaroo Island nematodes and their close relatives on the South Australian mainland are discussed.

KEY WORDS: *Hemicycliophora fluvialis* sp. nov., *Eutobrilus heptapapillatus*, *Hemicriconemoides minor*, Rocky River, Kangaroo Island, nematodes, morphology, measurements.

Introduction

Rocky River is one of the more pristine rivers or streams on Kangaroo Island running, as it does, through Flinders Chase National Park throughout its length and thus being free from pollution from farmed lands and human habitation. Its nematode microfauna has not been studied or compared with mainland species. Kangaroo Island is thought to have been separated from the mainland for about 9,500 years (Lampert 1979) and some divergence from the mainland populations might be expected.

In this paper the ionic composition of the water from several of the island's rivers that run through farm lands is compared with that from Rocky River. Measurements of some free-living and plant parasitic nematodes are made and compared with related mainland species. These relationships are discussed and a new species is described.

Materials and Methods

Sites

Soil and water samples were collected from the Rocky River site (1) (35° 57′ S, 136° 42′ E) on two occasions, firstly on 3 June 1993 and secondly, four years later, on 5 October 1997. On the first occasion samples were collected from other rivers on Kangaroo Island (Fig. 1) for comparison. These sites, in order of increasing salinity, were (2) Stunsail Boom River, collected on the seaward side of the bridge across the river on the South Coast Rd, (3) Harriet River, collected on the seaward side of the bridge across the river on the South Coast Rd, (4) Eleanor River, collected close to the bridge across the river on the South Coast Rd, (5) Chapman River, collected on the landward side of Willoughby Rd and (6) Cygnet River, collected about 50 m up stream of the bridge at the township.

Collection and processing of samples

Water samples were filtered through a 0.2 µm membrane filter and stored in sterile screw-capped bottles prior to analyses of major soluble ions as described previously (Bird 1995). Soil samples taken adjacent to the river using a 4.7 cm diameter corer were treated in a misting machine as described by Yeates & Bird (1994). Samples of water-saturated soil at the rivers' edges were also collected using the corer but this soil was mixed with water and sieved through a range of sieves as described by Bird (1999). The 1993 samples were collected throughout the island by the author assisted by H. R. B. Jack and the 1997 samples from Rocky River by A. McK. McHugh assisted by M. McHugh.

Soil from Kyeema Conservation Park, supplied by F. Reay and containing *Hemicriconemoides minor*, was also placed in the misting machine and the living nematodes extracted and photographed.

Treatment of nematodes

Living nematodes under a dissecting microscope were picked from the containers into which they had

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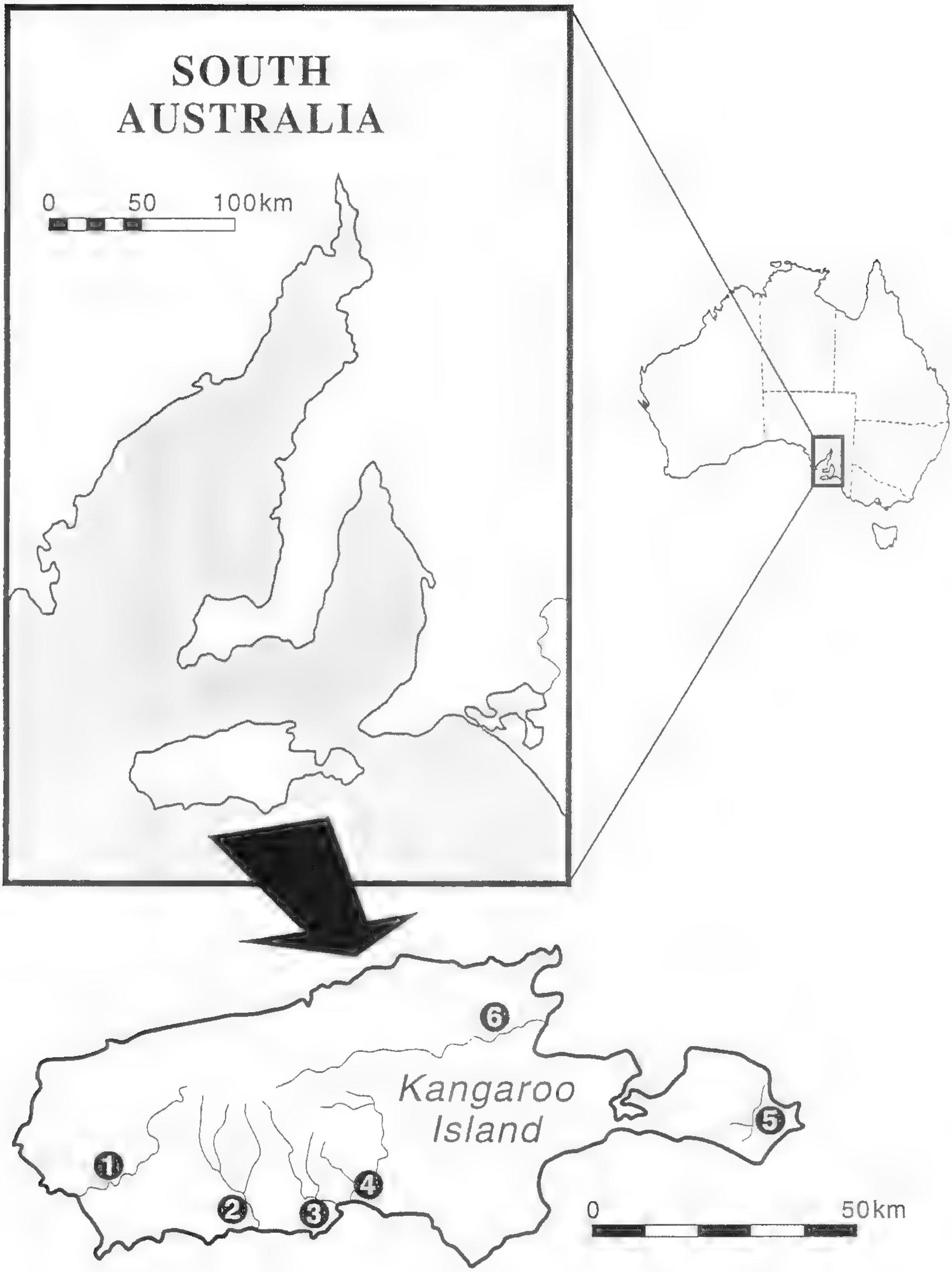
SOUTH
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Fig. 1. Map showing collecting sites with rivers listed in order of increasing salinity (see Table 1). (1) = Rocky. (2) = Stunsail Boom. (3) = Harriet. (4) = Eleanor. (5) = Chapman. (6) = Cygnet.

been separated and fixed in hot FA 4:1 before being processed to anhydrous glycerol as described previously (Bird 1995). Both living and fixed nematodes were photographed using a Vanox AHBT research microscope equipped with bright field and interference contrast (Nomarski) optics with Ilford Delta 400 film.

The type series has been deposited in the South Australian Museum, Adelaide (SAMA), CSIRO Division of Entomology, Canberra ACT (ANIC) and the Waite Institute Nematode Collection, University of Adelaide (WINC)

De Man's indices and abbreviations for morphological terminology are as follows.
a: body length ÷ maximum body diameter; b: body length ÷ pharyngeal length; c: body length ÷ tail length; c': tail length ÷ body diameter at cloaca; L: total body length; m: length of conus (anterior) part of buccal stylet x 100 ÷ total stylet length; n: number of specimens; R: number of body annules; RB: breadth of one body annule; R_{an}: number of annules on tail; R_{ex}: number of annules between labial disc and first annule after secretory-excretory (S-E) pore; $R_{pharynx\ (oes)}$: number of annules between labial disc and pharyngo-intestinal valve; R_{st}: number of annules between labial disc and base of stylet knobs; RV: number of annules from vulva to tail tip; R_{van}: number of annules between vulva and anus; V%: distance of vulva from anterior end x 100 ÷ L; VL: distance between vulva and tail tip; $^{VL}/_{VB}$: distance between vulva and tail tip ÷ body width at vulva.

Results

The water environment

Most of the water samples were collected in midwinter when all the springs and rivers had running water. Nevertheless, some of the rivers, such as the Cygnet and Chapman (Fig. 1, Table 1), are clearly estuarine some distance from their mouths. They also have more calcium, magnesium, phosphorus and sulphur than the other rivers listed, particularly Rocky River which runs throughout its length in the Flinders Chase National Park and so is not exposed to agricultural effluents. It is pleasing to note (Table 1) that over the four-year period from 1993-1997 there was no increase in the ionic components in its water; in fact, there appears to have been a slight decrease, possibly due to the difference in the time of year.

Nematodes

Hemicycliophora fluvialis sp. nov.
(FIGS 2-5)

Type: Holotype ♀ Rocky River, KI (35° 57' S, 136 42' E), coll. A. F. Bird, 3.vi.1993, SAMA AHC 28115.
Paratypes: 10 ♀♀, same data as holotype, SAMA AHC 28115, ANIC 700, WINC 2022.

Description

Body straight to ventrally curved, outer cuticle loose fitting. Outer cuticle with circumferential surface markings on either side of narrow band or groove running unbroken through centre of each annule. No breaks observed in annulations. No lateral lines apparent. Lip region continuous with body annules. Labial disc distinct and curved. Three lip annules, the third being largest. Stylet long, basal knobs posteriorly sloped and rounded with posterior cavity. Median bulb, isthmus and terminal bulb of pharynx distinct. Secretory-excretory (S-E) pore at junction of pharynx and intestine or slightly anterior. Genital branch single, outstretched. Spermatheca oval, containing sperm in all specimens examined. Vulval lips irregular. Post-vulval region cylindrical, tapering towards tail terminus annulated to its tip. Anus obscure and not observed.

Female (Measurements of holotype) (Figs 2-5)

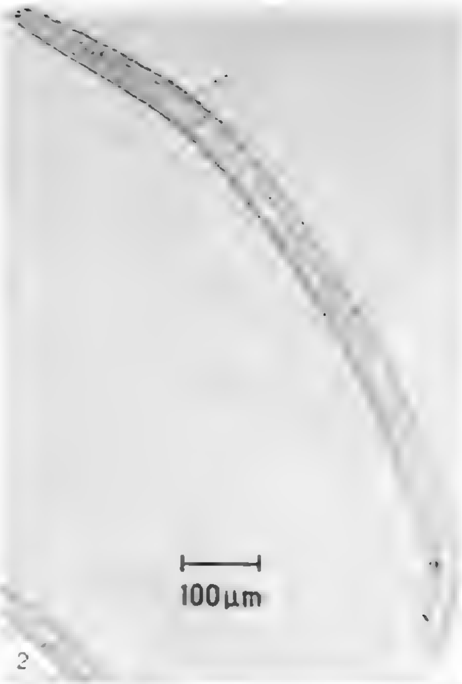
Length 1109 µm; a = 32; b = 5.7; V = 86; VL = 136 µm; VL/VB = 4.3; stylet 116 µm; m = 86; R = 351; R_{ex} = 53; RV = 50; R_{st} = 31; $R_{pharynx\ (oes)}$ = 55.

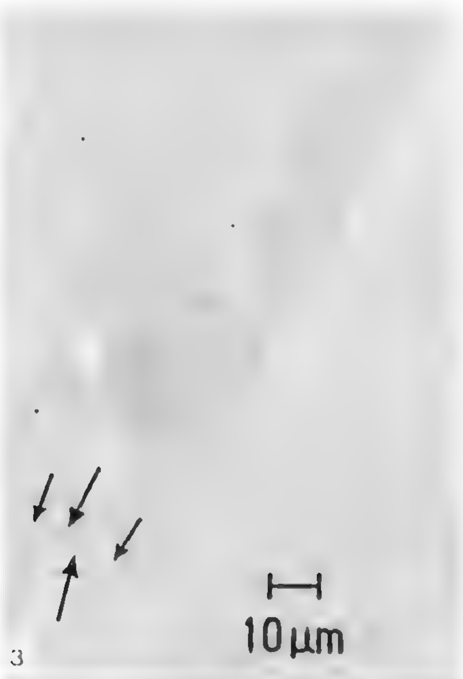
TABLE 1. *Analyses of major soluble ions (mg l⁻¹) in water from various rivers on Kangaroo Island.*

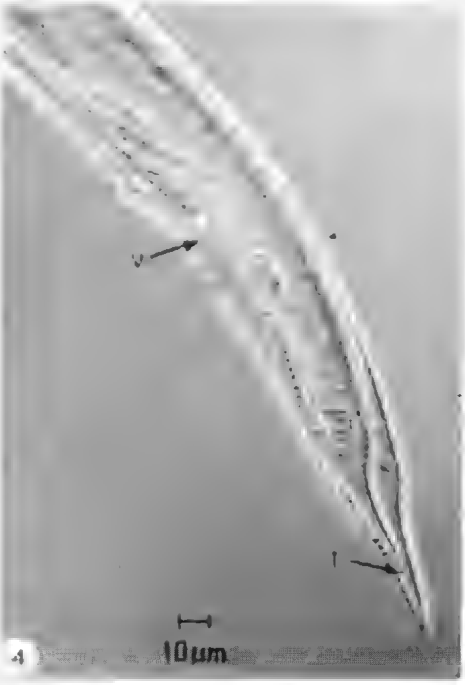
Date	River	Na	Cl	Ca	Mg	K	P	S	^{*1}EC	^{*2}TSS
3 June 1993	Stunsail Boom	269	438	12	30	5.5	<0.3	12	1.3	0.09
"	Harriet	1940	3160	68	181	59	0.3	118	9.6	0.64
	Eleanor	1930	3370	167	205	27	0.3	79	9.8	0.65
"	Chapman	3610	4430	460	586	82	0.5	334	17.8	1.19
	Cygnet	4750	6970	540	650	37	1.0	257	22.4	1.50
"	Rocky	87	148	2.8	11	2.5	<0.3	4.5	0.45	0.03
5 October 1997	Rocky	62.6	111	2.5	7.7	2.5	0.1	3.0	0.45	0.03

^{*1}EC = electrical conductivity (deci-siemens m⁻¹).

^{*2}TSS = total soluble salts (estimated percentage).







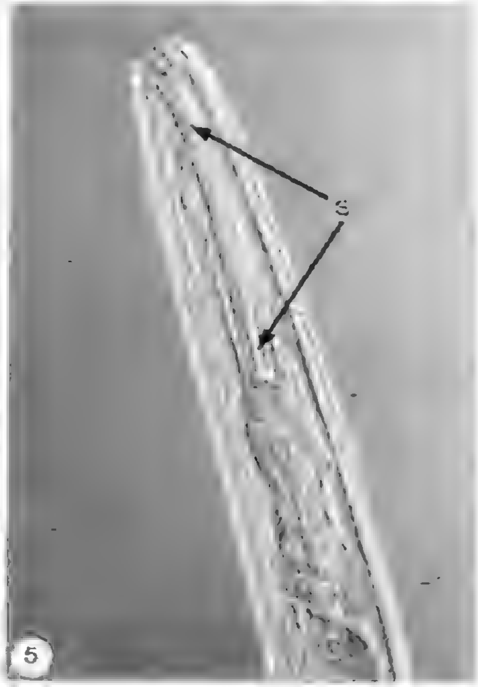


Fig. 2. *Hemicycliophora fluvialis* sp. nov. Holotype female, showing dimensions of the whole nematode.

Fig. 3. Surface of outer cuticle of holotype, showing narrow band or ridge running unbroken through the centre of each annule from side to side (small arrows). The annules also run unbroken across the surface of the cuticle (large arrows) and there is no evidence of lateral lines.

Fig. 4. Tail region of the holotype at higher magnification showing vulva (v) and annulated tapering tail. Note the shorter distance between vulva and tail tip (t) contrasted with that of *H. charlestoni* (Fig. 6).

Fig. 5. (Same magnification as Fig. 4). Head of holotype showing the long stylet (s) with its posteriorly sloped basal knobs, the distinct median bulb, isthmus and terminal bulb.

Paratype females (Measurements Table 2)

Etymology

The name is derived from L. *fluvialis*, of or belonging to a river.

Diagnosis and relationships

Hemicycliophora fluvialis sp. nov. resembles *H. charlestoni* Reay, 1984 but differs in having its vulva closer to the tail tip, fewer annules between its vulva and tail tip, no observable lateral lines, unbroken mid-annular transverse bands or grooves and a lower VL/VB ratio (Figs 3, 4, 6, Table 2). *Hemicycliophora fluvialis* differs from *H. litoralis* Reay, 1984 in having a shorter distance between its vulva and tail tip, no observable lateral lines, unbroken mid-annular transverse bands or grooves, fewer annules between its S-E pore and the tip of its head, a lower VL/VB ratio and in the absence of the characteristic vulval fold of the outer cuticle found in most *H. litoralis* (Figs 3, 4, 7, Table 2) (Reay 1984; Ye & Geraert 1997). The new species differs from *H. wallacei* Reay, 1984 in having a much larger stylet (114 µm compared with 82 µm), more annules between its vulva and tail tip and a higher VL/VB ratio (Table 2) and from *H. eucalypti* Reay, 1984 in having a lower De Man's index b, a larger stylet (114 µm compared with 104 µm), more annules, a higher R_{ex}, RV and VL/VB ratio (Table 2).

Eutobrilus heptapapillatus (Joubert & Heyns, 1979) Tsalolikhin, 1981

(FIGS 8-10, Table 3)

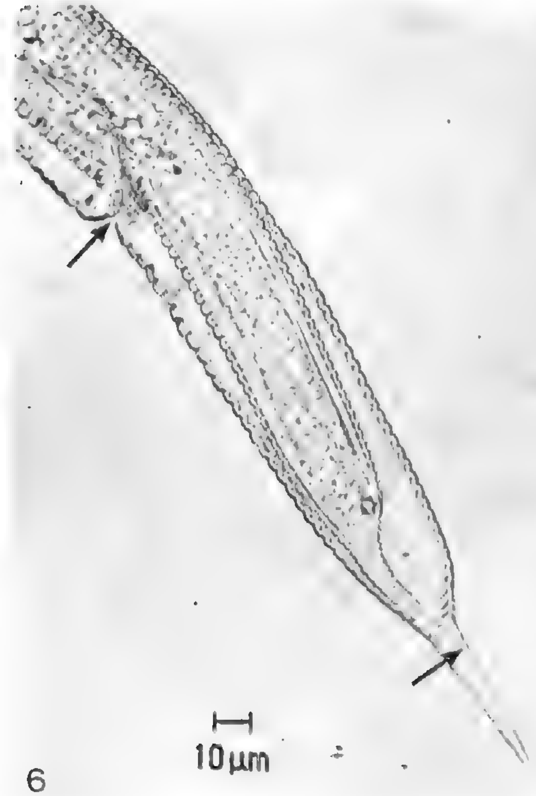
Material examined

7 ♂♂ Rocky River, KI (35° 57′ S, 136° 42′ E) coll. A. F. Bird, 3. vi. 1993, SAMA AHC 28116, ANIC 701, WINC 2023.

Measurements: Table 3

Relationships and remarks

Eutobrilus heptapapillatus is one of the most common nematode inhabitants at the water's edge of



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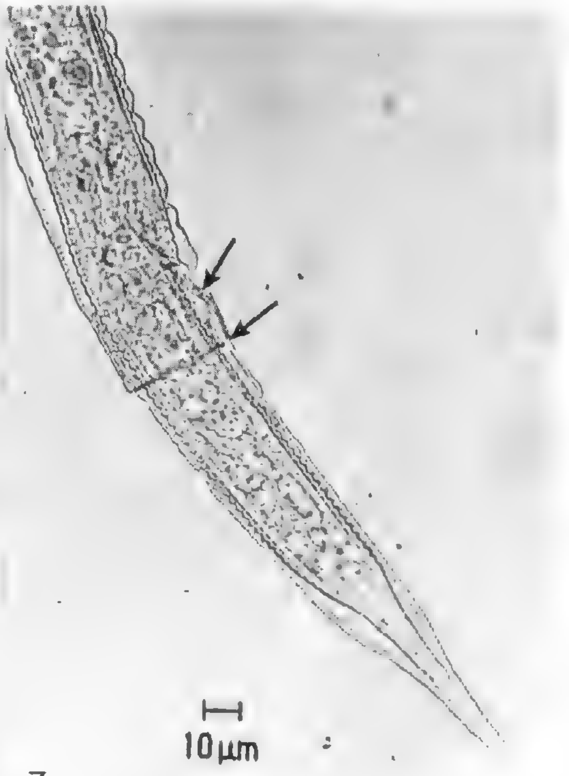

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Fig. 6. Tail region of *H. charlestoni* (paratype ♀WINC 168A - (K)) showing the distance between vulva and tail tip (arrows) for comparison with that of *H. fluvialis* sp. nov. (Fig. 4).

Fig. 7. Tail region of *H. litoralis* (paratype ♀ WINC 178C - (ff)) showing the characteristic vulval fold of the outer cuticle (arrows)

TABLE 2. *Comparisons of measurements of females of* Hemicycliophora fluvialis *sp. nov. from Rocky River (KI) with those published for other species from South Australia.*

	H. fluvialis n = 10			*H. charlestoni* (Reay 1984) n = 12		*H. litoralis* (Reay 1984) n= 52		*H. wallacei* (Reay 1984) n = 27		*H. eucalypti* (Reay 1984) n = 11	
Parts measured (µm)	Range	Mean	SD	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Body length (L)	974-1278	1096	±83	1000-1420	1222	850-1380	1114	870-1130	1007	870-1200	1056
De Man's index a	29-39	34	±4	[*1]nd		nd		nd		nd	
" b	5.2-5.9	5.5	±0.3	5.3-6.5	6.0	4.7-6.6	5.5	5.1-6.3	5.9	5.4-6.7	6.2
V%	85-88	86.2	±1.0	82-87	84	82-86	84	87-90	89	86-89	87
VL	120-160	138	±13	159-220	195	156-200	178	101-131	111	116-148	137
Stylet length	107-118	114	±4.5	100-120	112	94-118	109	77-88	82	97-113	104
m	79-88	82	±3.2	82-84	83	82-85	84	79-85	83	83-87	84
R	279-352	307	±27	277-316	297	299-380	326	267-305	285	190-221	206
R_{ex}	50-54	52	±1.5	49-58	53	60-73	66	49-57	53	39-44	41
R_{st}	25-33	30	±2.6	nd		nd		nd		nd	
$R_{pharynx\ (oes)}$	48-58	52	±3.4	nd		nd		nd		nd	
RV	49-59	53	±3.2	54-65	60	48-69	55	31-44	36	30-37	33
VL/VB	4.0-4.8	4.4	±0.3	4.5-6.3	5.2	4.8-7.3	5.7	3.1-3.9	3.5	3.2-4.2	3.7

[*1] nd = not determined.

TABLE 3. *Comparisons of measurements of males of* Eutobrilus heptapapillatus *from Rocky River (KI) with other populations.*

	Rocky River n = 7		South Africa (Swart & Heyns 1988) n = 7		Lake Albert (Bird 1995) n = 5		Lake Alexandrina (Bird 1995) n = 5	
Parts measured (µm)	Range	Mean SD	Range	Mean	Range	Mean	Range	Mean
Body length (L)	1700-2136	1952 ± 185	1550-2120	1920	1873-2000	1931	1800-1990	1896
Max. body width	45-68	55 ± 7	[*1]nd	53	64-77	71	60-70	66
Pharynx (oes) length	303-361	331 ± 24	nd	369	305-327	311	270-315	290
Tail length	187-209	199 ± 7	211-300	244	168-191	179	140-192	173
Body width at anus	30-34	33 ± 1	nd	38	36-41	38	32-40	38
Spicule	50-57	54 ± 3	48-57	53	50-55	54	52-56	53
Gubernaculum	27-33	30 ± 2	35-39	37	23-36	31	30-36	33
De Man's index a	31-40	36 ± 3	32-41	36	26-30	27	28-31	29
" b	5.2-6.2	5.9 ± 0.3	5.1-5.3	5.2	5.7-6.6	6.2	6.1-7.0	6.6
" c	8.5-10.5	9.8 ± 1	6.2-8.8	7.9	10.4-11.6	10.8	9.9-12.9	11.1
" c′	5.7-6.7	6.1 ± 0.3	5.8-8.0	6.5	4.4- 5.3	4.7	4.4-4.8	4.6
[*2]% dist. S_5-S_4	19-26	22 ± 2	16-18	17.4	16-23	20	17-22	19

[*1] nd = not determined.

[*2] % dist. S_5-S_4 = distance between supplementary organs 5 and 4, expressed as a percentage of the sum of the distances between these supplements (Bird 1995).

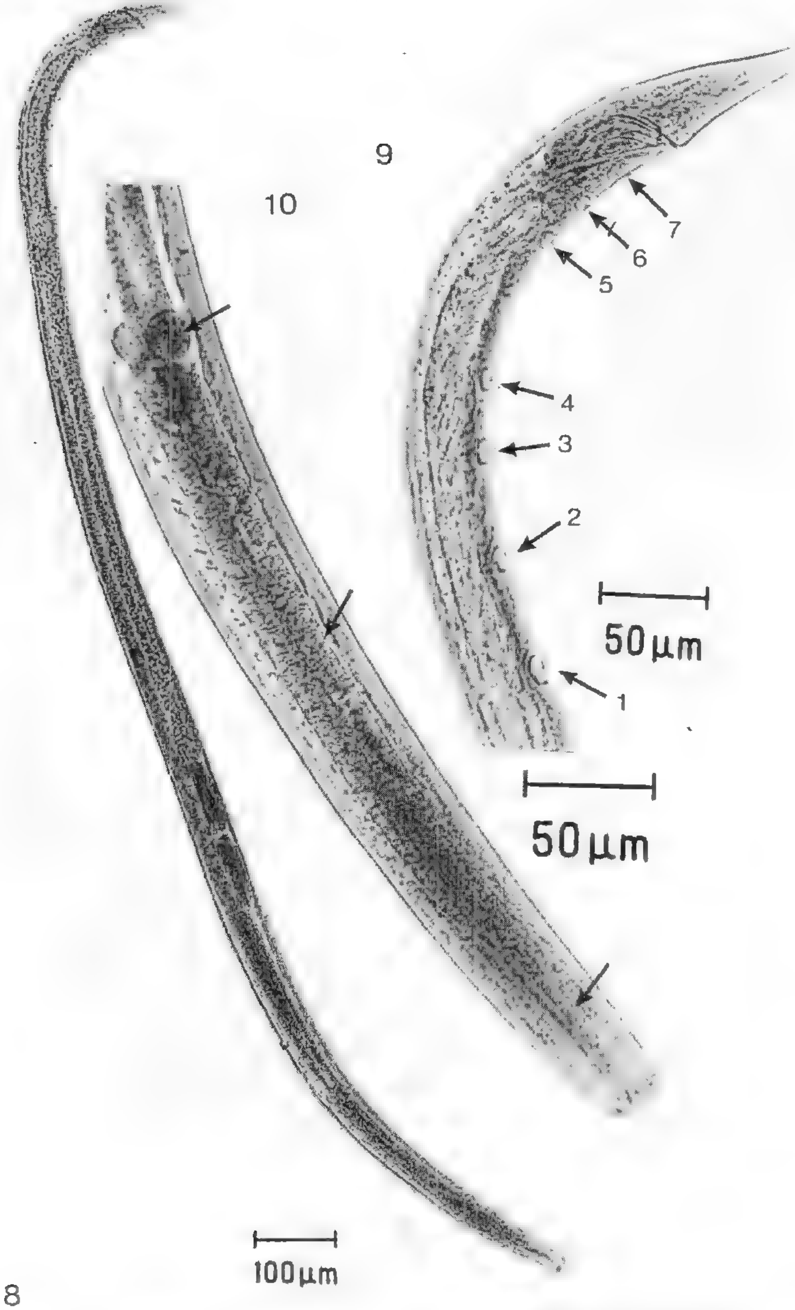
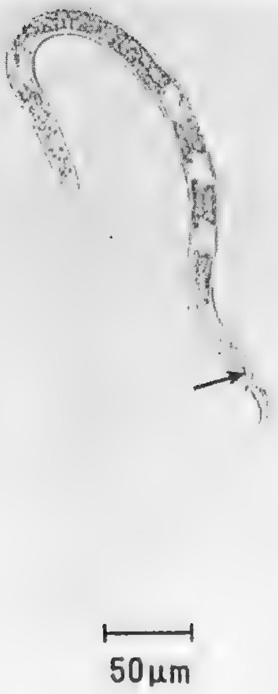


Fig. 8. Montage of whole *Eutobrilus heptapapillatus* ♂ showing its overall thinner appearance than the same species from the mainland lakes (Table 3).

Fig. 9. Tail region of nematode shown in Fig. 8 at a higher magnification and showing the supplementary organs (numbered arrows).

Fig. 10. Head region of nematode shown in Fig. 8 at a higher magnification and showing the pharynx and associated glands (arrows).



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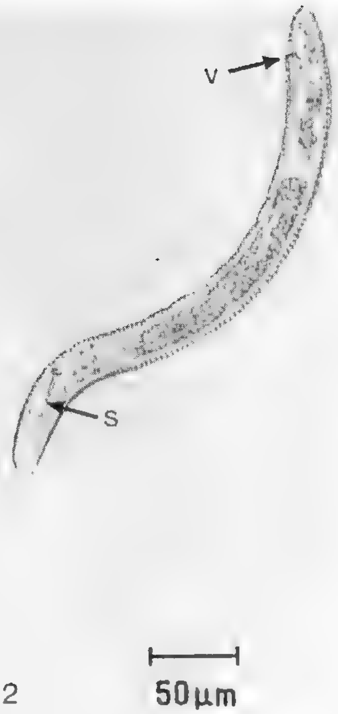

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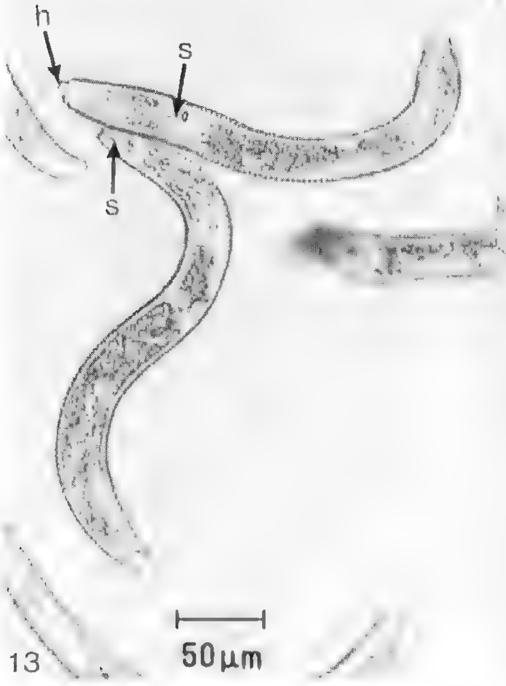

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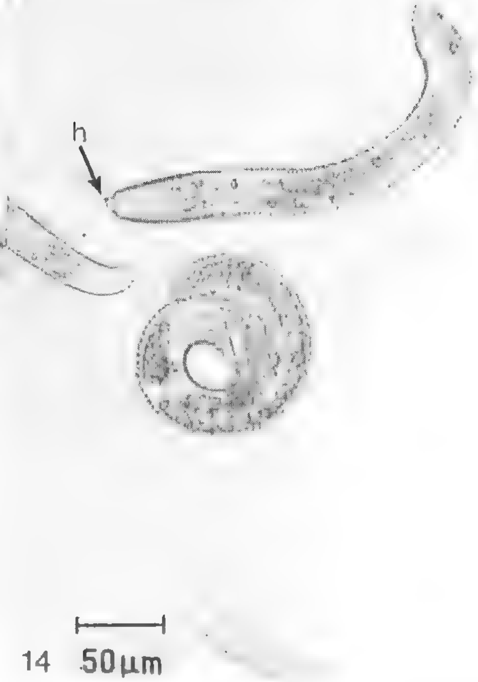

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Fig. 11. Living *Hemicriconemoides minor* ♂ showing shape and size. Note copulatory spicules (arrow) and absence of a buccal stylet.

Fig. 12. Living *H. minor* ♀ showing shape and size. Note position of vulva (v) and the pronounced buccal stylet (s).

Figs 13 & 14. Living *H. minor* ♀♀ showing evidence for serpentine movement (Fig. 13) and ring formation (Fig. 14). Note the off set heads (h) (cephalic annules) and the buccal stylets (s). These mainland specimens have identical measurements to the Rocky River population (Table 4).

Rocky River, making up almost 40% of the nematode population of the samples collected. This *E. heptapapillatus* population appears to be morphologically intermediate between the South African population (Swart & Heyns 1988) and those from Lakes Albert and Alexandrina in South Australia (Bird 1995). The population from Kangaroo Island resembles its South African counterpart in maximum body width and De Man's indices a and c´ and is thinner than the populations from the South Australian lakes (Fig. 8, Table 3). It resembles the lake populations in the size of the gubernaculum and percentage distance between the supplementary organs S_5 and S_4 (Fig. 9, Table 3). The Kangaroo Island population is intermediate between the South African and South Australian lakes populations in pharynx length (Fig. 10, Table 3), tail length and De Man's indices b and c. It has a narrower body width at the level of its anus than any of the other populations but all the populations resemble each other in body length and spicule size (Table 3).

The morphological differences between the Rocky River population of *E. heptapapillatus* and populations of this species from Lakes Alexandrina and Albert may be a reflection of the isolation of Kangaroo Island from the mainland of South Australia some 9,500 years ago (Lampert 1979). It is thought that prior to separation from the mainland the ancient River Murray ran past the eastern tip of Kangaroo Island less than 10 km away from it. The subsequent retreating of the river, the formation of the island and the onset of more arid conditions, as indicated by changes in the vegetation, would have subjected the tobrilids in Rocky River to environmental pressure greater than those in the billabongs of the River Murray.

Hemicriconemoides minor Brzeski & Reay, 1982
(FIGS 11-14, Table 4)

Material examined

15 ♀♀ from soil adjacent to Rocky River, KI (35° 57´ S, 136° 42´ E) coll. A. F. Bird, 3. vi. 1993, SAMA AHC 28117, ANIC 702, WINC 2024.

Remarks

Kuitpo Forest near the township of Meadows and 30 km south of Adelaide is the type locality for *Hemicriconemoides minor*. However, this species is widely spread throughout the southern parts of Australia and has been found in virgin karri and marri forests south of Manjimup, Western Australia, in forest soil near Cape Jervis, South Australia, in

TABLE 4. *Comparisons of measurements of females of a* Hemicriconemoides minor *population collected close to the banks of Rocky River (35° 57´ S, 136° 42´ E) on Kangaroo Island compared with those of the paratypes and holotype from a Kuitpo Forest population on the mainland of South Australia.*

		Rocky River			Kuitpo Forest (Brzeski & Reay 1982)		
					Paratypes		Holotype
		n = 15			n = 16		
Parts measured (μm)		Range	Mean	SD	Range	Mean	
Body length (L)		293-383	328.8	± 21.4	290-370	320	340
De Man's index	a	13.6-17.7	15.4	± 1.3	12-15	14	15
"	b	3.0-3.9	3.3	± 0.3	2.8-4.4	3.4	3.3
"	c	[1]nd	nd		19-27	23	26
"	V	87.7-94.9	91.1	± 2.1	91-94	92	92
VL/VB		1.2-1.5	1.3	± 0.1	1.2-1.5	1.3	1.5
Stylet		63.3-70.0	65.3	± 2.1	56-68	63	65
R		110-127	118	± 4.5	112-125	118	117
RB (n=5)		3.3-4.1	3.5	± 0.4	nd	nd	nd
R_{st}		24-26	25.1	± 0.5	nd	nd	nd
$R_{pharynx\ (oes)}$		36-41	38.5	± 1.5	nd	nd	nd
RV		9-11	10.1	± 0.6	10-13	12	13
R_{ex}		nd	nd		32-39	37	36
R_{van}		nd	nd		2-5	4	5
R_{an}		nd	nd		6-8	7	7

[1] nd = not determined.

woodland adjacent to the River Murray in the Sunraysia district of Victoria, on the slopes of Mt William in the Grampian Mountains of Victoria and in rainforest near the Hellyer River, 64 km south of Burnie in Tasmania (Brzeski & Reay 1982; Reay & Colbran 1986). It is thus not surprising that it has now been found on Kangaroo Island in the soil under native bush in Flinders Chase National Park about 20 m from Rocky River.

Comparison of measurements of the Flinders Chase females with the holotype female and paratype females of *H. minor* from Kuitpo Forest (Table 4) show that they are remarkably similar.

Hemicriconemoides minor belongs to the family Criconematidae. As its specific name suggests, it is a small nematode with the adult female having a characteristic stubby shape (Figs 12-14). Both males and females are about $^1/_3$ mm in length. Criconematids are commonly known as ring nematodes because of their sausage-shaped body that may bend into a ring in the living state (Fig. 14). These nematodes have pronounced body annules and a long stylet. The genus *Hemicriconemoides* is characterized by the female having a double cuticle, the outer being sheath-like with retrose annulations. The head may be rounded in outline (Fig. 12) or offset, as can be seen in the living state (Figs 13, 14). The spermatheca in the *H. minor* specimen depicted in Figure 12 is filled with sperm and the vulva is open. Males were not found in soil from the sample site adjacent to Rocky River although they have been described from the Grampian Mountains in Victoria (Reay & Colbran 1986) and were found in soil from Kyeema Conservation Park, east of Willunga and south of Adelaide (Fig. 11). They are narrower than females and lack a buccal stylet. Males have not been found in many of the sites from which females have been described.

Because it was not possible to locate clearly the positions of either the S-E pore or the anus in the 15 female specimens measured from Rocky River (Table 4), figures for De Man's index c and R_{ex}, R_{van} and R_{an} are not given. However, figures for RB, R_{st} and $R_{pharynx\ (oes)}$, which have not previously been determined, are provided. In all cases where comparable measurements have been made (Table 4) the Rocky River population closely resembles the 16 paratype females of *H. minor* from Kuitpo Forest, in spite of a physical separation by sea for 9,500 years.

Discussion

It is interesting to speculate upon the effects of environmental change on animal populations. Both *H. fluvialis* and *E. heptapapillatus* collected from water logged soils at the water's edge of Rocky River showed differences from closely related or similar species/populations on the mainland of South Australia whereas the population of *H. minor* collected from soil adjacent to the river but under natural vegetation was indistinguishable from a species/population on the mainland (Table 4). It is likely that the environment of the river bed in Rocky River which dries up into pools in the summer and the site up river from the road bridge which dries out completely (D. Smitherson pers. comm. 1999) would fluctuate much more than that of the bottoms of lakes Albert and Alexandrina where other populations of *E. heptapapillatus* are found. Subjection to regular stresses of drying and wetting could explain why, for instance, *E. heptapapillatus* from Rocky River may have some similar morphological characteristics to *E. heptapapillatus* from a stagnant water hole in the Tsitsikama National Park in Cape Province, RSA, which neither population shares with those of *E. heptapapillatus* from the two lakes (Table 3). An example of this can be found in the maximum widths. That of *E. heptapapillatus* from the lakes is greater than that of the specimens from Rocky River and Tsitsikama National Park (71 and 66 µm compared with 55 and 53 µm). It would be interesting to know if the Kangaroo Island and South African populations have greater capability of surviving desiccation than the lakes' populations.

Environmental fluctuations at the site where *H. minor* was collected, under native vegetation in soil some 20 m from the river's edge, would not be nearly as great as at the riparian site and would be similar to the various mainland sites where *H. minor* has been collected. This may account for their close morphological similarities (Table 4).

Although a considerable amount of research has been done on the macrofauna of Kangaroo Island by many workers (Tyler *et al.* 1979) there has been little or no research into microscopic soil and fresh water nematodes. However, they are very much a part of the soil and water environment and are a natural component of any studies on environmental biology and biodiversity.

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I thank J. Bird for constructive criticism of the manuscript. CSIRO Land and Water provided accommodation, facilities and the expertise of A. Beech (water analyses), G. E. Rinder (mapping) and the library staff. I should like to thank R. J. Ellis (District Ranger Kangaroo Island W) for permission to collect soil samples from Flinders Chase National Park. This research was made possible by a grant from the Australian Biological Resources Study

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A NEW SPECIES OF EIMERIA (APICOMPLEXA: EIMERIIDAE) FROM THE STICK-NEST RAT, LEPORILLUS CONDITOR (RODENTIA: MURIDAE)

By Michael G. O'Callaghan & Peter J. O'Donoghue†*

Summary

O'Callaghan, M. G. & O'Donoghue, P. J. (1999) A new species of Eimeria (Apicomplexa: Eimeriidae) from the stick-nest rat, Leporillus conditor (Rodentia: Muridae). Trans. R. Soc. S. Aust. (1999) 123(4), 133-135, 30 November, 1999.

A new species of Eimeria is described from five of eight (62.5%) stick-nest rats, Leporillus conditor from South Australia. Sporulated oocysts of Eimeria leporilli sp. nov. are ovoidal to sub-spheroidal, 19.3 x 15.7 μm, with a double oocyst wall, no micropyle, no oocyst residuum, with four ellipsoidal sporocysts 9.4 x 6.2 μm, slightly pointed at one end with a knob-like Steida body, each containing two sporozoites. Attempts to infect laboratory rats, Rattus norvegicus, with sporulated oocysts from stick-nest rats were unsuccessful.

Key Words: Coccidia, Eimeria, Eimeria leporilli sp. nov., Rodentia, Muridae, Leporillus conditor, stick-nest rat, Australia.

Transactions of the Royal Society of S. Aust. (1999), **123**(4), 133-135.

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A new species of *Eimeria* is described from five of eight (62.5%) stick-nest rats, *Leporillus conditor* from South Australia. Sporulated oocysts of *Eimeria leporilli* sp. nov. are ovoidal to sub-spheroidal, 19.3 x 15.7 µm, with a double oocyst wall, no micropyle, no oocyst residuum, with four ellipsoidal sporocysts 9.4 x 6.2 µm, slightly pointed at one end with a knob-like Steida body, each containing two sporozoites. Attempts to infect laboratory rats, *Rattus norvegicus*, with sporulated oocysts from stick-nest rats were unsuccessful.

KEY WORDS: Coccidia, *Eimeria*, *Eimeria leporilli* sp. nov., Rodentia, Muridae, *Leporillus conditor*, stick-nest rat, Australia.

Introduction

Enteric coccidia have not previously been reported in the stick-nest rat, *Leporillus conditor* (Sturt, 1858). Indeed, all previous records of eimeriid coccidia in rodents from Australia have been restricted to *Rattus norvegicus*, *R. rattus* and *Mus musculus* (cf. Mackerras 1958). A novel *Eimeria* sp. was discovered in *L. conditor* and is described here as new. The validity and host specificity of the *Eimeria* sp. was examined by attempted cross-transmission to *Rattus norvegicus*.

Materials and Methods

Faecal samples were collected from eight stick-nest rats from Franklin Island, South Australia from 1988 to 1997. Two samples were collected from animals which were subsequently transferred from the wild population on Franklin Island to a captive colony at the Monarto Fauna Facility, South Australia. Faecal samples were stored at room temperature for three weeks in 2% (w/v) aqueous potassium dichromate to allow oocysts to sporulate. Sub-samples were mixed in saturated sucrose solution (S.G. 1.33) and oocysts recovered by centrifugal flotation. Oocysts were examined microscopically using an oil immersion 100x objective with a Nomarski differential interference contrast system and were measured using an eyepiece graticule calibrated with an Olympus objective micrometer. Measurements in the text are given in micrometres (µm), mean ± standard deviation with range in parentheses.

A phototype of the sporulated oocyst has been deposited in the US National Museum, Beltsville Maryland, Parasite Collection (USNPC No. 88842).

Cross-transmission study

Two two month old laboratory-reared coccidia-free outbred Sprague-Dawley rats, *Rattus norvegicus* Berkenhout 1769, were obtained from the Institute of Medical and Veterinary Science, Adelaide. Animals were housed in a plastic cage with pre-sterilized bedding and accessed water and sterilized commercial rodent pellets *ad libitum*. Both were exposed to natural light/dark and temperature patterns (av. min. 17° C, av. max. 21° C) and isolated from other rodents. One rat was inoculated with 5,000 and the other with 10,000 sporulated oocysts harvested from three stick-nest rats by centrifugal flotation in saturated sucrose solution, washed three times in tap water, counted in a haemocytometer and given orally using a syringe fitted with plastic tubing. These oocysts were harvested from faecal samples collected in July, 1997 and were stored at room temperature in 2% (w/v) aqueous potassium dichromate for less than 82 days. Faecal samples were collected before inoculation to ensure the inoculated animals were not passing oocysts. Following inoculation, faecal samples were collected daily and examined for oocysts for 24 days.

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Results

Coccidial oocysts were detected in faeces from five of eight (62.5%) stick-nest rats examined. The morphological configuration of the oocysts conformed to those of the genus *Eimeria* in that they contained four sporocysts per oocyst and two sporozoites per sporocyst. The coccidian species detected was considered new on the basis of morphological characteristics, novel host species and apparent host specificity as infections could not be established in *R. norvegicus*.

Eimeria leporilli sp. nov.
(FIGS 1-3)

Material examined

Oocysts in faeces from 5 *Leporillus conditor*, 4 originating from Franklin Island, SA, (32° 27´ S. 133° 40´ E), 2. vi. 1988, 21. vi. 1988, 27. vi 1988, 14. vii.1997, and 1 from captive animals transferred from Franklin Island to Monarto, SA (35° 07´ S. 139° 09´ E). 27. vii. 1997. USNPC No. 88842.

Description

Oocysts ovoidal or subspheroidal, 19.3 ± 2.3 (14 - 25) x 15.7 ± 1.6 (11.5 - 19) (n = 100); mean length:width ratio 1.2; oocyst wall bi-layered, outer layer colourless, smooth, 1.0 thick; inner layer colourless, 0.6 thick; micropyle and oocyst residuum absent; predominantly 1, but up to 5 refractile polar granules present; 4 ellipsoidal sporocysts 9.4 ± 1.25 (7.3 - 13) x 6.2 ± 0.71 (4.2 - 8.2) (n = 100); slightly pointed at one end with a conspicuous knob-like Steida body; sub-Steida body absent; 2 sporozoites filling sporocyst; large refractile globule 2.4 - 3.2 in diameter at posterior end; ellipsoidal sporocyst residuum, 2.4 in diameter at equator of sporocyst, composed as an aggregation of numerous granules.

Type host

Leporillus conditor (Sturt, 1848) Stick-nest rat.

Locality

Franklin Island, SA (32° 27´ S. 133° 40´ E).

Location in host

Oocysts in faeces; endogenous stages unknown.

Etymology

Specific name derived from the generic name of the host.

Cross-transmission study

Over the 24 day observation period, coccidia were not recovered from the faeces of two *R. norvegicus* inoculated with sporulated oocysts from stick-nest rats.

Discussion

Coccidia of the genus *Eimeria* are typically host specific; it is rare for these parasites to infect more than one host and many species are known only by the morphology of the oocysts and by the identity of the host in which they are found (Joyner 1982). Upton *et al.* (1992) suggested that some rodent

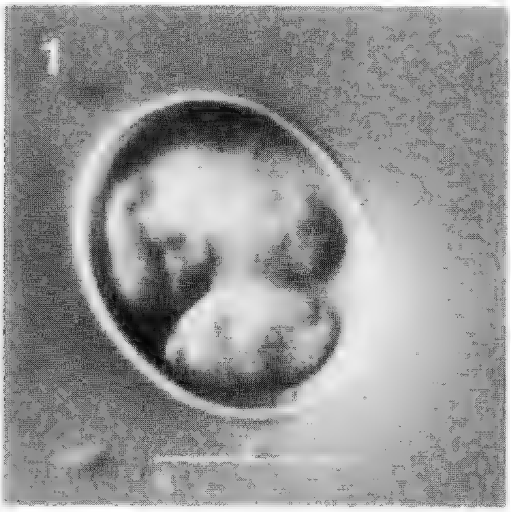

Fig. 1. *Eimeria leporilli* sp.nov. from captive stick-nest rat - sporulated oocyst. Scale bar = 10 µm.

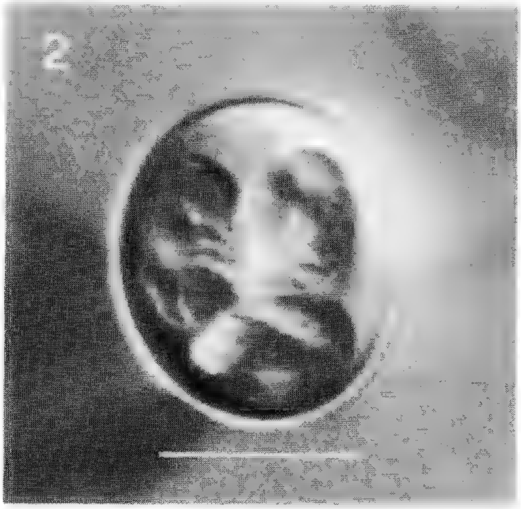

Fig. 2. *E. leporilli* sp. nov. from stick-nest rat on Franklin Island - sporulated oocyst. Scale bar = 10 µm.

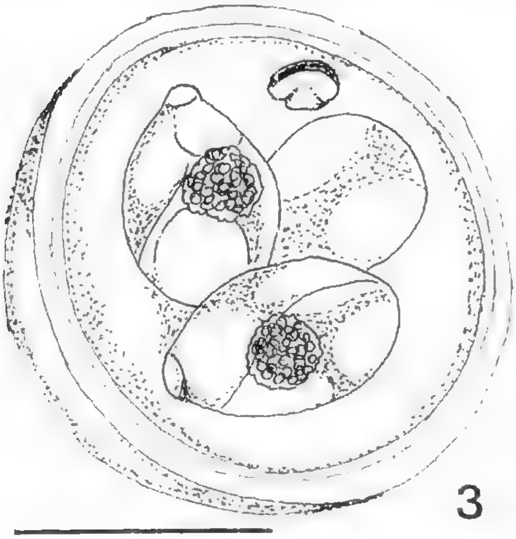

Fig. 3. Composite line drawing of sporulated oocyst of *E. leporilli*. Scale bar = 10 µm.

coccidia are less specific in their host range and may be able to infect different, usually phylogenetically related, species. In this study, the *Eimeria* sp. detected in stick-nest rats did not establish an infection in experimentally inoculated *R. norvegicus*. The inability to infect *R. norvegicus* confirms the distinctness from coccidia previously reported in rodents in Australia (Mackerras 1958). However, the host range of coccidian species from native rodents remains to be determined by further comprehensive coprological and cross transmission studies. In addition, histological studies on gut sections are required to determine the endogenous developmental cycles and to indicate the potential pathogenicity of infections.

Eimeria leporilli sp. nov. exhibited variation in oocyst and sporocyst size, up to 40% and 43% respectively in each animal. Considerable variation in oocyst and sporocyst size is known to occur for many *Eimeria* species, some varying as much as 40% (Duszynski 1971). In the absence of other distinguishing characteristics, the coccidia described here are considered to be a single species with considerable size variation in the oocyst and sporocyst.

Acknowledgment

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CLOACINIDAE (NEMATODA: STRONGYLOIDEA) INCLUDING A NEW SPECIES DORCOPSINEMA SIMILE, FROM DORCOPSULUS VANHEURNI (MARSUPIALIA: MACROPODIDAE) FROM PAPUA NEW GUINEA

*BY L. R. SMALES**

Summary

Smales, L. R. (1999) Cloacinidae (Nematoda: Strongyloidea) including a new speces, Dorcopsinema simile, from Dorcopsulus vanheurni (Marsupialia: Macropodidae) from Papua New Guinea. Trans. R. Soc. S. Aust. 123(4), 137-142, 30 November, 1999.

Paralabiostrongylus bicollaris, Dorcopsistrongylus labiacarinatus, Coronostrongylus coronatus and Macropostrongylus sp. are recorded from the stomach of the lesser forest wallaby Dorcopsulus vanheurni from Doido in Papua New Guinea.

Key Words: Dorcopsulus vanheurni, Dorcopsinema, nematodes, Cloacinidae, marsupials, Australia, Papua New Guinea.

Transactions of the Royal Society of S. Aust. (1999), **123** (4), 137-142.

CLOACINIDAE (NEMATODA: STRONGYLOIDEA) INCLUDING A NEW SPECIES, *DORCOPSINEMA SIMILE*, FROM *DORCOPSULUS VANHEURNI* (MARSUPIALIA: MACROPODIDAE) FROM PAPUA NEW GUINEA

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Summary

SMALES, L. R. (1999) Cloacinidae (Nematoda: Strongyloidea) including a new species, *Dorcopsinema simile*, from *Dorcopsulus vanheurni* (Marsupialia: Macropodidae) from Papua New Guinea. *Trans. R. Soc. S. Aust.* **123**(4), 137-142, 30 November, 1999.

Paralabiostrongylus bicollaris, *Dorcopsistrongylus labiacarinatus*, *Coronostrongylus coronatus* and *Macropostrongylus* sp. are recorded from the stomach of the lesser forest wallaby *Dorcopsulus vanheurni* from Doido in Papua New Guinea. *Dorcopsinema simile* sp. nov. is described from the same host and locality. *Dorcopsinema simile* differs from *D. dorcopsis*, the only other species of *Dorcopsinema* occurring in forest wallabies, in having the nerve ring anterior to the deirids rather than posterior, larger eggs (120 µm x 68.5 µm compared with 115 µm x 57.5 µm) a shorter vagina (300-470 µm compared with 680 µm) and lateral branchlets arising anterior to the bifurcation of the dorsal ray rather than posterior to it. The fourth stage larva is described. A revised key to the species of *Dorcopsinema* is given. An analysis of the helminths occurring in *Dorcopsulus*, *Dorcopsis* and *Dendrolagus* suggests that the forest wallabies have a more diverse community than the tree-kangaroos, including components which are exclusive to the island of New Guinea as well as components that are common to both the Australian continent and New Guinea.

KEY WORDS: *Dorcopsulus vanheurni*, *Dorcopsinema*, nematodes, Cloacinidae, marsupials, Australia, Papua New Guinea.

Introduction

The genus *Dorcopsinema* Mawson, 1977 comprises strongyloid nematodes of the family Cloacinidae (Stossich, 1899) occurring in the stomachs of tree kangaroos, *Dendrolagus* Mueller & Schlegel, 1839 and forest wallabies *Dorcopsis* Schlegel & Mueller, 1842 (see Baylis 1940; Mawson 1977; Smales 1982a, 1997). There are, however, few records of parasitic helminths from the related genus of forest wallabies *Dorcopsulus* Matschie, 1916 and none from *Dr. vanheurni* (Thomas, 1922) (see Spratt *et al.* 1991). Four specimens of the small forest wallaby *Dr. vanheurni* collected from the Chimbu Province of Papua New Guinea in 1984 by R. Speare were found to have a diverse community of stomach nematodes. A new species of *Dorcopsinema* is described in this paper. New host records for other species of the Cloacinidae found in the stomachs of the animals examined are given below and new species of the genus *Cloacina* von Linstow, 1898 are reported elsewhere.

Materials and Methods

Stomach contents of lesser forest wallabies were fixed in 10% formalin in the field. Subsequently the contents were washed in water to remove the formalin, nematodes were removed, washed again and stored in 70% ethanol. Worms were cleared in lactophenol prior to examination. Specimens from *Dorcopsulus* sp. deposited in The Natural History Museum, London (BMNH), were also examined. Measurements of 10 specimens, in micrometres unless otherwise stated, were made using an ocular micrometer and are presented as the range followed by the mean in parentheses. Figures were prepared with the aid of a drawing tube. Host names follow Flannery (1995). Nematode classification and terminology follow Beveridge (1987). All material has been deposited in the South Australian Museum, Adelaide (SAMA).

Results

Eight specimens of *Paralabiostrongylus bicollaris* Smales, 1982 (Cloacininae Stossich, 1899: Labiostrongylinea Beveridge, 1983) from three host animals, 39 specimens of *Dorcopsistrongylus labiacarinatus* Smales, 1982 (Cloacininae: Pharyngostrongylinea Popova, 1952) from four hosts, 37 specimens of *Coronostrongylus coronatus* Johnston & Mawson, 1939 (Cloacininae: Coronostrongylinea Beveridge, 1986) from four hosts and one specimen of *Macropostrongylus* sp. Yorke & Maplestone, 1926 (Cloacininae: Macropostrongylinea Lichtenfels, 1980) from one host were found. Each of these is a new host record

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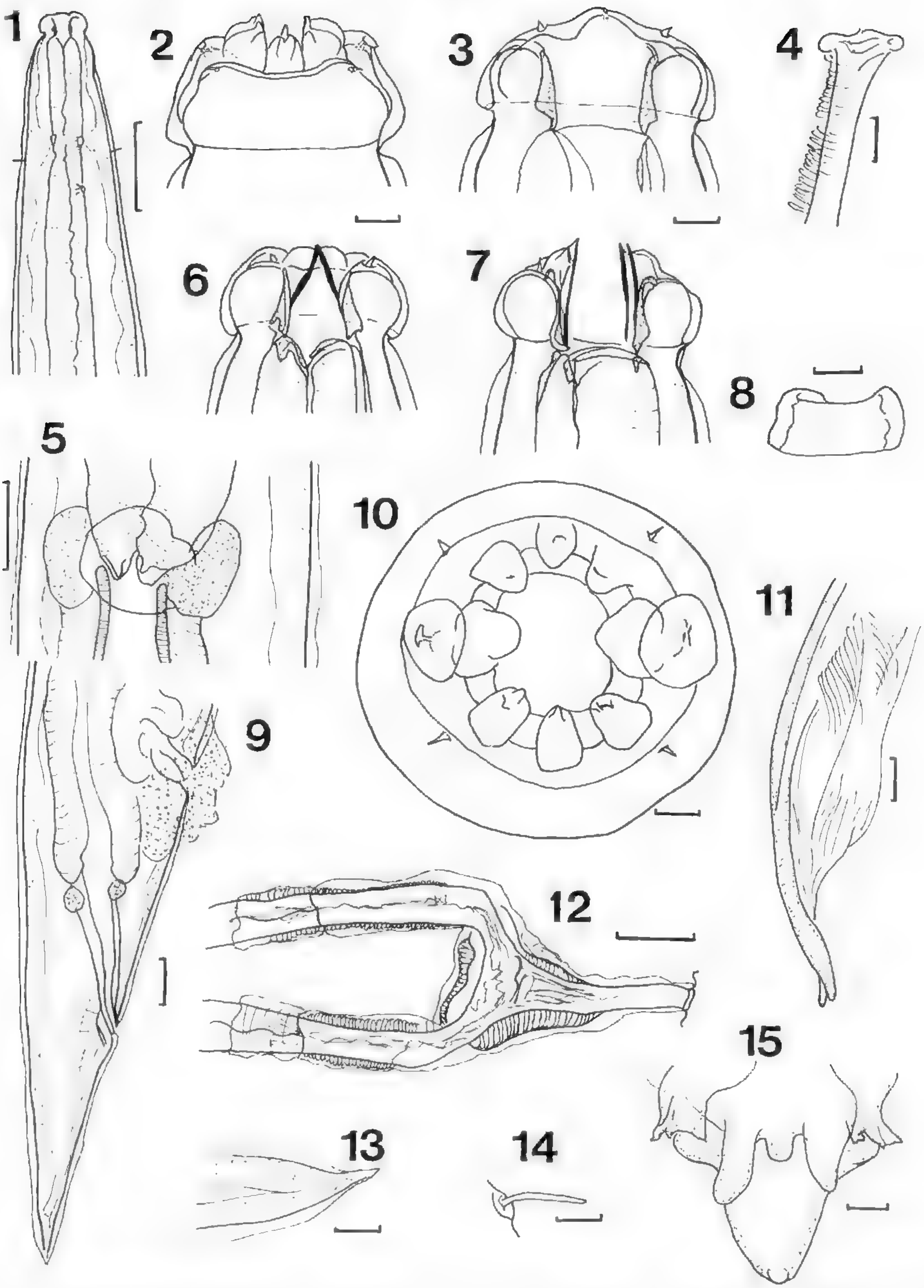
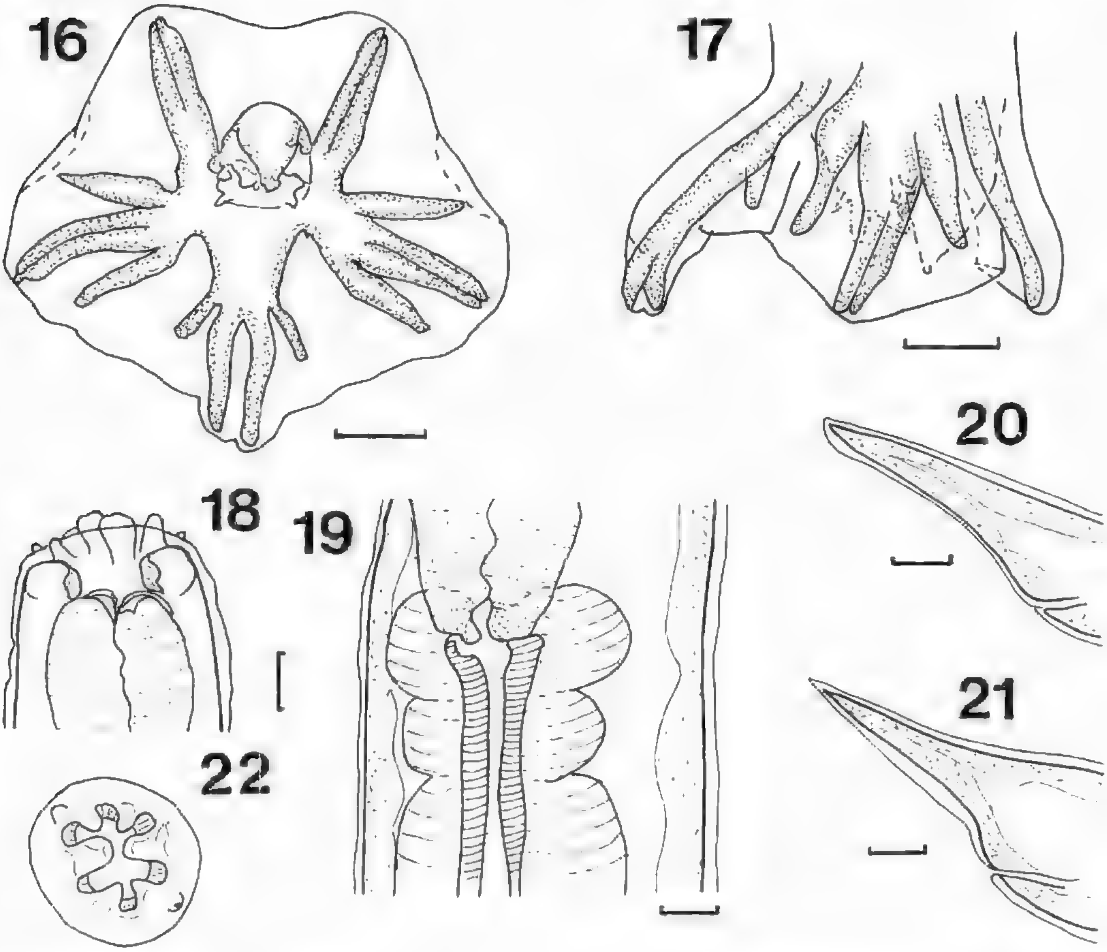


Figs 1-15. *Dorcopsinema simile* sp. nov. 1. Anterior end (ventral view). 2. Cephalic end, lip-like elements extended (ventral view). 3. Cephalic end, lip-like elements not extended (lateral view). 4. Spicule, anterior end. 5. Oesophago-intestinal junction (lateral view). 6. Cephalic end, optical section (dorsal view). 7. Cephalic end, optical section (lateral view). 8. Gubernaculum (ventral view). 9. Posterior end, female (lateral view). 10. Cephalic end (*en face* view). 11. Spicule tip (lateral view). 12. Ovejector (ventral view). 13. Female tail tip. 14. Deirid. 15. Genital cone (dorsal view). Scales bars = 500µm 1; 50µm 2 - 4, 6, 7, 13; 200µm 5, 9, 12; 25µm 8, 10, 11, 14, 15.



Figs 16 – 22. *Dorcopsinema simile* sp. nov. 16. Bursa (apical view). 17. Bursa (lateral view). 18. Fourth stage larva, cephalic end (lateral view). 19. Fourth stage larva, oesophago -intestinal junction showing developing diverticula (lateral view). 20. Fourth stage larva, developing female tail. 21. Fourth stage larva, developing male tail. 22. Fourth stage larva, cephalic end (*en face* view). Scale bars = 100µm 16, 17; 25µm 18, 19, 22; 50µm 20, 21.

Dorcopsinema simile sp. nov.
(FIGS 1-22)

Types : Holotype ♂, allotype ♀, paratypes 54 ♂♂ 72 ♀♀ from stomach of *Dorcopsulus vanheurni* (Thomas,1922), Doido (6° 33′ S, 144° 50′ E), Chimbu Province, Papua New Guinea, coll. R. Speare; 17.v.1984 SAMA AHC 31326, AHC 31327, and AHC 31328 respectively.

Other material examined : From *Dorcopsulus van heurni* : 2 ♂♂, 1 ♀, 4 larvae same data AHC31329. From *Dorcopsulus* sp., 1 ♂, 2 ♀♀ Lae (6° 44′ S, 147° 00′ E), Morobe Province, Papua New Guinea, coll. N.T. Talbot, BMNH 1970. 499-508.

Description

Relatively large worms; body with fine transverse cuticular striations. Cephalic extremity with wide, well-defined fleshy collar bearing two amphids, each on dome-like projection, and four cephalic papillae; peri-oral cuticle forming eight sclerotised lip-like processes arising within buccal capsule. Buccal capsule short, cylindrical, walls well sclerotised, within region of collar. Oesophagus long, clavate, about 20% body length. Oesophago-intestinal diverticula small; length of diverticula less than maximum width of oesophagus.

Male

Length 16 – 24 (20) mm, maximum width 665 1105 (760). Buccal capsule 60 – 85 (75) wide x 75 – 100 (88) deep. Oesophagus 3,500 – 4,760 (4,110) long. Nerve ring 580 – 735 (665), deirids 735 – 960 (855), secretory-excretory (S-E) pore 890 – 1155 (1020) from anterior end. Bursal lobes not separate;

dorsal lobe longest, ventral lobes shortest. Ventroventral and ventrolateral rays apposed, reaching margin of bursa; externolateral ray divergent, not reaching margin of bursa; mediolateral and posterolateral rays apposed, reaching margin of bursa; externodorsal ray arising close to lateral trunk, not reaching margin of bursa; dorsal trunk stout; bifurcating at about $^1/_3$ its length, rays reaching margins of bursa; each ray branching anterior to level of bifurcation, lateral branchlets not reaching margin of bursa. Spicules 1685 – 2055 (1850) long, 9% body length; anterior extremities irregularly knobbed; distal tips slightly curved, finely striated broad alae not extending to spicule tips. Genital cone prominent: anterior lip larger conical, extending almost to limit of ventral lobes; posterior lip smaller with 3 pairs posteriorly directed appendages, short central projection. Gubernaculum rectangular.

Female

Length 28 – 32 (31) mm, maximum width 1020 – 1530 (1190). Buccal capsule 80 – 100 (97) wide x 92 – 101 (99) deep. Oesophagus 4930 – 5950 (5640) long. Nerve ring 790 – 870 (835), deirids 870 – 970 (925), S - E pore 935-1225 (1065) from anterior end. Tail 970 – 1190 (1090) long ending in pointed tip; vulva immediately anterior to anus, 2175 – 2550 (2290) from posterior end. Vagina short, straight, 300 – 470 (410) long; vestibule muscular, about same length as sphincters, infundibula shorter. Eggs ellipsoidal 119 – 122 (120) x 66 – 69 (68.5).

Fourth stage larva (n = 3)

Length 5–8 mm, width 270-660. Oesophagus 1700-2295 long. S - E pore 335-670 from anterior end. Fleshy collar not developed at cephalic end, 6 peri-oral, lip-like processes present. Anterior end of intestine developing into diverticula. Tail 235 – 250 long.

Etymology

The specific name *simile* refers to the similarities between this new species and *Dorcopsinema dorcopsis*, also occurring in forest wallabies.

Remarks

Dorcopsinema simile sp. nov. is very similar to *D. dorcopsis* particularly in having eight peri-oral lip like processes around the mouth, a fleshy cephalic collar and in the length of the oesophagus and spicules. *Dorcopsinema simile* differs in the relative positions of the nerve ring and deirids, the nerve ring being more anterior than in *D. dorcopsis* (583 – 737 compared with 737 – 985). This results in the deirids being posterior to the nerve ring rather than anterior to it as in *D. dorcopsis*. Other differences between the two species are that the eggs of *D. simile* are larger (120 x 68.5) than those of *D. dorcopsis* (115 x 57.5). *D. simile* females have shorter tails (970-1190 compared with 1120-1430) and shorter vaginae (300-470 compared with 680) than *D. dorcopsis*. *Dorcopsinema simile* has three pairs of appendages on the posterior lip of the genital cone and the lateral branchlets of the dorsal ray arise slightly anterior to its bifurcation from the dorsal trunk whereas *D. dorcopsis* has four pairs of appendages on the posterior lip of the genital cone and the lateral branchlets of the dorsal ray arise slightly posterior to its bifurcation from the dorsal trunk. Although these morphological differences may seem slight they are consistent and are sufficient to differentiate *D. dorcopsis* from *D. simile*. Within the Labiostrongylinea the significance of such minor morphological differences between species has been confirmed by enzyme electrophoresis (Chilton & Smales 1996; Smales & Chilton 1997). Furthermore, species pairs, readily distinguished by the relative positions of deirids and nerve ring have been differentiated by Chilton *et al.* (1993) and Beveridge (1998) for other cloacinid species.

Dorcopsinema simile occurs in *Dr. vanheurni* whereas *D. dorcopsis* occurs in *Do. muelleri* (Schlegel, 1866) and *Do. luctuosa* (D'Albertis, 1874) (see Smales 1997).

Key to the species of *Dorcopsinema*

revised from Smales 1997

1. With fleshy head collar bearing amphids and cervical papillae; eight sclerotised lip-like processes; spicules > 1650 µm long. Parasites of *Dorcopsis* 2
   With or without clearly defined fleshy head collar; six sclerotised lip-like processes. Parasites of *Dendrolagus* 3
2. With deirids posterior to nerve ring; lateral branchlets arising anterior to the bifurcation of the dorsal ray; vagina <480 µm long ... *D. simile*
   With deirids anterior to nerve ring; lateral branchlets arising posterior to the bifurcation of the dorsal ray; vagina > 600 µm long ....*D. dorcopsis*
3. With clearly defined head collar; deirids near collar; spicules < 1275 µm long; female tail without spike ....*D. mbaiso*
   Without clearly defined head collar; deirids close to nerve-ring; spicules > 1300 µm long; female tail with spike ....*D. dendrolagi*

Discussion

Although small, the sample of four individuals surveyed in this study is indicative of the diversity of nematode species occurring in most kangaroos and wallabies (Spratt *et al.* 1991). Representatives of all the tribes, except the Zoniolaiminea (Popova, 1952), of the Cloacininae (Beveridge 1987) have been found. *Paralabiostrongylus bicollaris* and *Ds. labiocarinatus* are exclusive to the island of New Guinea, occurring also in *Do. hageni* Heller, 1897 and *Do. luctuosa* (Smales 1982b; Spratt *et al.* 1991). As discussed by Smales (1997), hosts collected in Papua New Guinea and identified as *Dorcopsis veterum* Lesson, 1872 (syn. *D. muelleri*), by Smales (1982a) and Spratt *et al.* (1991) are now known to be *Do. luctuosa* (Flannery 1995). *Coronostrongylus coronatus* has been previously reported from the forest wallabies *Do. hageni* and *Do. luctuosa* and is also found in several macropodid genera in Australia (Spratt *et al.* 1991). Similarly, *Macropostrongylus* species occur in both Australian and Papua New Guinean hosts (Mawson 1977; Beveridge 1985)

Dorcopsinema occurs only in hosts on the island of New Guinea. It has not been found in the Australian species of tree kangaroos (Spratt *et al.* 1991). Australian tree kangaroos studied to date have a depauperate helminth community as compared with other macropodid species. Seven *De. lumholtzi* Collett, 1884 from Queensland examined for parasites (Beveridge *et al.* 1992) had only two species, *Labiostrongylus dendrolagi* Smales, 1995 and *Zoniolaimus dendrolagi* Beveridge, 1983, present in the stomach. Hosts from the island of New Guinea, however, have a more diverse stomach fauna, including *Cloacina* spp., *L. redmondi* Smales, 1982, *Macropostrongyloides dendrolagi* Beveridge, 1997, *Mbaisonema coronatum* Beveridge, 1997, *Z. nugmensis* Beveridge, 1983, *Pharyngostrongylus dendrolagi* Beveridge, 1982, *Dorcopsinema* spp. and *Popovastrongylus* sp. (see Flannery *et al.* 1996; Beveridge 1997).

Tree kangaroos have evolved into a group of arboreally adapted species unique to New Guinea (Flannery 1995). The most primitive group, however, includes the two species *De. bennettianus* De Vis, 1887 and *De. lumholtzi* which are found only in Australia (Flannery 1995). Ancestors of these Australian species are thought to have migrated south across Torres Strait and now represent a remnant of New Guinean fauna left on Cape Yorke Peninsula (Johnson 1995; Martin & Johnson 1995). The forest wallabies *Dorcopsulus* and *Dorcopsis* are now exclusive to New Guinea. Ancestral Australian tree kangaroos may have lost components of their helminth communities during migration south to Cape Yorke Peninsula or following isolation from the northern populations of tree kangaroos on the island of New Guinea. Alternatively New Guinean tree kangaroos may have acquired a richer helminth fauna through host switching from the indigenous forest wallabies, after the isolation of New Guinea from the Australian continent.

Fourth stage larvae of *D. simile* examined in this study had three pairs of lip-like processes not four as found in the adults. This suggests that three pairs of lip-like processes may be a primitive condition and four pairs of lip-like processes an advanced character. If three pairs of lip-like processes is the primitive condition then the species occurring in forest wallabies have the derived condition. *Dorcopsinema dorcopsis*, the other species of *Dorcopsinema* occurring in forest wallabies, also has four pairs of lip-like processes but *D. mbaiso* and *D. dendrolagi*, occurring in tree kangaroos have only three pairs. Forest wallabies, however, are primitive browsing species while tree kangaroos are evolved arboreal species (Flannery 1989). By contrast, trends towards simplicity of male characters from *D. dorcopsis* to *D. mbaiso* were noted by Smales (1997) suggesting a period of co-evolution of *Dorcopsinema* and tree kangaroos. The helminth data from both groups of macropodid hosts are fragmentary and additional surveys of their helminth populations are needed before the existence of any patterns can be determined

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PROGAMOTAENIA ABIETIFORMIS SP. NOV. (CESTODA: ANOPLOCEPHALIDAE) FROM ONYCHOGALEA FRAENATA (MARSUPIALIA: MACROPODIDAE) FROM CENTRAL QUEENSLAND

By C. Turni & L. R. Smales†*

Summary

Turni, C. & Smales, L. R. (1999) Progamotaenia abietiformis sp. nov. (Cestoda: Anoplocephalidae) from Onychogalea fraenata (Marsupialia: Macropodidae) from Central Queensland. Trans. R. Soc. S. Aust. 123(4), 143-147, 30 November, 1999.
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Key Words: Onychogalea fraenata, cestode, Progamotaenia, bridled nailtail wallaby.

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KEY WORDS: *Onychogalea fraenata*, cestode, *Progamotaenia*, bridled nailtail wallaby

Introduction

The Anoplocephalidae Cholodkovsky, 1902 is a cosmopolitan family of cestodes occurring in mammals, birds and reptiles (Beveridge 1994). Species of the genus *Progamotaenia* Nybelin, 1917 occur exclusively in the small intestine and bile ducts of macropodoid and vombatid marsupials from Australia and Papua New Guinea (Spratt *et al.* 1991). Within the genus, *P. bancrofti* (Johnston, 1912) and *P. zschokkei* (Janicki, 1906) have been recorded from, amongst other macropodids, the two extant nailtail wallabies, *Onychogalea fraenata* (Gould, 1841) and *O. unguifera* (Gould, 1841) (Beveridge 1980). Recent collections of cestodes from *O. fraenata* from Taunton National Park in Central Queensland revealed a third species of *Progamotaenia* which is described below.

Materials and Methods

Cestodes collected from the intestine of a bridled nailtail wallaby were fixed in 10% formalin and then stored in 70% ethanol. Additional material deposited in the South Australian Museum, Adelaide (SAMA), AHC 25880 which had been relaxed in water prior to fixation in 10% formalin and then stored in 70% ethanol was also examined. Cestodes were stained with Carmine, dehydrated, cleared in X3B and mounted in Permount or with Celestine blue, dehydrated, cleared in clove oil and mounted in Canada balsam. Serial longitudinal sections were cut at a thickness of 7 µm and stained with haemotoxylin and eosin. The measurements of 10 specimens are given in millimetres as the range followed by the mean in parentheses. Drawings were made with the aid of a drawing tube. All specimens have been deposited in the SAMA.

Progamotaenia abietiformis sp. nov.
(FIGS 1-9)

Types: Holotype from small intestine of *Onychogalea fraenata* (Gould 1841), Taunton National Park (23° 33' S, 149° 13' E), Queensland, coll. C. Turni, June 1996, SAMA AHC 28071; paratypes: whole mounts AHC 28072-28108, 28112-28114; numerous specimens spirit material AHC 31314; serial sections AHC 28109-28111; additional specimens, numerous specimens 15.iii. 1994 SAMA AHC 25880.

Description

Length 5.92-12.4 (8); width 0.68-0.83 (0.77); scolex diameter 0.72 -1.20 (0.88); sucker diameter 0.215-0.322 (0.272) x 0.215-0.291 (0.251); neck 0.05-0.34 (0.19); 34-57 (42) proglottides; mature proglottides 0.64-0.79 (0.72) x 0.14-0.38 (0.25); gravid proglottides 0.64-0.83 (0.76) x 0.22-0.46 (0.33); dorsal osmoregulatory canal 0.012-0.033 (0.019); ventral osmoregulatory canal 0.014-0.034 (0.021) in diameter; cirrus sac in mature proglottides 0.289-0.435 (0.333) x 0.0495-0.067 (0.059); cirrus

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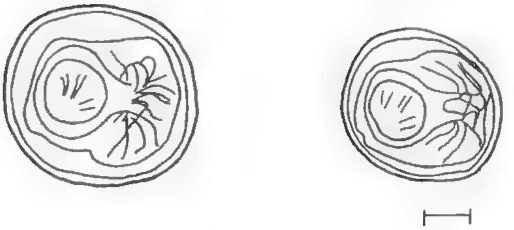

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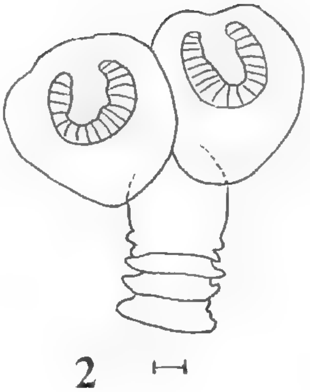

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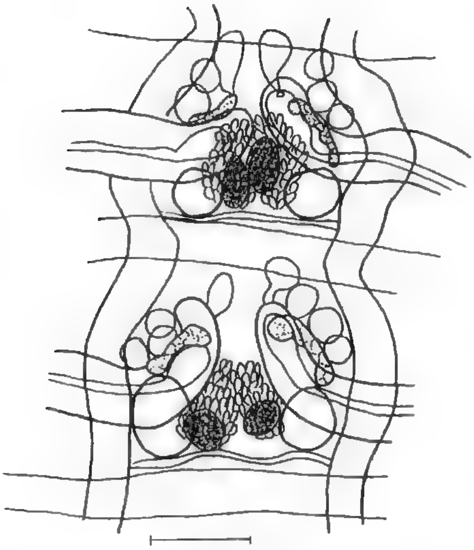

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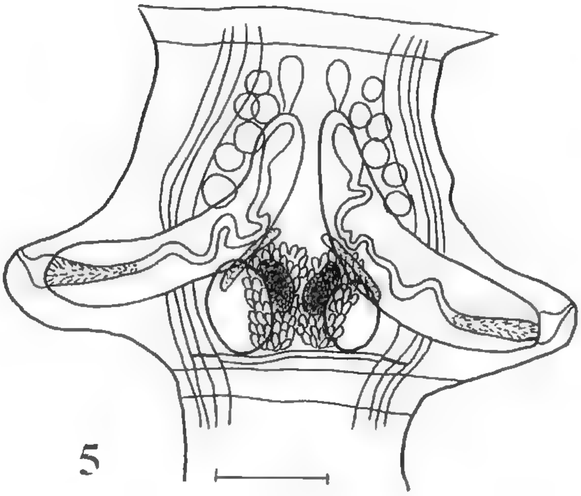

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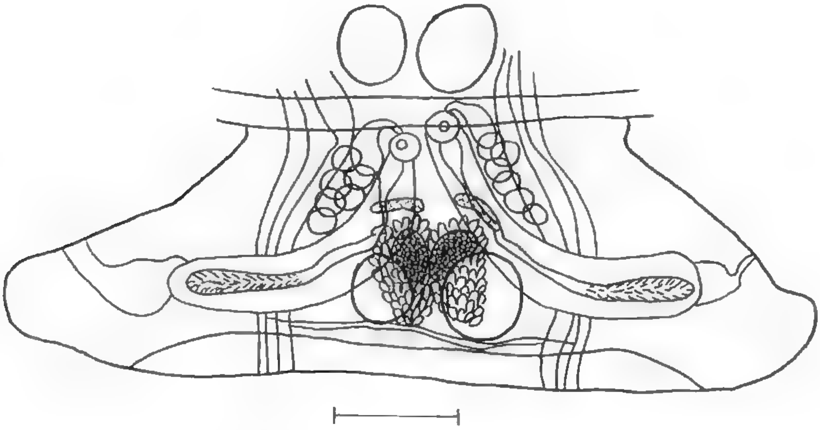

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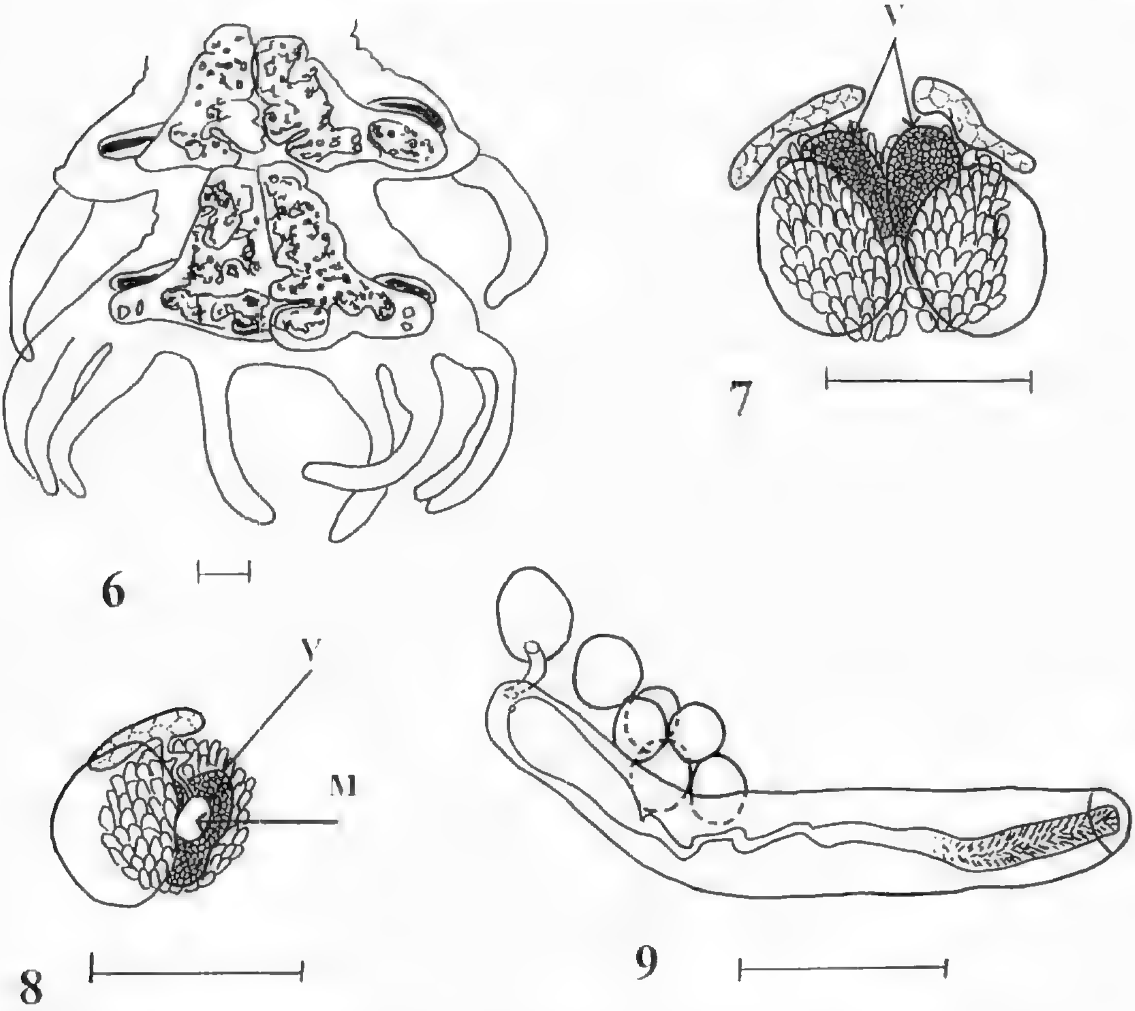
Figs 1-5. *Progamotaenia abietiformis* sp. nov. 1. Eggs showing pyriform apparatus, the two horns not visible in all views. 2. Scolex. 3. Mature proglottides prior to and during uterus filling. 4. Mature proglottis, contracted. 5. Mature proglottis, fully extended. Scale bars = 0.01mm 1; 0.1mm 2-5.



Figs 6-9, *Progamotaenia abietiformis* sp. nov. 6. Gravid proglottides. 7. Female genitalia, dorsal view. 8. Female genitalia, optical section showing Mehlis' gland. 9. Male genitalia. Scale bars = 0.1mm. M = Mehlis' gland, V = vitellarium

sac in gravid proglottides 0.268-0.487 (0.386) x 0.049-0.074 (0.062); 11-13 (12) testes per proglottis; testis 0.031-0.039 (0.032) x 0.025-0.039 (0.032); seminal receptacle 0.057-0.084 (0.073) x 0.031-0.073 (0.058); vitellarium 0.030-0.069 (0.045) x 0.018-0.039 (0.022); ovary 0.057-0.100 (0.073) x 0.031-0.094 (0.051); Mehlis' gland 0.016-0.018 (0.017) x 0.018-0.029 (0.024); egg 0.031-0.055 (0.042) x 0.031-0.055 (0.040); pyriform apparatus 0.012-0.018 (0.015) x 0.017-0.022 (0.020); oncosphere 0.012-0.014 (0.013).

Short, narrow cestode with relatively few proglottides. Broad scolex with four acetabulate suckers on peduncles extending antero-laterally. Anterior borders of suckers cleft. Proglottides craspedote with broad, fringed velum consisting of 12-16 tentacle-like projections overlapping adjacent proglottis. First mature proglottis 16-28 (22). Mature proglottides with length to width ratio of 1:2-1:4.6. Gravid proglottides ratio of 1:1.7-1:4.1. Dorsal osmoregulatory canal situated lateral to ventral canal; ventral canal slightly wider than dorsal canal; transverse canals connecting both lateral canals posterior to seminal receptacle. Genital pore marginal opening into wide, long, simple genital atrium. Genital atrium bending anteriorly to open in mid-section of lateral margin of proglottides. Cirrus sacs long, thick-walled, crossing osmoregulatory canals dorsally then curving anteriorly and dorsally, terminating anterior to ovaries. Cirrus sacs almost meeting in centre of proglottis, running anteriorly parallel towards border of preceding proglottis. Cirrus heavily armed, widest at distal end, mid-section narrower and not as heavily armed, proximal end unarmed, sinuous leading into elongate internal seminal vesicle. External seminal vesicle elongate, ventral to cirrus sac, extending anteriorly. Testes in two groups of 5-7, round to oval, 11-13 per proglottis, dorsal and ventral to cirrus sac, lateral and anterior to uterus, restricted laterally by osmoregulatory canals. Seminal receptacle large, ovoid, ventral to cirrus sac and lateral to vitellarium. Vitellarium ovoid to elongate, compact. In early mature proglottides, vitellarium dorsal to ovaries, lying over anterior half of ovary. In later mature proglottides, with fully everted cirrus, vitellarium lying over posterior half of ovary. Ovaries ovoid, lobulate, compact, ventral to seminal receptacle; touching, sometimes even slightly overlapping each other in centre of proglottis. Mehlis' gland ovoid, medial to ovary, between ovary and vitellarium. Uteri tube-like, paired in each proglottis, extending at approximately 45° towards centre of proglottis, ventral to ovaries, beginning to fill at proglottis 23-32 (27). In gravid proglottides uteri sacciform, appearing almost longitudinal as diverticula extend mainly medially on posterior part of uteri. Towards posterior end of cestode uteri, in gravid proglottides, extend toward postero-lateral margin of proglottides crossing longitudinal osmoregulatory canals dorsally. Uteri abutting, even slightly overlapping in centre of proglottis. Egg spherical to elliptical, thick-shelled. Pyriform apparatus conical, terminating in two blunt horns (not visible in all views) with numerous long fine filaments. Cirrus developed by 20-27th (22) proglottis; internal seminal vesicle filled with sperm in 21-28th (23) proglottis; insemination occurs in 19-25th (21) proglottis. vaginal atrophy not seen.

Etymology

The name is derived from *abies*, the Latin name for fir tree, referring to the shape of the whole cestode.

Discussion

Progamotaenia abietiformis sp. nov. most closely resembles a complex of similar species, *P. dorcopsis*, *P. lagorchestis*, *P. thylogale* and *P. queenslandensis*, all of which have a fringed velum, paired uteri, testes in two groups and an external seminal vesicle (Beveridge 1985). It differs from this complex in its small size (up to 12.4 mm compared with 32 mm or longer in the other species), small number of proglottides (up to 57 compared with at least 95 in the other species) and the small number of testes (11-13 compared with at least 36 in the *P. lagorchestis* species complex) (Beveridge 1985). *Progamotaenia spearei*, which also has a fringed velum, paired uteri and testes in two lateral groups but no external seminal vesicle, is a small cestode with few proglottides and a small number of testes (Beveridge 1980). However, *P. abietiformis* is smaller (5.92-12.4 mm compared with 26-30 mm), has fewer proglottides (34-57 compared with 71-85), fewer testes (11-13 compared with 30-40) and has a velum with 12-16 tentacle-like projections compared with 25-35 tongue shaped projections for *P. spearei* (Beveridge 1980). Other distinctive features of *P. abietiformis* are the long cirrus sacs almost meeting in the mid-line and the ovaries which are central and abut. With regard to the position of the female genitalia *P. abietiformis* is most similar to *P. aepyprymni*, whose fully developed ovaries almost abut (Beveridge 1976).

In the genus *Progamotaenia* the uterus is usually transverse (Beveridge 1994) and the pyriform apparatus normally does not end in horns except for *P. diaphana* (Beveridge 1976) and *P. gynandrolinearis* (Beveridge & Thompson 1979). In *P. abietiformis*, however, the uterus in the mature proglottides is at 45° and the pyriform apparatus ends in horns.

Progamotaenia abietiformis can be distinguished from *P. bancrofti* (Johnston, 1912) and *P. zschokkei* (Janicki, 1906), the other species found in *O. fraenata*, by size (*P. abietiformis* is much smaller) and the shape of scolex since only *P. abietiformis* has suckers on peduncles extending antero-laterally. *Progamotaenia bancrofti* has no pyriform apparatus, *P. zschokkei* has a single uterus and both have a large number of testes (more than 60 compared with 11-13 for *P. abietiformis*) (Beveridge 1976, 1980).

The description of *P. abietiformis* is based on the collection of material from two specimens of *O. fraenata* from the Taunton National Park, Central Queensland. Since *O. fraenata* is an endangered species, the last natural population being confined to Taunton National Park, *P. abietiformis* is also an endangered species.

Cestodes of the *P. lagorchestis* species complex are four closely related but distinct species (Beveridge 1985). Their hosts, however, *Thylogale stigmatica* (Gould, 1860) (*Progamotaenia queenslandensis* and *P. thylogale*), *T. billardierii* (Desmarest, 1822) (*P. thylogale*), *T. thetis* (Lesson, 1827) (*P. thylogale*), *Lagorchestes conspicillatus* (Gould, 1842) (*P. lagorchestis*), *Dorcopsis luctuosa* (D'Albertis, 1874) (syn. *D. veterum* see Smales 1997) (*P. dorcopsis*) and *Macropus rufogriseus* (Desmarest, 1817) (*P. thylogale*) (Beveridge 1985; Beveridge & Thompson 1979), are not. Macropodines can be separated into two clades with one clade consisting of the New Guinean forest wallabies, *Dorcopsis* and *Dorcopsulus*, and the other including the genera *Macropus*, *Lagorchestes*, *Thylogale* and *Onychogalea* (Burk *et al.* 1998). Although *L. conspicillatus* is the only host whose range currently overlaps that of *O. fraenata* (Burbidge & Johnson

1995; Evans & Gordon 1995) former distributions of each of the hosts, including fossil material of *Dorcopsis* spp. from Australia (Calaby 1995; Flannery 1995; Johnson & Vernes 1995), are indicative of the potential for host switching in the past.

Acknowledgments

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NOTES ON THE INSECT FAUNA OF THE FRUIT GALLS OF ANTHOCERCIS ANISANTHA (SOLANACEAE) IN WESTERN AUSTRALIA

BRIEF COMMUNICATION

Summary

Anthocercis Labill. is an endemic Australian genus of ten species, concentrated in the south-west of Western Australia, with two taxa extending to South Australia[1,2]. Anthocercis species mostly occur in disturbed sites and are frequently early colonisers following fire or mechanical disturbance but a few species also occupy relatively stable habitats associated with rocky outcrops and similar landforms[3]. Despite their conspicuous nature and relative abundance, little has been recorded of their biology or ecology.

Transactions of the Royal Society of S. Aust. (1999), **123**(4), 149-150

BRIEF COMMUNICATION

NOTES ON THE INSECT FAUNA OF THE FRUIT GALLS OF *ANTHOCERCIS ANISANTHA* (SOLANACEAE) IN WESTERN AUSTRALIA

Anthocercis Labill. is an endemic Australian genus of ten species concentrated in the south-west of Western Australia, with two taxa extending to South Australia[1]. *Anthocercis* species mostly occur in disturbed sites and are frequently early colonisers following fire or mechanical disturbance but a few species also occupy relatively stable habitats associated with rocky outcrops and similar landforms[2]. Despite their conspicuous nature and relative abundance, little has been recorded of their biology or ecology.

Fruit galls have been recorded in four taxa of *Anthocercis* to date, namely, *A. ilicifolia* Hook. subsp. *ilicifolia*, *A. intricata* Miers, *A. littorea* Labill. and *A. viscosa* R. Br. (apparently only subsp. *caudata* Haegi; see Haegi[3])[2,5] but *A. littorea* is the only taxon in which the gall fauna has been studied. Fruit galls in this species are induced by the cecidomyiid midge *Asphondylia anthocercidis* Kolesik[4] which is in turn accompanied by a suite of parasitic and inquiline chalcidoids[5]. Whittemore[5] recorded seven species (in six families) of chalcidoid wasps in *A. anthocercidis* induced galls on *A. littorea* in the Perth region of Western Australia. Of these, a species of *Sigmophora* (Tetrastichinae) was found to be the most abundant.

Recently, several new *Asphondylia* spp. have been found to cause fruit and stem galls on native and introduced Solanaceae, some of which are classed as agricultural weeds in Australia[6]. Information on the host range of these morphologically close insects is essential to understand their life cycles and assess the impact of their infestation on the population dynamics of the plants.

We report here the first record of fruit galls in *Anthocercis anisantha* Endl., along with information on gall fauna. A small number of fruit galls (Fig. 1) was collected by the first author from a single plant of *A. anisantha* subsp. *anisantha* (Lepschi, Lally & Maslin 3537) near Mollerin Rock Tank, approximately 41.5 km NW of Beacubbin in south-western Western Australia (30° 33' S, 117° 34' E), in September 1997. Galls were subsequently placed in plastic vials and maintained at room temperature in Perth for approximately two weeks until all insect fauna had emerged. No attempt was made to record emergence times, numbers of individual insects, sex ratios or other such data.

Insect material was identified by PK (gall midges) and MG (wasps) and is deposited in the South Australian Museum, Adelaide (SAMA) (gall midges only), University of California, Riverside (UCRC) (wasps only) and Western Australian Museum, Perth (WAMA). The plant voucher was identified by BJL and is deposited in the Australian National Herbarium, Canberra (CANB) and the Western Australian Herbarium, Perth (PERTH).

Two insect species were reared from the fruit galls, the recently described[4] gall midge *A. anthocercidis* and a chalcidoid wasp, *Sigmophora otys* (Walker). The occurrence of fruit galls in *A. anisantha* represents a new host plant record for *A. anthocercidis*, which was formerly known to induce galls in *A. littorea* only. However, it seems likely that *A. anthocercidis* (or at least a taxon closely related to it) could be responsible for the fruit galls observed in the other taxa of *Anthocercis* mentioned above. All these species have similar distributions and habitats to the two recorded hosts of *A. anthocercidis* (*A. anisantha* and *A. littorea*), and also share a similar gross floral morphology.

The presence of the wasp *S. otys* in the fruit galls examined in this study also represents a new host record (i.e. *A. anthocercidis*) for that species[7]. Whittemore[5] treated *Sigmophora* (?*S. otys*) recorded in her study as an inquiline, but other data suggest *Sigmophora* is more likely to be a primary parasitoid of *Asphondylia*[7,8]. Graham[8] records species of *Sigmophora* as gregarious ectophages of the larvae and pupae of various genera of cecidomyiid midges (typically *Asphondylia*, but also *Contarinia* Rondani, *Eumarchalia* Del Guercio, *Kiefferia* Mik and *Schizomyia* Kieffer) throughout the Old World.

We are grateful to E. Hines, CSIRO Division of Entomology, Canberra, for assistance with the production of Figure 1.

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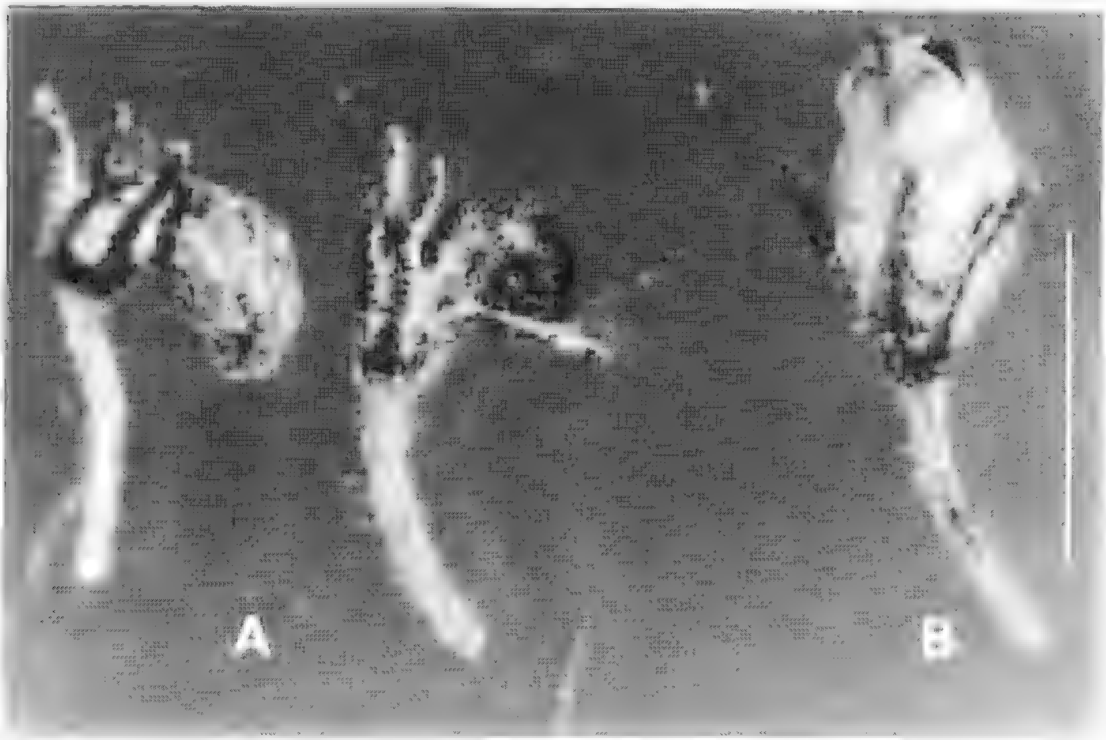

Fig. 1. *Anthocercis anisantha* galls and fruit. A. Fruit galls induced by *Asphondylia anthocercidis*. B. Normal (ungalled) fruit of *A. anisantha*. Scale bar = 5 mm.

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ILIAL SHAFT CURVATURE: A NOVEL OSTEOLOGICAL FEATURE DISTINGUISHING TWO CLOSELY RELATED SPECIES OF AUSTRALIAN FROGS

BRIEF COMMUNICATION

Summary

The status of the Australian frog Limnodynastes spenceri Parker (1940)[1], as a species distinct from L. ornatus (Gray, 1842)[2], has been the subject of controversy. In the course of the study of fossil material it was noted that there was a distinct curvature of the shaft of the ilium of L. ornatus, whereas the ilium of L. spenceri appeared straight[3]. The present study was undertaken as a component of studies of fossil material seeking means of distinguishing species by features of the ilium.

Transactions of the Royal Society of S. Aust. (1999), **123**(4), 151-152.

BRIEF COMMUNICATION

ILIAL SHAFT CURVATURE: A NOVEL OSTEOLOGICAL FEATURE DISTINGUISHING TWO CLOSELY RELATED SPECIES OF AUSTRALIAN FROGS

The status of the Australian frog *Limnodynastes spenceri* Parker (1940)[1], as a species distinct from *L. ornatus* (Gray, 1842)[2], has been the subject of controversy. In the course of the study of fossil material it was noted that there was a distinct curvature of the shaft of the ilium of *L. ornatus*, whereas the ilium of *L. spenceri* appeared straight[3]. The present study was undertaken as a component of studies of fossil material seeking means of distinguishing species by features of the ilium.

Limnodynastes ornatus was described from material collected at Port Essington in the Northern Territory. The species is now recognised to occupy much of the northern and eastern seaboard of Australia[4].

Initial concepts of what constituted *L. ornatus* involved a species that ranged broadly over the northern half of the continent. Parker[1] described *L. spenceri* from Alice Springs. This latter species is currently used to accommodate the central Australian individuals formerly referred to as *L. ornatus*, but more extensive interdigital webbing of the feet in *L. spenceri* is one of the few distinguishing morphological features.

Not all authors have supported the recognition of more than one species[5-7]. More recently the populations have been considered distinct, being distinguished principally by features other than external morphology[1,8,9]. A phylogenetic analysis[10] examined the evolutionary relationships within the genus *Limnodynastes* but data were not sensitive enough to resolve the species status of *L. ornatus* and *L. spenceri*.

The ilium has been used to distinguish and identify fossil species of Australian frogs[11]. This bone is the largest component of the anuran pelvis and varies in length of shaft, posterior shape and the presence and absence of various protuberances[3]. The length of the ilial shaft is an adaptation to jumping and symmetrical propulsion in swimming and it is considered that longer ilial shafts are generally associated with species displaying saltatorial habits, whereas shorter shafts are characteristic of terrestrial or fossorial species that tend to walk rather than jump[12]. The posterior of the ilium provides the point of attachment for muscles responsible for propulsion. The size and shape reflect the different habits of species. The posterior of the ilium is more likely to be larger in species that require powerful leg muscles (i.e. those that are significantly adapted to jumping, swimming or burrowing (M.J.T. unpub.)).

The length of the ilium has been shown to be linearly related to snout-vent (S-V) length in *Cyclorana australis* (Gray)[13]. This relationship was examined for *L. spenceri* and *L. ornatus* to determine if there was a similar relationship. Specimens of the two species were obtained from collections at the Department of Environmental Biology, University of Adelaide. Further specimens of *L. spenceri* were provided by the South Australian Museum.

The snout-vent length (S-V) of each specimen was measured to the nearest 0.1 mm using Helios dial callipers before the specimens were dissected to remove the ilium. Small ilia (which are prone to distortion due to dehydration (M.J.T. unpub.)) were preserved in 65% ethanol. The length of the ilium was measured from the tip of the dorsal acetabular expansion to the end of the ilial shaft (AB in Fig. 1). Snout-vent length for each specimen was plotted against ilium length (IL) for each species. Each ilium was then aligned horizontally in a lateral plane under a dissecting microscope and the outline drawn using a camera lucida. The curvature of the ilial shaft was measured indirectly from these drawings as follows (refer to Fig. 1). The length of the ilial shaft, CB, was measured from the superior extremity of the dorsal acetabular prominence to the distal end of the ilial shaft. The midpoint, D, of this line was found. A line perpendicular to CB from D was drawn to intersect with the dorsal surface of the ilial shaft, E. The curvature of the ilial shaft was expressed as the angle formed by CEB. The smaller the angle formed by CEB the greater the curvature of the ilial shaft (compare (a) and (b) in Fig 2).

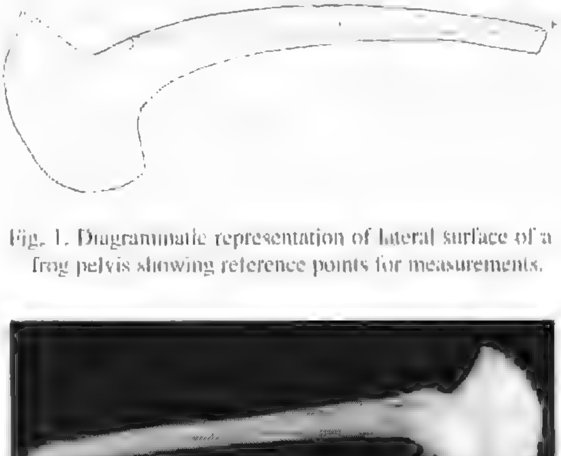

Fig. 1. Diagrammatic representation of lateral surface of a frog pelvis showing reference points for measurements.

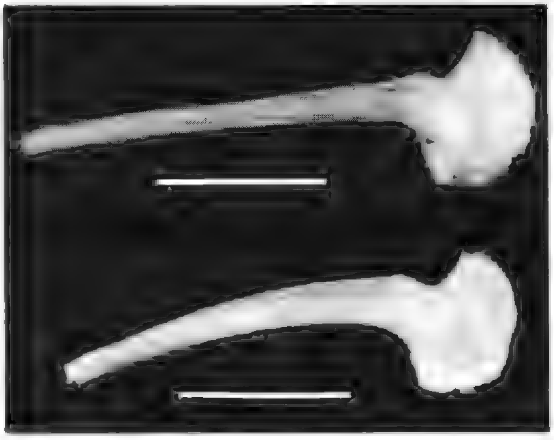

Fig. 2. Lateral views of pelvises of *Limnodynastes spenceri* (top) and *L. ornatus* (bottom). Note the difference in the curvature of the ilial shaft. Scale bars = 5 mm.

The normality of ilial shaft curvature data was confirmed before differences between the two data sets were tested using a two sample t-Test, assuming equal variance.

Strong relationships between S-V length and ilial shaft length were found with R^2 values of 0.96 for both *L. ornatus* and *L. spenceri* (Figs 3, 4). Comparison of the linear equations of the trend lines showed that *L. ornatus* and *L. spenceri* demonstrated similar S-V v. ilial length relationships. The limited number of *L. spenceri* specimens available constrained the data in the S-V range of 21-30 mm.

The curvature of the ilial shaft for *L. ornatus* was found to be significantly greater than that of *L. spenceri* at a confidence level of 99%. The mean angle for *L. ornatus* was 170.4°, whereas that for *L. spenceri* was 177.6°, a mean difference of 7.2°.

Limnodynastes ornatus is known from the Cainozoic of Queensland[3] but it is not known whether *L. spenceri* coexisted or had in fact diverged from it before this era. The slight but significant difference in the shape of the ilial shaft will provide a simple means of distinguishing these species if suitable deposits are found in Central Australia.

We are grateful to M. Hutchinson, South Australian Museum, who provided several specimens of *Limnodynastes spenceri* for use in this study, L. Russell for Figure 2 and to the referees for their constructive criticism.

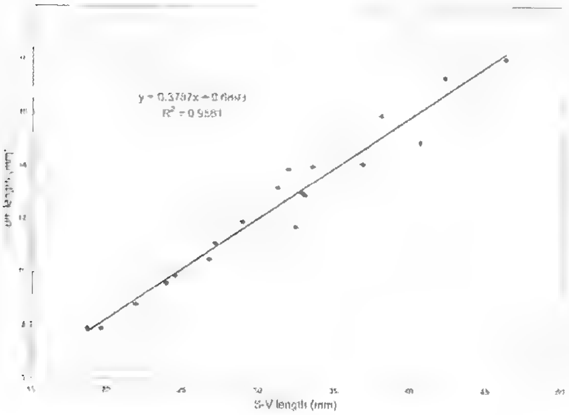

Fig. 3. Regression line of ilial length plotted against S-V length of *Limnodynastes ornatus*.

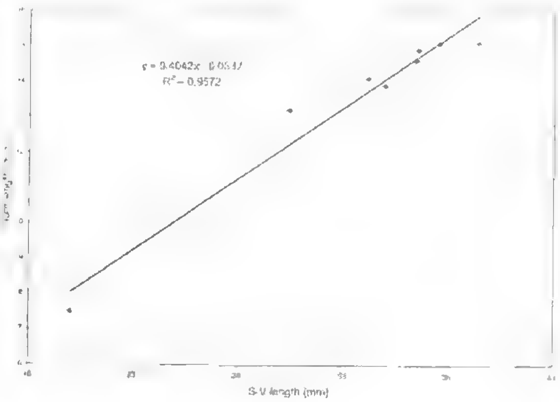

Fig. 4. Regression line of ilial length plotted against S-V length of *Limnodynastes spenceri*

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AN ADDITIONAL RECORD OF A MEIOLANIID TURTLE FROM THE PLEISTOCENE OF NORTHERN QUEENSLAND

BRIEF COMMUNICATION

Summary

The extinct meiolaniids are an enigmatic group of turtles characterised by cranial horns and tail clubs. They are confined to the Southern Hemisphere and their phylogenetic relationships have been the subject of much discussion[1]. The oldest known Australian meiolaniids come from Oligocene and Miocene deposits in South Australia, New South Wales and Queensland[2 4]. Most of the Australian material collected to date however, comes from Late Pleistocene deposits from Lord Howe Island[5,6]. There are additional Pleistocene occurrences of meiolaniid from Walpole Island, New Caledonia, the Darling Downs of Queensland and from the Wyandotte Formation[7]. This note reports the presence of further meiolaniid fossils from Pleistocene deposits of Bluff Downs, north-eastern Queensland.

Transactions of the Royal Society of S. Aust. (1999), **123**(4), 153-154.

BRIEF COMMUNICATION

AN ADDITIONAL RECORD OF A MEIOLANIID TURTLE FROM THE PLEISTOCENE OF NORTHERN QUEENSLAND

The extinct meiolaniids are an enigmatic group of turtles characterised by cranial horns and tail clubs. They are confined to the Southern Hemisphere and their phylogenetic relationships have been the subject of much discussion[1]. The oldest known Australian meiolaniids come from Oligocene and Miocene deposits in South Australia, New South Wales and Queensland[2-4]. Most of the Australian material collected to date however, comes from Late Pleistocene deposits of Lord Howe Island[5,6]. There are additional Pleistocene occurrences of meiolaniid from Walpole Island, New Caledonia, the Darling Downs of Queensland and from the Wyandotte Formation[7]. This note reports the presence of further meiolaniid fossils from Pleistocene deposits of Bluff Downs, north-eastern Queensland.

Bluff Downs is currently only known as a Pliocene site with a wide range of taxa already having been reported[8-14]. During field investigations in 1992, further fossil exposures were located upstream from, and on the opposite side to, the main Pliocene quarries. The fossils were located in a gully that cut through a black soil plain and included mammals, crocodiles and turtles. A detailed examination of the fossils revealed little softening of features normally associated with transportation or re-working and it was therefore assumed that the original site of deposition was relatively close. There were no overlying formations that could give an age to the fossils.

However, the new collecting locality, named Jaw Site, contained a diagnostic P^3 of the diprotodontid marsupial, *Zygomaturus trilobus* Macleay, a species with a Pleistocene distribution[15]. This tooth differed from the P^3 of a new species of *Zygomaturus* that had been recovered from the Bluff Downs Pliocene sediments (Lat. 19° 43′ S, Long. 145° 36′ E), indicating that Jaw Site was not Pliocene in age[16]. Furthermore, there was no evidence of the commonly found Pliocene diprotodontid *Euryzygoma* which was a major component of the Bluff Down Local Fauna[8]. The age of the site was therefore either Plio-Pleistocene or Pleistocene by biocorrelation.

A number of bone fragments with distinctive sculpturing was identified as being possible meiolaniid tail club fragments. This identification was confirmed by E. Gaffney of the American Museum of Natural History. One group of fragments (QM F25854) contained 12 individual pieces including one partial tail club spike and the distal ends of caudal vertebrae (Fig. 1 A, B). The other group (QM F25855) contained two tail club spike fragments and a number of smaller bone shards (Fig. 1 C). The tails of these land-dwelling turtles were covered with articulated bony rings armoured with spikes.

The Wyandotte meiolaniid was identified as having affinities with *Meiolania platyceps* from Lord Howe Island rather than the mainland species *M. oweni* from Kings Creek, Darling Downs[5]. Unfortunately not enough material has been recovered to make any constructive taxonomic assignment for the Bluff Downs specimens except for identification as a meiolaniid. Unlike its Lord Howe Island counterpart, the Bluff Downs meiolaniid had a number of giant reptiles to contend with including several species of crocodile[13], a large varanid and python[8]. Whether the significant armour the meiolaniid possessed was enough to protect it from these potential predators will perhaps never be known. Its development and elaboration during the Tertiary perhaps suggests some sort of defence strategy.

The author wishes to thank E. Gaffney who identified the specimens and R. Molnar who facilitated the identification. The Smith Family of Bluff Downs Station continue to provide assistance and support for the ongoing research into the Bluff Downs Local Fauna. The collection of the Bluff Downs material was supported in part by an ARC

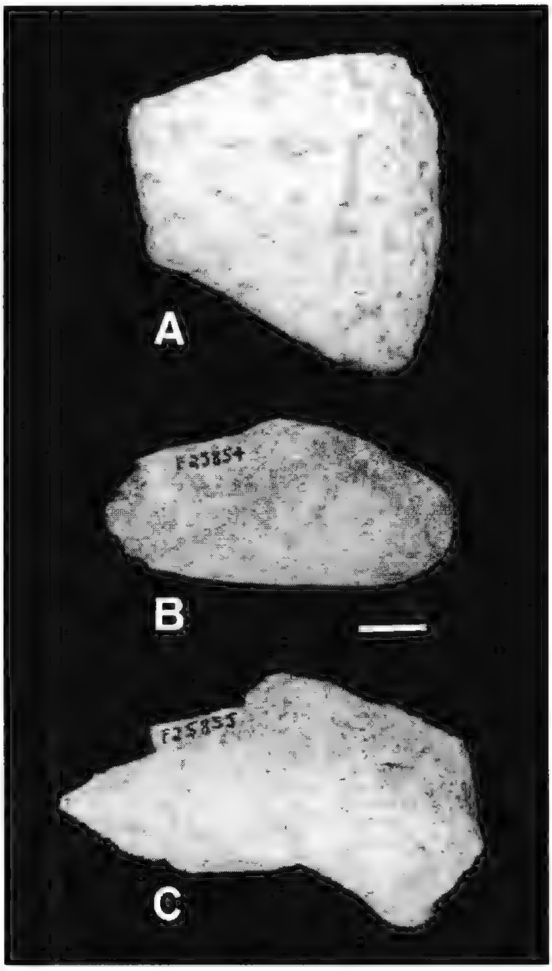

Fig. 1. Meiolaniid turtle fragments. QM F25854. A. Partial tail club spike. B. Distal end of caudal vertebra. C. QM F25855. Tail club spike fragment. Scale bar = 5 mm.

Program Grant to M. Archer, a grant from the Department of Arts, Sport, the Environment, Tourism and Territories to M. Archer, S. Hand and H. Godthelp, a grant from the National Estate Program Grants Scheme to M. Archer and A. Bartholomai, and grants in aid to the Riversleigh Research Project from the University of New South Wales, Wang Australia Pty Ltd, ICI Australia and the Australian Geographic Society.

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DESIGNATION OF LECTOTYPES OF THREE SPECIES OF CISSEIS (COLEOPTERA: BUPRESTIDAE)

BRIEF COMMUNICATION

Summary

While it is usual to designate lectotypes in a generic review, the following cases have emerged from a current study of the genus Cisseis LaPorte & Gory[1] and in order to have these changes incorporated into a Catalogue of Australian Buprestidae, due to be completed in 2000, it is necessary to publish them at this stage.

Transactions of the Royal Society of S. Aust. (1999), **123**(4), 155.

BRIEF COMMUNICATION

DESIGNATION OF LECTOTYPES OF THREE SPECIES OF *CISSEIS* (COLEOPTERA: BUPRESTIDAE)

While it is usual to designate lectotypes in a generic review, the following cases have emerged from a current study of the genus *Cisseis* LaPorte & Gory[1] and in order to have these changes incorporated into a Catalogue of Australian Buprestidae, due to be completed in 2000, it is necessary to publish them at this stage.

Cisseis laticollis var. *cyaneopyga* Carter, 1923[2] (♀ syntype, no data, The Natural History Museum, London; ♀ syntype, Lake Austin, W. Australia, H. W. Brown, K 67292, Australian Museum, Sydney) is conspecific with *Cisseis goerlingi* Carter, 1936[3] (♀ holotype, Marloo stn., Wurarga, W. Australia, Australian Museum, Sydney). *Cisseis laticollis* Carter, 1923 is a Queensland species clearly separate from the other species which is found only in arid areas of Western Australia. After examining all specimens I hereby elevate *Cisseis cyaneopyga* Carter to full specific status and designate as the lectotype the female specimen in the Australian Museum collection labelled *Cisseis laticollis* var. *cyaneopyga* Carter, Lake Austin, W. Australia, H. W. Brown, K67292, with a printed red label on which is written 'Lectotype, *Cisseis cyaneopyga* Carter, Designated by S. Barker, 1999.'

Carter[2] described *Cisseis marmorata* var. *prasina* from two male specimens in the collection of The Natural History Museum, London, one labelled NSW, the other without data, and two male specimens in the collection of the South Australian Museum, one labelled S. Australia, the other Australia. I have examined these specimens and find that they are a good species. They are all green in colour, whereas *C. marmorata* LaPorte & Gory males have a green head and pronotum and brown elytra. As well, their genitalia are of a different shape from those of male *Cisseis marmorata*. I hereby elevate *Cisseis prasina* Carter to full species and designate as the lectotype the male specimen in the collection of the South Australian Museum labelled 'Australia Blackburn's collection', numbered in red ink 3267 and with a printed red label on which is written 'Lectotype *Cisseis prasina* Carter, Designated by S. Barker, 1999'. A series of associated male and female specimens collected at Milmerran by the late J. McQueen is housed in the Australian National Insect Collection, Canberra. The females are brown with white markings on the elytra and are larger than the males of the species.

Kerremans[4] described *Cisseis cyanura*. The four syntypes of the types series are lodged in the Natural History Museum, London, collection. Of these one male is clearly a different species from the other three. On the pin it bears a B. Levey identification label stating that it is a specimen of *C. nigroaenea* Kerremans, 1898. The remaining three specimens, two males and a female appear to be conspecific although the male genitalia vary slightly. I hereby designate the male specimen which has the broadest parameres as the lectotype of *Cisseis cyanura* Kerremans. The specimen bears a printed red label on which is written 'Lectotype *Cisseis cyanura* Kerremans, Designated by S. Barker, 1999.'

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[1] **LaPorte F. L. & Gory, H. L.** (1839) " Histoire naturelle et iconographie des insectes coléoptères" vol. 2.

[2] **Carter, H. J.** (1923) Proc. Linn. Soc. N.S.W. **48**, 159-176.

[3] **Carter, H. J.** (1936) *Ibid.* **61**, 98-110.

[4] **Kerremans, C.** (1898) Ann. Soc. Ent. Belg. **92**, 113-182.

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