

RECORDS
of the
AUCKLAND
INSTITUTE
AND MUSEUM

Volume 32, 1995

RECORDS
of the
AUCKLAND INSTITUTE
AND MUSEUM

Volume 32

AUCKLAND, NEW ZEALAND
1995

Editors
B.J. GILL and N.J. PRICKETT

ISSN 0067-0464
RECORDS OF THE AUCKLAND INSTITUTE AND MUSEUM
Vol. 32

Published by Order of the Council
T.L.R. WILSON, Director

[Vol. 31, 1994, was published on 24 March 1995]

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Private Bag 92018, Auckland 1, New Zealand

Printed by Uniprint, Auckland

RECORDS OF THE AUCKLAND INSTITUTE AND MUSEUM

VOLUME 32

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LATE ORDOVICIAN CRINOIDS FROM HAILES KNOB, UPPER TAKAKA, NEW ZEALAND

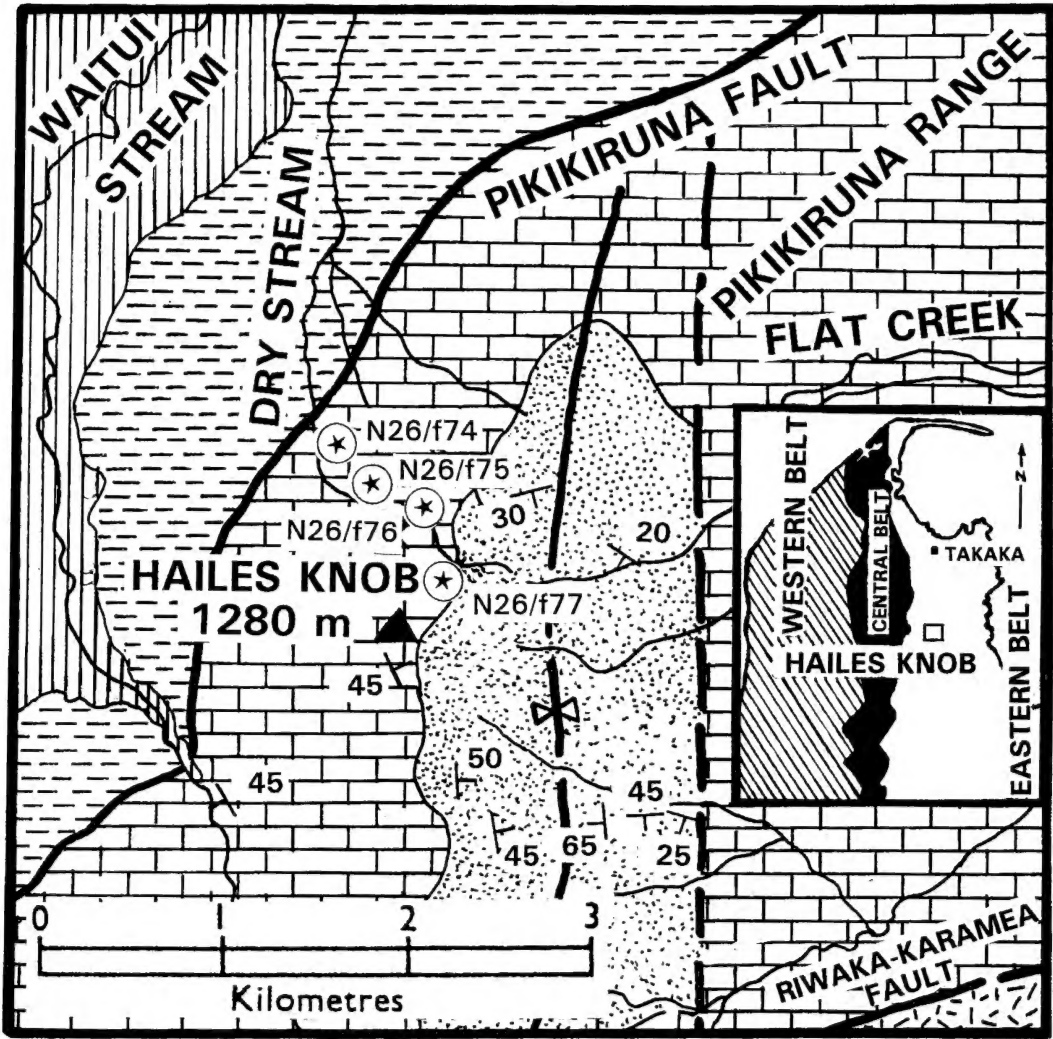
MICHAEL K. EAGLE

Abstract. Late Ordovician crinoid faunas are described from the Arthur Marble of Hailes Knob, Upper Takaka, north-west Nelson. Three camerate crinoids and the first inadunate crinoid from New Zealand are recorded with the genera *Reteocrinus*, *Archaeocrinus*, *Deocrinus* and *Aetheocrinus* being recognised. They are the earliest crinoids to be described from this country and are interpreted here as having migrated from a North American mid-continental shelf environment.

The earliest pelmatozoans discovered in New Zealand are those of Early Ordovician (Arenigian) age found at Springs Junction, Mt Owen and Mt Arthur, South Island. They exist as recrystallised external and internal casts that have been structurally distorted beyond identification. Further Late Ordovician (Ashgillian) pelmatozoans are found in Arthur Marble at Hailes Knob, Upper Takaka, north-west Nelson. These are also internal and external stem columnal casts. The lack of recognisable thecae in this assemblage has previously deterred formal description, however, some recently collected columnals show sufficient morphological detail to enable them to be identified. This paper records for the first time columnal morphology of some of these earliest known fossil crinoids of New Zealand.

PREVIOUS WORK

McKay (1879, 1892), Cox (1881) and Park (1890) surveyed the older Palaeozoic rocks in the eastern part of north-west Nelson. Marshall (1912) and Benson (1921, 1923) refer to the chronostratigraphy of the area. Benson *et al.* (1936) reviewed the lower Palaeozoic fossils of north-west Nelson and Henderson *et al.* (1959) completed a regional map. H.W. Wellman discovered a fossiliferous, leached, calcareous grit "float" boulder containing brachiopods and crinoid ossicles in Dry Stream in 1960. This boulder was lodged at Victoria University (V972) and subsequently proved to be derived from the Hailes Knob Quartzite (Cooper & Wright 1972), overlying Arthur Marble. Grindley (1961) mapped the Arthur Marble found in the Upper Takaka area as Late Ordovician in age. Cooper (1965, 1968) recorded known fossil localities of the area. Wright (1968) recorded conodont taxa from a boulder from the western face of Hailes Knob and deduced an Ashgillian or Late Caradocian age for the "Arthur Marble" found there. Cooper & Wright (1972) recorded Lower Silurian Hailes Knob Quartzite and fossils from Hailes Knob, north-west Nelson, thereby filling an important gap between the Late Ordovician and Early Devonian faunal sequence in New Zealand. Cooper (1975) subsequently summarised sedimentary, igneous and tectonic early geological histories of the north-west part of the South Island of New Zealand.



- | | | | |
|---|---|---|------------------------|
|  | Cenozoic |  | FOSSIL LOCALITY |
|  | Hailes Knob Quartzite (Silurian) | | |
|  | Quartz-sandstone, phyllite (Ordovician-Silurian) | | |
|  | Arthur Marble (Late Ordovician) | | |
|  | Igneous and metamorphic (Riwaka Complex) | | |

Fig. 1. Locality map of north-west Nelson. Geographical sketch map showing the distribution of the eastern, central, and western depositional belts [after Cooper & Wright (1972) and Cooper (1975)], and the Late Ordovician crinoid fossil localities at Hailes Knob.

GEOLOGY

The Pīkikiruna Scarp containing numerous but isolated limestone outcrops, rises 600 m from the Upper Takaka - Takaka tectonic depression and forms the north-western margin of the Pīkikiruna Range. Hailes Knob (1280 m) is part of the north-east trending Pīkikiruna Range, and is 12 km south of Takaka (Fig. 1). Most of the Pīkikiruna Range drains to the south-east, however the Waitui Stream and Dry Stream drain north-west of Hailes Knob, sometimes disappearing through subterranean marble caverns.

The contact between Hailes Knob Quartzite and Arthur Marble (Grindley 1971) is best exposed in Dry Stream, 1 km north-east of Hailes Knob. The Arthur Marble found there is at least 320 m thick, and is a black to dark-grey, fine-grained, graphitic limestone with exposed inter-bedded muddy and micaceous layers. Graphitic phyllite and schistose bands are common at the top of the formation. Authigenic, euhedral, pyrite crystals are common and interlaminar folding and contorted bedding are usual at several horizons. Several rock outcrops and derived fossiliferous boulders show structural deformation (Cooper & Wright 1972). Fossil crinoid columnals are common throughout but are locally abundant in several stratigraphic levels (Fig. 2).

Cooper (1975) considered the sediments of the north-western area of the South Island formed part of a single Gondwana Palaeozoic segment. This segment included the western, central and eastern depositional belts of north-west Nelson that were direct analogues of the Ballarat and Melbourne Troughs (Brown *et al.* 1968) and interposed Heathcote Axis (Hills & Thomas 1954), of Central Victoria, Australia. On this basis, the Hailes Knob collecting sites are located within the Early Palaeozoic eastern (Melbourne Trough) sediments which were deposited as a continuous Central Victorian and north-west Nelson Belt. These sediments underwent a major diastrophic and metamorphic episode narrowly confined to the Australian Benambran Orogeny of this time (Cooper 1975).

Fossil localities are listed with their New Zealand Fossil Record File numbers in Table 1. All localities from the Upper Takaka district lie within NZMS 260 Sheet N26. Specimens from a fossil locality denoted by a registration number prefixed with "AK", are held at the Auckland Institute and Museum. Those with "E", are held at the University of Auckland Geology Department.

MATERIAL

Previous workers such as Donovan (1984) found it convenient to divide crinoid columnals into two groups, meric (each columnal composed of more than one calcite plate) and holomeric (columnals formed from a single ossicle). A typical columnal is usually thought of as being circular with a circular lumen. Holomeric columnals occur throughout the Ordovician of Europe, however, gaps exist in the stratigraphic range of some genera/morphogenera. New crinoid columnal features appear in the Late Ordovician, coincident with the increase in columnal diversity and numbers. All (but one) known crinoids of the sub-classes Camerata and Inadunata are stem-bearing. No known camerate species has been recorded in which the column is divided into segments by longitudinal sutures; columnals are not composed of tetrameres or pentameres as in some species of the Sub-class Inadunata (Ubaghs 1978).

Any evolutionary study based on fragmentary fossil remains of crinoids is inherently unreliable and cannot demonstrate relationships between disarticulated remnants. Only particularly distinctive columnals are of any practical use in taxonomy since homeomorphs between distantly related taxa are probably common (Hicks 1873). A British Ordovician inadunate example is *Ramseyocrinus cambriensis* which has a column possessing tetrameric



Fig. 2. Photograph of an *in situ* band of fossil crinoid columnals at locality N26/f75 from which specimens of *Archaeocrinus*, *Deocrinus* and *Reteocrinus* were collected.

Table 1. Distribution of Late Ordovician crinoid genera reported from the Arthur Marble at Hailes Knob. A - abundant; C - common; UC - uncommon.

N.Z. Fossil Record No.	N26/939137 N26/f74	N26/942136 N26/f75	N26/945133 N26/f76	N26/947130 N26/f77
INADUNATA				
<i>Aethocrinus</i> sp.	-	-	-	UC
CAMERATA				
<i>Reteocrinus</i> sp.	A	A	A	A
<i>Archaeocrinus</i> sp.	A	A	A	-
<i>Deocrinus</i> sp.	-	C	C	-

columnals proximally and tetragonal holomeric columnals distally. Ubaghs (1978) argues that “although some Camerata have very distinctive columns, most dissociated columnals and pluricolumnals cannot now be attributed certainly to any particular camerate genus. Rarely stated is general agreement that main component parts and ossicles of the body of camerate crinoids are homologous to specified parts and ossicles of other crinoids”.

Using both North American, Russian and British material, Sprinkle (1973), Stukalina (1966) and Donovan (1984) have discussed the early evolution of the pelmatozoan column in ancestral hohlwurzels. The Russian system of columnal morphogeneric nomenclature (Yeltysheva 1956; Stukalina 1966) emphasises the lumen outline e.g. *Pentagonocyclicus* has a circular columnal with a pentagonal lumen. Moore (1939) and Wright (1983), however, give priority to the facet outline. *Cyclopentagonopa* is similarly a circular columnal with a pentagonal lumen and is conspecific with *Pentagonocyclicus*. Pentagonal symmetrical ossicles have been divided into a number of morphogenera by previous authors but the nomenclature does not reflect the true diversity of these columnals (Wright 1983), nor their actual stratigraphic range (Donovan 1984). The New Zealand Late Ordovician fossil crinoids support morphogeneric models, and enough morphological detail is present in the the New Zealand specimens to enable them to be attributed to described genera. Nomenclature in this paper follows Moore (1978) and Ubaghs (1978).

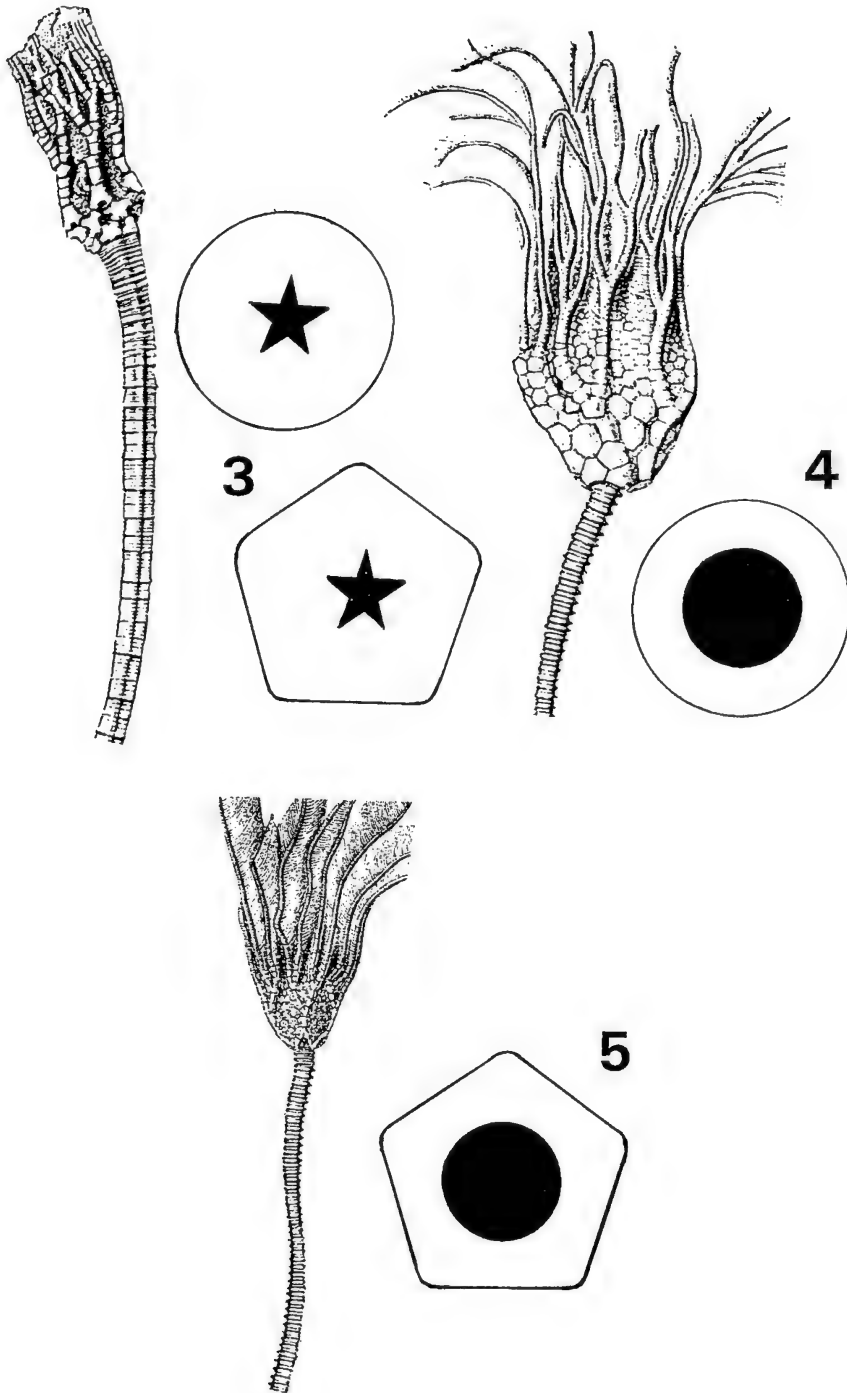
SYSTEMATIC DESCRIPTIONS

Class	CRINOIDEA Miller, 1821
Subclass	CAMERATA Wachsmuth & Springer, 1885
Order	DIPLOBATHRIDA Moore & Laudon, 1943
Suborder	EUDIPOBATHRINA Ubaghs, 1953
Superfamily	RHODOCRINITACEA Roemer, 1855
Family	RETEOCRINIDAE Wachsmuth & Springer, 1885
Genus	<i>Reteocrinus</i> Billings, 1859
Type species	<i>Reteocrinus stellaris</i> Bigsby, 1868:23 (<i>nomen vanum</i>). Trenton, Canada.
Material:	AK 94172; AK 94173; AK 94174; AK 94175; E 520 (hypotypes).

Description: Column transverse; section passing from pentagonal to round distally; holomeric; columnals possess a pentastellate lumen.

Remarks: *Reteocrinus* is found in the Trenton Limestone (middle Ordovician), Trenton, Ottawa, Canada (type locality), and columnals of the genus are also found in the Ordovician (Caradocian) of Britain. The common occurrence of holomeric columnals with pentastellate lumina in the Ashgill of the South European province is analogous to their abundance at Hailes Knob at the same time (Fig. 3). There appears to be more of the round columnal configuration than the pentagonal and diameter sizes are 1-8 mm. Just as the British specimens may be an indication of the mixing of faunas as the Iapetus Ocean closed, the presence of *Reteocrinus* in Arthur Marble may mean a faunal concentration due to regional shallowing.

Family	ARCHAEOCRINIDAE Moore & Laudon, 1943
Genus	<i>Archaeocrinus</i> Wachsmuth & Springer, 1881
Type species	<i>Glyptocrinus lacunosus</i> Billings, 1857, original description. Trenton, Canada.
Material:	AK 94177; AK 94178; AK 94179; E 521 (hypotypes).



Figs 3-5. Reconstructions and columnal transverse sections of camerate crinoids. 3. *Reteocrinus* sp. (proximal section above, distal section below). 4. *Archaeocrinus* sp. 5. *Deocrinus* sp. in Arthur Marble from localities N26/f74, N26/f75, N26/f76. Reconstructions after Springer (1911b) (3) and Wachsmuth & Springer (1897) (4).

Description: Column round; holomeric; columnals possess a large circular lumen often degenerating distally; distance from axial connective commissure to columnal edge variable, proportional to lumen diameter.

Remarks: Billings (1857) described the columnal as “easily distinguished from that of any other species occurring in the Trenton Limestone” (Middle Ordovician), Trenton, Ottawa, Canada (the type locality). The abundant, round columnals found in the Arthur Marble of Hailes Knob are similar, being mainly small (2-7 mm long; Fig. 4). The large joints of the few pluricolumnals present are proportionally broad while the constrictions between them are wide and deep, being a diagnostic feature of *Archaeocrinus*. Round, holomeric, columnals with large lumens are found in European and North American Ordovician rocks. They have been variously morphogenetically described, and many genera are now synonymised under “*Cyclocyclopa*” (Moore, 1939) and “*Cyclocyclicus*” (Yeltysheva, 1955). Round columnals with large, circular axial canals are known from British, European and North American (Tremadocian-Arenigian) cystoids. Identification of archaeocrinoid forms at the Upper Takaka locality to species level is not possible, however, Hailes Knob columnals show a synostiosial articulation, not the usual holomeric glyptocystitid type of articulation of the cystoids.

Family ANTHRACOCRINIDAE Strimple & Watkins, 1955
Genus *Deocrinus* Hudson, 1907
Type species *Rhodocrinus asperatus* Billings, 1859:27, original description. Chazyan, Canada.
Material: AK 94180; AK 94181; E 522 (hypotypes).

Description: Column pentalobate; holomeric; columnals possess a large, circular lumen; distance from axial connective commissure to columnal edge variable, proportional to lumen diameter.

Remarks: These columnals are common in the Arthur Marble. They are 2-8 mm in diameter. Fusion of the meres has produced a coincident crystallographic orientation and an increase in lumen diameter reminiscent of columnals of the northern European morphogenus *Bystrowicrinus* (Yeltysheva & Stukalina 1963). Retention of a circular lumen in *Deocrinus* (Fig. 5) instead of the stellate configuration developed by *Bystrowicrinus* and *Reteocrinus* is the main difference between the genera. The first appearance of *Deocrinus* columnals in the Middle Ordovician and their later appearance in Arthur Marble at Hailes Knob, suggests that they evolved from a similar ancestor to *Bystrowicrinus*. *Deocrinus* and *Bystrowicrinus* columnals are almost exclusively limited to the North American faunal province until the Ashgillian. The New Zealand specimens appear similar to European and British forms of *Deocrinus*.

Class CRINOIDEA Millar, 1821
Subclass INADUNATA Wachsmuth & Springer, 1885
Order CLADIDA Moore & Laudon, 1943
Suborder DENDROCRININA Bather, 1899
Superfamily MASTIGOCRINACEA Jaekel, 1918

Family AETHOCRINIDAE Ubaghs, 1969
Genus *Aethocrinus* Ubaghs, 1969
Type species *Aethocrinus moorei* Ubaghs, 1969, monotypy. Europe: Montagne Noire, South France.
Material: AK 94176; E 523 (hypotypes).

Description: Column pentalobate in transverse section; heteromorphic; column columnals divided by longitudinal sutures into pentameres; large pentagonal axial canal; constant, greatly reduced distance from the axial connective commissure to columnal edge.

Remarks: Columnals identifiable as *Aethocrinus* sp. at the Hailes Knob locality are uncommon. The largest measures 6 mm in diameter but most are 2-5 mm (Fig. 6). The presence of meric sutures in the column of *Aethocrinus* sp. allowed bending and the orientation of aboral calyx crowns when filter-feeding. In a holomeric columnal such as the proxistele of *Megistocrinus reeftonensis* (Lochkovian) of Reefton, New Zealand, flexure was facilitated by crenulated, symplectial articulation (Prokop 1970). Devoid of such symplexy, and because individual columnals were bound together solely by ligaments at the meric sutures, *Aethocrinus* sp. indet. could not have similarly flexed. Flexibility was instead achieved by the inter-ossicle movements of stacked meres, arrayed perpendicular to the longitudinal axis of the stem (Donovan 1990). Only marginal movement was possible between adjacent columnals. *Aethocrinus* was originally described from the Early Ordovician (Tremadocian-Arenigian) of France, but is also known from throughout the Arenigian of Britain and elsewhere.

AGE

Wright (1968) proposed a conodont age of Late Ordovician (Late Caradocian to Ashgillian of the standard British sequence or Bolindian of the Victorian sequence) for the Arthur Marble at Hailes Knob. This age is correlated with the presence of *Deocrinus* sp. columnals which remained almost exclusively limited to the North American faunal province until the Ashgillian. This age is here referred to those marble and limestone lenses of the western exposure of Hailes Knob and derived boulders from that face now located in Dry Stream, Upper Takaka Valley.

FAUNAL ASSOCIATIONS AND PALEOECOLOGY

During the Late Ashgillian, the American and European marine communities appear to have contained few crinoid species, were shallow, epifaunal, often consisting of only two or three genera of crinoids, with perhaps several species of stropheodontid brachiopods (such as the restricted *Hirnantia* community of the Late Ordovician of Britain), with a few corals and bryozoans. The Hailes Knob faunal community contains a similar assemblage and appears to be a southern hemisphere analogue. Crinoids are important indicators of depositional environments (Cain 1968), indicating a shallow water biotope during the Late Ordovician.

In addition to crinoids, the Hailes Knob community contains unidentified sponge and brachiopod impressions, tabulate corals (*Proheliolites goldfussi*, *Plasmaporella* cf. *inflata* and *Paleopora inordinata*) and the rugose coral genus *Strepelasama* (Fig. 7). All are shallow water species. The tabulate and compound rugose corals frequently acted as framework organisms in reefs at this time. Though a shallow sea requirement for the existence of tabulate and rugose corals is unproven (Hill 1956; Hill & Stumm 1956), the known fauna suggests that the Hailes Knob assemblage may have constituted such a reef.

Although large numbers of crinoids remain persistent reef dwellers to this day, they also populate the inter-reef and off-reef environments (Manten 1970). Crinoid mass occurrences are known from present seas. Clark (1915a) described the dredging of tens of thousands of individuals from single localities. Lane (1973) and earlier workers referred to such crinoid colonies, patches and stands, as "gardens" or "meadows".

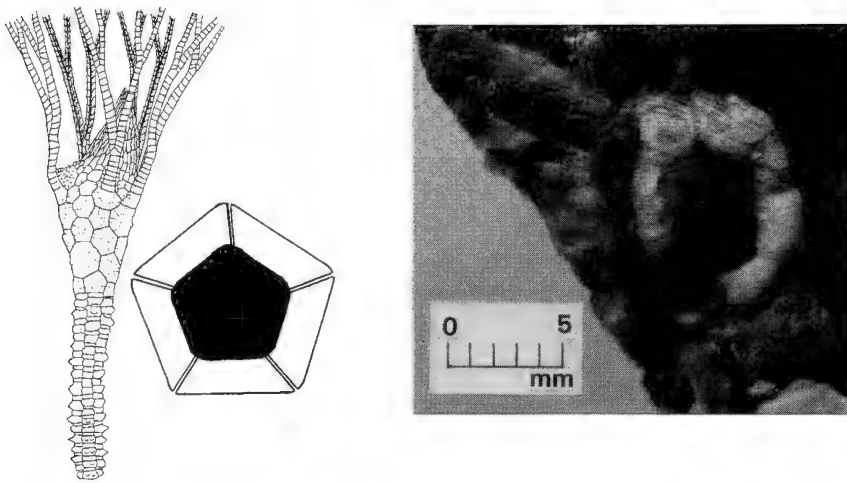


Fig. 6. Reconstruction of *Aethocrinus moorei* after Ubaghs (1969) (left). Photograph (right) and transverse section diagram (centre) of *Aethocrinus* sp. indet. pentameric columnal etched by acetic acid from Arthur Marble, locality N26/f77.

Interpretation of the crinoid record in terms of assemblages or communities is complicated by the rapidity with which crinoid ossicles disarticulate after death (Liddell 1975; Cain 1968). Articulated crinoids from the Silurian starfish bed in the Pentland Hills, England, provide evidence in the form of fine-grained matrix for a quiet-water deposition and rapid burial needed to preserve complicated echinoderms, such as Palaeozoic crinoids, in articulated condition (Brower 1975). Similar lithological conditions are uncommon in New Zealand, hence, the bulk of Palaeozoic crinoid evidence in this country consists of disarticulated columnals or their impressions. Elsewhere, Palaeozoic crinoids are often manifest as “pelmatozoan” or “crinoidal” limestones abundant from Early Cambrian through to Permian times. They particularly occur where terrigenous sedimentation has remained relatively low, such as at the Hailes Knob (eastern Melbourne Trough) segment of the Gondwanan continental sea shelf. Modern crinoid abundance suggests that taxonomically diverse “pelmatozoan” assemblages are more consistent with shelf or upper bathyal depths in the past than with deep-water conditions (Fell 1966a). The distribution of fossil crinoid limestones or “criquinities” as annotated by Laudon (1957), is rarely found in New Zealand but exemplified by the Hailes Knob locality.

The absence of molluscs in the Arthur Marble of Hailes Knob may be an indication that the deposit is not *in situ*. The Hailes Knob assemblage may simply be a chance accumulation of transported pelmatozoan debris. This is supported by the fact that most epifaunal echinoderms, crinoids in particular, do best in an environment of well-oxygenated, subtidal, non-turbid water where current movement is gentle but sufficient to provide an adequate food supply (Booolootian 1966; Macurda & Meyer 1975). The generally long, slender stems of pelmatozoan crinoids are well suited to serve as paleocurrent indicators (Klähn 1929; Wiman 1933; Schwarzacher 1963; Anderson 1968). Pluricolumnals in the Arthur Marble show severe post-mortem movement and are variously paleocurrent orientated. This phenomenon would explain the absence of crinoid cups; fast-flowing currents would have obliterated calices by scattering individual thecae plates. Not so easily explained, however, is the absence of recognisable basal stem holdfast mechanisms.

The strength of these proposed paleocurrents, presumably detritus and plankton-laden, suggests an environmental niche suited to crinoid suspension filter-feeding. The extensive populations of various filter-feeding biota that lived at Hailes Knob suggests the existence of abundant Palaeozoic plankton, of which we know very little.

Conodonts have previously been used to date this open, flat-bottomed benthic marine community where only a small biotic fragment has been preserved (i.e. no nautiloides or graptolites are known from the locality) (Barnes & Fahraeus 1975). East Australian and Hailes Knob Late Ordovician conodonts include the genus *Belodina* which indicates affinities with North American mid-continental faunas (Wright 1968) as do the crinoids described herein. Disarticulated crinoids usually constitute a large proportion of the sediment in North American biotopes and where there was a lack of clastic sediment, wide fossil bands indicate that various sessile species probably covered the sea-floor. This is also a feature of the Hailes Knob locality. Historically, trilobites are extremely rare or absent from this community and this is so at Hailes Knob. It may be due to the substrate being either a hard, biogenic lithoherm or compacted calcareous sands, both being unsuitable for sediment deposit feeders.

DISCUSSION

The articular facet of each of the Ordovician crinoid columnals from Hailes Knob described in this paper, whether Camerata or Inadunata, as in almost all crinoids, have a

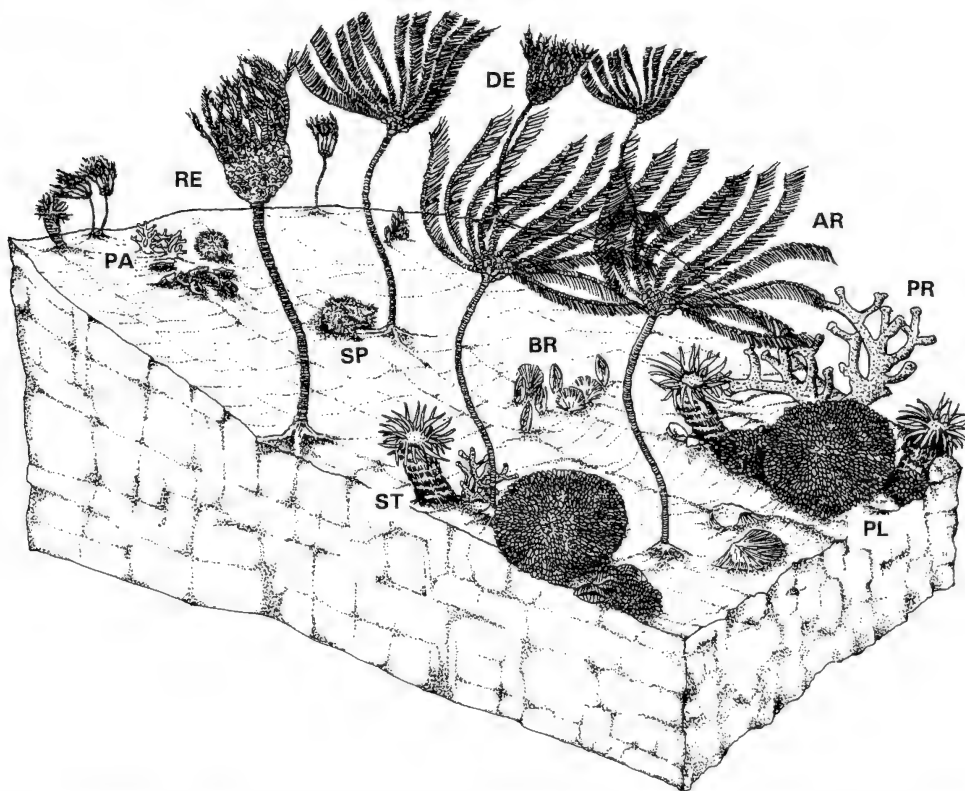


Fig. 7. Schematic drawing of the inner shelf Hailes Knob *in situ* biocarbonate and lithoherm community (10-100 m). No scale implied. AR = *Archaeocrinus* sp. indet.; BR = brachiopods indet.; DE = *Deocrinus* sp. indet.; PA = *Paleopora inordinata*; PL = *Plasmoporella* cf. *inflata*; PR = *Proheliolites goldfussi*; RE = *Reteocrinus* sp. indet.; SP = sponges indet.; ST = *Streptelasma* sp.

characteristic, regularly symmetrical axial canal outline (circular, pentagonal, pentastellate). All the Hailes Knob crinoid columnals possessed large-diameter axial canals that reduced weight and decreased the effective width of each meric suture. The broad cavity created by the axial canal aided flexure and accommodated visceral and perhaps neural organs.

Adaptive trends in the evolution of Palaeozoic crinoids are characterised by an intensified function of movement. This is suggested by the various known skeletal articulation forms of stem ossicles and gradual constriction of the axial canal. This constriction is correlated with the thickening of the stem walls and a proportional increase in the articular facet. Observed morphogenetic changes are useful in Palaeozoic phylogenetic classification (Stukalina 1964, 1966, 1988). The Hailes Knob genera, composed of pentamerous and monolithic columnals, are indicative of the exceptional diversity of adaptive trends that existed world-wide at this time.

The holomeric columnals of the type species *Reteocrinus stellaris* (Biggsby, 1868), *Archaeocrinus lacunosus* (Billings, 1857), and *Deocrinus asperatus* (Billings, 1859) exhibit a planar surface with little or no relief. They are primary circling structures composed of fused meres (Stukalina 1988), having rare synostiosial articulation that barely enabled lateral flexure. The Hailes Knob specimens are obviously primitive in columnar structure and articulation compared with later New Zealand Mesozoic and Cenozoic articulate columnals (Eagle 1993, 1994a). They are typical representatives of crinoid columnals developed from meric columns to form simple, benthic, sessile stems.

All modern brachiopods, crustaceans, molluscs and crinoids have a pelagic larval or veliger stage which drifts with ocean currents for between days and a few months. Late Ordovician species probably went through the same ontogenetic stage, migrating across the oceans of the time (McKerrow & Zeigler 1972). Like New Zealand Late Ordovician shallow marine trilobites and brachiopods, New Zealand crinoids have North American and European

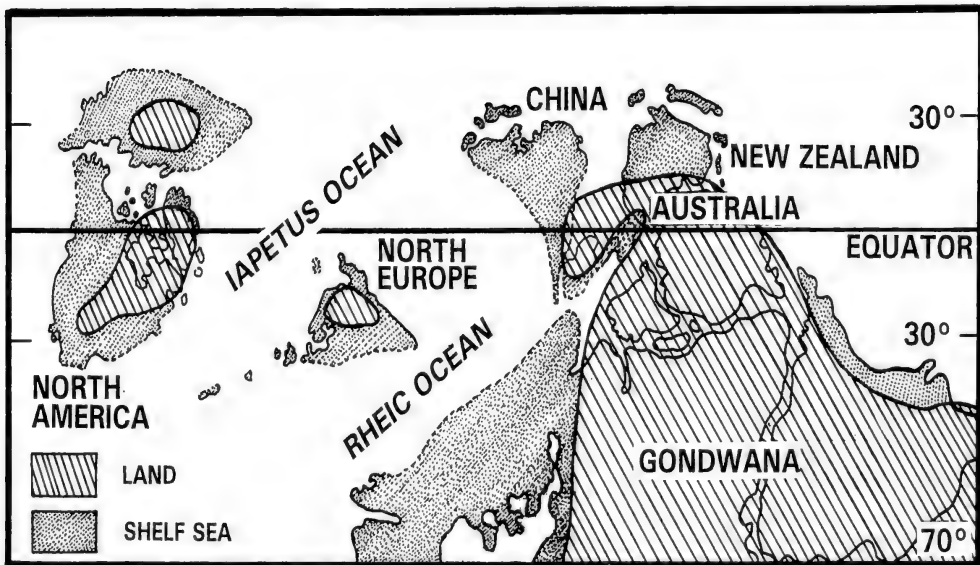


Fig. 8. Mercator projected diagrammatic map of the world during the Late Ordovician illustrating the geographic land and marine relationships between the North American Province, the North European Province, The Iapetus and Rheic Oceans, Gondwana and the Equator (after Cocks & McKerrow 1978).

affinities (Eagle 1994b) (Fig. 8). At present there is no known East Australian - Asian connection as for other groups such as conodonts. It may exist however, disguised in Late Ordovician limestone fragments at such Early Silurian localities as Borenore, New South Wales, where tabulate corals and crinoid columnals have been found (Packham 1969; Laseron 1969). The common occurrence of both pentameric and holomeric crinoid columnals with pentastellate lumina in the Ashgillian of the South European province indicates faunal mixing as the Iapetus Ocean closed; only one *Bystrowicrinus* columnal has been found from the south of the Iapetus suture in pre-Ashgillian rocks (Donovan 1984).

The absence of trimeric, tetrameric or bimeric columnals and the occurrence of only pentameric and holomeric columnals at the Hailes Knob locality may mean that some crinoid groups failed to migrate east or west of the Iapetus and Rheic Oceans at this time. It is suggested that certain crinoids migrated to the Hailes Knob locality between the North American mid sea-shelf westward to the Australasian (Gondwanan) sea-shelf and perhaps also eastward via shallow European seas in the Caradocian. Marked changes have previously been noted in the geographic distribution of some fossil groups in the Mid-Ordovician and this may reflect a climatic change favourable to crinoids at that time (Cocks & Fortney 1982). Climatic or oceanic conditions may have prevented larval distribution either east or west even though there is no paleogeographic evidence of a major land barrier (Cocks & McKerrow 1978). The common premise that the Southern European migration to New Zealand of meric and holomeric columnal species was the only point of faunal origin fails in the light of the proven earlier North American affinities of the Ashgillian sessile crinoids discussed in this paper and of associated species found in the assemblage.

In the Late Ordovician, North American, European and Gondwanan faunal provinces were within 30° N and 30° S latitude, near the equator (Fig. 8). Isolation probably encouraged divergent evolution and the Hailes Knob locality is perhaps indicative of a local Gondwanan shelf marine province that restricted entry to some crinoid faunas and confined others.

Crinoid skeletal material preserved in the New Zealand fossil record from the late Ordovician of Hailes Knob to the present provides an opportunity to study ecologic changes over a long time interval. Because of the great time-span involved, crinoids may provide a reliable biostratigraphic correlation tool in New Zealand.

Acknowledgements. I am indebted to the late John Kelly of Hailes Knob, Upper Takaka, who showed me Dry Creek and Arthur Marble and the hospitality of a true friend. Thanks are also due to a patient Parkes family, to Glenys Stace (Auckland Institute and Museum) who climbed more than a mountain, and to Ian Keyes (Institute of Geological and Nuclear Sciences) for constructive criticism of the manuscript; to Krzysztof Pfeiffer (Auckland Institute and Museum) for Fig. 6. Field work was funded by a grant from the Lottery Grants Board, Science Research Committee.

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EARLY MIOCENE BEACH, ROCKY SHORE, AND ENCLOSED BAY FOSSIL COMMUNITIES, WAIHEKE ISLAND, AUCKLAND

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Abstract. One hundred and eighty-seven macrofossil taxa (including 54 bivalves, 89 gastropods, three echinoderms, three chordates, six corals, two brachiopods and four plants) are recorded from three early Miocene Kawau Subgroup sequences on Waiheke Island, east of Auckland city. This doubles the number of fossil taxa previously recorded from these classic localities. Fossils from intertidal and shallow subtidal rocky reefs, coarse shelly gravel, and inner shelf sandy seafloor are generally mixed together in varying proportions in the conglomerates and sandstone units that were deposited intertidally and at inner shelf depths (0-50 m). Fine sandstone deposited in quiet water at middle and perhaps shallow outer shelf depths (c. 50-150 m) contains fossil faunas largely composed of sand-inhabiting organisms.

PREVIOUS WORK

Fossils were first reported from Waiheke Island by Powell & Bartrum (1929) following the discovery of rich fossil beds at Double-U Bay in 1927 by Mr E.W. Tetley, a geology student of Prof. Bartrum, who had a family house on Waiheke Island. Bartrum joined with his colleague from Auckland Museum, Baden Powell, and they made several collecting trips to the locality. They also observed that similar beds were present at the west end of Oneroa Beach, "where they constitute the shore-platform buried beneath modern beach-sands and only rarely exposed to view ... but the shells there are so badly leached that their collection is exceedingly difficult." Powell & Bartrum (1929) recorded a single molluscan species from Oneroa Beach and 78 from Double-U Bay, describing nine bivalves, 32 gastropods and one chiton as new, with Double-U Bay as their type locality (Fossil Record No. R10/f9001). Several species were named after Mr Tetley, and others after Oneroa.

In the 1930s, Powell discovered the similarly rich fossil sequence in the bay south of Squadron or Church Bay. From this locality (R11/f7001), which we now call Fossil Bay, Powell (1938) recorded 35 fossil molluscs, including four bivalves and five gastropods which he described as new. Six of these have their type locality at Fossil Bay and three have their type locality at Double-U Bay. Powell (1976) provided an updated list of the 90 molluscan fossil taxa from these two localities. It contains 51 gastropods, 37 bivalves, one chiton and one scaphopod.

Squires (1958) recorded the solitary coral, *Truncatoflabellum sphenodeum* from both Double-U and Fossil Bays. Feldmann & Keyes (1992) recorded two fossil decapod crustacea (*Callianassa* sp., *Upogebia* sp.) from Double-U Bay. Grant-Mackie (1993: 13-14, fig. 3.3) gave a general account and interpretation of the major elements in the Fossil Bay faunal sequence. He recorded a head of the coral *Alveopora polyacantha* growing in

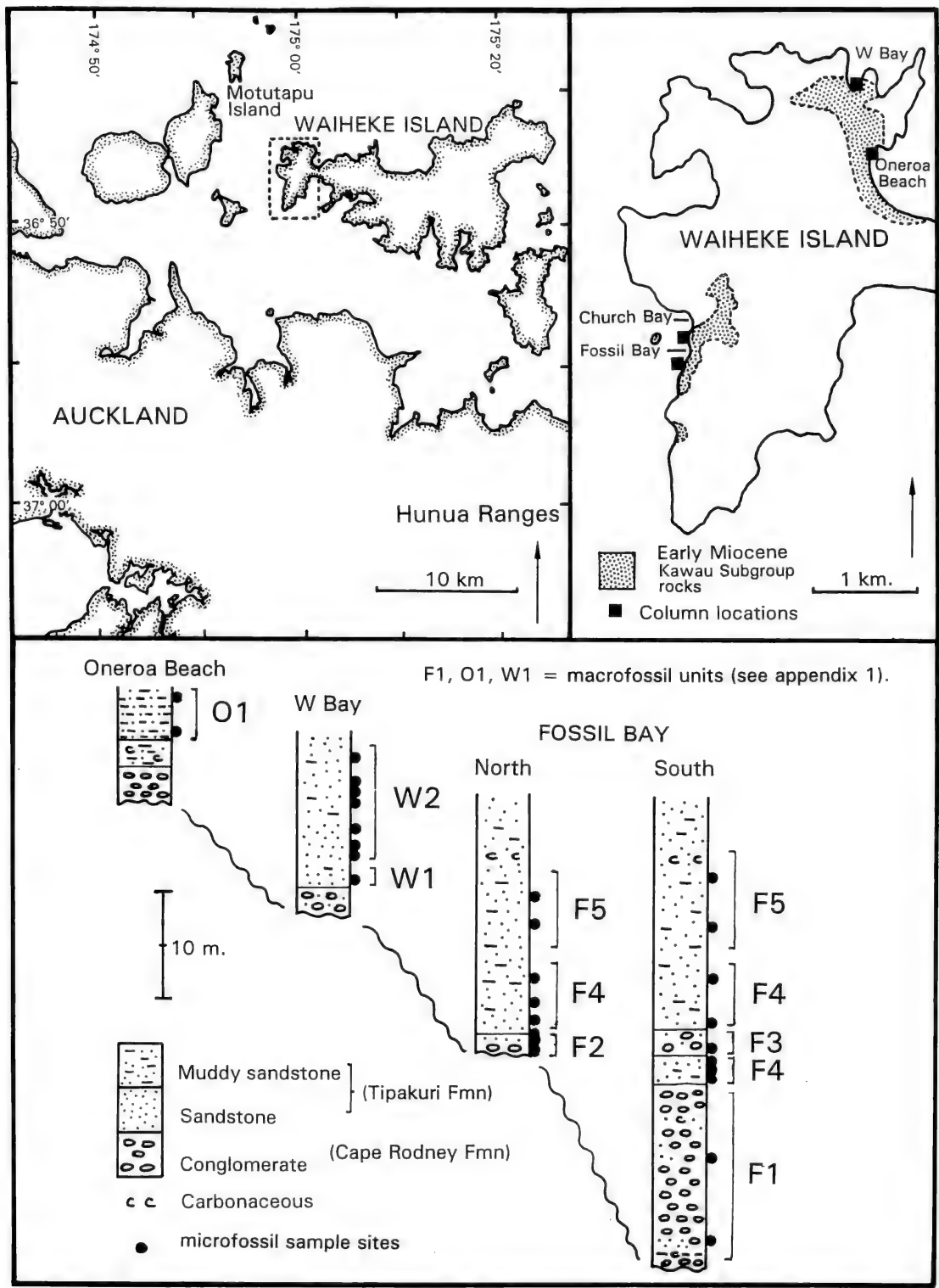


Fig. 1. Geological map of western Waiheke Island, with stratigraphic columns for the early Miocene Kawau Subgroup at Oneroa Beach, Double-U Bay and Fossil Bay (after Hayward & Brook 1984). No stratigraphic relationship is implied by the arrangement of the columns.

situ at the north end of Fossil Bay and also noted the presence of two other corals (cup-like corals typical of shaded conditions and *Oculina virgosa*) and the heart urchin *Opissaster rotundatus*.

Double-U Bay is also the type locality of one fossil foraminifer (*Notorotalia powelli*) described by Finlay (1939), and of two fossil ostracoda (*Trachylebris retizea*, *Loxococoncha propunctata*) described by Hornibrook (1953) from matrix sent to them by Powell. Hayward & Brook (1994) recorded 129 species of fossil foraminifera from 29 quantitative samples from all three sequences. They interpret the faunas as indicating regional subsidence with a beach fauna at the base of the Fossil Bay sequence progressively deepening to mid-outer shelf depths at the top of the Double-U Bay and Oneroa Beach sequences.

The geology of the early Miocene rocks on Waiheke Island has been mapped by Halcrow (1956) and Kermode (1992). Stratigraphic columns and descriptions of the sequences at the three main localities have been presented in Hayward & Brook (1984, 1994) and Ricketts *et al.* (1989).

GEOLOGY (Fig. 1)

Waiheke Island is composed of Triassic to Jurassic Waipapa Group greywacke basement unconformably overlain in places by the eroded remnants of an early Miocene transgressive sequence (basal Waitemata Group) which progressively buries an irregular coastal topography of actively eroding greywacke stacks, cliffs and embayed islands (Ballance 1974, Ricketts *et al.* 1989). Quaternary erosion is re-exhuming this pre-Waitemata topography as it strips off the softer Miocene rocks.

The basal Waitemata Group rocks (Kawau Subgroup - Hayward & Brook 1984) on Waiheke Island exhibit different transgressive sequences in different areas or paleobays. They are the thickest, finest-grained and most fossiliferous Kawau Subgroup sequences known. They outcrop in three main areas:

Fossil Bay

Waipapa Group greywacke outcrops as paleohighs forming the points on either side of Fossil Bay. Early Miocene sedimentary rocks form a gentle syncline filling the 400-m-wide paleobay between the two greywacke highs. They are exposed in the cliffs backing Fossil Bay and intertidally beneath the fine gravels of the beach.

In the shore platform and cliffs at the south end of Fossil Bay (Fig. 2), a 17-m-thick, weakly bedded, basal conglomerate laps onto and buries the irregular greywacke high. The subangular to subrounded greywacke pebble and cobble conglomerate (Cape Rodney Formation; Hayward & Brook 1984) contains several thin lenses of carbonaceous and shelly sandstone with scattered fossil shells. The upper 10 m exhibits 2-m-scale foreset bedding. In the cliffs behind the south end of the beach the conglomerate is overlain by 27 m of massive to weakly stratified, calcareous, muddy fine sandstone (Oneroa Member of Tipakuri Formation; Hayward & Brook 1984). A 2-m-thick lens of shelly, recrystallised, calcareous, sandy pebble conglomerate occurs within this sequence, 3 m above the base of the Oneroa Member.

On the northern side of Fossil Bay, a 1.5-m-thick graded bed of shelly pebble conglomerate to coarse sandstone laps onto and over the greywacke high. It is overlain by 22 m of calcareous, muddy fine sandstone (Oneroa Member).



Fig. 2. View north across the south end of Fossil Bay, Waiheke Island, with the early Miocene strata dipping away to the left. Basal conglomerate (unit F1) forms the reefs in the foreground, with the redeposited cemented conglomerate (unit F3) forming the narrow reef that crosses the beach beyond. The highest strata (unit F5), comprising muddy fine sandstone, form the high cliff behind the beach.

Double-U Bay (Fig. 3)

In the cliffs and shore platforms of Double-U Bay, on the north coast of Waiheke Island, Kawau Subgroup rocks occur in a 200-m-wide, gentle syncline with greywacke paleohighs on either side. At the eastern end of the bay, the sequence consists of 0-2 m of pebble, cobble conglomerate with occasional fossilised wood and shell moulds (Cape Rodney Formation) overlain by 15 m of weakly stratified, calcareous, fossiliferous, muddy fine sandstone (Oneroa Member).

Oneroa Beach

In the low cliffs behind the north-west end of Oneroa Beach, a greywacke paleohigh is overlapped by a similar sequence of 1-3 m of slightly carbonaceous, sandy pebble conglomerate with occasional shell moulds (Cape Rodney Formation). This is similarly overlain by 10 m or more of weakly stratified, calcareous, muddy fine sandstone (Oneroa Member) that is sporadically exposed in a weathered state in the vegetated cliffs. Rain storms periodically uncover fresher material beneath the sand at the top of the beach.

FOSSIL COLLECTIONS

The macrofauna listed here is based on years of collecting carried out initially by A.W.B. Powell and J.A. Bartrum in the 1920s and 1930s, by many University paleontology course students under the supervision of JAGM and others in the 1960s-1990s and by MKE, BWH and Auckland Museum colleagues in the 1990s. This paper updates the mollusc fossil lists of Powell (1938, 1976) with many additional records from other phyla.



Fig. 3. View west across Double-U Bay, Waiheke Island. The reef in the foreground is composed of basal conglomerate overlain by muddy fine sand (unit W1). The cliffs behind the beach are composed of stratigraphically higher muddy fine sand (unit W2).

Fossil Record Numbers are those of the New Zealand Fossil Record File (prefixed by R10 or R11). All macrofossils are held in the collections of Auckland Institute and Museum (AK) and the Department of Geology, University of Auckland (AU) (Appendix 1).

The rich fossil macrofauna from the basal Waitemata sequence collected from Oneroa Beach, Double-U Bay and Fossil Bay, Waiheke Island, has extremely variable preservation. Some specimens are preserved in excellent condition, some are broken into many pieces (probably during pre-burial transport), many are partly decalcified, and others are simply reduced to steinkerns.

FOSSIL ASSOCIATIONS

All collected macrofaunal taxa are listed in Appendix 1. The paleontological and paleoenvironmental assessment that follows is largely based on the known ecology of genera living today and of modern species most closely related morphologically to these fossils.

SOUTH FOSSIL BAY GRAVEL FAUNA

Macrofauna - R11/f190 (F1)

A sparse fossil fauna, dominated by bivalves, occurs in a few of the layers in this foreset-bedded sandy gravel. Most common are the robust shells of the bivalves *Eucrassatella ampla*, *Crenostrea gittosina*, *Lutraria trapezoidalis* and *Tucetona aucklandica*, the gastropods *Maoricolpus waitemataensis* and *Zefallacia benesulcata* and algal rhodoliths.

Eucrassatella, *Lutraria* and *Tucetona* are infaunal, suspension-feeding bivalves that live at inner shelf depths in coarse sand or gravel. Other shallow-burrowing bivalves found less commonly in this gravel are the thin-shelled, deposit-feeding *Hedecardium greyi* and *Maoricardium oneroaense*.

Thick-shelled *Crenostrea gittosina* is an extinct species of oyster that probably lived intertidally or in shallow subtidal depths attached to hard substrates. The golden oyster *Anomia trigonopsis* probably lived attached to a hard substrate at shallow subtidal depths or under rocks and overhangs at extreme low water. Spines of the large cidaroid *Phyllacanthus titan* are also present in the gravel.

Shells of the deposit-feeding *Zefallacia benesulcata* and *Maoricolpus waitemataensis* are quite common. The modern New Zealand *M. roseus* is almost entirely subtidal, living most commonly in shelly gravel habitats. Also present are the remains of the subtidal, infaunal sand-dwelling scaphopod *Fissidentalium*.

The carnivorous gastropod *Lepsiella intermedia* probably lived intertidally or in shallow subtidal habitats on hard rocky substrates, like its modern counterparts. Also requiring rock or shell for attachment is the filter feeder *Sigapatella patulosa* which like the living *S. novaezealandiae* probably lived under rocks at low tide or in a coarse inner shelf substrate. Living in similar places would have been the triviid *Willungia fracta*, which has been found only in this association on Waiheke. Like the Recent New Zealand *Trivia merces*, it probably grazed on sponges growing on rock rubble and dead shells.

All elements of this fossil fauna are intertidal or shallow subtidal species (less than c. 10 m depth). Most, if not all, have been mixed together by post-mortem wave and current transport and buried in a steeply prograding gravel deposit, possibly a pocket beach in a bay surrounded by greywacke reefs and low cliffs. Some of the fossils lived intertidally and subtidally on the rocky habitat, others lived on and in surrounding coarse gravel. A few taxa, such as *Fissidentalium*, *Opissaster* and possibly *Maoricolpus*, possibly lived slightly further offshore in sand and their shells were washed inshore during storms.

Foraminiferal microfauna - R11/f8, 9 (Hayward & Brook 1994)

Some sandstone lenses within these basal conglomerates contain low diversity foraminiferal faunas with no planktics, dominated by *Elphidium crispum* (50-90%) with subdominant *E. kanoum* and associated *E. advenum* and *Bucella lotella*. In present day sediments similar faunas with a large dominance of *Elphidium charlottensis* are typical of mid tidal to shallow subtidal sand and gravel beaches (0-2 m depth) in moderately sheltered bays (Hayward 1982). The presence of *E. advenum* and *Bucella* suggests the possibility of slightly lowered salinity at times (Hayward & Hollis 1994).

Paleoenvironment

The fossils in this unit suggest that this was a low tidal or shallow subtidal (0-2 m), steeply prograding gravelly pocket beach in a bay surrounded by low cliffs and intertidal and subtidal greywacke reefs and coarse bouldery gravel.

NORTH FOSSIL BAY SANDY GRAVEL FAUNA (Fig. 4)

Macrofauna - R11/f191 (F2)

This 1.5-m-thick graded bed of shelly pebble conglomerate to coarse sandstone contains a diverse fossil fauna with over 50 taxa present.

The deposit laps onto and over an irregular greywacke stack. A significant component of the fossil fauna lived on or in this rocky substrate. Among these are the suspension-feeding, rock-boring *Parapholas aucklandica* and nestling bivalve *Irus* which commonly occurs in the bore holes left open by dead rock borers. *Parapholas* bored into relatively

hard greywacke in the low tidal or shallow subtidal zone. Obliquely bored holes, up to 50 mm long, are commonly still present in the surface of the fossil greywacke stack or sometimes in greywacke pebbles within the conglomerate. Some of these preserve *Parapholas* shells *in situ*.

These and other sessile bivalves comprise 35% of the bivalve taxa. Three intertidal or shallow subtidal bivalves that cement themselves to a firm substrate are the large oyster *Crenostrea gittosina*, *Cleidothaerus albidus* and *Chama*. *Chama* lives around low tide throughout the tropics today and permanently cements itself to rocks or large shells. *Cleidothaerus albidus* lives around the shallow subtidal coastlines of Australasia today, usually cementing its right, cup-shaped valve to a rock or seaweed holdfast.

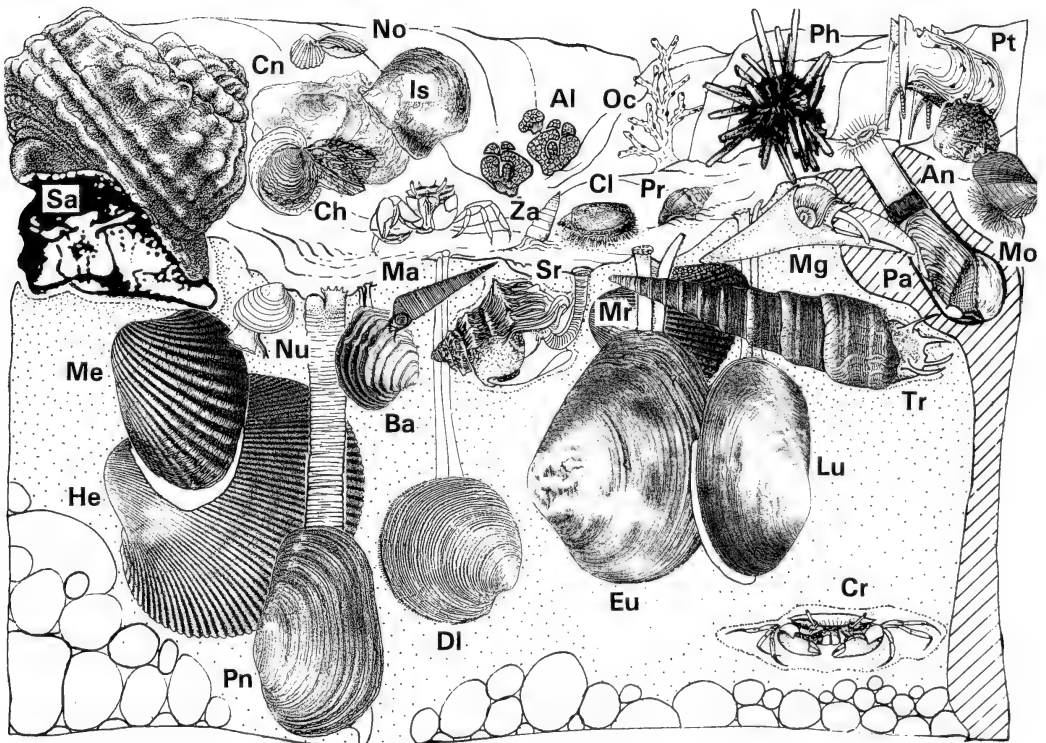


Fig. 4. Schematic drawing of the shallow inner shelf, sandy gravel macrofauna from north Fossil Bay. Al= *Alveopora polyacantha*; An= *Anomia trigonopsis*; Ba= *Bassina speighti*; Ch= *Chama* sp.; Cl= *Chlamys* (*Mimachlamys*) sp.; Cn= *Crenostrea gittosina*; Cr= crab chela; DI= *Dosinia* (*Asa*) cf. *lambata*; Eu= *Eucrassatella ampla*; He= *Hedecardium* (*Titanocardium*) *greyi*; Is= *Isognomon* cf. *zealandica*; Lu= *Lutraria trapezoidalis*; Ma= *Maoricolpus waitemataensis*; Me= *Megacardita squadronensis*; Mg= *Magnatica* (*Spelaenacca*) *waitemataensis*; Mo= *Modiolarca* cf. *impacta*; Mr= *Maoricardium oneroaensis*; No= *Notosaria antipoda*; Nu= *Nucula* cf. *nitidula*; Oc= *Oculina virgosa*; Pa= *Parapholas aucklandica*; Ph= *Phylacanthus titan*; Pn= *Panopea worthingtoni*; Pr= *Paracomina lignaria*; Pt= *Pteria oneroaensis*; Sa= *Sarmaturbo superbus*; Sr= *Struthiolaria lawsi*; Tr= *Tropicolpus* (*Amplicolpus*) *gittosinus*; Za= *Zefallacea benesulcata*. No scale implied. (Ma, Mo, Nu, Ph after Morton & Miller 1968; Ba, Cr, DI, Eu, He, Lu, Me, Mo, Pn, Pr, Sa, Tr, Tu after Beu *et al.* 1990).

Byssally-attached, suspension-feeding bivalves include *Pteria oneroaensis*, *Isoptomon* cf. *zealandicus*, *Chlamys* and *Anomia trigonopsis*. All attach themselves to a hard substratum at low tide or in shallow subtidal depths. *Chlamys* may have nestled in sponges as they often do today. The presence of cidaroid spines attests to the presence of *Phyllacanthus titan* nestling in cracks in the rocky reef. Also present at low tide beneath overhangs or subtidally on rocks or large shells was the brachiopod *Notosaria antipoda*. Probably also living subtidally under darker overhangs were a few chaliciform hermatypic corals. Unidentified barnacles and a chiton are also present. They may have lived attached to the rocky substrate or to the coarse gravel around its base. A small submassive head of the hermatypic coral *Alveopora polyacanthus* has been found *in situ* on the rather unstable gravel substrate around the base of the greywacke reef.

Three epifaunal, ciliary-feeding slipper limpets of the genera *Crepidula* and *Sigapatella*, probably lived on these rocks or the shells of attached oysters or mussels. Several fossil microgastropod algal-grazers, such as *Eatoniella* and *Pareora*, may also have lived on and around the greywacke substrate. The large extinct turbinid, *Sarmaturbo superbus*, was another algal grazer which like the related living South African *Turbo* (*Sarmaticus*) *sarmaticus* probably lived beneath submerged rocks in the lower half of the intertidal zone.

At least two carnivorous gastropods, *Lepsiella intermedia* and *L. maxima*, probably lived on the rocky substrate preying on its bivalve and other fauna. Small unchamfered, circular holes have been found in both juvenile *Crenostrea* and *Anomia* shells, and were probably drilled by carnivorous buccinid or muricid gastropods.

Approximately half the fossil fauna in this deposit lived in or on the pebbly and coarse sandy substrate. The most common of the bivalves are the infaunal suspension-feeders *Eucrassatella ampla*, *Lutraria trapezoidalis*, *Panopea worthingtoni* and *Dosinia* cf. *lambata* and deposit-feeders *Maoricardium oneroaensis* and *Hedecardium greyi*. All probably lived in shallow inner shelf depths (c. 0-20 m). Today *Panopea zelandica* is a deep burrower (0.5-0.8 m) in sand (Morton & Miller 1968) and its fossil precursor has a similar pallial sinus, implying that it occupied the same habitat.

Less common bivalves in this unit include the large *Megacardita squadronensis*, heavy-shelled *Tucetona aucklandica* and infaunal *Bassina speighti* and *Melliteryx mirifica*. This fossil *Bassina* was possibly a shallow-burrower in sand above wave base, like the recent New Zealand species *Bassina yatei*. The *Melliteryx* probably lived in shallow inner shelf sand like the modern deposit-feeding, Australasian species *Melliteryx parva*.

Fine-gravel- and sand-dwelling gastropods include six ciliary deposit-feeders, *Maicolpus waitemataensis*, *Tropicolpus waitemataensis* (one of New Zealand's largest turritellids), *Zefallacia benesulcata*, *Pyrazus consobrinus*, *P. waitemataensis* and *Struthiolaria lawsi*. *Pyrazus* is an epifaunal inhabitant of tropical, intertidal mangrove forest environments (Beu *et al.* 1990).

The microgastropod, *Pissina impressa*, lives today on intertidal and shallow subtidal *Zostera* grass or under stones with *Corallina* turf (Beu *et al.* 1990). The small pyramidellid gastropod, *Linopyrga* cf. *pseudorugata* is probably comparable to the living New Zealand, sometimes ectoparasitic, *Linopyrga rugata* which lives in coarse sand and gravel. Carnivorous gastropods include *Magnatica waitemataensis*, *Polinices oneroaensis*, *Paracomina finlayi* and *P. lignaria*.

The infaunal scaphopod *Fissidentalium* and burrowing spatangoid *Opissaster rotundatus* probably lived in sandy gravel along with free-living and attached forms of

reteporiform and membraniporiform bryozoan. Many solitary fan corals, *Truncatoflabellum sphenodeum*, appear to have lived nesting in the sandy gravel at this locality. They consist of the free-living anthoryathus, with the attached anthocaulus being quite rare in all Waiheke collections.

This macrofauna appears to be an equal mix of taxa that lived in a moderately exposed hard rocky reef environment and those that lived in and a sedimentary substrate. A range of sediment conditions is indicated, from stable pebble gravels, through possible muddy flats to more mobile sand. Some species were intertidal inhabitants, but the majority lived at shallow inner shelf depths (0-20 m).

Foraminiferal microfauna - R11/f17,18,124 (Hayward & Brook 1994)

The three foraminiferal faunas recovered from this unit have few planktics (0-2%) and diverse benthics codominated by *Notorotalia powelli*, *Cibicides mediocris*, *Bolivina finlayi*, *Buliminella elegantissima*, *Virgulopsis pustulata*, *Nonionella novozealandiae*, *Melonis simplex* and *Anomalinoidea fasciatus*. These appear to be mixed faunas derived from a variety of high energy, shallow inner shelf (c. 0-10 m) and lower energy, deeper inner shelf (c. 10-40 m) environments (Hayward 1986a, Hayward & Brook 1994).

Paleoenvironment

The combined fossil evidence suggests that this sandy gravel accumulated around the base of a rocky reef. Initially it may have been shallow subtidal in 0-2 m of water, but its upper parts appear to have accumulated in water depths of perhaps 10-20 m. Faunal elements from various local habitats have been mixed together by post-mortem wave and current transport.

SOUTH FOSSIL BAY REDEPOSITED CEMENTED GRAVEL FAUNA

Macrofauna - R11/f192 (F3)

This 2-m-thick lens of recrystallised shelly, sandy pebble conglomerate within the sandstone sequence contains a diverse fauna of mixed origins. Some of the fossils are derived from low tidal or shallow subtidal rocky reef or coarse gravel habitats (c. 0-10 m depth). These include a number of bysally-attached, suspension-feeding bivalves such as *Perna tetleyi*, *Isognomon* cf. *zelandicus*, *Chlamys*, and *Anomia trigonopsis*. All have comparatively light shells requiring mooring to a rock or large shell. The large oyster *Crenostrea gittosina* lived cemented to the rocky substrate.

Hard substrate-inhabiting gastropods present include chains of *Crepidula* aff. *opuraensis*, which probably settled on shells or rocks, and the large *Sarmaturbo superbus*. Large cidaroid spines are from *Phyllacanthus titan*. Species of this warm water genus live today nestled in cavities and cracks in surge channels in reefs, clinging to stones and coral for camouflage and protection.

Many of the bivalves present in this unit lived infaunally in sand and fine gravel at shallow inner shelf depths (0-20 m). These include the shallow-burrowing suspension-feeders *Pleuromeris*, *Dosinia bensoni*, *Scalpomacra biconvexa*, *Lutraria trapezoidalis*, and *Eucrassatella ampla*, the deep-burrowing suspension-feeder *Panopea worthingtoni*,

and the shallow-burrowing deposit-feeders *Hedecardium greyi* and *Maoricardium oneroaensis*.

Ciliary deposit-feeding gastropods in this unit are *Tropicolpus gittosinus*, *Maoricolpus waitemataensis*, *Zefallacia benesulcata*, *Pyrazus waitemataensis* and *Struthiolaria lawsi*. The turrnellids probably lived in gravel or coarse sand and *Struthiolaria* in medium to fine sand together with the infaunal scaphopod *Fissidentalium* and spatangoid *Opissaster rotundatus*.

Carnivorous gastropods of soft sediment substrates include *Polinices oneroaensis* and *Paracomina lignaria*. Like its descendants, the infaunal, sand-dwelling *Polinices* probably preyed mainly upon burrowing molluscs. The *Lima* found in this deposit was probably a shallow water bivalve similar to its modern New Zealand counterpart (Morton & Miller 1968).

Thus this sandy pebble conglomerate has a mixed fauna derived from hard intertidal and shallow subtidal reefs and boulder substrates, and from more mobile, shallow inner shelf (0-20 m), fine gravel and sand substrates.

Foraminiferal microfauna - R11/f21

A single microfauna was recovered from less cemented parts of this unit. It lacks planktics and is codominated by *Cibicides mediocris*, *Elphidium crispum* and *Cribrorotalia ornatissima* suggestive of a moderately exposed, coarse sediment, inner shelf (0-30 m) environment and may contain elements that have been mixed together after death (Hayward & Brook 1994).

Paleoenvironment

This unit is probably a slump deposit of coarse shelly gravel that has slid several tens of metres out into deeper water (c. 30 m) and onto the fine sandy floor of the bay. The gravel probably originally accumulated at shallow subtidal depths (0-10 m) in an area of intertidal and subtidal rocky reefs, with a sandier substrate nearby.

FOSSIL BAY MUDDY FINE SAND FAUNA (Fig. 5)

Macrofauna - R11/f193, f194 (F4, F5)

The most diverse fauna in these Waiheke Island sequences occurs in the muddy fine sand in the foreshore in the middle of Fossil Bay and in the cliffs behind. Ninety-eight taxa have been recorded from this unit (Appendix 1), including 29 bivalves and 47 gastropods.

Codominant members throughout the unit are the burrowing deposit- and suspension-feeding *Dosinia bensoni*, *Tellina hesterna*, *Struthiolaria lawsi* and *Opissaster rotundatus*, the small gastropods *Brookula*, *Cylichnina enucleata*, *Acteon oneroaensis* and *Linopyrga* cf. *pseudorugata*, and the carnivorous gastropod *Polinices oneroaensis*. The most abundant taxon in the upper parts of the unit is the tiny, epifaunal *Nucula* cf. *nitidula*. All were sand-dwellers and presumably lived together in or on the substrate in which their remains have been fossilised. Many infaunal bivalves, especially in the lower part of the unit, are found with valves conjoined in life position within the sand. Other frequently encountered infaunal taxa include the bivalves *Melliteryx merifica*, *Hedecardium greyi*, *Scalpomactra biconvexa*, *Zenatia acinaces*, *Caryocorbula* aff. *zealandica*, *Notocorbula pumila*,

gastropods *Maoricolpus waitemataensis*, *Tropicolpus gittosinus*, *Amalda platycephala* and scaphopod *Fissidentalium*.

A few rarer fossils come from gravel or hard rocky environments and have presumably been washed in after death. These include the byssally-attached or cemented bivalves *Perna*, *Isognomon*, *Anomia* and *Crenostrea*, intertidal gastropods *Sarmaturbo* and *Lepsiella*, slipper limpets *Crepidula* and *Sigapatella*, serpulid *Spirorbis*, and barnacle *Armatobalanus motuketeketeensis*. Almost all of these occur only in the lower part of the unit and in small numbers.

The presence of these moderately shallow, gravel- and hard-substrate-dwelling molluscs in the lower but not the upper part of the unit suggests that the area may have been deepening during its deposition and the hard substrata became buried. This is further supported by the upwards disappearance of other shallower-water taxa such as *Eucrassatella ampla*, *Dosinia* cf. *lambata*, *Hiatella*, *Eatoniella*, *Zefallacia benesulcata*, *Pareora*, *Maoricolpus*, *Echinophoria* and *Cabestana*, and the appearance in the upper part of the unit of deeper-water forms such as *Nemocardium*, *Solecurtus*, *Waihaoia*, *Antalis*

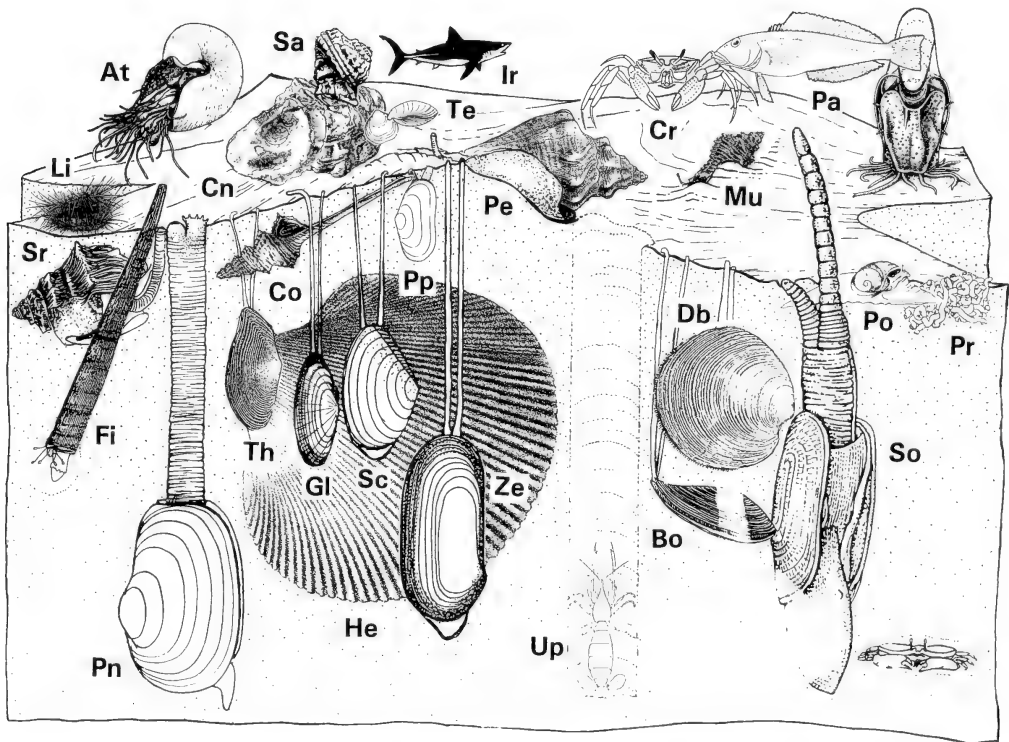


Fig. 5. Schematic drawing of the largely *in situ* Fossil Bay, muddy fine sand macrofauna. It is inferred to have lived at deep inner to mid shelf depths. At= *Aturia cubaensis*; Bo= *Bartrumia oneroaensis*; Cn= *Crenostrea gittosina*; Co= *Coluzea dentata*; Cr= crab chela; Db= *Dosinia (Raina) bensoni*; Fi= *Fissidentalium* sp.; Gl= *Gari* cf. *oamarutica*; He= *Hedecardium (Titanocardium) greyi*; Ir= *Isurus hastalis*; Li= *Lima colorata*; Mu= *Murexsul echinophorus*; Pa= *Parapercis finlayi*; Pe= *Penion exoptatus*; Pn= *Panopea worthingtoni*; Po= *Polinices oneroaensis*; Pp= *Paphies anteaustralis*; Pr= *Protula* sp.; Sa= *Sarmaturbo superbus*; Sc= *Scalpomactra biconvexa*; So= *Solecurtus* cf. *bensoni*; Sr= *Struthiolaria lawsi*; Te= *Terebratulina suessi*; Th= "*Tellina*" *hesterna*; Up= *Upogebia* sp.; Ze= *Zenatia acinaces*. No scale implied. (Gl, Po, Th, Ze after Morton & Miller 1968; Cn, Co, Db, Fi, He, Mu, Pe, Sa after Beu *et al.* 1990).

and the solitary coral *Peponocyathus*. The site probably deepened from inner to mid shelf depths as the unit was being deposited.

Slightly carbonaceous partings within upper parts of the muddy sandstone sometimes contain leaves that washed in from nearby land, became waterlogged and sank to the seafloor to be preserved. Leaves of kauri *Agathis*, southern beech *Nothofagus* and flax *Phormium*, have been identified.

Thirty-seven mostly rare taxa have been found in the muddy fine sandstone at Fossil Bay and not at the other two localities. These include the sand-dwelling bivalves *Paphies anteaustralis* (pipi), *Nemocardium*, *Gari* cf. *oamaruica* and *Myadora*, carnivorous gastropods *Frignatica vaughani*, *Cabestana tetleyi*, *Sassia bartrumi*, *Joculator*, *Monophorus*, *Nassarius*, *Chicoreus*, *Murexsul*, *Amalda platycephala*, *Alcithoe turrita* and *Austrotoma finlayi*, small gastropods *Brookula*, *Lodderia*, *Pissina impressa*, *Caecum* and *Cylichna*, cephalopod *Aturia cubaensis*, scaphopod *Antalis*, serpulids *Protula* and *Spirorbis*, decapod *Upogebia*, coral *Peponocyathus minimus*, brachiopod *Terebratulina suessi*, shark *Isurus hastalis* and fish *Parapercis finlayi* and *Coelorhynchus*.

Foraminiferal microfauna - R11/f7,10,11,12,13,14,15, 21,125,126,127,128,130
(Hayward & Brook 1994)

The percentage of planktic foraminifera increases progressively upsection - the nine lowest microfaunas have 0-10% and the four highest have 11-40%. The three lowest samples on the south side of the bay (R11/f10,11,130) are dominated by the benthics *Nonionella novozealandiae*, *Bolivina finlayi*, *Notorotalia powelli*, *Buliminella elegantissima* and *Virgulopsis pustulata*, a combination suggestive of moderately sheltered, fine sediment, deep inner shelf (20-50 m) environments (Hayward & Brook 1994). The nine highest samples are all dominated by *Quinqueloculina seminula* and *Nonionella novozealandica* with subsidiary *Bolivina finlayi*, *Notorotalia powelli* and *Virgulopsis pustulata* suggestive of a sheltered, fine sediment environment at slightly deeper inner to shallow mid shelf depths (c. 30-70 m).

Paleoenvironment

The fossil fauna indicates that this muddy fine sand accumulated on the sea floor in a bay at depths deepening from inner shelf at the base to shallow mid shelf at the top. Intertidal and shallow subtidal rocky reefs and gravel were nearby early on, but may have been buried later by accumulating sand.

DOUBLE-U BAY MUDDY FINE SAND FAUNA (Fig. 6)

Macrofauna - R10/f15, f81-84, f120 (W1, W2)

A rich and diverse fauna of 29 bivalves, 43 gastropods and 19 other taxa is recorded from the muddy fine sandstone at Double-U Bay. It is similar in diversity to the muddy fine sandstone faunas at Fossil Bay and Oneroa Beach. Despite this, Double-U Bay has only 60% of its fauna in common with either Fossil Bay or Oneroa. They have more similar bivalve faunas (65-75% in common) than gastropod faunas (50-55%).

The most common members of this fauna are the deposit-feeding gastropods *Tropicolpus gittosinus*, *Struthiolaria lawsi*, *Zefallacia benesulcata*, *Pyrazus consobrinus*, *P. waitemataensis*, *Cylichnina enucleata*, burrowing, suspension-feeding bivalves

Bartrumia oneroaensis, “*Tellina*” *hesterna*, *Zenatia acinaces*, and *Dosinia bensoni* and small, epifaunal, deposit-feeding *Nucula* cf. *nitidula* and *N. cf. otamatea*. The only common carnivore is the sediment-inhabiting naticid *Polinices oneroaensis*.

Other infaunal molluscs that lived in this sandy substrate include the suspension-feeding bivalves *Tawera* cf. *bartrumi*, *Limopsis zelandica*, “*Tellina*” *robini*, *Gari* cf. *lineolata*, *Eumarcia curta*, *Panopea worthingtoni* and deposit-feeding bivalves *Diplodonta*, *Melliteryx mirifica*, *Eucrassatella ampla*, *Maoricardium oneroaense*, *Hedecardium greyi* and microgastropods *Powellisetia*, *Nozeba candida*, *Pareora* and *Acteon oneroaensis*. Also present is the infaunal spatangoid *Opissaster rotundatus*. Carnivorous gastropods that lived on or in this sandy substrate included *Austrofusus oneroaensis*, *Paracomina lignaria*, *Penion exoptatus*, *Morum harpaformis*, *Amalda platycephala*, *Austrotoma excavata*, *Tomopleura transenna* and *Sassia arthritica*.

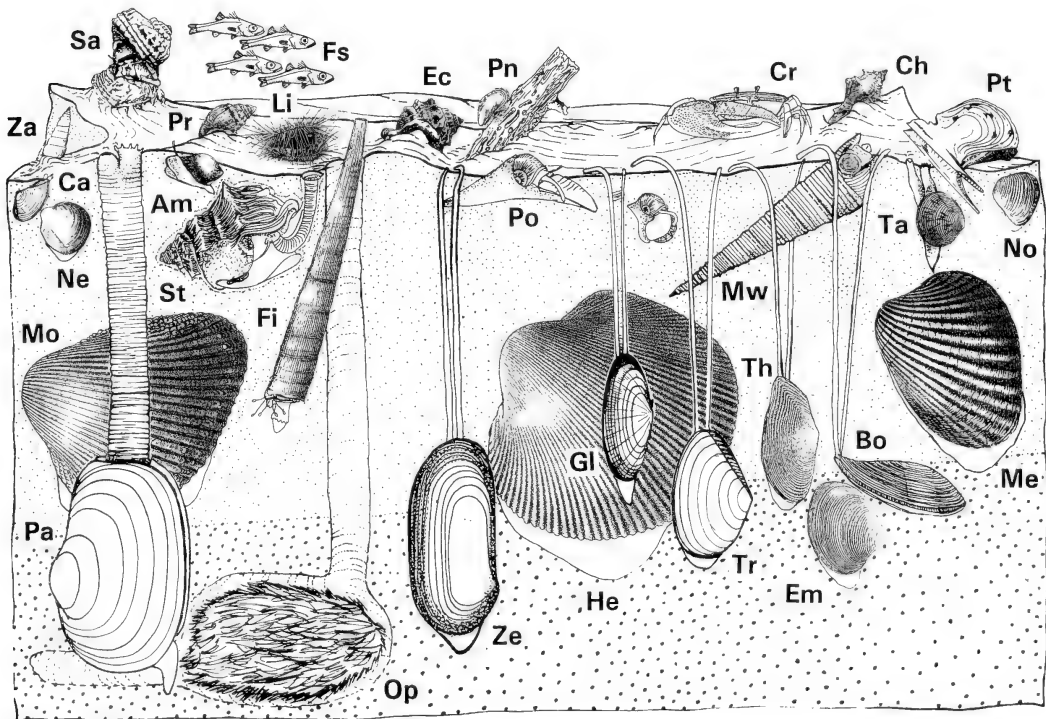


Fig. 6. Schematic drawing of the largely *in situ* Double-U Bay, muddy fine sand macrofauna, from inferred deep inner to mid shelf depths. Am= *Amalda (Baryspira) platycephala*; Bo= *Bartrumia oneroaensis*; Ca= *Caryocorbula* aff. *zelandica*; Ch= *Chicoreus (Siratus) komiticus*; Cr= crab chela; Ec= *Echinophoria oneroaensis*; Em= *Eumarcia (Atamarcia) curta*; Fi= *Fissidentalium* sp.; Fs= fish scales sp. indet.; Gl= *Gari* cf. *lineolata*; He= *Hedecardium (Titanocardium) greyi*; Li= *Lima colorata*; Me= *Megacardita squadronensis*; Mo= *Maoricardium oneroaense*; Mw= *Maoricolpus waitemataensis*; Ne= *Nemocardium (Varicardium) patulum*; No= *Notocorbula pumila*; Op= *Opissaster rotundatus*; Pa= *Panopea worthingtoni*; Pn= *Perna tetleyi*; Po= *Polinices oneroaensis*; Pr= *Paracomina lignaria*; Pt= *Pteria oneroaensis*; Sa= *Sarmaturbo superbus*; St= *Struthiolaria lawsi*; Ta= *Tawera* cf. *bartrumi*; Th= “*Tellina*” *hesterna*; Tr= “*Tellina*” *robini*; Za= *Zefallacea benesulcata*; Ze= *Zenatia acinaces*. No scale implied. (Ca, Gl, Po, Ta, Tr, Ze after Morton & Miller 1968; Ch, Db, Ec, Eu, Em, Fi, He, Me, Mo, Mw, Ne, No, Pr, Th after Beu *et al.* 1990).

The lower part of the sandstone unit, which overlies conglomerate and laps onto greywacke reefs nearby, also contains a considerable diversity of taxa that inhabited hard substrates and their shells were presumably carried out onto the sandy seafloor after their death. These include a number of bivalves that would have been byssally-attached or cemented to rocks or large shells, such as *Limatula* cf. *craigensis*, *Crenostrea gittosina*, *Pteria oneroaensis*, *Isognomon*, *Perna tetleyi* and *Modiolarca* cf. *impacta*.

Also present in the lower unit are the shells of a number of herbivorous gastropods that grazed algae from hard rock or gravel surfaces, such as the extinct paua *Haliotis* cf. *waitemataensis*, *Tugali navicula*, limpet *Cellana thompsoni*, chiton *Ischnochiton vetustus*, littorinid *Bembicium priscum* and turbinids *Sarmaturbo superbus* and *Modelia* aff. *granosa*. Spines of the large, rock-inhabiting cidaroid *Phyllacanthus titan* are present along with rare specimens of the small brachiopod *Notosaria antipoda* and the chelae of several unidentified crabs. Five species of rock or gravel-inhabiting, ciliary-feeding, slipper limpets of the genera *Crepidula* and *Sigapatella* are also present along with the barnacle *Armatobalanus motuketeketeensis*.

Shells of carnivorous gastropods from nearby rock or gravel habitats found mostly in lower parts of the sandstone include *Lepsiella intermedia*, *L. maxima* and *Echinophoria oneroaensis*.

Thus the macrofauna of the lower part of this unit is a mix of inner shelf, sand-inhabiting taxa that are preserved more or less *in situ* and a diverse fauna derived from adjacent intertidal and shallow subtidal rocky reefs and gravel.

Lower parts of the sandstone contain scattered carbonised remains of small pieces of sunken driftwood riddled with the tubes and occasional small bivalve shells of the wood borer *Bankia turneri*. Also present are sparse mostly unidentifiable leaf fossils, including kauri *Agathis* and the cone of a conifer.

Thirty-one taxa, mostly gastropods, have been found at Double-U Bay but are unknown in the other two localities. These include the bivalve genera *Limopsis*, *Limatula*, *Pteromyrtea*, *Eumarcia* and *Tawera*, the gastropod genera *Tugali*, *Cellana*, *Haliotis*, *Modelia*, *Bembicium*, *Powellisetia*, *Nozeba*, *Buccinulum*, *Pterotyphis*, *Morum*, *Rugobela* and *Anapepta*, and the chiton *Ischnochiton*. Also present only in the lower parts of this sandstone at Double-U Bay are the traces of two borings in thick-shelled bivalves: *Zapfella* the trace of an acrothoracican barnacle and *Entobia cretacea*, the galleries of boring sponges.

Foraminiferal microfauna - R10/f10, 11, 12, 79, 81, 82, 83, 84 (Hayward & Brook 1994)

These eight microfaunas exhibit increasing planktic foraminiferal percentages up-sequence, from 5% near the base to 75% at the top. The benthics are dominated by *Nonionella novozealandica* with subsidiary *Bolivina finlayi*, *Cassidulina laevigata*, *Anomalinoidea* sp., *Quinqueloculina seminula*, *Notorotalia powelli*, *Virgulopsis pustulata* and *Epistominella iota*. This association is typical of quiet conditions at deep inner to mid shelf depths and the individual faunas support a deepening trend from c. 20-50 m to c. 50-100 m (Hayward & Brook 1994).

Planktic foraminiferal percentages of over 50% at depths shallower than 100 m are unusual (Hayward 1986a) and indicate special conditions. Most of the fossil planktics have small tests and are of low diversity more typical of neritic (coastal) water populations. This suggests that consistently strong on-shore winds and currents bringing oceanic water, rich in planktics, into the coastal environment (e.g. Hayward 1986b) is an unlikely explanation. A more probable explanation is supplied by the results of two studies around

present day New Zealand that have shown unusually high percentages (20-70%) of small, neritic planktic foraminifera in the sediments of moderately deep water (20-40 m) basins in the large enclosed harbours of Port Pegasus and Port Fitzroy (Hayward *et al.* 1994, Hayward & Grenfell 1994). It appears that the planktic tests are carried into the embayment by strong tidal currents and have time to sink through the water column and settle out in the quiet waters of the deep basin without being washed out to sea again.

Paleoenvironment

The macrofauna indicates that the lower part of this unit was a sand-floored bay at shallow inner shelf depths (c. 5-20 m), with nearby intertidal and subtidal rocky reefs and gravel. Both macro- and microfaunas support a deepening trend upwards through the section with the gravels and rocky areas probably being buried by sediment. The microfauna indicates that the area subsided to depths of about 50-100 m by the time sand in the top of the section was accumulating and that the area may have been within an enclosed deep-water harbour for much of this time.

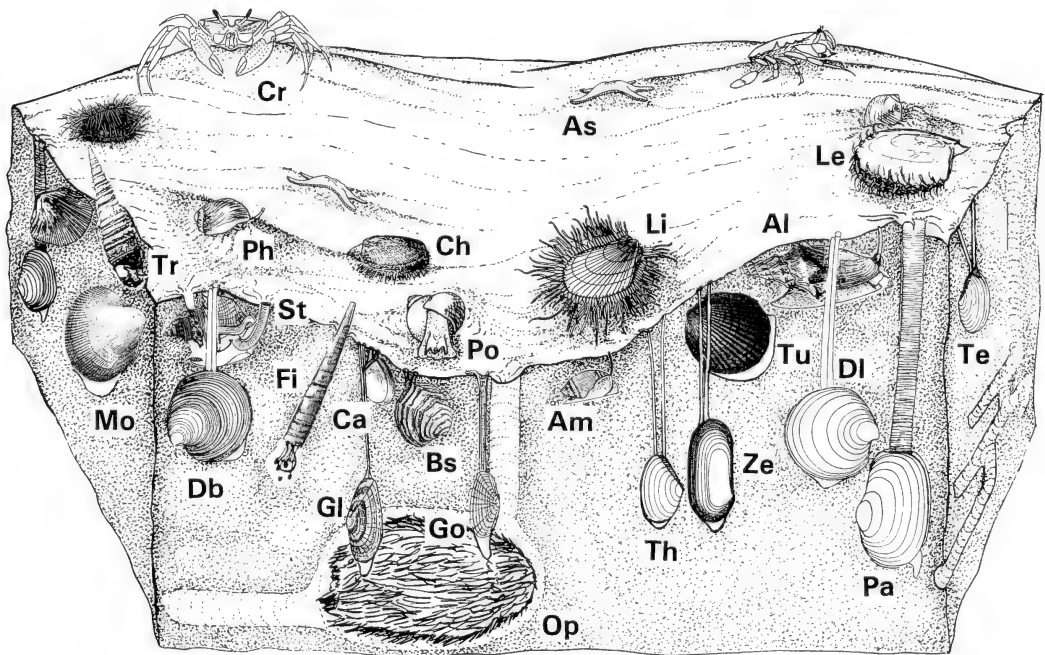


Fig. 7. Schematic drawing of the largely *in situ* Oneroa Beach, fine sand macrofauna, inferred to have lived at mid to shallow outer shelf depths. Al= *Alcihoë turrita*; Am= *Amalda (Baryspira) platycephala*; As= *Asterioidea* ossicles; Bs= *Bassina speighti*; Ca= *Caryocorbula* aff. *zealandica*; Ch= *Chlamys (Mimachlamys)* sp.; Cr= crab chela; Db= *Dosinia (Raina) bensoni*; Dl= *Dosinia (Asa)* cf. *lambata*; Fi= *Fissidentalium* sp.; Gl= *Gari* cf. *lineolata*; Go= *Gari* cf. *oamarutica*; Le= *Lentipecten hochstetteri*; Li= *Lima* sp.; Mo= *Maoricardium oneroaensis*; Op= *Opissaster rotundatus*; Pa= *Panopea worthingtoni*; Ph= *Polinices huttoni*; Po= *Polinices oneroaensis*; St= *Struthiolaria lawsi*; Te= "*Tellina*" *robini*; Th= "*Tellina*" *hesterna*; Tr= *Tropicolpus (Amplicolpus) gittosinus*; Tu= *Tucetona aucklandica*; Ze= *Zenatia acinaces*. No scale implied. (Gl, Go, St, Th, Ze after Morton & Miller 1968; Bs, Ca, Db, Dl, Fi, He, Mo, Tr, Tu after Beu *et al.* 1990).

ONEROA BEACH FINE SAND FAUNA (Fig. 7)

Macrofauna - R11/f189 (O1)

A rich and diverse fauna consisting of 29 bivalves, 37 gastropods and five other taxa is recorded from the fine sandstone at Oneroa Beach. The most common members of the fauna are the infaunal, sediment-inhabiting turret shell *Tropicolpus gittosinus*, scaphopod *Fissidentalium* and small bivalve *Caryocorbula* aff. *zealandica*, together with the sand-dwelling, carnivorous gastropod *Paracomina lignaria*. Also present in significant numbers are numerous soft sediment-dwelling species, particularly infaunal deposit- and suspension-feeding bivalves, such as the small *Nucula*, thin-shelled *Gari*, large *Megacardita squadronensis*, shallow-burrowing *Dosinia bensoni*, *Dosinia* cf. *lambata* and burrowing gastropod *Struthiolaria lawsi*. Sand-dwelling carnivorous gastropods are also well represented and include *Polinices oneroaensis*, *Penion exoptatus*, *Pagodula waitemataensis*, *Alcithoe*, *Conolithes wollastoni* and *Tomopleura transenna*. Several ossicles attest to the presence of carnivorous starfish.

A small number of rare species required a hard substrate, such as a rock or shell for attachment and have probably been washed into the site following death. These include the byssally-attached bivalves *Pteria oneroaensis*, *Isognomon*, *Anomia* and *Chlamys*, and four species of the slipper limpets *Crepidula* and *Sigapatella*.

Twenty-one taxa have been found at Oneroa Beach but are unknown in the other two, better-studied localities. These include the sand-dwelling bivalves *Lentipecten hochstetteri* and *Leptomya waitemataensis*, sand-dwelling carnivorous gastropods *Polinices huttoni* and *Conolithes wollastoni*, the small gastropods *Argalista impervia*, *Eulima*, *Notacirsa*, *Neoguraleus* cf. *leptosoma*, *Oamaruia*, *Latirus*, *Volvulella* and *Subonoba*, and the shell- or rock-rubble-dwelling gastropods *Trivia* and *Willungia maoria*.

Thus most of the Oneroa Beach fauna probably lived in the fine sand substrate in which it has been fossilised. About 10% of the total fauna appears to be derived from a shelly rubbly substrate and was probably washed into this finer sediment after death. An estimate of water depth is difficult. Some of the rarer fossils (*Sarmaturbo*, *Anomia*) are typical of moderately high energy, intertidal or shallow subtidal depths, but the majority are more characteristic of quieter deeper water, ranging from deep inner to outer shelf (c. 20-150 m).

Foraminiferal microfauna - R11/f26, 27 (Hayward & Brook 1994)

These two microfaunas possess common planktics (65-70%). Both are dominated by *Bolivina finlayi* with subsidiary *Cassidulina laevigata*, *Bolivina* spp., *Cibicides vortex*, *Anomalinoidea* spp. and *Trifarina parva*. These appear to be the deepest water microfaunas present at Waiheke and are typical of quiet water at mid or shallow outer shelf depths (c. 50-150 m). Once again the high percentage of small planktic tests is thought to indicate an enclosed deep-water harbour situation rather than oceanic waters overhead.

Paleoenvironment

Most of the macro- and microfauna probably lived together in fine sand on the sheltered floor of a c. 50-150 m deep enclosed harbour.

RARE OR UNCOMMON TAXA

The Waiheke Island fossil fauna contains many unusual shallow-water taxa derived from several soft shore facies and a seldom preserved early Miocene rocky shore community. Similar faunal elements to those identified from Oligocene strata at Mt Luxmore, Castle Hill Basin, Mason River, and early Miocene basal Waitemata facies on Kawau Island (Eagle & Hayward 1994), are found here.

Fifteen mollusc species are known only from these Waiheke Island strata: *Maoricardium oneroaense*, *Scalpomactra biconvexa*, *Leptomya waitemataensis*, *Tawera* cf. *bartrumi*, *Bembicium priscum*, *Sigapatella patulosa*, *S. subvaricosa*, *Echinophoria oneroaensis*, *Sassia arthritica*, *S. (Haurokoa) bartrumi*, *Austrofusus (Neocola) oneroaensis*, *Buccinulum compactum tetleyi*, *Penion exoptatus*, *Rugobela sepelibilis* and *Ischnochiton vetustus*.

Chaliciform hermatypic corals and *in situ* heads of reef coral (*Alveopora polyacantha*) have been recorded only from two or three localities, all in the early Miocene Kawau Subgroup of northeastern New Zealand (e.g. Squires 1962, Hayward & Brook 1981, Hayward *et al.* 1990, Eagle *et al.* 1994). Another unusual warm-water record for the early Miocene of New Zealand is *Pteria oneroaensis*.

Molluscs uncommon elsewhere in New Zealand because of the paucity of rocky shore associations in the fossil record, but found in the Miocene sediments of Waiheke Island include: *Dosinia (Raina) bensoni*, *Cleidothaerus albidus*, *Coluzea dentata*, *Pterotyphis (Prototyphis)* cf. *awamoanus*, *Haliotis (Notohaliotis) waitemataensis* and *Sarmaturbo superbus*. An unusual acrothoracican barnacle (*Zapfella*) boring in bivalves at the Double-U Bay locality. Crabs (identified by numerous chelae) are common to most fossil localities on Waiheke Island. Their record is complimented by the presence of two other extant, shallow-burrowing genera of decapod crustacea, *Callianassa* and *Upogebia*.

The record of *Conilithes wollastoni* extends its time range back from the Altonian into the Otaian stage. Unusual for Kawau Subgroup strata are the moderately well preserved leaf fossils in the fine sandstone of Fossil Bay and identified as: an *Agathis* male cone, *Phormium* leaves, large leaves of *Nothofagus*, an unidentified conifer cone and further indeterminate leaves.

AGE

MACROFAUNAL EVIDENCE

The bivalve genera *Bartrumia* and *Perna* make their first known appearance in the Otaian stage of the early Miocene, as do the species *Lima colorata*, *Alcithoe turrita*, *Coluzea dentata*, *Crepidula monoxyla*, and the cephalopod *Aturia cubaensis*. This is the type locality of *Bartrumia oneroaensis*, a tellinid species known only from Otaian strata here on Waiheke Island (Powell & Bartrum 1929), Hays and Tipakuri Streams (Eagle & Hayward 1992), Kawau Island (Eagle *et al.* 1994), and the Mount Harris Formation (Beu *et al.* 1990). The bivalves *Megacardita squadronensis* and *Lectipecten hochstetteri (sensu stricto)*, have their last known appearance in the Otaian. The presence of the gastropod species *Tropicolpus (Amplicolpus) gittosinus*, *T. tetleyi*, *Sarmaturbo superbus* and *Struthiolaria lawsi*, which are known only from the Otaian, confirms this early Miocene age.

MICROFAUNAL EVIDENCE

The shallow water foraminiferal faunas from Waiheke contain no taxa that are stage specific in determining the age of the sequence. Occasional rare foraminifera in similar basal Waitemata (Kawau Subgroup) strata along the east coast of Auckland provide a fairly accurate assessment of the age of the Waiheke sequences. The presence in these sections of *Ehrenbergina marwicki* (Otaian-Altonian), *Catapsydrax dissimilis* (Duntroonian-Otaian) and *Haeuslerella hectori* (Whaingaroan-Otaian) indicates an Otaian (early Miocene) age, which is the accepted age for all of the Kawau and overlying Warkworth Subgroups in the Waitemata Group (Hayward & Brook 1984, Hayward 1993).

The combined macrofaunal and microfaunal evidence gives an early Miocene, Otaian age (c. 22-19 million years old).

PALEOENVIRONMENTS AND PALEOGEOGRAPHY

The three fossiliferous Waiheke sequences studied here appear to have accumulated in separate enclosed bays around the coast of the subsiding greywacke land or island. Current biostratigraphic resolution does not allow us to determine whether all three bays existed at the same time or whether they were of slightly different age formed successively as the land subsided.

Each of the three early Miocene bays has a marine sequence of basal conglomerate overlain by fossiliferous fine sandstone. Within these sequences faunas from a variety of intertidal to mid shelf environments are preserved, often with fossils derived from several habitats mixed together. Three conglomerate units at Fossil Bay are interpreted as a steep, low tidal to shallow subtidal beach (0-2 m), a subtidal (0-20 m) sandy gravel fringing a rocky reef and a similar shelly gravel that has slumped into deeper water (c. 30 m). All contain fossils derived from intertidal reefs, subtidal reefs and coarse gravels and subtidal sands.

The fine sandstone units in all three bays are dominated by inner to mid shelf sand-dwelling organisms. Lower parts of these units at Fossil and Double-U Bays also contain a significant component of intertidal and shallow subtidal rocky and gravel shore inhabitants that have washed in after their death. These rocky substrate elements become much rarer higher in the sequences indicating that the nearby rocky areas had probably been buried by the accumulating sand.

Many of the more abundant macrofossils in the sandstone units are common to each sequence but there are also numerous rarer taxa that have so far been found only in one of the three. Even so, the macrofaunas only provide a general indication of the paleowater depth (mostly inner to mid shelf) and from this we are unable to determine any relative depth differences between the sequences.

On the other hand, the foraminiferal microfaunas indicate progressive deepening (from shallow inner to mid shelf depths) as both the Fossil and Double-U Bay sequences were deposited. They also indicate that the top of the Double-U Bay sequence was deeper than the top of the Fossil Bay sequence and that the Oneroa Beach sandstone was as deep as or deeper (mid to shallow outer shelf) than the top of the Double-U Bay sequence.

Other early Miocene Kawau Subgroup sequences nearby on Motuihe and Motutapu Island, indicate that the Waiheke sequences document just a short interval within a long period of major subsidence, in the order of 1-2 km, that formed the Waitemata Basin (Ricketts *et al.* 1989, Hayward 1993). The Waiheke sequences record some of the earliest subsidence, when nearby land areas or islands had not yet subsided beneath the waves

and their erosion provided the gravel, sand and mud that accumulated in these ancient bays preserving the fossil assemblages within them. Once all local land areas had been submerged, this area became starved of sediment and there followed a long period with little or no sediment accumulation, until the area had subsided to mid bathyal depths and sand-bearing turbidites from the northwest could flow across the basin floor to reach it (Ricketts *et al.* 1989, Hayward 1993).

Acknowledgements. We are grateful to Margaret Morley, Glenys Stace and participants on Auckland Museum Geology Club and Auckland University Geology Stage 3 trips for their assistance in the field. We also appreciate the helpful comments of Hugh Grenfell and Fred Brook, who kindly read the draft manuscript.

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APPENDIX 1. Systematic list of macrofauna from Waiheke Island, Auckland. Taxonomy follows Beu *et al.* (1990) for Mollusca. Where no voucher specimen number is given, specimens are held in the Geology Department, University of Auckland. Specimen numbers: A = abundant (>10); C = common (6-10); U = uncommon (2-5); R = rare (1).

FOSSIL LOCALITIES:

Fossil Bay -

F1 South end, basal conglomerate R11/f190

F2 North end, sandy conglomerate and grit R11/f7741,f115,f122,f123,f124,f191

F3 South end, cemented conglomerate R11/f7656,f131,f149,f192

F4 lower muddy fine sandstone R11/f7740,f100,f125,f126,f129,f130,f132,f193

F5 upper muddy fine sandstone R11/f7742,f127,f128,f133,f134,f135,f194

Double-U Bay -

W1 lower muddy fine sandstone R10/f79,f80,f121,f155

W2 upper muddy fine sandstone R10/f81,f82,f83,f84,f120,f154

Oneroa Beach -

O1 fine sandstone R11/189

	F1	F2	F3	F4	F5	W1	W2	O1	Voucher
MOLLUSCA									
BIVALVIA									
NUCULIDAE									
<i>Nucula cf. nitidula</i> A.Adams, 1856	-	U	-	R	A	U	C	U	AK98511
<i>Nucula cf. otamatea</i> Laws, 1939	-	-	-	-	-	U	-	-	AK98526
ARCIDAE									
<i>Arca waitemataensis</i> (Powell & Bartrum, 1929)	-	-	-	-	-	-	U	R	
GLYCYMERIDIDAE									
<i>Tucetona aucklandica</i> (Powell, 1938)	R	R	-	-	-	-	-	R	AK70346
LIMOPSIDAE									
<i>Limopsis zelandica</i> (Hutton, 1873)	-	-	-	-	-	R	-		AK98438
MYTILIDAE									
<i>Modiolarca cf. impacta</i> (Hermann, 1782)	-	R	-	-	-	U	-	R	
<i>Perna tetleyi</i> (Powell & Bartrum, 1929)	-	-	R	R	-	R	-		AK72103
PTERIIDAE									
<i>Pteria oneroaensis</i> (Powell & Bartrum, 1929)	-	U	-	-	-	R	-	U	AK70645
ISOGNOMIDAE									
<i>Isognomon cf. zealandicus</i> (Hutton in Suter, 1917)	-	R	-	R	-	-	-	R	
<i>Isognomon</i> sp.	-	-	U	-	-	R	R	-	
PECTINIDAE									
<i>Chlamys (Mimachlamys)</i> sp.	-	R	R	-	-	-	-	R	AK98503
<i>Lentipecten hochstetteri</i> (Zittel, 1864)	-	-	-	-	-	-	-	R	AK98453
ANOMIIDAE									
<i>Anomia trigonopsis</i> Hutton, 1877	R	U	U	R	-	-	-	R	AK98506
LIMIDAE									
<i>Lima colorata</i> Hutton, 1873	-	-	-	-	R	R	R	-	AK98520
<i>Limatula (Limatula) cf. craigensis</i> Fleming, 1955	-	-	-	-	-	R	-	-	AK98439
<i>Lima</i> sp.	-	-	R	-	-	-	-	R	

	F1	F2	F3	F4	F5	W1	W2	O1	Voucher
GRYPHAEIDAE									
<i>Crenostrea gittosina</i> (Powell & Bartrum, 1929)	U	C	U	R	-	R	R	-	AK72109
LUCINIDAE									
<i>Pteromyrtea</i> sp.	-	-	-	-	-	U	-	-	
UNGULINIDAE									
<i>Diplodonta</i> sp.	-	-	-	R	R	R	-	-	
CHAMIDAE									
<i>Chama</i> sp.	-	R	-	-	-	-	U	R	
ERYCINIDAE									
<i>Melliteryx mirifica</i> Powell & Bartrum, 1929	-	R	-	R	U	R	-	-	AK72091
CARDITIDAE									
<i>Megacardita squadronensis</i> (Powell, 1938)	-	R	-	-	-	R	-	U	AK72162
<i>Pleuromeris</i> sp.	-	-	R	R	-	-	-	-	
CRASSATELLIDAE									
<i>Eucrassatella ampla</i> (Zittel, 1864)	C	C	U	U	-	U	-	-	
CARDIIDAE									
<i>Maoricardium oneroaense</i> (Powell, 1938)	U	U	U	-	-	R	R	R	
<i>Hedecardium</i> (<i>Titanocardium</i>) <i>greyi</i> (Hutton, 1873)	R	U	U	R	U	R	R	R	AK98488
<i>Nemocardium</i> (<i>Varicardium</i>) <i>patulum</i> (Hutton, 1873)	-	-	-	-	-	R	-	-	AK98422
MACTRIDAE									
<i>Lutraria trapezoidalis</i> Powell & Bartrum, 1929	R	U	R	-	U	-	R	-	AK98492
<i>Scalpomactra biconvexa</i> Powell & Bartrum, 1929	-	-	R	R	R	-	-	R	AK72132
<i>Zenatia acinaces</i> (Quoy & Gaimard, 1835)	-	-	-	R	U	C	U	R	
MESODESMATIDAE									
<i>Paphies anteaustralis</i> (Dell, 1950)	-	-	-	-	R	-	-	-	AK98430
TELLINIDAE									
<i>Bartrumia oneroaensis</i> (Powell & Bartrum, 1929)	-	-	-	-	U	C	C	R	AK72085
" <i>Tellina</i> " <i>hesterna</i> (Powell & Bartrum, 1929)	-	-	-	C	C	C	C	R	AK71693
" <i>Tellina</i> " <i>robini</i> (Finlay, 1924)	-	-	-	R	R	R	R	R	
PSAMMOBIIDAE									
<i>Gari</i> cf. <i>lineolata</i> (Gray, 1835)	-	-	-	-	-	R	R	U	
<i>Gari</i> cf. <i>oamarutica</i> Finlay, 1930	-	-	-	-	-	-	R	R	AK98433
<i>Gari</i> n.sp.	-	-	-	-	R	-	-	-	AK98429
SEMELIDAE									
<i>Leptomya waitemataensis</i> Powell & Bartrum, 1929	-	-	-	-	-	-	-	R	AK72079
SOLECURTIDAE									
<i>Solecurtus</i> cf. <i>bensoni</i> Finlay, 1924	-	-	-	-	R	-	R	-	AK98428
VENERIDAE									
<i>Bassina speighti</i> (Suter, 1913)	-	R	-	-	-	-	-	R	AK98441
<i>Dosina</i> sp.	-	-	-	-	-	-	-	R	
<i>Dosinia</i> (<i>Raina</i>) <i>bensoni</i> Marwick, 1927	-	-	R	C	C	C	U	U	AK98413
<i>Dosinia</i> (<i>Asa</i>) cf. <i>lambata</i> (Gould, 1850)	-	U	-	U	-	-	U	U	
<i>Eumarcia</i> (<i>Atamarcia</i>) <i>curta</i> (Hutton, 1873)	-	-	-	-	-	U	-	-	
cf. <i>Irus</i> (<i>Notirus</i>) sp.	-	R	R	-	-	-	-	-	
<i>Tawera</i> cf. <i>bartrumi</i> Marwick, 1927	-	-	-	-	-	U	-	-	AK98510

	F1	F2	F3	F4	F5	W1	W2	O1	Voucher
CORBULIDAE									
<i>Caryocorbula</i> aff. <i>zealandica</i> (Quoy & Gaimard, 1835)	-	-	-	-	U	U	R	C	AK98517
<i>Notocorbula pumila</i> (Hutton, 1885)	-	-	-	-	-	U	R	R	AK98527
HIATELLIDAE									
<i>Hiatella</i> sp.	-	-	-	R	-	-	-	-	
<i>Panopea worthingtoni</i> Hutton, 1873	-	C	R	R	R	U	R	R	AK98420
PHOLADIDAE									
<i>Parapholas aucklandica</i> Powell, 1938	-	C	-	-	-	-	-	-	AK70586
TEREDINIDAE									
<i>Bankia turneri</i> Powell & Bartrum, 1929	-	-	-	U	-	U	-	-	AK72016
MYOCHAMIDAE									
<i>Myadora</i> sp.	-	-	-	-	R	-	-	-	
CLEIDOTHAERIDAE									
<i>Cleidotheraerus albidus</i> (Lamarck, 1819)	-	R	-	-	-	-	-	-	AK98416
GASTROPODA									
HALIOTIDAE									
<i>Haliotis (Notohaliotis)</i> cf. <i>waitemataensis</i> Powell, 1938	-	-	-	-	-	R	-	-	
FISSURELLIDAE									
<i>Tugali navicula</i> Finlay, 1927	-	-	-	-	-	R	-	-	
NACELLIDAE									
<i>Cellana thomsoni</i> Powell & Bartrum, 1929	-	-	-	-	-	R	-	-	
SKENEIDAE									
<i>Brookula</i> sp.	-	-	-	C	C	-	-	-	
<i>Lodderia</i> sp.	-	-	-	-	R	-	-	-	
TURBINIDAE									
<i>Modelia</i> aff. <i>granosa</i> (Martyn, 1784)	-	-	-	-	-	U	-	-	
<i>Sarmaturbo superbus</i> (Zittel, 1864)	U	C	R	R	-	R	-	R	AK98415
<i>Argalista impervia</i> Finlay, 1930	-	-	-	-	-	-	-	R	AK98457
LITTORINIDAE									
<i>Bembicium priscum</i> Powell & Bartrum, 1929	-	-	-	-	-	U	-	-	
RISSOIDAE									
aff. <i>Ihungia</i> sp.	-	-	-	-	R	-	-	-	
<i>Pissina impressa</i> (Hutton, 1885)	-	-	-	R	-	-	-	-	
<i>Pissina</i> sp.	-	U	-	U	-	-	-	-	
<i>Powellisetia</i> sp.	-	-	-	-	-	R	-	-	
IRAVADIIDAE									
<i>Nozeba candida</i> Finlay, 1924	-	-	-	-	-	R	-	-	
EATONIELLIDAE									
<i>Eatoniella</i> sp.	-	R	-	R	-	-	-	-	
CAECIDAE									
<i>Caecum</i> cf. <i>digitulum</i> Hedley, 1904	-	-	-	R	-	-	-	-	
CERITHIIDAE									
<i>Zefallacia benesulcata</i> Powell & Bartrum, 1929	U	U	R	R	-	U	-	R	AK72173
PAREORIDAE									
<i>Pareora</i> sp.	-	C	-	R	-	U	-	-	

	F1	F2	F3	F4	F5	W1	W2	O1	Voucher
POTAMIDIDAE									
<i>Pyrazus consobrinus</i> Powell & Bartrum, 1929	-	R	-	-	-	C	R	-	AK72124
<i>Pyrazus waitemataensis</i> Powell & Bartrum, 1929	-	U	R	-	-	U	-	R	AK72125
TURRITELLIDAE									
<i>Maoricolpus waitemataensis</i> (Powell & Bartrum, 1929)	U	U	U	U	-	U	U	-	AK72160
<i>Maoricolpus</i> sp.	-	-	-	-	-	-	R	-	AK98521
<i>Tropicolpus tetleyi</i> (Powell & Bartrum, 1929)	-	-	-	-	-	-	U	-	AK9849
<i>Tropicolpus (Amplicolpus) gittosinus</i> (Powell & Bartrum, 1929)	-	R	R	R	U	U	C	C	AK72159
STRUTHIOLARIDAE									
<i>Struthiolaria lawsi</i> Powell & Bartrum, 1929	-	R	R	C	U	C	U	U	AK72146
CALYPTRAEIDAE									
<i>Crepidula</i> aff. <i>costata</i> (Sowerby, 1824)	-	R	-	-	-	U	-	U	
<i>Crepidula</i> aff. <i>opuraensis</i> (Bartrum & Powell, 1928)	-	R	R	R	-	R	-	R	AK98497
<i>Crepidula monoxylla</i> (Lesson, 1830)	-	-	-	-	-	R	-	R	
<i>Sigapatella patulosa</i> Powell & Bartrum, 1929	R	R	R	R	U	C	-	R	AK72141
<i>Sigapatella perampla</i> (Powell & Bartrum, 1929)	-	-	-	R	-	U	R	-	AK72174
<i>Sigapatella subvaricosa</i> Powell & Bartrum, 1929	-	-	-	R	-	-	-	-	
TRIVIIDAE									
<i>Willungia maoria</i> Powell, 1938	-	-	-	-	-	-	-	R	AK98443
<i>Willungia fracta</i> (Tomlin, 1916)	R	-	-	-	-	-	-	-	AK98445
<i>Trivia</i> n.sp.	-	-	-	-	-	-	-	R	AK98442
NATICIDAE									
<i>Magnatica (Spelaenacca) waitemataensis</i> (Powell, 1938)	-	R	-	-	-	-	-	-	AK70435
<i>Polinices oneroaensis</i> Powell & Bartrum, 1929	-	R	R	C	C	C	C	U	AK98525
<i>Polinices huttoni</i> Ihering, 1907	-	-	-	-	-	-	-	R	
<i>Polinices</i> sp.	-	-	-	-	-	R	-	-	AK98519
<i>Frignatica vaughani</i> (Marwick, 1924)	-	-	-	R	-	-	-	-	
CASSIDAE									
<i>Echinophoria oneroaensis</i> (Powell, 1938)	-	-	-	R	-	U	-	-	AK72062
RANELLIDAE									
<i>Cabestana tetleyi</i> (Powell & Bartrum, 1929)	-	-	-	R	-	-	-	-	AK98505
<i>Sassia arthritica</i> (Powell & Bartrum, 1929)	-	-	-	R	-	R	-	-	AK72041
<i>Sassia (Haurokoa) bartrumi</i> (Powell, 1938)	-	-	-	R	-	-	-	-	AK72090
CERITHIOPSIDAE									
<i>Joculator</i> sp.	-	-	-	R	R	-	-	-	
TRIPHORIDAE									
<i>Monophorus</i> cf. <i>facelinus</i> (Suter, 1908)	-	-	-	R	R	-	-	-	
EULIMIDAE									
<i>Eulima</i> aff. <i>otaioensis</i> Laws, 1933	-	-	-	-	-	-	-	R	AK98452
<i>Eulima</i> n.sp.	-	-	-	-	-	-	-	R	AK98449
EPITONIIDAE									
<i>Notacirsa</i> cf. <i>prisca</i> (Suter, 1917)	-	-	-	-	-	-	-	R	AK98455

	F1	F2	F3	F4	F5	W1	W2	O1	Voucher
BUCCINIDAE									
<i>Austrofuscus (Neocola) oneroaensis</i> Powell & Bartrum, 1929	-	-	-	R	-	R	-	-	AK72010
<i>Buccinulum compactum tetleyi</i> Powell & Bartrum, 1929	-	-	-	-	-	-	U	-	
<i>Paracomina finlayi</i> (Powell & Bartrum, 1929)	-	R	-	-	-	-	-	-	AK71715
<i>Paracomina lignaria</i> (Powell & Bartrum, 1929)	-	R	U	U	-	R	R	C	AK71705
<i>Penion exoptatus</i> (Powell & Bartrum, 1929)	-	-	-	R	R	R	-	U	AK72012
NASSARIIDAE									
<i>Nassarius (Hima) aff. socialis</i> (Hutton, 1886)	-	-	-	R	-	-	-	-	
TURBINELLIDAE									
<i>Coluzea dentata</i> (Hutton, 1877)	-	-	-	-	R	-	-	-	AK98417
MURICIDAE									
<i>Lepsiella intermedia</i> Powell & Bartrum, 1929	R	R	-	-	-	U	-	-	AK72077
<i>Lepsiella maxima</i> Powell & Bartrum, 1929	-	R	-	U	-	U	-	-	AK72078
<i>Chicoreus (Siratus) komiticus</i> (Suter, 1917)	-	-	-	-	R	-	-	-	AK98419
<i>Murexsul echinophorus</i> Powell & Bartrum, 1929	-	-	-	-	R	U	-	-	
<i>Murexsul cf. scobinus</i> Finlay, 1930	-	-	-	-	R	-	-	-	AK98425
<i>Pterotyphis (Prototyphis) cf. awamoanus</i> (Finlay, 1930)	-	-	-	-	-	-	R	-	AK98437
<i>Pagodula waitemataensis</i> (Powell & Bartrum, 1929)	-	-	-	R	R	-	R	U	AK98516
MITRIDAE									
<i>Eumitra waitemataensis</i> (Powell & Bartrum, 1929)	-	-	-	R	-	-	U	R	AK72054
HARPIDAE									
<i>Morum (Oniscidea) harpaformis</i> Powell & Bartrum, 1929	-	-	-	-	-	U	-	-	AK72097
OLIVIDAE									
<i>Amalda (Baryspira) platycephala</i> (Powell & Bartrum, 1929)	-	-	-	U	U	U	-	R	AK98423
VOLUTIDAE									
<i>Waihaoia</i> n.sp.	-	-	-	-	U	-	-	-	AK98427
<i>Alcithoe</i> sp.	-	-	-	-	-	-	-	U	
<i>Alcithoe (Alcithoe) turrita</i> (Suter, 1917)	-	-	-	U	-	-	-	-	AK98421
CONIDAE									
<i>Conolithes wollastoni</i> Maxwell, 1978	-	-	-	-	-	-	-	U	AK98447
TURRIDAE									
<i>Austrotoma finlayi</i> Powell, 1938	-	-	-	R	-	-	-	-	AK72013
<i>Austrotoma excavata</i> (Suter, 1917)	-	-	-	-	-	R	-	R	AK98498
<i>Inquisitor cf. awamoensis</i> (Hutton, 1873)	-	-	-	R	-	-	-	R	
<i>Neoguraleus</i> sp.	-	-	-	R	-	-	-	R	
<i>Neoguraleus (Fusiguraleus) cf. leptosoma</i> (Hutton, 1885)	-	-	-	-	-	-	-	R	AK98456
<i>Rugobela sepebilis</i> (Powell & Bartrum, 1929)	-	-	-	-	-	U	-	-	AK72066
<i>Tomopleura transenna</i> (Suter, 1917)	-	-	-	-	-	U	-	U	
<i>Scrinium cf. callimorphum</i> (Suter, 1917)	-	-	-	-	-	-	-	R	AK98448

	F1	F2	F3	F4	F5	W1	W2	O1	Voucher
CANCELLARIIDAE									
<i>Anapepta</i> n.sp.	-	-	-	-	-	-	R	-	AK98435
<i>Oamaruia</i> n.sp.	-	-	-	-	-	-	-	R	AK98446
<i>Inglisella</i> n.sp. Finlay, 1924	-	-	-	-	R	-	U	-	AK98424
<i>Latirus</i> n.sp.	-	-	-	-	-	-	-	R	AK98444
ACTEONIDAE									
<i>Acteon oneroaensis</i> Powell & Bartrum, 1929	-	-	-	C	U	U	U	R	AK72001
<i>Acteon</i> n.sp.	-	-	-	-	-	-	-	R	AK98451
SCAPHANDRIDAE									
<i>Cylichna</i> sp.	-	-	-	-	R	-	-	-	AK9852
RETUSIDAE									
<i>Cylichnina enucleata</i> Powell & Bartrum, 1929	-	-	-	C	C	U	C	R	
<i>Volvulella</i> cf. <i>reflexa</i> (Hutton, 1886)	-	-	-	-	-	-	-	R	AK98450
PYRAMIDELLIDAE									
<i>Linopyrga</i> cf. <i>pseudorugata</i> (Marshall & Murdoch, 1921)	-	R	-	-	-	-	R	-	AK98504
<i>Turbonilla</i> sp.	-	R	-	C	U	-	-	-	
<i>Subonoba</i> sp.	-	-	-	-	-	-	-	R	
CEPHALOPODA									
ATURIIDAE									
<i>Aturia cubaensis</i> (Lea, 1841)	-	-	-	-	R	-	-	-	AK98426
SCAPHOPODA									
DENTALIIDAE									
<i>Fissidentalium</i> sp. indet.	R	R	U	U	U	R	U	C	AK98482
<i>Antalis</i> cf. <i>nana</i> (Hutton, 1873)	-	-	-	-	R	-	-	-	AK98418
POLYPLACOPHORA									
<i>Ischnochiton vetustus</i> Powell & Bartrum, 1929	-	-	-	-	-	U	-	-	
gen. et sp. indet.	-	R	-	-	-	-	-	-	
POLYCHAETA									
SERPULIDAE									
<i>Protula</i> sp.	-	-	-	R	R	-	-	-	
<i>Spirorbis</i> sp.	-	-	-	R	-	-	-	-	
gen. et sp. indet.	R	-	-	-	A	-	-	-	
PORIFERA									
clionid borings	-	R	R	-	-	R	-	-	
CRUSTACEA									
CIRRIPPEDIA									
gen. et sp. indet.	-	U	U	-	U	-	-	-	
ARCHAEOBALANIDAE									
<i>Armatobalanus motuketeketeensis</i> Buckeridge, 1983	-	-	-	R	-	U	U	-	AK98440
DECAPODA									
<i>Callianassa</i> sp.	-	-	-	-	-	-	U	-	AU9822-3
<i>Upogebia</i> sp.	-	-	-	-	U	-	-	-	AU11631
gen. et sp. indet. (chela, etc.)	-	R	-	U	R	C	U	R	

	F1	F2	F3	F4	F5	W1	W2	O1	Voucher
COELENTERATA									
PORITIDAE									
<i>Alveopora polyacantha</i> Reuss, 1867	-	R	-	-	-	-	-	-	
TURBINOLIIDAE									
<i>Peponocyathus minimus</i> (Yabe & Eguchi, 1937)	-	-	-	-	U	-	-	-	
FLABELLIDAE									
<i>Truncatoflabellum sphenodeum</i> (Tenison-Woods, 1880)	-	C	-	-	-	-	-	-	AK98414
OCULINIDAE									
<i>Oculina virgosa</i> Squires, 1958	-	R	-	-	-	-	-	-	
chaliciform hermatypes - zooxanthellates	R	U	-	-	-	R	-	-	
reef coral indet.	-	-	-	-	-	-	R	-	
cerioid reef scleractinian	-	-	-	-	-	R	-	-	
BRYOZOA									
celleporiform	-	-	-	-	-	-	R	-	
membraniporiform	-	R	-	-	-	-	-	-	
vinculariiform	-	-	-	R	R	-	-	-	
reteporiform	-	U	R	-	-	-	-	-	
BRACHIOPODA									
CANCELLOTHYRIDIDAE									
<i>Terebratulina suessi</i> (Hutton, 1873)	-	-	-	-	R	-	-	-	
HEMITHYRIDIDAE									
<i>Notosaria antipoda</i> (Thomson, 1918)	-	R	-	-	-	R	-	R	
ECHINODERMATA									
ASTEROIDEA									
ossicles indet.	-	-	-	-	-	-	-	U	AK98454
CIDARIDAE									
<i>Phyllacanthus titan</i> Fell, 1954	R	R	R	-	-	-	-	-	
SPATANGOIDEA									
<i>Opissaster rotundatus</i> (Zittel, 1864)	U	R	R	C	U	R	U	R	AK98478
CHONDRICHTHYES									
LAMNIDAE									
<i>Isurus hastalis</i> Agassiz, 1843	-	-	-	-	R	-	-	-	AK98479
TELEOSTEI									
MUGILOIDIDAE									
<i>Parapercis finlayi</i> Schwarzhans, 1980	-	-	-	-	R	-	-	-	AK98431
MACROURIDAE									
? <i>Coelorhynchus</i> sp.	-	-	-	-	R	-	-	-	AK98432
gen. et sp. indet. (scales)	-	-	-	-	-	R	-	-	
ICHTNOFOSSILS									
<i>Nerites</i> sp. indet.	-	-	-	R	-	-	-	-	
<i>Thalassinoides</i> sp. indet.	-	-	-	-	-	-	U	-	
<i>Skolithos</i> sp. indet.	-	-	-	R	-	-	-	-	
<i>Zapfella</i> sp. (acrothoracican barnacle boring in bivalves)	-	-	-	-	-	C	-	-	
<i>Entobia cretacea</i> Portlock, 1929 (sponge boring)	-	-	-	-	-	C	-	-	

F1 F2 F3 F4 F5 W1W2 O1 Voucher

ALGAE

RHODOPHYCEAE

rhodolith sp. indet.

C C C - - - - -

TERRESTRIAL FLORA

PLANTAE

Agathis sp. indet.

- - - - R R - -

Phormium sp. indet.

- - - - R - - -

Nothofagus sp. indet.

- - - - R - - -

conifer cone sp. indet.

- - - - - R - -

leaves sp. indet.

- - - - - R - -

AN INVASION OF AUSTRALIAN BLUE MOON AND BLUE TIGER BUTTERFLIES (LEPIDOPTERA: NYMPHALIDAE) IN NEW ZEALAND

JOHN W. EARLY, G. RICHARD PARRISH AND PADDY A. RYAN

Abstract. Large numbers of two Australian butterflies, *Hypolimnas bolina nerina* and *Tirumala hamata hamata*, were reported in April-June 1995 in New Zealand, mostly in the north and west of the North Island. Meteorological evidence indicates that they probably arrived on 9-10 April from between about 24° and 32° S on Australia's east coast, and with a trans-Tasman passage time of 54-60 hours. A few specimens of other Australian butterflies (*Danaus chrysippus petilia*, *Cynthia kershawi*, *Junonia villida calybe* and possibly *Melanitis leda bankia* (Nymphalidae)) and moths (*Utetheisa pulchelloides vaga* (Arctiidae) and *Elygaea materna* (Noctuidae)) were also recorded over the same period.

Various organisms regularly arrive in New Zealand having been blown across the Tasman Sea from the Australian east coast. These include plant pathogens, fern spores, orchid seeds, and a variety of insects such as aphids, scale insects, fig wasps, moths and butterflies (Close et al. 1978; Ryan & Harris 1990; Gardner & Early in press). Immigrant Lepidoptera from Australia are frequently intercepted, sometimes in large numbers. Fox (1978) and Gibbs (1980) give good summaries of this phenomenon and review the literature. Which species arrives depends largely on the time of year, e.g., the painted lady (*Cynthia kershawi* McCoy) usually appears in spring (October-November) while the blue moon butterfly (*Hypolimnas bolina nerina* (F.)) makes its appearance only in autumn (April-May); these times coincide with periods of migratory movements within Australia. The blue moon is a sporadic visitor and occasional specimens appear in most years. On rare occasions they have arrived in large numbers and attracted considerable public attention. Two notable blue moon invasions have been documented: 720 specimens were observed in 1956 (Ramsay & Ordish 1966), and 108 specimens in 1971 (Ramsay 1971, 1973). Influxes of this size require several factors to coincide: the butterflies must be locally numerous and active in Australia; there must be appropriate meteorological conditions to get them airborne and keep them so while in transit; and they must settle out on New Zealand (Tomlinson 1973).

April 1995 seems to have been another of those times when the necessary conditions lined up to produce an invasion. The interesting thing about this influx was the additional presence of the Australian blue tiger, *Tirumala hamata hamata* (Macleay) rather than the blue moon alone. The purpose of this paper is to document the phenomenon, record localities where sightings were made, and to determine the origin of the specimens.

The records on which this paper is based derive from public enquiries to the Department of Conservation (Whangarei), the Auckland Museum, Landcare Research, MAF Lynfield (Auckland), Mr Peter Peckham (New Plymouth), the Museum of New Zealand (Wellington), Mr Jim Harding (Nelson), the Department of Conservation (Nelson) and the Otago Museum (Dunedin). No requests for information or sightings were made through the media, although a few smaller local newspapers (*Northland Age Courier*,

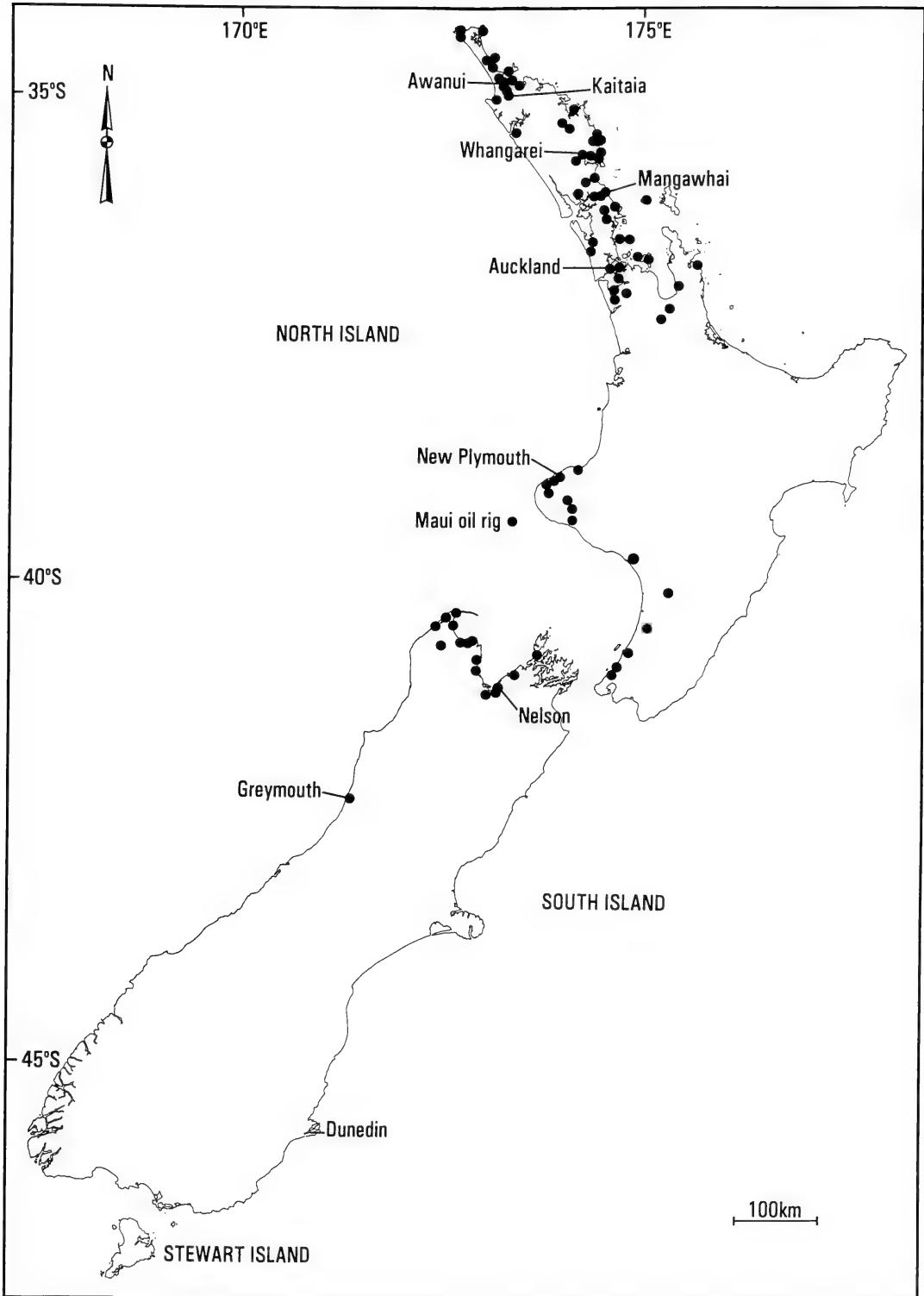


Fig. 1. Sightings of *H. bolina nerina* and/or *T. hamata hamata*, 9 April - 12 June 1995.

Northern Advocate, *Mangawhai Memo*, *Taranaki Daily News*, *Observer*, *Nelson Evening Mail*) ran articles and so stimulated local interest resulting in additional records. Most callers with enquiries about “strange and unusual butterflies” gave good descriptions that matched one of the two species, and several had consulted books and accurately identified them themselves. The sightings are supported by several voucher specimens and photographs in the Auckland Museum (AMNZ 1323-1328, 1506-1507, 1735), the Museum of New Zealand and the Otago Museum.

RECORDS

The first two specimens we are aware of were observed on Sunday 9 April 1995. The first, a blue tiger, was collected at about 1330 h 5 km west of Kaitaia, Northland (AMNZ 1506). The second, a blue moon, was seen in the evening on the Maui oil rig which is approximately 40 km off the Taranaki coast from Opunake, and almost 500 km south of Kaitaia. In total, there were 103 sightings of blue moons and 57 of blue tigers representing at least 142 and 67 specimens respectively. Several observers reported seeing groups of “several”, “dozens”, “lots” and “a flock”, and groups often contained both species. Most (75%) sightings occurred over the period 12-22 April which included the Easter holiday; sporadic sightings continued until 12 June.

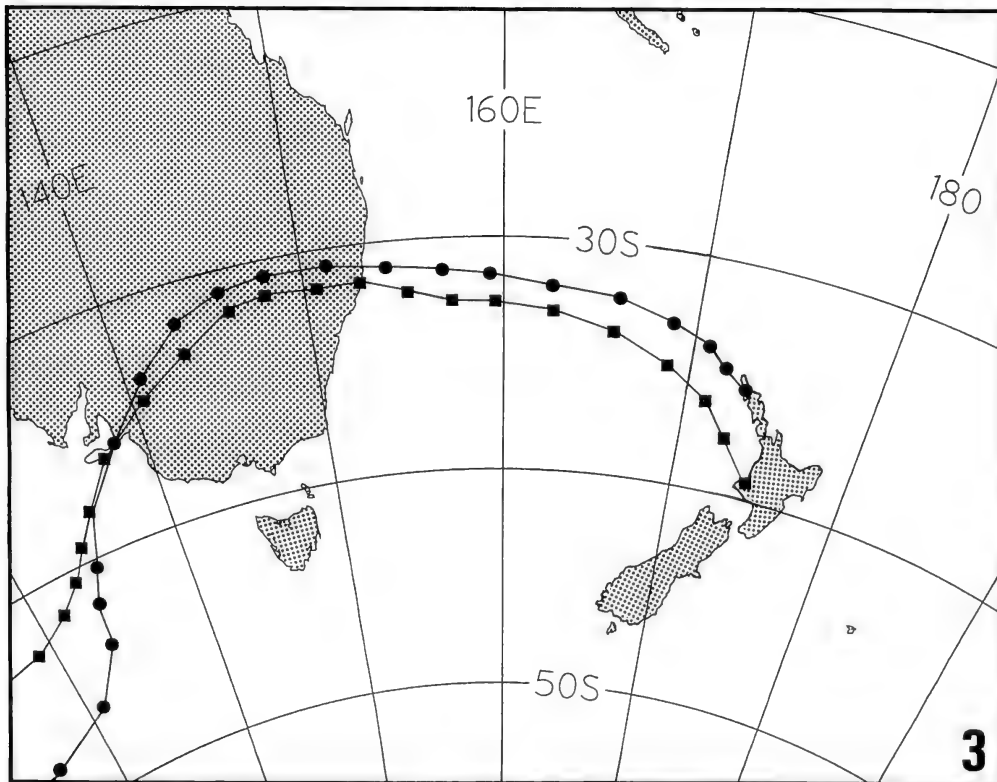
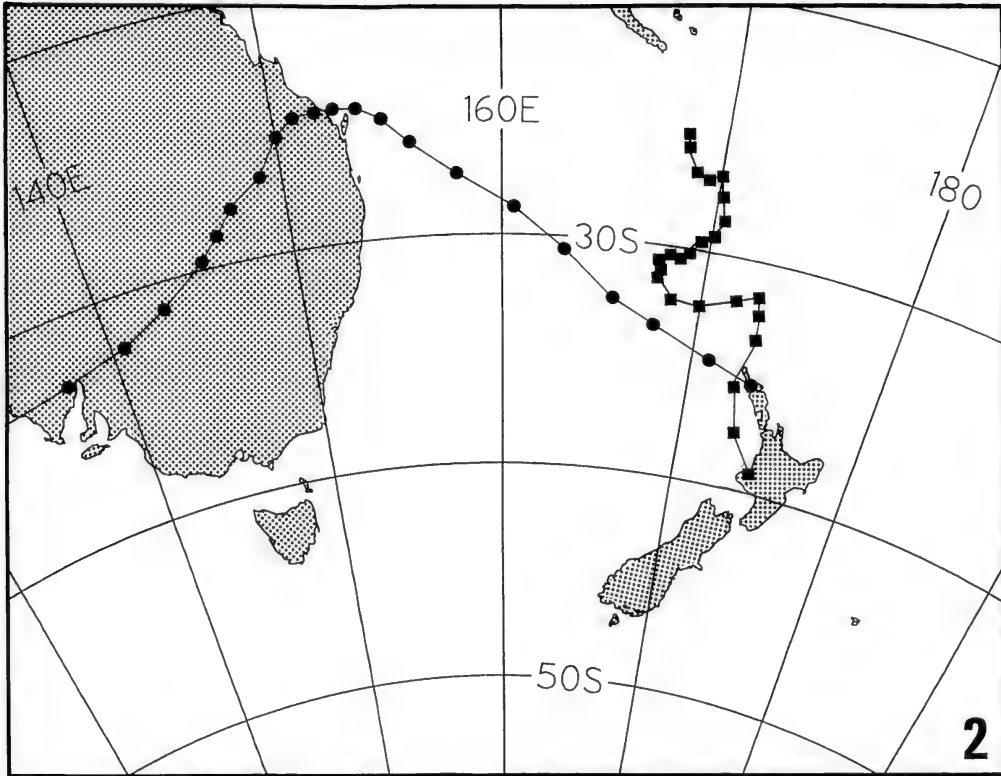
Most records came from Northland (Fig. 1). Very few butterflies were seen around metropolitan Auckland. Considerable numbers were also recorded from Taranaki, Manawatu, the Kapiti Coast, and Nelson. The southernmost blue moon record came from Greymouth. A detailed list of locality records and dates is available on request. Their distribution is shown in Fig. 1 where the two species are not differentiated since both were often found together.

As with previous instances of immigrant butterflies, many specimens were in near perfect condition. Several observers reported them feeding on flowers of *Lantana* sp., *Grevillea* sp., *Hebe* sp., *Aster novi-belgii* (Michaelmas daisy) and *Solanum muricatum* (pepino).

In addition to the blue moon and blue tiger butterflies, six other Australian Lepidoptera were reported and are listed in Table 1. Although most of the butterflies were seen in the North Island, two of the three records of the fruit sucking moth (*Elygea materna*) came from Dunedin and Stewart Island respectively, and one of the three lesser wanderer butterflies (*Danaus chrysippus petilia*) also came from Dunedin. The Dunedin records predate the earliest blue moon and blue tiger records by 2-3 days.

DISCUSSION

This influx of foreign butterflies is the third recorded occasion involving large numbers of the blue moon, but it differed from the previous two in that it also included the largest number of blue tigers ever seen in New Zealand. The latter species is one of our rarest Australian butterfly visitors, only four specimens being known by Gibbs (1980). Numbers of each species in Table 1 should be treated with caution. Group sightings indicate that there were more present than those listed in Table 1. In some localities many butterflies apparently remained in the area over several days (e.g., Mangawhai, Northland), so repeated sightings of the same individuals were likely. Their main value is to indicate the relative abundance of the species, and that butterflies arrived in a significant influx rather than their usual sporadic appearance. It is inappropriate to compare numbers with those recorded by Ramsay & Ordish (1966) and Ramsay (1971, 1973) from the 1956 and



Figs 2-3. Trajectory plots of air movement at 1000 m. 2. Arrival at 1200 UTC Sunday 9 April 1995. 3. Arrival at 0000 UTC Monday 10 April 1995. ● = trajectory for arrival at Kaitaia, ■ = trajectory for arrival at New Plymouth. Points on each trajectory are 6 hours apart.

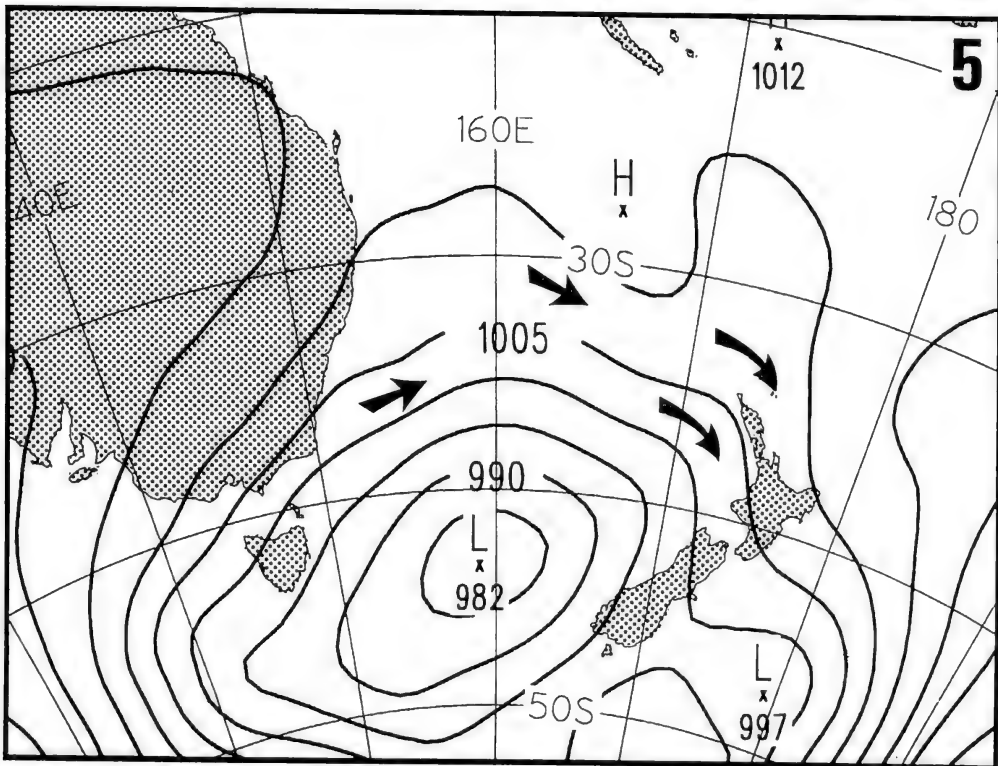
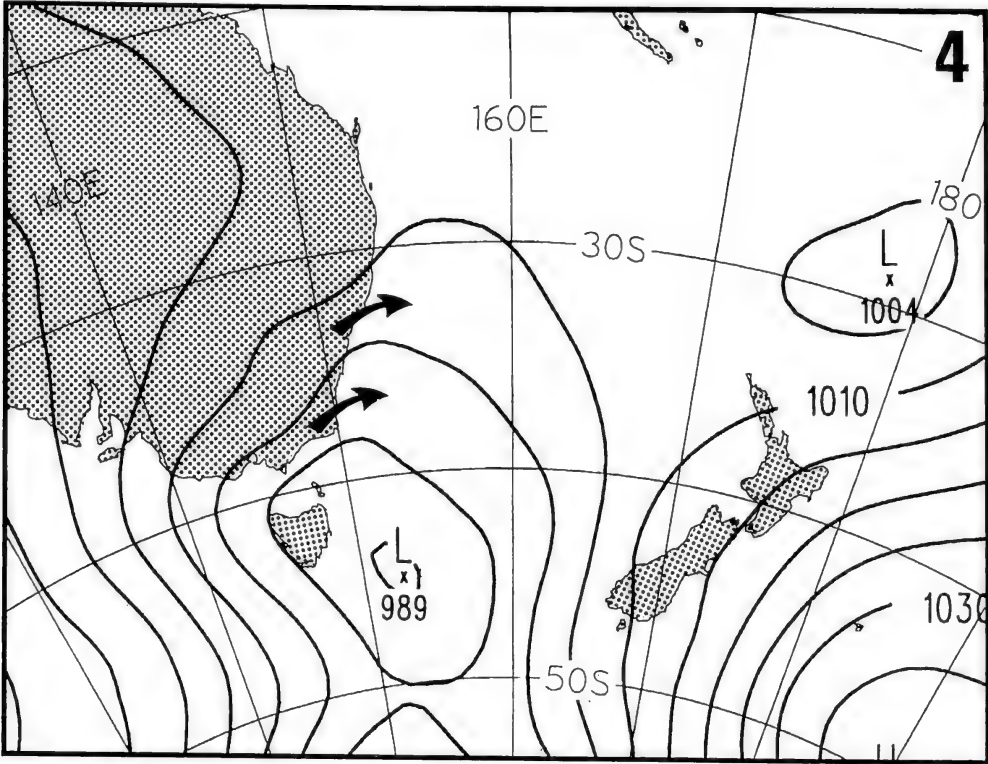
Table 1. Records of Australian Lepidoptera in New Zealand, April-June 1995 (* = unconfirmed record).

Species	Common name	Number of specimens	Locality
<i>Hypolimnas nerina bolina</i> (Fabricius)	blue moon butterfly	142	North & South Is; see Fig. 1
<i>Tirumala hamata hamata</i> (Macleay)	blue tiger butterfly	67	North & South Is; see Fig. 1
<i>Danaus chrysippus petilia</i> (Stoll)	lesser wanderer	3	Northland (Awanui, Waima), Dunedin
<i>Cynthia kershawi</i> McCoy	painted lady	1	New Plymouth
<i>Junonia villida calybe</i> (Godart)	meadow argus	1	New Plymouth
* <i>Melanitis leda bankia</i> (Fabricius)	evening brown	1	New Plymouth
<i>Utetheisa pulchelloides vaga</i> Jordan	crimson speckled footman	2	New Plymouth, Wellington
<i>Elygaea materna</i> (L.)	fruit sucking moth	3	Northland (Awanui), Dunedin, Stewart I.

1971 invasions, respectively, because of differences in degree of publicity and requests for sightings.

Where did they come from? All species in Table 1 are widely distributed in the Indo-Australian and Pacific regions, some reaching up into the Oriental region. *Tirumala hamata* is found from Java, Sulawesi and the Philippines eastward through the southern Moluccas, New Guinea and Solomons to Fiji, Tonga and Samoa, and southward to northern and eastern Australia (Ackery & Vane-Wright 1984). Several morphs with localised distributions within this range are recognised, and the one concerned with here, *T. hamata hamata*, is restricted to Australia, the islands of Torres Strait and New Guinea. Similarly, *H. bolina* with its constituent subspecies is distributed from India and Taiwan, through south-east Asia to the islands of the central Pacific (Fiji, Samoa, Tonga); the subspecies recorded here, *H. bolina nerina*, is restricted to New Guinea, northern and eastern Australia, the Bismarck Archipelago, Solomons, Vanuatu and Norfolk Island (Common & Waterhouse 1972).

Analysis of weather maps and back-plotted airflow trajectories is required to narrow down the butterflies' likely geographical origin. On 9 April, a period of northeasterly winds over much of the North Island was replaced by a prolonged period of northwesterlies about a depression located to the southwest of New Zealand in the Tasman Sea. The NW wind was already established in Kaitaia at the time the first butterfly was collected (J. Bond, pers. comm.). Speculation as to the butterflies' possible origin in the Pacific islands on account of the NE wind flow onto New Zealand for the few days preceding their arrival can be dismissed on two grounds. Firstly, they are not the representative subspecies/distinctive populations that are found on the Pacific islands. Secondly, although trajectories ending over the North Island before the 9th seem to originate from the east, there is no meteorological evidence that their origin is in the tropics. Rather, they appear to originate around 40° S, spiralling counterclockwise before arriving over New Zealand in an ENE current (M.R. Sinclair, in litt.).



Figs 4-5. Weather maps for 0000 UTC. Arrows show wind direction; numbers are mean sea level pressure (hPa). 4. Friday 7 April 1995, butterflies will have left Australia by now. 5. Sunday 9 April 1995, approximate time of arrival of first butterfly.

Back-plotted trajectories for arrival in Northland (Kaitaia) and Taranaki (New Plymouth) at midday local time (0000 UTC) on 9 April 1995 for the 1000 m level do not give a clear indication as to the butterflies' point of origin, perhaps due to the changing wind systems and some of the assumptions and errors involved in trajectory calculation (see Tomlinson 1973). Trajectories ending 12 hours later (1200 UTC on the 9th, Fig. 2) make some sense for a Kaitaia arrival and indicate a southern Queensland origin, but not for a New Plymouth arrival. By 0000 UTC on 10 April (Fig. 3) both trajectories suggest an Australian origin and a rapid transit of about 54-60 hours of the Tasman Sea. Fig. 2's Kaitaia trajectory indicates departure between 1800 UTC on 6 April and 0000 UTC on the 7th (0400-1000 h Australian Eastern Standard Time, 7 April). Around this time, much of the Australian east coast experienced southwesterly winds (Fig. 4) which could have displaced the butterflies northeastwards out to sea, then spiralled around clockwise to bring them to New Zealand on a northwesterly wind (Fig. 5).

Comparison of the trajectories in Figs 2 and 3 is interesting because although the earlier one for Kaitaia (Fig. 2) indicates an origin from over the Queensland coast near 25° S, the later one (Fig. 3) is from northern New South Wales, just south of 30° S. These trajectory calculations are based on a parcel of air at 1000 m. It is difficult to know at what altitude butterflies cross the Tasman, but it may well be at much lower levels, from 0-100 m. Gibbs (1980) argued that the distribution of butterflies following an invasion favours coastal locations to such an extent that it is highly suggestive of a sea-level approach. The observation of a blue moon on the Maui oil rig, some 40 km offshore, lends credence to this idea. Updraughts during the NW winds in this study were slight (around 200 mm/s, M.R. Sinclair, pers. comm.) and both the blue moon and blue tiger, which are strong fliers, would be able to maintain their vertical position and not be carried passively to great altitudes during passage. Airflow at lower altitudes, e.g. around 100 m, would be slightly weaker than at 1000 m and turned slightly towards lower pressure, making the current more northerly (M.R. Sinclair, in litt.). This would result in both a slightly longer transit time, and make the butterflies' point of origin at a slightly lower latitude.

The precise geographical origin of these immigrant Lepidoptera cannot be pinpointed but it appears to be somewhere on Australia's east coast between about 24° S and 32° S, i.e. between Bundaberg (southern Queensland) and Port Macquarie (northern New South Wales). The moths and other butterflies listed in Table 1 are also found in this region (Common 1990; Common & Waterhouse 1972). Except for the two specimens recorded from Dunedin (see below), all were probably displaced by a single meteorological event (e.g., a cold front as it swept up the Australian coast) but may have continued to arrive in New Zealand on persistent NW winds over a period of perhaps 24 hours.

The single specimens of *E. materna* and *D. chrysippus petilia* from Dunedin must be excluded from the above invasion of Australian Lepidoptera. They were sighted on 6 and 7 April respectively, predating the first specimens of the blue moon and blue tiger invasion by up to three days. Northeast winds prevailed at that time so they cannot possibly have arrived on the same weather system as the other butterflies. Their origin remains unknown. They may have arrived from Australia on an earlier northwesterly airflow but were not detected until some time after arrival. Other lesser wanderers predating the invasion were found near Auckland (JWE unpubl.).

Suitable host plants for oviposition and larval development of the blue moon and blue tiger are present in New Zealand (see Gibbs 1980), but there is no evidence of even temporary establishment. They are essentially tropical/subtropical species and, despite their repeated appearance here (probably over the last 2 million years), are likely to

remain occasional/regular immigrants and not become permanent members of our small butterfly fauna.

Notes Added in Proof

1. Dr Courtney Smithers (Research Associate, Australian Museum, Sydney) informed JWE (in litt., 15 Oct 1995) that hundreds of blue tigers arrived on Norfolk Island on 9 April 1995, the same day that the first butterflies of the New Zealand invasion were seen (see Smithers, C.N. The first record of *Tirumala hamata hamata* (W.S. Macleay) (Lepidoptera: Nymphalidae) on Norfolk Island. *Norfolk Nature Notes*, July 1995, pp 395-396). Dr Smithers (in litt.) also reported hearing of a migrating group of *T. hamata*. They were observed on 7 April 1995 from a yacht at sea approximately 125 km south of Bundaberg, Queensland, where a dense population was reported flying east over a 7-9 km front. It is impossible to know whether these were the same butterflies that eventually arrived in Norfolk Island and/or New Zealand, but this sighting confirms that migrating butterflies cross the Tasman Sea at low altitudes rather than by rapid passage in high altitude air flows.

2. A single *T. hamata hamata* was taken in April from the eastern Bay of Plenty (Whanarua Bay, 37° 41'S, 177° 47'E) and a blue moon from Hawkes Bay (Te Awanga, 39° 38'S, 176° 59'E). These records represent a considerable eastward extension of the range of New Zealand interceptions.

Acknowledgements. We thank all those who wrote, telephoned, sent specimens, and who generously shared their records, particularly Cynthia Baker (Mangawhai), Peter Peckham (New Plymouth), Jim Harding (Nelson) and Tony Harris (Otago Museum, Dunedin). Mark Sinclair (NIWA, Wellington) performed the trajectory analyses and provided considerable assistance with the meteorological data and its interpretation. Rosemary Gilbert and Hugh Grenfell prepared the illustrations. John Dugdale, Ray Pierce and Fred Brook gave helpful criticism of the manuscript. To all these, we are grateful.

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NOTES ON THE LAND REPTILES OF WALLIS AND FUTUNA, SOUTH-WEST PACIFIC

B. J. GILL

Abstract. This first account of the land reptiles of the Wallis and Futuna islands is based largely on specimens I collected in 1993 and that J.-C. Thibault and I. Guyot collected in 1985-6. Four species of gecko, seven skinks and a terrestrial snake are known from the group, with a greater diversity on Futuna than on Wallis. Many are common and widespread Pacific species. Of those that are not, *Emoia adspersa* is confirmed from Futuna after examination of specimens collected last century. *E. murphyi*, which was hitherto recorded only further east in the Samoa-Tonga area, is reported from Futuna for the first time. *E. trossula* is tentatively identified from Futuna, but further study may show that the population belongs instead to the closely-related *E. samoensis*. The known distribution of the snake *Candoia bibroni* now includes Futuna and 'Alofi.

Résumé. Ce premier inventaire des reptiles terrestres des îles Wallis et Futuna est largement basé sur des spécimens que j'ai collectés en 1993 et ceux collectés par J.-C. Thibault et I. Guyot en 1985-6. Quatre espèces de geckos, sept scinques et un serpent terrestre sont connus de ce groupe d'îles où la diversité spécifique est supérieure à Futuna qu'à Wallis. Beaucoup de ces espèces sont communes et largement distribuées dans le Pacifique. Parmi les espèces plus restreintes, la présence d'*Emoia adspersa* est confirmée sur Futuna après examen de spécimens collectés au siècle dernier. *E. murphyi*, connu auparavant seulement plus à l'est dans la région des Samoa-Tonga, est mentionné pour la première fois de Futuna. *E. trossula* est identifié avec réserve de Futuna; des études ultérieures pourraient montrer que ces populations appartiennent à l'espèce proche *E. samoensis*. La distribution du serpent *Candoia bibroni* englobe maintenant Futuna et 'Alofi.

The French Overseas Territory of Wallis and Futuna lies west of Western Samoa and north-east of Fiji. Wallis ('Uvea) is a low island (to 144 m a.s.l.) of 96 km² surrounded by about 20 islets enclosed within a barrier reef. Futuna (80 km²) and its neighbour 'Alofi (c. 35 km²), previously called the Hoorn (or Horne) Islands, are high islands (to c. 500 m a.s.l.) about 230 km south-west of Wallis and they lack a surrounding lagoon. Guyot & Thibault (1988) and Anonymous (1986) gave maps of the islands.

I spent seven days on Wallis (22-27 September and 4-6 October 1993) travelling all the roads of 'Uvea by car, covering some central and northern parts on foot, and landing on three islets (Nukulaelae, Nukuloa and Nukuhione) on 23 September. I spent seven days on Futuna (27 September to 4 October 1993) during which time I travelled the circular coast-road by car, walked along the coast between the villages of Fiua and Taoa, and climbed inland from Leava through plantation, secondary forest and "toafa" fernland. Rough seas precluded a visit to 'Alofi.

No previous account of the land reptiles of the territory has been published. The Whitney South Sea Expedition visited both islands in 1925 and collected many birds (Guyot & Thibault 1987), but the account of the herpetology of the expedition (Burt & Burt 1932) cites only two specimens from Wallis and none from Futuna (the latter is listed on p. 469 as "Satune (Fatuna)" (*sic*) in the Samoan group).

Here I report my observations of reptiles, and specimens collected, the latter now held at the Auckland Institute and Museum (AIM). Other museum voucher specimens known to me are cited. Specimens collected by Thibault and Guyot in 1985–6 are at the Muséum National d'Histoire Naturelle, Paris (MNHN), and I have examined a selection of these. The two specimens from Wallis collected by the Whitney South Sea Expedition are at the American Museum of Natural History, New York (AMNH). Four specimens from 'Alofi are at The Field Museum, Chicago (FMNH).

The Museum für Naturkunde der Humboldt-Universität, Berlin (ZMB), has nine skinks from "Futuna, Fidji Inseln", all of which I have examined. I have identified them as follows: *Emoia nigra* (5), *E. adspersa* (2), *E. trossula* (1) and *E. murphyi* (1). They are attributed to the Godeffroy brothers who had a private museum in Hamburg last century. The collectors and dates of collection are not known (R. Günther, *pers. comm.*), but two specimens were used by Peters (1874), so these, and perhaps all nine, were collected before 1874. In the Pacific there are two islands named Futuna (Motteler 1986), the one with which this paper is concerned, and Futuna (= Erronan) in Vanuatu. The former is an isolated island only 250 km from the north-east edge of the Fiji archipelago, so it seems understandable that early collectors would link this Futuna with Fiji. For this reason, and because all the Godeffroy lizards that are not *E. nigra* belong to species that do not occur in Vanuatu, I am content that the ZMB specimens are from the Futuna of the Wallis and Futuna group. Among the collectors sent to the South Pacific by the Museum Godeffroy was Dr E. Gräffe (Watling 1982) who visited Futuna in 1866 and again in 1867 (Guyot & Thibault 1987).

The records of reptiles are summarised in Table 1. All the species of Wallis and Futuna occur also in Western Samoa, except that *Emoia trossula* on the former is a counterpart to *E. samoensis* on the latter. My identification key to Western Samoan reptiles (Gill 1993) suffices for Wallis and Futuna if *trossula* is read for *samoensis* (the

Table 1. The land reptiles of Wallis, Futuna and 'Alofi. o = collected or seen by me in 1993 (specimens at AIM), x = not found by me but collected by Guyot & Thibault in 1985–86 (specimens at MNHN), z = based on specimens at ZMB.

	Wallis	Futuna	'Alofi
Geckos			
<i>Gehyra oceanica</i>	o	o	x
<i>Hemidactylus frenatus</i>	o	o	
<i>Lepidodactylus lugubris</i>	o	o	x
<i>Nactus pelagicus</i>		o	
Skinks			
<i>Cryptoblepharus poecilopleurus</i>		x	
<i>Emoia adspersa</i>		z	
<i>Emoia cyanura</i>	o	o	
<i>Emoia impar</i>			x
<i>Emoia murphyi</i>		o	x
<i>Emoia nigra</i>	o	o	x
<i>Emoia trossula</i>		o	
Snakes			
<i>Candoia bibroni</i>		x	o

characters chosen for the key are nearly the same in the two species). Where measurements are given in the present paper, SVL stand for snout–vent length. I follow the redefinition of the cryptic species *E. cyanura* and *E. impar* as set out by Ineich & Zug (1991).

ANNOTATED SPECIES LIST

OCEANIC GECKO *Gehyra oceanica* (Lesson, 1828)

Wallis. Common in forest away from human habitations (AIM H1614, H1623) and as a house gecko on outside and inside walls (AIM H1594–5, H1601, H1609–10, H1625). Other records: MNHN 1986.675–6.

Futuna. Seen under bark of forest trees. Three large rounded eggs (AIM H1627), found in a rotten log in a plantation, are assumed to belong to this species. Other records: MNHN 1986.679–80 (Futuna); 1986.677–8 (‘Alofi).

HOUSE GECKO *Hemidactylus frenatus* Duméril & Bibron, 1836

Wallis. Common house gecko. AIM H1593, H1596–7.

Futuna. Common house gecko. AIM H1615–7, H1619–20.

SAD GECKO *Lepidodactylus lugubris* (Duméril & Bibron, 1836)

Wallis. Common on ‘Uvea as a house gecko and in vegetation close to human habitations (AIM H1598–1600, H1605–8, H1611–3). Also found in vegetation distant from habitations (AIM H1624). Found on Nukuhione Islet close to a *fale* (AIM H1602–4). Of 13 adults from Wallis, seven seem closest to Clone C of Ineich & Ota (1992) and five seem to be Clone A. Members of the same clone were always found together. The thirteenth specimen (AIM H1624), from a forest tree away from human habitations, has a few irregularly spaced dorsal blotches and seems atypical. Other records: MNHN 1986.681–5.

Futuna. Common as a house gecko (AIM H1618, H1638–42) and in vegetation away from dwellings (AIM H1621). Other records: MNHN 1986.686, 1986.688 (Futuna); 1986.687 (‘Alofi). FMNH 211866–9 (‘Alofi, examined by I. Ineich, *pers. comm.*).

PACIFIC SLENDER-TOED GECKO *Nactus pelagicus* (Girard, 1857)

Futuna. One specimen found at Tavai in a taro field (AIM H1622).

SNAKE-EYED SKINK *Cryptoblepharus poecilopleurus* (Wiegmann, 1834)

Futuna. In December 1985 Thibault and Guyot collected an immature specimen (MNHN 1986.689; 25 mm SVL) from a littoral site on the north side of Point Vele.

MICRONESIAN SKINK *Emoia adpersa* (Steindachner, 1870)

Futuna. Peters (1874: 160) described a new species, *Euprepes (Mabuia) parvisquameus*, now synonymised with *E. adpersa* (see Schwaner & Brown 1984), from Western Samoa “und den Fidji-Inseln (Futuna)”. The syntypes are at ZMB (R. Günther, *pers. comm.*), not presumed lost as stated by Brown (1991). ZMB 5930 (77.1 mm SVL) and ZMB 53774 (74.6 mm SVL) are pale grey–brown with no dorsal striping, and dark speckling on the back, sides and limbs. They have 56 mid–body scale rows and 24–25 fourth toe lamellae, which agrees with the diagnosis of *E. adpersa* (Brown 1991). This confirms the presence of this species in Wallis and Futuna. *E. adpersa* is not unexpected as it occurs in Western Samoa and Niuafu’ou (northern Tonga; Gill, Rinke & Zug 1994) which are close to Futuna.

WHITE-BELLIED SKINK *Emoia cyanura* (Lesson, 1826)

Wallis. Common, in open areas, plantations, forest and forest edges. AIM H1562–72, H1574–8, H1592. Other records: MNHN 1986.656–60 (determined by I. Ineich).

Futuna. Common, as above. AIM H1579–81, H1585–8. Other records: MNHN 1986.663–4 (Futuna, determined by I. Ineich).

DUSKY-BELLIED SKINK *Emoia impar* (Werner, 1898)

Futuna. In January 1986 Thibault and Guyot collected two specimens (MNHN 1986.661–2, determined by I. Ineich) on ‘Alofi in forest 150 m above sea-level.

MURPHY’S SKINK *Emoia murphyi* Burt, 1930

Futuna. I saw *murphyi*-like skinks basking on several garden walls at Fiua, and caught three specimens (AIM H1582–4; 42–68 mm SVL). They have speckled dorsal surfaces and no longitudinal stripes, 28 mid-body scale rows and 61–69 fourth toe lamellae. This agrees with the meristics of *E. murphyi* from Samoa and Tonga which have 26–32 mid-body scales and 60–81 lamellae (Brown 1991). In life the Futuna specimens had a pale brown back and bright yellow-green underparts. In contrast, specimens of *E. murphyi* from Samoa and Tonga that I have seen in life had a greyish back and bright lime-green underparts.

In January 1986 Thibault and Guyot collected two specimens from forest near the shore on ‘Alofi (MNHN 1986.665–6; both 78 mm SVL) and a juvenile from a valley on Futuna (MNHN 1986.674; 33 mm SVL). In preservative all three specimens have darkened. There is now no sign of bright ventral colours, but for MNHN 1986.665 the MNHN catalogue notes “ventre et dessous de la tête très vert”. The Thibault–Guyot specimens were entered in the MNHN catalogue as *Emoia samoensis*, but they have 28 mid-body scale-rows and 61–67 fourth toe lamellae. I conclude that they belong to the same taxon as the AIM specimens.

Also conspecific is ZMB 5932 (46.5 mm SVL), collected last century, which has 28 mid-body scale-rows and 71 fourth toe lamellae.

PACIFIC BLACK SKINK *Emoia nigra* (Jacquinot & Guichenot, 1853)

Wallis. Common, in gardens, plantations and forest. AIM H1573, H1590–1. Other records: AMNH 40575–6 (‘Uvea); MNHN 1986.667 (‘Uvea), 1986.672–3 (Nukuloa Islet).

Futuna. Common, as above. Also seen foraging on supralittoral rocks and among creepers at the high-tide line on a sandy beach. Other records: MNHN 1986.668, 1986.671 (Futuna); MNHN 1986.669–70 (‘Alofi). ZMB 5927–9, 53772–3 (‘Futuna’); maximum SVL 107.7 mm.

DANDY SKINK *Emoia trossula* Brown & Gibbons, 1986

Futuna. I saw several large skinks basking on tree trunks in forest of the escarpment east of Leava. They were about as large as *E. nigra* and I took them to be *E. trossula* or *E. samoensis*. Watched closely through binoculars they were dark grey-green dorsally (almost as dark as *nigra*), with transverse bands and bright streaks just visible. The sides of the head were pale, and pale ventral colours extended dorsally a little at the sides.

In the hills behind Leava at about 100 m above sea-level I caught a juvenile skink (AIM H1589, 32 mm SVL) under the bark of a forest tree near a banana plantation. It is pale brown dorsally with dark transverse markings and has about 36 mid-body scale rows (the count varies between 34 and 39) and 44–45 fourth toe lamellae. This is within

the established range for Fijian *E. trossula* – mid-body scales 32–40, lamellae 43–54; Brown (1991) – though it is also close to the range for *E. samoensis*.

ZMB 5931 (82.5 mm SVL), collected from Futuna last century, is brown with a striking dorsal pattern of dark transverse bands and bright cream-coloured longitudinal streaks (Fig. 1). This pattern is typical of *Emoia trossula* but rare in *E. samoensis* (Brown 1991). ZMB 5931 has 32 or 33 mid-body scale rows, 39–41 fourth toe lamellae and 68–70 dorsal scale rows between the parietals and the tail base opposite the vent.

Because of the bright streaks on ZMB 5931, and the presence of such streaks on specimens that I saw through binoculars, I tentatively assign the Futuna population to *E. trossula*.

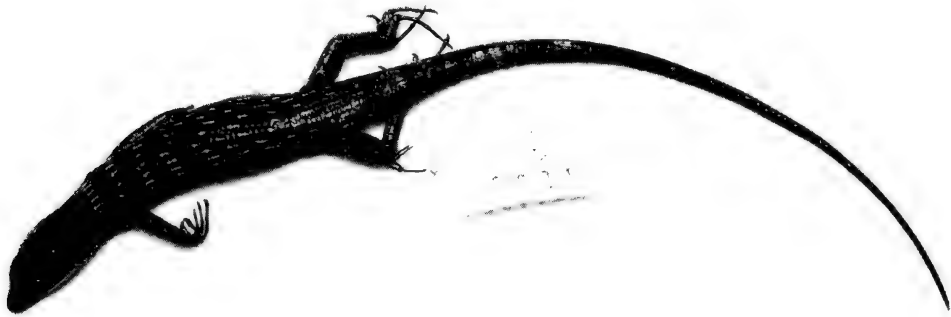


Fig. 1. *Emoia trossula* (ZMB 5931; 82.5 mm SVL) collected from Futuna last century. Photo: A. Carpenter.

PACIFIC BOA *Candoia bibroni* (Duméril & Bibron, 1844)

Futuna. Claude Lépert gave me a dried specimen (AIM H1626, c. 860 mm total length), and later sent me a spirit specimen (AIM H1637, c. 830 mm), both collected on 'Alofi. MNHN 1986.690, collected at Point Vele, Futuna, in 1985, is about 980 mm long. All three specimens have a rounded canthus rostralis, an enlarged preocular, and supralabials excluded from the eye by a row of small scales. These features establish that the specimens are *bibroni* and not one of the other two species of *Candoia* in the Pacific.

OTHER NOTES

I took fresh weights of lizards with a Pesola spring balance. The heaviest specimens were as follows: *Gehyra oceanica* 15.6 g, *Hemidactylus frenatus* 5.4 g, *Lepidodactylus lugubris* 1.8 g, *Emoia cyanura* 3.1 g, *E. murphyi* 5.7 g, *E. nigra* 19.9 g. Two or more species of house gecko in the same building were noted at three sites. *Lepidodactylus lugubris* was common to all. One site (Wallis) had *Gehyra oceanica*, one had *Hemidactylus frenatus* (Futuna) and the third (Wallis) had both.

There are many small lakes on 'Uvea and some frogs have been collected (MNHN 1986.691–3). I have not examined them but they are said to be the Australian species *Litoria aurea*, whose date of introduction is unknown. J.–C. Thibault (*pers. comm.*) found the frogs to be abundant during wet weather in January 1986 at lakes Kikila, Lanumaha and Alofivai. They were in lakeside vegetation and on the open water. Amplexus was noted.

DISCUSSION

On current evidence the confirmed terrestrial reptile fauna of Wallis and Futuna comprises 12 species – three geckos and two skinks on Wallis; four geckos, seven skinks and a terrestrial snake on Futuna (including ‘Alofi). The species list may increase still further. The most probable additions are the skink *Lipinia noctua*, and the geckos *Gehyra mutilata*, *Hemidactylus garnotii* and *Hemiphyllodactylus typus*, which are widespread in the Pacific.

All the species of lizards on Futuna are likely to occur on its neighbour ‘Alofi, and *vice versa*. It would not be surprising if *Nactus pelagicus* and *Emoia impar* turn up on Wallis, but the lesser diversity on Wallis, which is the same for land birds (Gill 1995), is probably real and reflects, at least partly, the greater destruction of forest habitats on Wallis. *Cryptoblepharus* may prove to be more common, although on both Wallis and Futuna I searched specifically for it on tree trunks, walls and rocks close to the shore, without success.

More specimens are needed to confirm the identity of skinks here recorded as *Emoia trossula* on the basis of a recently-collected juvenile and an adult from last century. Further work is also needed on the taxonomic status of *E. trossula* and *E. samoensis*. They are not well separated on scalation. Some Fijian, Tongan and Cook Island *trossula* lack the white streaks on the back and sides that tend to be diagnostic, whereas a few *samoensis* from Samoa have the streaks (Brown 1991). The presence on Futuna of *E. trossula* (or *samoensis* as the case may be) is not surprising given that between them the two species occupy all the main islands immediately to the south and east of Futuna. *E. trossula* has also been noted on Rotuma, Futuna’s nearest neighbour to the north-west (Zug *et al.* 1988).

Emoia murphyi, previously known only from Western Samoa and northern Tonga (Gill 1993), is now shown to occur further west on Futuna. This too is not surprising, since Wallis and Futuna lies only about 600 km west of the Samoas, and the two island groups are considered to belong together in a distinct biogeographic region (Dahl 1980). Similarly, the presence of *Candoia bibroni* on Futuna and ‘Alofi, though a new record not noted in the review by McDowell (1979), is not unexpected. This species occurs widely in the eastern Solomon Islands, Vanuatu, the Loyalty Islands, Fiji and the Samoas (McDowell 1979).

Acknowledgements. I thank the following staff of the *Services de l’économie rurale et de la pêche* for local transport by car and boat: André le Dréau, Hervé Cosson, Marc Sauvage and Dominique Sage. For kindness and hospitality I am indebted to André and Jean le Dréau, Dominique and Maryse Sage, Claude Sallès, Claude and Rose Lépert, François Gillmann and Malia Manusauaki. For providing specimens I thank Claude Lépert. I am grateful to Dr J.-C. Thibault for helpful correspondence and to Dr I. Ineich for lending specimens in the MNHN collection, commenting on an early draft of the paper and writing the French abstract. Dr J.-H. Dittrich helped me to trace the German specimens that Dr R. Günther kindly lent from ZMB. This study was partly funded by a grant from the Auckland Museum C.H. Worth Memorial Fund.

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FIVE NEW SPECIES OF *CLIMOCELLA* N. GEN. (PUNCTOIDEA: CHAROPIDAE)

J.F. GOULSTONE

Abstract. *Climocella* n. gen. is established to hold a group of charopid snails (family *sensu* Solem, 1979; 1982) with spirally lirate protoconchs that were left without a name when Climo (1981) used *Mocella* for the radially costate group then known as *Subfectola*. *Climocella akarana* n. sp., *C. cavelliaformis* n. sp., *C. haurakiensis* n. sp., *C. kaitaka* n. sp. and *C. rata* n. sp. are described, all living in Auckland and its environs. *C. maculata* (Suter, 1890) is redefined.

Iredale (1915), reviewing *Manual of the New Zealand Mollusca*, gave the name *Mocella* to Suter's group of *Endodonta corniculum* (Reeve, 1852), which had a "protoconch spirally striate". He selected *Helix corniculum* Reeve, 1852 as the type for this genus. Species in the genus were *Mocella alloia* (Webster, 1904), *M. corniculum* (Reeve, 1852), *M. kenepuruensis* (Suter, 1909), *M. prestoni* (Sykes, 1895), *M. segregata* (Suter, 1894) but he did not recognise *M. corniculum* var. *maculata* (Suter, 1891). Additions to the genus were *M. manawatawhia* (Powell, 1935), *M. accelerata* (Climo, 1970) but *M. alloia* was synonymised with *Allodiscus urquharti* Suter, 1894 (Climo 1970). Iredale (1941:91) found that *H. corniculum* had been used previously by Reeve so he substituted the name *Mocella cogitata* but Climo (1970) pointed out that a new name for the New Zealand *corniculum* was not needed as *Helix eta* Pfeiffer, 1853 was available. Climo (1970) also synonymised *M. kenepuruensis* and *M. corniculum* var. *maculata* with *M. eta*. Climo (1981) found that the holotype of *Helix eta* (British Museum (Natural History) reg. no. 1962725; this number was recorded only in his 1970 paper) had a protoconch with axial striations and a shell which he considered to be identical with one known to earlier collectors by the species name *caputspinulae* (Reeve, 1852) and finally placed by Powell (1939) in a subgenus *Fectola* (*Subfectola*). Climo (1981) further found that the holotype of *Helix caputspinulae* Reeve, 1852, the type species for *Subfectola* (British Museum (Natural History) reg. no. 1962724), had also been misidentified and was a snail in the pulmonate family Punctidae Morse, 1864. The name *caputspinulae* thus became the earliest for the type species of *Paralaoma* Iredale, 1913 and *Subfectola* a synonym of *Paralaoma*. Roth (1987) covers the synonymies of the widely distributed and much named *Paralaoma caputspinulae* in more detail. Climo then used the name *Mocella* to describe the former members of *Subfectola* and the type for the genus became *Mocella eta* Pfeiffer, 1853. Because of the complexity of the changes, under "Systematics" I have given full synonymies of the type species for *Mocella* and *Fectola* up to 1981. Note that Climo (1978) found another misidentification in the type species of *Fectola* so that the genus in the list below is not the present day *Fectola*, but the one envisaged by Iredale. This use of Iredale's names in a sense differing from his original intent caused some confusion and Hazelwood (1991) discusses the implications in greater depth.

Climo (1981) failed to formally supply a name for the remaining genus after he transferred the name *Mocella*. In this paper I therefore propose a new genus, *Climocella*, based on *maculata* Suter, 1890 and four of the new species described below. The group is

distinctive in having up to 12 lirae on the protoconch. In a more general way the individual species have 3.5 to 4.5 accelerating whorls, post-nuclear sculpture of axial ribs with finer axials between, microscopic spiral sculpture sometimes going over the primary axials and a moderately open umbilicus. The spire is sunken to slightly raised and shells are uniform white or colour patterned. Although protoconch sculpture alone is not sufficient to hold species within a genus when anatomical details may suggest other affinities, it has been a very convenient feature for separating this group and I will maintain the status quo for this paper. Solem (1983: 167, 168) transferred some Pacific snails from *Mocella* to *Sinployea* Solem, 1983 on evidence from dissected penial material but stated his action was “somewhat arbitrary”.

On shell features only, members of the group are difficult to separate and previous workers have relied heavily on finer protoconch details. Auckland is one area in which the genus is prominent but it has always been difficult to ascertain the number of species present or to satisfactorily separate them. This paper is limited to describing five species from around Auckland that differ in a mixture of shell and anatomical features, without giving total distribution details, and redefining *C. maculata* which has a southern distribution and on which the new genus will be based. Four of these species, and perhaps five, were represented in the list of material examined by Climo (1970:316) and designated “*Mocella eta*”. The illustration he gave of this species was of a shell from Rangitoto which was almost certainly *Climocella haurakiensis* n. sp. Anatomical details have been published for *C. maculata* by Climo (1970:351, fig. A), *C. manawatawhia* by Climo (1973:614, fig. F) and an unnamed species from Te Pahi, Northland by Climo (1970:351, fig. C). *C. manawatawhia* is confined to the Three Kings Islands on present evidence.

In the present study drawing has been freehand from material viewed under a dissecting microscope up to 100X magnification with a linear graticule. Illustrations of shells (Figs 1-9), protoconchs (Figs 10-17) and anatomy (Figs 18-49) are grouped together for comparative purposes. I have endeavoured to show salient features of anatomy that will facilitate separation of species without detailed dissection. The scanning electron micrographs were kindly made available by the Museum of New Zealand from images held on file.

The taxon descriptions and distributions given in this paper are based on specimens held in the Auckland Museum (AIM; lot numbers preceded by “AK”) and the Museum of New Zealand (NMNZ; lot numbers preceded by “M”). The initial digits 123 have been dropped from the M numbers in the lists of “Other Material Examined”. For type material, the number of specimens is given in parentheses following the accession number. The following names, which appear often in the distribution records, are referred to by initials only: F.M. Climo, J.F. Goulstone, B.F. Hazelwood, P. Mayhill, D.J. Roscoe. Map references are from the N.Z.M.S. 260 series and all dates refer to the 20th century.

SYTEMATICS

SUPERFAMILY: PUNCTOIDEA Morse, 1864.

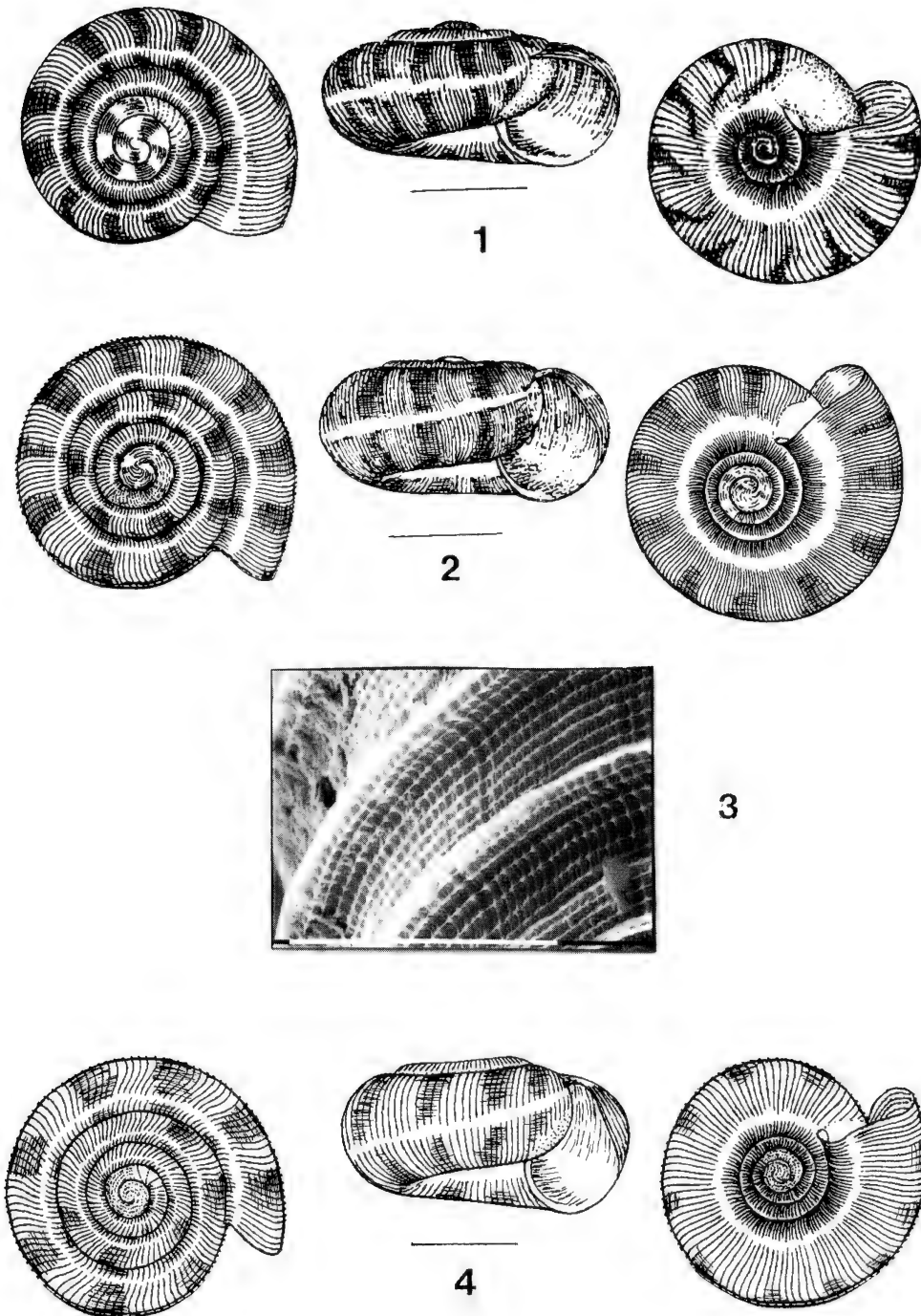
FAMILY: CHAROPIDAE Hutton, 1884.

GENUS: *MOCELLA* Iredale, 1915

TYPE SPECIES: *Helix corniculum* Reeve, 1852 (by original designation).

1852 *Helix corniculum* Reeve (1851 = 1852): *Conch. Icon.*, 7, pl. 133, fig. 826 (non Reeve, 1852, pl. 92, fig. 502).

1853 *Helix eta* Pfeiffer: *Monog. Heliceorum viventium* 3:107.



Figs 1-4. Shell details. Scale line on line drawings = 1 mm, on micrograph each division = 0.1 mm. 1. *Climocella maculata* (Suter), Mt. Cook, Hooker Valley, Governors Bush, A.E. Brookes c. 1930, 2.6 mm x 1.4 mm (AK85035). 2. *C. akarana* n. sp., Clevedon, 2.5 mm x 1.25 mm (holotype AK72702). 3. *C. akarana* n. sp., Waiuku (M.69276). 4. *C. cavelliaformis* n. sp., Waiwera, 2.75 mm x 1.4 mm (holotype AK72704).

- 1878 *Patula eta* (Pfr.): *Nomencl. Hel. Viv.*: 98.
 1884 *Patula corniculum* (Rve.): Hutton, *Trans. N.Z. Inst.* 16:192.
 1890 *Patula corniculum* var. *maculata* Suter, *Trans. N.Z. Inst.* 23:89.
 1892 *Patula eta* var. *maculata* (Suter): Pilsbry, *Man. Conch.* 2(8):96.
 1893 *Charopa corniculum* (Rve.): Hedley & Suter, *Proc. Linn. Soc. N.S.W.* 2(7):655.
 1893 *Charopa corniculum maculata* (Suter): Hedley & Suter, *Proc. Linn. Soc. N.S.W.* 2(7):655.
 1894 *Endodonta* (*Charopa*) *corniculum* (Rve.): Suter, *J. Conchyliol.* 41:264.
 1894 *Endodonta* (*Charopa*) *maculata* (Suter): *J. Conchyliol.* 41:265.
 1909 *Endodonta* (*Charopa*) *kenepuruensis* Suter: *Proc. Malac. Soc. Lond.* 8:218.
 1915 *Mocella corniculum* (Rve.): Iredale, *Trans. N.Z. Inst.* 47:482.
 1915 *Mocella kenepuruensis* (Suter): Iredale, *Trans. N.Z. Inst.* 47:482.
 1937 *Mocella corniculum* (Rve.): Powell, *Shellfish of New Zealand*: 89.
 1941 *Mocella cogitata* Iredale: *Australian Zoologist* 10:91.
 1946 *Mocella cogitata* Iredale: Powell, *Shellfish of New Zealand*, 2nd ed.: 94. Also 3rd ed., 1958:119, and 4th ed. 1962:112, 1967:112.
 1970 *Charopa* (*Mocella*) *eta* (Pfr.): Climo, *Rec. Dom. Mus.* 6(18):314.
 1976 *Charopa* (*Mocella*) *eta* (Pfr.): Powell, *Shellfish of New Zealand*. 5th ed.:116.
 1979 *Charopa* (*Mocella*) *eta* (Pfr.): Powell, *N.Z. Mollusca*: 310.

GENUS: *PECTOLA* Iredale, 1915

SUBGENUS: *SUBPECTOLA* Powell, 1939.

TYPE SPECIES: *Helix caputspinulae* Reeve, 1852.

- 1852 *Helix caputspinulae* Reeve: *Conch. Icon.*: 7, pl. 133, fig. 818.
 1853 *Helix epsilon* Pfeiffer: *Monog. Heliceorum viventium* 3:97.
 1878 *Patula* (*Charopa*) *epsilon* (Pfr.): *Nomencl. Hel. Viv.*: 97.
 1880 *Paryphanta epsilon* (Pfr.): Hutton: *Man. N.Z. Moll.*: 23.
 1884 *Microphysa caputspinulae* (Rve.): Hutton, *Trans. N.Z. Inst.* 16:194.
 1887 *Patula* (*Microphysa*) *epsilon* (Pfr.): Tryon, *Man. Conch.* 2(3):102.
 1893 *Charopa caputspinulae* (Rve.): Hedley & Suter, *Proc. Linn. Soc. N.S.W.* 2(7):659.
 1894 *Endodonta* (*Charopa*) *caputspinulae* (Rve.): Suter, *J. Conchyliol.* 41:266.
 1913 *Endodonta* (*Charopa*) *caputspinulae* (Rve.): Suter, *Manual of N.Z. Mollusca*: 715.
 1915 *Fectola caputspinulae* (Rve.): Iredale, *Trans. N.Z. Inst.*: 481.
 1939 *Fectola* (*Subfectola*) *caputspinulae* (Rve.): Powell, *Rec. Auck. Inst. Mus.* 2(4):238.
 1946 *Fectola* (*Subfectola*) *caputspinulae* (Rve.): Powell, *Shellfish of New Zealand*, 2nd ed.:94. Also 3rd ed., 1958:119, 4th ed., 1962:112, 1967:112 and 5th ed., 1976:116.
 1970 *Charopa* (*Subfectola*) *caputspinulae* (Rve.): Climo, *Rec. Dom. Mus.* 6(18):330.
 1979 *Charopa* (*Subfectola*) *caputspinulae* (Rve.): Powell, *N.Z. Mollusca*: 309.
 1981 *Mocella eta* Pfeiffer = *Subfectola caputspinulae* sensu Powell 1939 not Reeve 1852: Climo, *Rec. Nat. Mus.* 2(3):9.

GENUS: *CLIMOCELLA* n. gen.

TYPE SPECIES: *Patula corniculum* var. *maculata* Suter, 1890.

Helix of authors (not of Linnaeus, 1758).

Patula of authors (not of Held, 1837).

Endodonta of authors (not of Albers, 1850).

Charopa of authors (not of Albers, 1860).

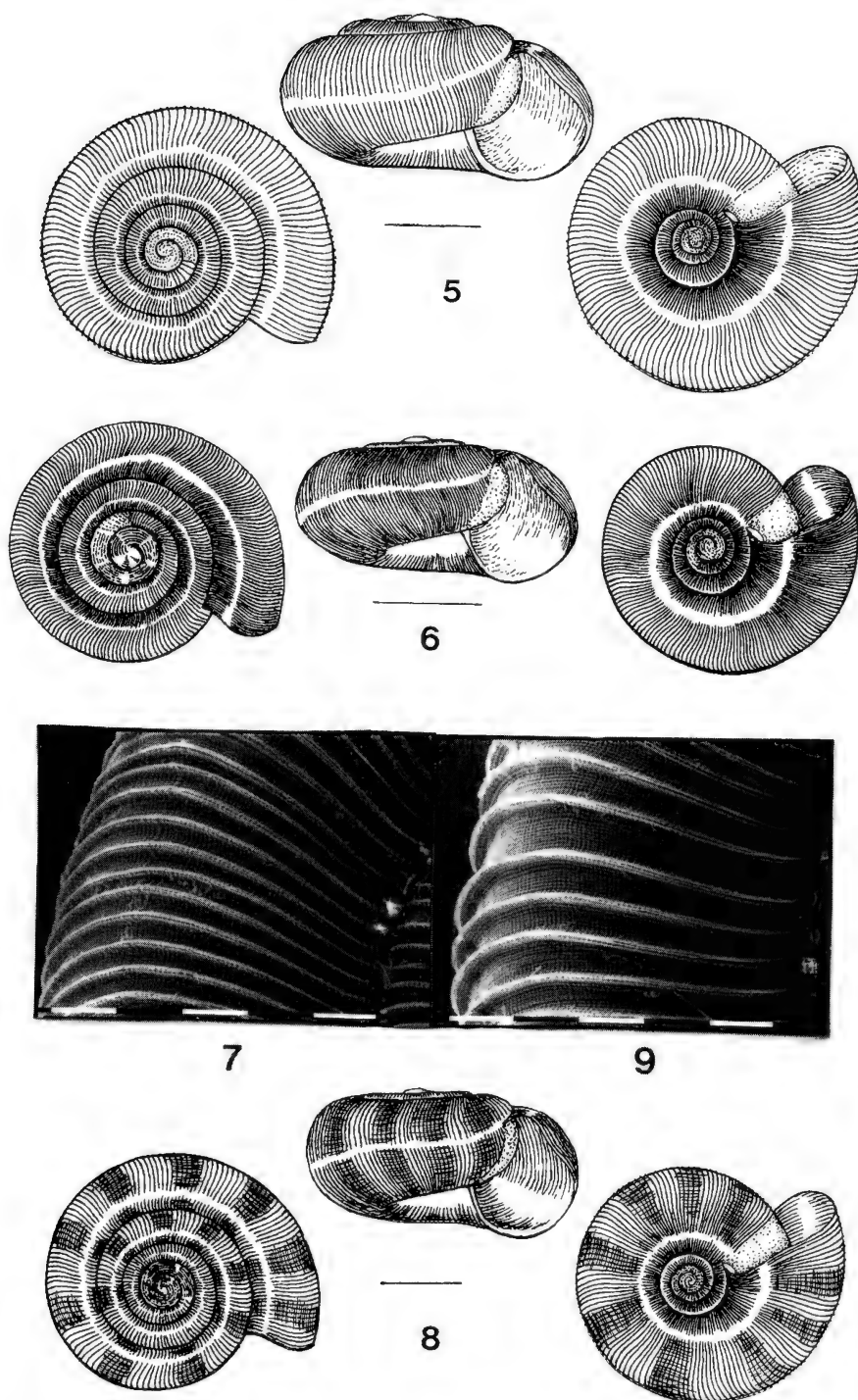
Mocella Iredale, 1915. Type species *Helix corniculum* Reeve 1852 (original designation) (preoccupied) = *Helix eta* Pfeiffer, 1853 = *Mocella cogitata* Iredale, 1941.

Mocella: Powell (1937, 1946, 1957, 1961, 1967).

Charopa (*Mocella*): Climo (1970).

Charopa (*Mocella*): Powell (1976, 1979).

Type specimen *Helix eta* Pfeiffer, 1853 misidentified, Climo (1981).



Figs 5-9. Shell details. Scale line on line drawings = 1 mm, on micrographs each division = 0.1 mm. 5. *Climocella haurakiensis* n. sp., The Noises, 3.45 mm x 2.1 mm (holotype AK72707). 6. *C. kaitaka* n. sp., Clevedon, 2.65 mm x 1.45 mm (holotype AK72709). 7. *C. kaitaka* n. sp., Mercer (M.69257). 8. *C. rata* n. sp., Hunua Ranges, Whakatiwai, 3 mm x 1.7 mm (holotype AK72713). 9. *C. rata* n. sp., Hapuakohe Range (M.63494).

“*Mocella*”: Brook & Goulstone (1995:8), Goulstone (1983:20-21, 1986:11, 1990:25, 1991:9, 1992:20), Goulstone *et al.* (1993:11), Mayhill (1994:51), Solem, Climo & Roscoe (1981:477).

ETYMOLOGY: Named for Dr Frank Climo.

GENERIC DESCRIPTION

Shell up to 3 mm in diameter. Four whorls, subdiscoidal. Spire flat or slightly convex, umbilicate, with straight, sinuous or slightly protractive axial ribs and fine secondary axials reticulated by spiral lirae. Ribs sharp, or rounded with the microscopic spiral lirae running over them. Protoconch with up to 12 prominent spiral striae often with a denser layer of spiral sculpture visible underneath. In some species the final section of the protoconch has axials which may be quite strong and wider apart than the teleoconch ribs or weaker and angled causing a cross-hatching with the spirals. Colour can be uniform white, brown or with a colour pattern of reddish brown axial bands or blotches over a white or straw background. Animal white, some species with a little white pigmentation on the albumen gland and stomach. A prominent epiphallus about the length of the expanded section of the penis, often inflated where it joins the vas deferens. Tubular base of spermathecal duct, oviduct and distal portion of the penis, usually long, thin and of similar length, often lying together and hard to separate in the retracted animal. Kidney bi-lobed, pericardial lobe much larger in some species. This generic description is based on the species *Climocella maculata* (Suter, 1890), *C. akarana* n. sp., *C. cavelliaformis* n. sp., *C. kaitaka* n. sp. and *C. rata* n. sp.

***Climocella maculata* (Suter, 1890) new combination Figs 1, 10, 18-21, 50**

- Patula corniculum* var. *maculata* Suter, 1890, *Trans. N.Z. Inst.* 23:89.
Patula eta var. *maculata* (Suter): Pilsbry (1892), *Man. Conch.* 2(8):96.
Charopa corniculum (Rve.) (in part): Hedley & Suter (1893), *Proc. Linn. Soc. N.S.W.* 2(7):655.
Charopa corniculum maculata (Suter): Hedley & Suter (1893), *Proc. Linn. Soc. N.S.W.* 2(7):655.
Endodonta (Charopa) corniculum (Rve.) (in part): Suter (1894), *J. Conchylol.* 41:264.
Endodonta (Charopa) corniculum maculata (Suter): Suter (1894), *J. Conchylol.* 41:265.
Endodonta (Charopa) kenepuruensis Suter, 1909 (in part), *Proc. Malac. Soc. Lond.* 8:218.
Mocella corniculum (Rve.) (in part): Iredale (1915), *Trans. N.Z. Inst.* 47:482.
Mocella kenepuruensis (Suter) (in part): Iredale (1915), *Trans. N.Z. Inst.* 47:482.
Mocella corniculum (Rve.) (in part): Powell (1937), *Shellfish of New Zealand*: 89.
Mocella cogitata Iredale, 1941 (in part), *Australian Zoologist* 10:91.
Mocella cogitata Iredale (in part): Powell (1946), *Shellfish of New Zealand*, 2nd ed.:94. Also 3rd ed., 1958:119, and 4th ed. 1962:112, 1967:112.
Charopa (Mocella) eta (Pfr.) (in part): Climo (1970), *Rec. Dom. Mus.* 6(18):314.
Charopa (Mocella) eta (Pfr.) (in part): Powell (1976), *Shellfish of New Zealand*. 5th ed.: 116.
Charopa (Mocella) eta (Pfr.) (in part): Powell (1979), *N.Z. Mollusca*: 310.
“*Mocella*” *maculata* (Suter, 1890): specimens in the Museum of N.Z. collections and known as such to N.Z. malacologists.

ETYMOLOGY: Derived from Latin, *macula* is a spot or mark.

REDESCRIPTION

Shell small, up to 2.7 mm x 1.4 mm, of 3.5 whorls, the last somewhat expanded, subdiscoidal, spire raised a little, suture moderately impressed. Protoconch of 1.25 whorls,

with 9 spiral lirae that stop at some widely spaced slightly oblique axials in the last quarter whorl (Fig. 10). These axials are sometimes weak or can be missing. Teleoconch with strong ribs, rounded on top, nearly straight. Interstices (about 1.5 times the width of the rib at most) with fine axials and weaker microscopic spirals. Ribs on the first teleoconch whorl number about 58 and on the final whorl 23 per mm. Umbilicus diameter about a quarter of the shell width, gradate. Colour horny with rather dull reddish brown axial bands at irregular intervals.

Penis a narrow rather knobby tube leading from the atrium into an irregularly shaped thicker organ. Epiphallus about the same length as the whole penis, entering the penis apex alongside the insertion of the short but thick retractor muscle. Epiphallus with a small bulge on one side where it joins vas deferens. Vagina long. Base of spermathecal duct relatively short and narrow, about two thirds length of vagina and one third its width. Spermoviduct with prominent, ovate, colourless bulge on one side, with oesophagus imbedded in a groove along this swelling (Fig. 20), prostatic gland set into it proximally and salivary glands nestled against distal end. Hermaphroditic duct exiting about half way along the albumen gland with long straight thickened section (1.25 mm approx.). Hermaphroditic glands positioned a third of the way along the digestive gland (Fig. 21). Kidney weakly bilobed, pericardial lobe stronger than rectal lobe.

REMARKS

The type specimens come from Hooker Valley, Mt. Cook. At the time of writing three of these types were affected with museum disease but easily recognisable as *Climocella maculata*. Climo (1970) records three syntypes with measurements but there were actually four syntypes in the tube and one (M.125411) is not *C. maculata*. I have chosen a lectotype from the three similar specimens. This shell description is of a specimen from the type locality collected by A.E. Brookes c. 1930 (AK85035, Fig. 1). The anatomical description was based on the dissection of one snail from Pongaroa, Hawkes Bay, collected by D.J. Roscoe 19/4/70, and appears identical with the dissection recorded by Climo (1970:351, fig. A) from Banks Peninsula.

From his distribution list Suter clearly considered all the coloured *Mocella* species as variety *maculata*. Climo (1970) sank *maculata* (Suter, 1890) to synonymy of *Mocella eta* (Pfeiffer, 1853). *C. maculata* can be recognised by its accelerating whorls, blotchy colour pattern, few or lack of secondary radials on the protoconch and distinctive spermoviduct easily seen with very little dissection.

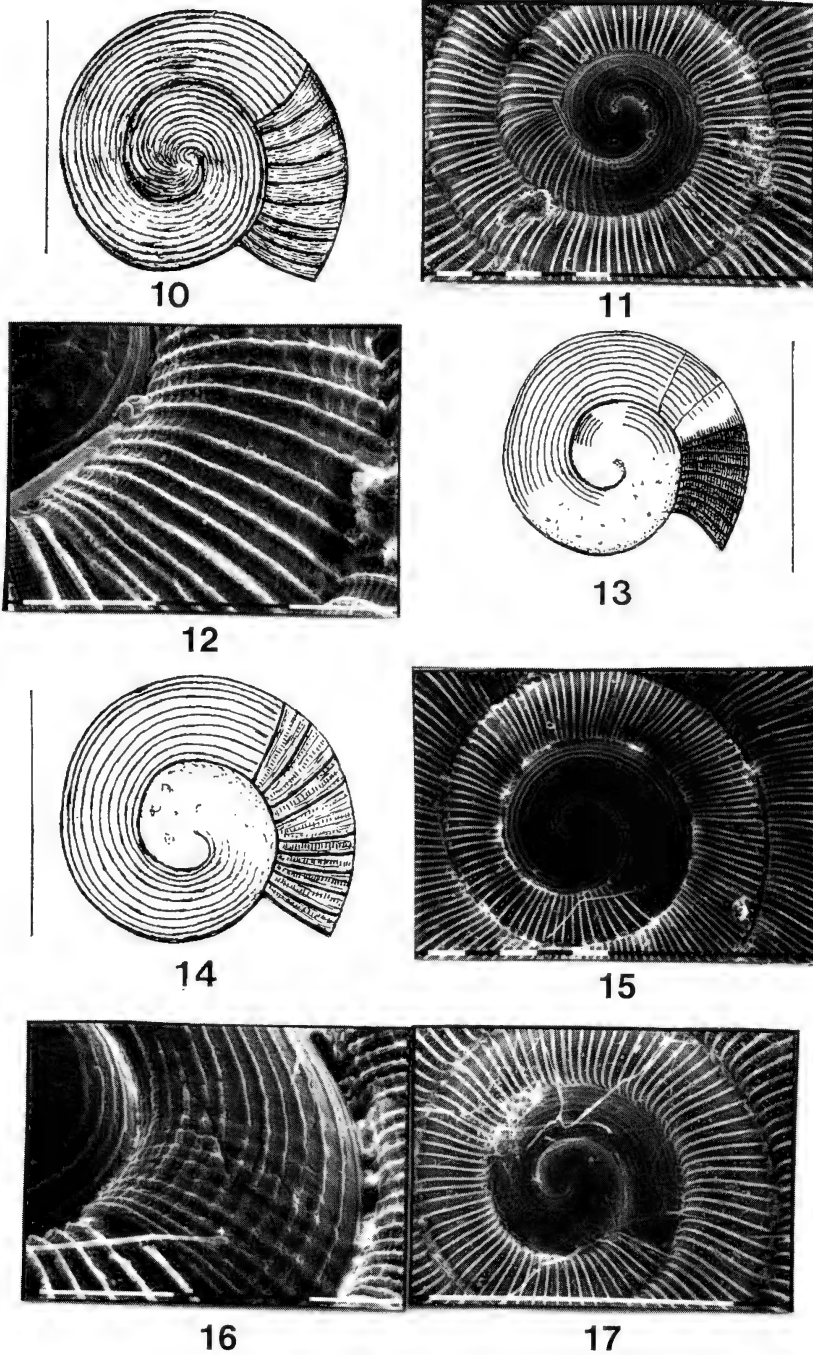
TYPE LOCALITY: Mt. Cook, Hooker Valley.

LECTOTYPE: NMNZ M.125151, 2.65 mm x 1.4 mm.

PARALECTOTYPES: Hooker Valley, NMNZ M.125410 (2); NMNZ M.125411 (1).

OTHER MATERIAL EXAMINED

Chatham Island: Many sites J.F.G. -/2/89, AK95603, AK95606, AK95616, AK95618, AK95650, AK95665, AK95711, AK95729, AK96441, AK96443. **Hawkes Bay:** Tangaio V20 446056, V20 447028, D.J.R. 16/12/94, M.120565-7; Pongaroa, D.J.R. 19/4/70; Napier, Poriate in middens V21, Otago School of Mines, AK95359. **Kaikoura:** Goose Bay O32 531589, J.F.G. 12/2/94, AK96379; Blue Duck Scientific Res., rimu P31 750858, J.F.G. 10/2/94, AK96382; Sawcut Gorge P29 916242, J.F.G. 9/2/94, AK96380. **Lyttelton:** Dyers Pass



Figs 10-17. Protoconch details. Scale line on line drawings = 0.5 mm, on micrographs each division = 0.1 mm. 10. *Climocella maculata* (Suter), Mt. Cook, Governors Bush (AK85035). 11-12. *C. akarana* n. sp., Waiuku (M.69276). 13. *C. cavelliaformis* n. sp., Waiwera (holotype AK72704). 14. *C. haurakiensis* n. sp., The Noises (holotype AK72707). 15-16. *C. kaitaka* n. sp., Mercer (M.69257). 17. *C. rata* n. sp., Hapuakohe Range (M.63494).

M36, H. Suter, AK85034. **Mt. Cook:** Hooker Valley, Governors Bush, A.E. Brookes, AK85035, AK96384. **Otago:** Shag Point, C.R. Laws, AK26427; Dunedin, Grahams Bush I44 222860, J.F.G. 20/1/91, AK96381; Waitati I44, A.W.B. Powell 1927, AK85033; Herbert Forest, kahikatea J42 319487, J.F.G.15/2/94, AK96385. **Wellington:** Te Aro St. R27 577887, D.J.R. 13/12/94, M.120564; Palliser Bay, Turanganui S28, A.C. O'Connor 1/9/46, AK85631.

DISTRIBUTION

The above is not an exhaustive list of museum holdings but establishes the main range of the species and representative areas of particular abundance in eastern and central parts of both islands from Hawkes Bay to Otago plus the Chathams. There is some shell variation within this range and *C. kenepuruensis* Suter needs to be evaluated before a more detailed distribution is established. In this respect the distribution map (Fig. 50) is also an approximation.

Climocella akarana n. sp. Figs 2, 3, 11, 12, 22-27, 50

Charopa (Mocella) eta Climo 1970:314, Powell 1979:310 (in part).

"*Mocella*" n. sp. aff. *maculata* Solem, Climo & Roscoe 1981:477.

"*Mocella*" sp. 3 Goulstone 1983:21; 1986:11; 1990:25; 1991:6,9; 1992:21 (in part).

In the Museum of New Zealand collection and among workers it has been designated "*northern maculata*".

ETYMOLOGY: The Maori name for Auckland is *Akarana*.

DESCRIPTION

Shell small, 2.8 mm x 1.5 mm, up to four whorls, subdiscoidal, spire slightly raised in most specimens but apex sunken in a few. Protoconch 1.5 whorls, with 9-10 spiral lirae, crowded near centre, more widely spaced over rest of surface; last third of protoconch with secondary axials starting faintly and very oblique, reticulated by spirals, getting stronger and straighter as teleoconch ribs are reached (Figs 11, 12). Teleoconch with axial ribs, strong at the base with rounded tops, interstices (twice the width of the ribs at widest) with fine radials reticulated by strong microscopic spirals, these crossing the main ribs as well. First teleoconch whorl with about 84 ribs sometimes wider apart at start. Ribs on fourth whorl about 24 per mm. Sutures deep causing prominent shoulder on body whorl. Umbilicus wide, its diameter a quarter to a third of shell width. Colour horny with regular reddish brown axial bands of variable width. These markings seem to vary locally and at some locations the reddish brown bands are bold and sharp.

Proximal section of penis thick, narrowing in the distal section, both parts of equal length. Epiphallus, about same length as total length of penis, entering penis alongside retractor muscle. Epiphallus quite bulbous where vas deferens joins, this feature being easily seen through pallial cavity membranes. Vagina short, free oviduct long, narrow, proximal section folded. Enlarged section of spermathecal duct wider than the oviduct at its origin but very slender towards the receptacle. Oesophagus, flanked by two small salivary glands, leaves the buccal mass level with the distal end of spermoviduct (Fig. 27). Albumen gland, abutting the base of kidney, is caught up in coils of intestine. Spermathecal sac rests against albumen gland at proximal end of spermoviduct. Hermaphroditic duct enters just at base of albumen gland, fine at point of entry but almost immediately thickening for about 0.4 mm. Structure

of the lobes of the two hermaphroditic glands, positioned nearly half way down digestive gland, hard to ascertain but proximal one was always smaller (Figs 24, 26).

REMARKS

Four specimens were dissected; Waikowhai Reserve (1), Clevedon Scenic Reserve (1), Rangitoto (2). This is the commonest and hardest *Climocella* around Auckland but can look very different at various locations. At the type locality the shells are almost colourless or have very pale markings whereas at Rangitoto they have bright colour markings and tend to grow larger, 2.8 mm was common whereas 2.5 mm was normal at “Ngaheretuku”. Obviously the colour-pattern is the main feature of *C. akarana*, for the next in abundance, *C. kaitaka*, has a plain shell. Unfortunately, worn specimens of *C. akarana* exhibit little or no colour-pattern and gerontic specimens can look very like other *Climocella*. Considered over a wider area *C. akarana* looks like *C. maculata* but with closer whorls, sometimes stronger colour-pattern and a wider umbilicus. There is no evidence that *C. maculata* lives near Auckland. Protoconch details for *C. akarana* will be the most useful for separating it as the other colour-patterned species do not have the strong secondary axials. In anatomy, the bulbous end of the epiphallus, squeezing out *in situ* between penis and spermoviduct midway beneath the pallial cavity, is a useful distinguishing feature.

TYPE LOCALITY: R11 898669, Manukau City, Clevedon, Twilight Rd., Royal Forest & Bird Protection Society Reserve, “Ngaheretuku”. Under a large kahikatea (*Podocarpus dacrydioides*) growing in the headwaters of a small stream where it was damp and dark.

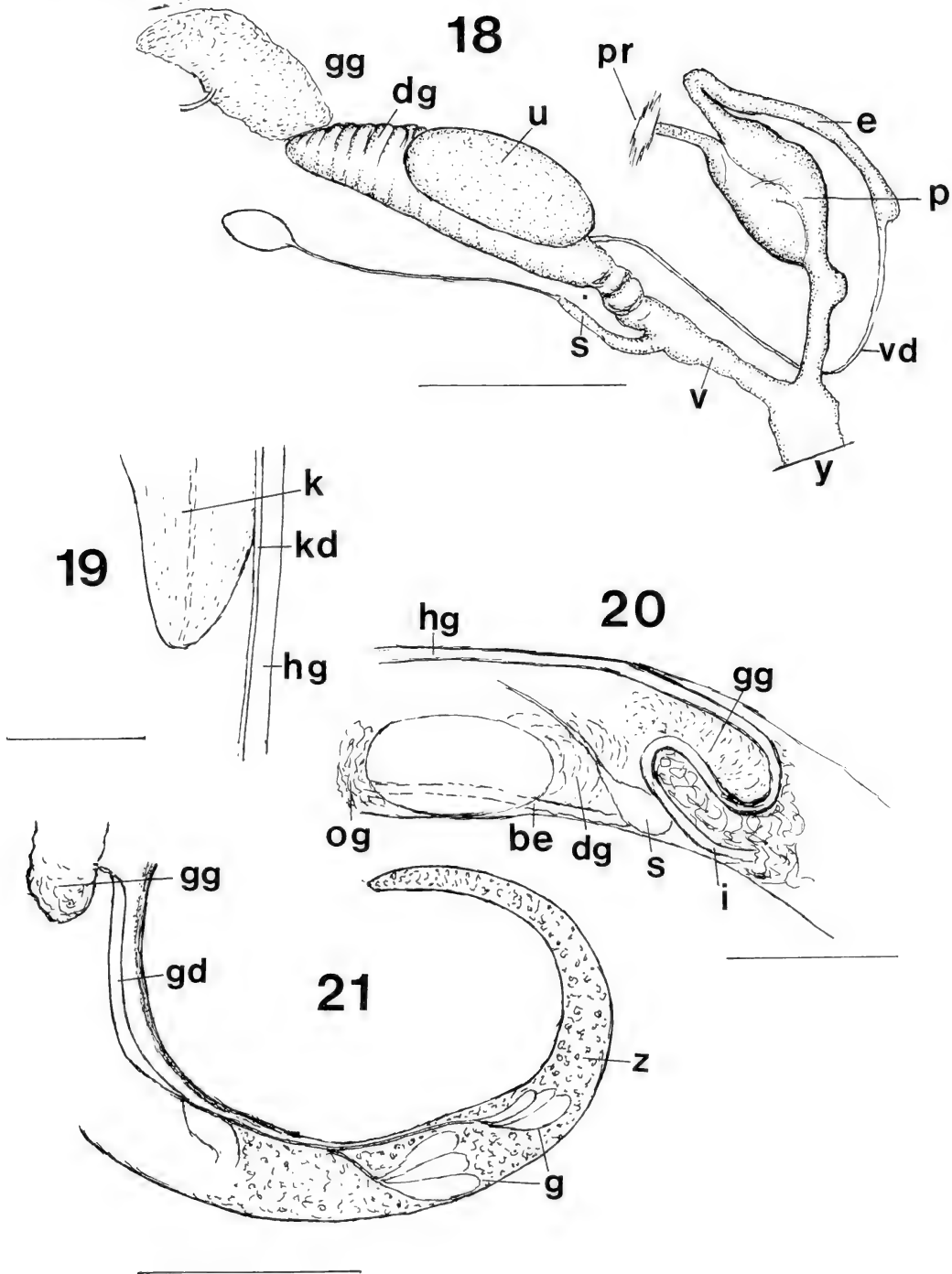
HOLOTYPE: Auckland Museum AK72702, 2.5 mm x 1.25 mm. J.F.G. 1/10/85.

PARATYPES: All from type locality. AK72703 (14) AK72711 (1), J.F.G. 1/10/85. NMNZ M.125006 (15) J.F.G. 1/10/85.

OTHER MATERIAL EXAMINED

Auckland: Mt. Wellington lava field R11, A.W.B. Powell 31/10/26, AK85606, C.A. Fleming, M.30610; Waikowhai R11, 28/2/26, AK85608; Lynfield, G. Kuschel 4/5/75, M.61784; Sylvania Cres., Blockhouse Bay, B.F.H 8/3/94, M.116736, B.F.H. & H. Taylor 4/10/86, M.99479; Mangere Mountain R11 762709, J.F.G. 1976, AK96617; Mangere Oxidation Ponds R11 659674, subfossil, J.F.G. 28/2/92, AK96660. **Auckland North:** Kaipara Pen. Q09, N. Douglas 22/10/72, AK85648; Whangateau Beach, B.F.H. 31/1/87, M.99469; Warkworth, Sandspit, B.F.H. & D.J.R. 25/12/78, M.104376; Okura Walkway R10 631018, J.F.G. 4/2/93, AK85622; between Waimauku & Muriwai, A. Suter, AK85632. **Auckland North Shore:** Birkenhead, Muriel Fisher Res., R11 626865, J.F.G. 16/1/94, AK87681; Tui Glen Bush, B.F.H. M.47755; Kendalls Beach, B.F.H. 1/1/91, M.107794. **Auckland South:** Raventhorpe Sc. Res. R12 848466, J.F.G. 31/7/88 AK85617; Mt. William Sc. Res., S12 904410, J.F.G. 1/4/84, AK96635, B.F.H. 1/10/83, M.78945, B.F.H. 7/10/84, M.80264; Patumahoe, Hunter Res., R12 737443, J.F.G. 1/9/85, AK96651; Manukau South Head, W. La Roche, AK85612; Pokeno, Tuakau Rd., 3.6 km from Pokeno P.O. B.F.H., M.68636. **Bowentown:** Heads, Tauranga Archaeological Surv., B. McFadgen 16/11/84, M.85843. **Coromandel Peninsula:** Port Jackson Sc. Res. S10 202202, J.F.G. 1/1/79, AK96649, AK96748; Port Jackson S10 221195, J.F.G. 1/1/78, AK96650; Moehau, Hope Str. S10 255133, J.F.G. 17/1/82, AK85624; Stony Bay, N. Douglas 6/1/69, AK85611; Colville: 250 m S of

motel T10 309048, D.J.R. 4/9/88, M.101072, T10 308036, 60 m P.M. 1/5/81; Matapua Bay T10 609919, 10 m, P.M. 1/3/94; Otama Forest Park T10 545912, 80 m, P.M. Waitara Rd. T10 555917, 60 m, P.M. 1/3/94. Korapuki Is. T10 652007, 40 m, P.M. 1/3/94. Stanley Is. T10 683031, 80 m, P.M. 1/3/94. Kauaeranga Valley, Waiwawa Hut T12 452596, AK96663, T12 459542, AK96664, J.F.G. 1/1/79; Whitianga, Mill Ck. T11 473766, J.F.G. 1/3/83, AK96666; Hot Water Beach, P.M. 1/9/77, M.76161; Tairua, Charlottes Farm, P.M. 1/5/81, M.76242; base of Karangahape Bluff, P.M. 1/1/81, M.82100. **Fitzgerald Glade:** Rotorua highway, A.G. Beu, 20/1/61, M.23408. **Great Barrier Island:** R.G. Ordish 23/11/63, M.31008; S08 277636, D. Hunt 1/2/87, M.100242; Whangaparapara S08 257508, AK85600, S09 264501, AK96624, J.F.G. 12/1/81; Port Fitzroy S08 226567, J.F.G. 26/3/90, AK96662; Northern Block S08 269618, J.F.G. 24/3/90, AK96625; Harataonga Sc. Res. T08 308555, J.F.G. 25/3/90, AK96636. **Gulf Islands:** Waiheke S11, G. Sadler, AK95056; Ponui Island, S11 055788, M. Walker 29/11/71, AK96616; Rangitoto, R11 765867, J.F.G. 26/9/76, AK96630, AK96693; The Noises: Motuoropapa R10 85994, J.F.G. 4/11/94, AK96626, P. Moors 1/4/78, M.57909; Scott Is., G.W. Ramsay 20/8/78, M.73616. **Hamilton:** Boundary Rd., B.F.H. 16/8/77, M.62744; Karapiro T15 426585, 19/10/82, M.73954; Raglan Rd., Forest Res. 8.85 km from Raglan intersection, B.F.H. 30/5/76, M.47765. **Hapuakohe Range:** Te Hoe S13 181110, B.F.H. 7/10/78, M.63527, M.63524, M.63493. **Hunua Ranges:** Whakatiwai Reg. Park S12 116550, J.F.G. 23/1/92, AK85612; Mangatawhiri S12, L. Fitzgerald 12/12/72, AK8604, S12 019531, J.F.G. 1/6/76, AK96086, S12 023531, J.F.G. 1/6/76, AK96620; Duders Bush S11 943738, J.F.G. 11/3/90, AK96087; Clevedon Sc. Res. S11 917665, J.F.G. 19/3/95, AK96586; Hunua Gorge, R12 887563, J.F.G. 1/8/84, AK96633, B.F.H. 3/5/76, M.47873; Mangatangi Dam, S12 067510, J.F.G. 1/12/85, AK96638; Wairoa Gorge S11 949615, J.F.G. 1/10/84, AK96641; Wairoa Dam S12 987528, J.F.G. 1/8/79, AK96643; Te Morehu Res. S11 043682 J.F.G. 1/8/83, AK96653; Cosseys Dam S12 974568, J.F.G. 1/3/83, AK96654; Red Hills Sc. Res. R12 862573, J.F.G. 8/9/86, AK96758. **Kawhia:** Te Kauri Park, B.F.H. 15/8/77, M.69866. Harbour Scenic Res., B.F.H. 15/8/77, M.72276, M.62620; Andersons Bluff, B.F.H. 22/10/77, M.57597. **Matamata:** A.E. Brookes, AK85598. **Ngaruawahia:** C. Broomfield 1977, M.57898; waterworks area, B.F.H. 17/9/77, M.57049. **Port Waikato:** R13, H.J. Finlay, AK85615; Colebaker Res., P.M. 1/4/83, M.87486; Waikaretu, limestone on Mannerings farm, B.F.H. 2/12/77, M.57350, M.58257, M.68569-70, M.72459, M.82007; Limestone Downs R13 645145, N. Douglas 13/2/81, M.77917, F.M.C. & D.J.R. 13/2/81, M.77949, Junior Naturalists Club 1972-73, M.45944. **Raglan:** Te Toto Gorge R14, 666717, J.F.G. 1/1/84, AK96665; cave talus, Karamu, Hamilton Junior Naturalists Club, per S. Easterbrook-Smith 1970-72, M.45668; Cogswell Rd., 7 km towards Raglan from Raglan deviation, P.M. 1/1/78, M.61985. **Waitakere Ranges:** Huia Ridge track, rimu Q11 452687, J.F.G. 1/10/82, AK 96717; Fairy Falls track Q11 492756, J.F.G. 1/9/82, AK96640; Titirangi R11 581720, J.F.G. 1/1/82, AK96655, B.F.H. 29/5/76, M.48553; Bethells, Q11 447807, J.F.G. 1/2/82, AK96656; Cornwallis, 20/5/27, AK85629; Huia Dam Q11 484695, J.F.G. 11/12/90, AK96657, AK96719; Piha Rd., Q11 453700, J.F.G. 18/9/82, AK96658; Walkers Bush, B.F.H. 5/10/78, M.63423, 26/10/83, M.75324, M.63443, M.75860; Whatipu, lookout rock on road Q11 462626, AK96659; Te Henga, P.M. 1/1/80, M.99264; Muriwai, Maori Pah Q11, AK85621 Dell collection, M.25383, M.84738; Spraggs Bush, B.F.H. 26/10/83, M.80308. **Waitomo:** Stubbs farm, B.F.H. 16/11/77, M.70505, 2/7/78, M.70157, M.61514. **Waiuku:** coastal flax, B.F.H. 14/1/78, M.69276; Harveys Bush, F.M.C. 15/2/81, M.82300; Waipipi Sc. Res. R12 580412, J.F.G. 1/1/76, AK96632, B.F.H. 3/1/77, M.51799, M.57662, F.M.C. & D.J.R. 12/2/81, M.78572, M.78552. Further material is held in bulk collections in the Auckland Museum.



Figs 18-21. Anatomy of *Climocella maculata* (Suter), Hawkes Bay, Pongaroa, D.J. Roscoe 19/4/70, shell width 2.7 mm. Scale lines = 1 mm. Abbreviations: b - buccal mass, be - oesophagus, dg - hermaphroditic gland, e - epiphallus, g - hermaphroditic gland, gd - hermaphroditic duct, gg - albumen gland, gt - talon, h - heart, hg - hindgut, i - intestine, iz - stomach, k - kidney, kd - ureter, mc - mantle collar, og - salivary glands, od - salivary gland ducts, p - penis, pi - black pigmentation, pr - penis retractor muscle, s - spermathecal shaft and its sac, u - spermoviduct, uv - free oviduct, v - vagina, vd - vas deferens, vrm - vagina retractor muscle, y - genital atrium, z - digestive gland. 18. Reproductive system. 19. Kidney. 20. Section of body between buccal mass and stomach. 21. Hermaphroditic glands and duct.

DISTRIBUTION AND HABITAT

In a survey of over 100 native species found in South Auckland (Goulstone 1990) *C. akarana* was found at 57 sites out of 141 sampled. The sites were grouped according to four degrees of modification. In the first category, the Hunua Ranges Water Catchment Area, least modified, *C. akarana* was found at 18 out of 34 sites. In the most modified category, small pieces of bush around Auckland, Manukau City and Franklin, *C. akarana* scored 12 out of 29 sites and it was the tenth most widespread native species in the area. On Rangitoto and in the deep crater of Mangere Mountain they live in dry scoria rocks with little overhead cover. They are also common in the Waitakeres (Goulstone 1983) and were found at 37 sites in a total of 86. The Coromandel Ranges had them at 19 out of a total of 57 sites (Goulstone unpubl.) and Great Barrier Island 9 sites out of 49 (Goulstone 1991). It is almost certainly a ground litter dweller and is particularly abundant in the West Coast limestone areas from Waitomo through Kawhia and Raglan to Port Waikato.

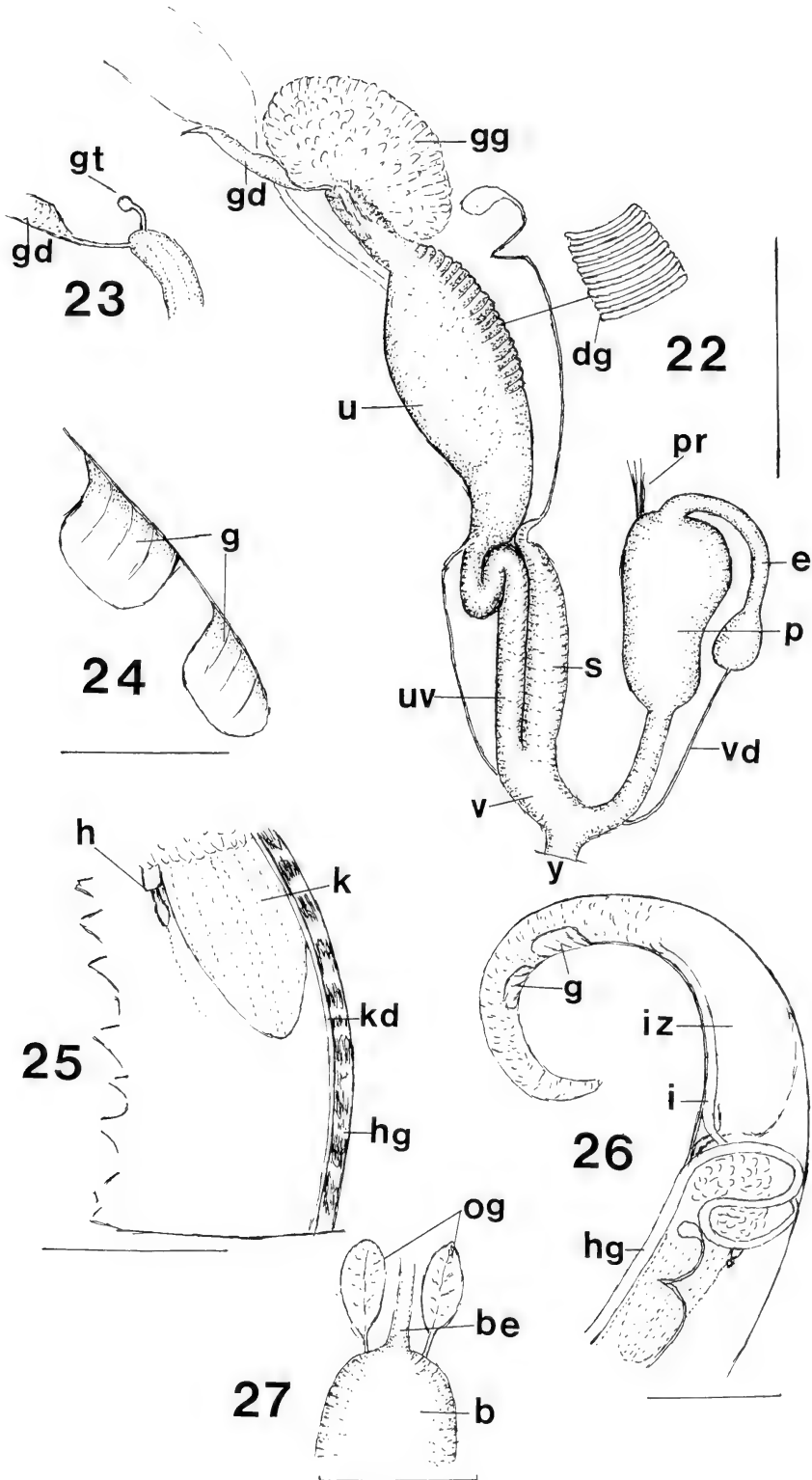
Climocella cavelliaformis n. sp. Figs 4, 13, 28-32, 50

ETYMOLOGY: This species has axial ribs with some similarity to the genus *Cavellia* which has ribs growing strongly forward from the suture in the direction of shell growth forming a definite sinus at the aperture.

DESCRIPTION

Shell small, up to 2.8 mm x 1.5 mm, four whorls slightly compressed (compared with *C. akarana*), subdiscoidal, spire flat but last whorl dropping a little. Sutures deep. Protoconch, 1.25 whorls with 9-10 spiral lirae crossed by two weak oblique axials on last section (Fig. 13). Teleoconch with axial ribs stout at the base with moderately sharp apex, interstices with a number of very fine axials reticulated by strong microscopic spirals which climb fairly well up the main ribs and over them where they are rounded near the sutures. First teleoconch whorl has approx. 68 radial ribs and final whorl about 21 per mm. Space between ribs at widest is up to twice width of the ribs. Ribs sinuous when they leave suture but from shoulder arc forward in the direction of growth to produce a shallow sinus at aperture. Umbilicus of medium width, its diameter one quarter to one third of total shell width. Most shells have a weak colour-pattern of blotchy reddish brown radials on a horn background, the markings more prominent on the last whorl.

Animal white with a little white stringy pigmentation over stomach area. Proximal end of penis short and thick opening into a longer narrow tube at the distal end. External epiphallus about total penis length with a very small swelling at its junction with the vas deferens. Vas deferens a substantial tube which for much of its length lies against the long narrow oviduct. Spermathecal duct twice diameter of oviduct at its origin reducing to a slender tube on a level with the distal end of the spermoviduct. Free oviduct and vagina, spermathecal duct, vas deferens, epiphallus and penis are held as a tight bundle of tubes in the retracted state, difficult to separate. Salivary glands, very long and delicate, are squashed into a space at end of the buccal mass between penis and distal section of spermoviduct (Fig. 29). Spermoviduct about a third the length of penis. Rear heart chamber is spherical and prominent below kidney, between spermathecal sac and albumen gland (Fig. 32). Hermaphroditic duct has straight swollen section about 1 mm long just before its entry to base of albumen gland, and two lobes of the hermaphroditic gland close to stomach nearly fill a cross section of digestive gland (Fig. 31). Pericardial lobe of kidney prominent, rectal lobe reduced.



Figs 22-27. Anatomy of *Climocella akarana* n. sp. Scale lines 22, 25, 26 = 1 mm; 24, 27 = 0.5 mm. Abbreviations as for Figs 18-21. 22. Reproductive system. 23. Talon greatly magnified. 24. Hermaphroditic glands. 25. Kidney. 26. Posterior section of body. 27. Salivary glands.

REMARKS

Two specimens were dissected, one from Blomfields Bush (A.W.B. Powell 1968) and one from Waiwera (J.F.G. 1995). This species most closely resembles *C. akarana* though on shell details it can readily be separated for it is tighter coiled with different protoconch detail and distinctive ribs. The ribs nowhere approach the obliqueness of a *Cavellia* and do not leave the suture at a strong angle forming a deep sinus at the aperture as in that genus. However, they show this tendency and it separates them from other species of *Climocella*. Climo (1970) in his description of the subgenus "*Mocella*" stated "there is no development of an apertural sinus", but I do not think he had seen specimens of *C. cavelliaformis* at the time. The round heart chamber, comparatively large resting against the albumen gland, is a prominent feature of the animal.

TYPE LOCALITY: North of Auckland City, just north of Waiwera, half way down the hill before the Puhoi turnoff. Regenerating forest with many cabbage trees (*Cordyline australis*) and nikau (*Rhopalostylus sapida*) on a steep northerly slope R10 608172.

HOLOTYPE: Auckland Museum, AK72704, 2.75 mm x 1.4 mm, B.F.H. 4/6/90.

PARATYPES: All from type locality. AK72705 (5) B.F.H. 4/6/90, AK72706 (1) whole organism, J.F.G. 14/4/95; NMNZ M.125007 (5) J.F.G. 14/4/95; NMNZ M.120552 (1), NMNZ M.120553 (2), B.F.H. 14/4/95.

OTHER MATERIAL EXAMINED

Hunua Ranges: Mataitai State Forest S11 655997, L. Uangakore 1/12/89, AK96619; Moumoukai Hill Rd., puriri S11 009630, J.F.G. 1/10/83, AK96747. **Kawau Island:** P. M. 1/8/83, M.87611. **North Shore:** Okura River, Blomfields Bush R10, A.W.B. Powell 3/5/68, AK85625, 29/2/68, whole organism AK81378; Okura walkway, Haig access Rd. R11 631018, B.F.H. 15/10/94, M.120562, M.120561, M.120560, J.F.G. 4/2/93, AK85622; 2.5 miles S of Pukapuka Rd., P.R. Jamieson 30/12/74, M.88647; Waiwera, Puhoi Hill, R10, A.W.B. Powell 5/3/47, AK85633; Waiwera Scenic Res., nikau R10 633153, B.F.H. 30/4/94, M.120563. **Waitakere Ranges:** Huia, Q11, L. Fitzgerald 5/3/72, AK85031. **Warkworth:** Dome Valley R09 565355, D.J.R. 2/1/78, M.104399.

DISTRIBUTION AND HABITAT

Climocella cavelliaformis has not been frequently collected but at the type locality they have a definite preference for nikau, indeed all the live specimens were taken from nikau fronds on the ground. No surveys have been carried out to ascertain whether there is a correlation between populations on the living tree and populations in the fallen fronds but in my experience there is not, in which case *C. cavelliaformis* should be considered a ground dweller with a preference for rotting nikau fronds. On present evidence its range is restricted and it is only abundant in one reserve at Waiwera.

***Climocella haurakiensis* n. sp. Figs 5, 14, 33-39, 50**

Charopa (Mocella) eta (Pfeiffer), Climo 1970:314; Powell 1979:310 (in part).

"*Mocella*" sp. 3, Goulstone 1986:11 (in part).

"*Mocella*" sp. 1, Goulstone 1983:20; 1990:25; 1991:6,9 (all in part).

ETYMOLOGY: The Hauraki Gulf, its islands and margins, seems to cover the range of this snail.

DESCRIPTION

Shell small, up to 3.5 mm x 2.1 mm, subdiscoidal, spire flat or a little raised, 4.5 whorls, last whorl slightly accelerated and dropping. Protoconch of 1.25 whorls with 9-10 spiral lirae (Fig. 14). Teleoconch whorls with axial ribs, moderately flexuous and strong, emerging at right angles from sutures which are deep but becoming a little protractive past the shoulder. Interstices, about twice width of ribs at most, have fine axials reticulated by close spiral lirae of similar strength which also cross the primary ribs. First teleoconch whorl has approx. 67 ribs, first few near protoconch somewhat wider apart. Final whorl has about 26 ribs per mm. Diameter of umbilicus one quarter of total shell width. Shells unicoloured, horny to light brown, juvenile specimens have a hint of radial colour bands on the first whorl. At type locality most shells were coated in black from the litter.

Animal with large buccal mass and salivary glands but small reproductive organs. No external epiphallus, vas deferens entering penis well below its apex. Penis a simple tube with retractor muscle at apex, bent at vas deferens entry about a third of way down from apex, joining vagina distally a short distance from atrium. Vagina, about same length as penis, stretches around buccal mass, and is sausage-shaped with one side attached to retractor muscle. Free oviduct short and narrow, closely circling the buccal mass to join the spermooviduct. Entry to spermathecal duct about same width as oviduct and about half the length, before it reduces to a slender tube leading to the receptacle. Spermooviduct is flattish, featureless, wide at the bottom where attached to buccal mass and tapering to apex where it joins albumen gland. Vas deferens, relatively short joins spermooviduct opposite oviduct, close to atrium, completing an encircling of buccal mass by genitalia. Albumen gland engulfed in large salivary glands as is small spermathecal sac. Hermaphroditic duct very fine and hermaphroditic gland a fine featherlike organ on columellar wall of digestive gland (Fig. 38). One of dissected animals had a sperm packet lodged in spermathecal duct. It was small, cigar shaped, glistening, and crystalline white.

REMARKS

Eight snails from Motuhoropapa Island, the Noises Group, were dissected. This animal seems different from *Climocella*, yet the shell is so similar to that of other *Climocella* I have decided to leave it with the group until its true affinities can be ascertained. Strangely this is the hardest species to identify as it looks like a *C. rata* without colour and has a similar protoconch detail. It is larger though, and inclined to be domed, whereas *C. rata* is flattish and the apex often slightly sunken. The ribs on the teleoconch of *C. haurakiensis* are slightly taller and sharper with the microscopic spirals not so pronounced.

TYPE LOCALITY: The Noises, Otata Island, Hauraki Gulf, R10 870988.

HOLOTYPE: Auckland Museum AK72707, 3.45 mm x 2.1 mm, G. Sadler.

PARATYPES: AK72708 (2), type locality, G. Sadler. AK72712 (6) Motuhoropapa Is. R10 859994, J.F.G. 4/11/94. NMNZ M.125008 (3), type locality, G. Sadler; NMNZ M.73918 (5), NMNZ M.73764 (1) Motuhoropapa R10 859994, D.W. Helmore & J.M. Cleary 17/12/78.

OTHER MATERIAL EXAMINED

Coromandel Ranges: Port Jackson, Pahi Ck. S10 221195, J.F.G. 1/12/78, AK96746; Port Jackson Sc. Res. S10 202202, J.F.G. 1/1/78, AK96721. **Great Barrier Island:** Port Fitzroy S08, A.E. Brookes, AK85682. **Hunua Ranges:** Waharau Regional Park under rata S1125600, J.F.G. 1/10/83, AK96621. **Motutapu Island:** middens, R. Nichol 1983, M.80035; under Rangitoto ash, B. McFadgen 13/11/74, M.47354. **Noises Islands:** Motuhoropapa in insect traps between 3/11/77 & 27/2/79, D.W. Helmore & J.M. Cleary, M.73708; L.L. Deitz, M.73736, M.73762; J.S. Dugdale, M.73731, M.73831; B.M. May, M.73902; J.C. Watt, M.73830; J.M. Cleary & M.F. Tocker, M.73908; D.W. Helmore, M.73926. **North Shore:** Le Roys Bush R11 652862, J.F.G. 26/12/90, AK85050. **Rangitoto Island:** A. Suter 31/7/32, AK85051; A.W.B. Powell 1/4/27, AK85049; Boulder Bay, P. Parkinson 1/6/69, M.37569; Rangitoto wharf R11 765867, J.F.G. 26/9/76, AK96629; 6/4/95, AK96694. **Waiheke Island:** between Oneroa and Palm Beach S11, 1/1/33, AK85657.

DISTRIBUTION AND HABITAT

This species favours the Hauraki Gulf Islands where it is easy to find though never abundant. On the Noises it was found living in the litter and specimens were particularly dirty. The large buccal mass and well developed salivary glands of this species is suggestive of a carnivorous habit (G. Barker pers. comm.). It appears at the moment to be confined to some islands in the Hauraki Gulf with some mainland locations around the edge. An archaeological excavation on Motutapu Island discovered 30 subfossil shells and this appears to have been its area of greatest abundance. Pitfall traps on Motuhoropapa Island in 1977-78 yielded several specimens, mostly juveniles. The snails may have crawled in, attracted by the dead insects.

Climocella kaitaka n. sp. Figs 6, 7, 15, 16, 40-42, 50

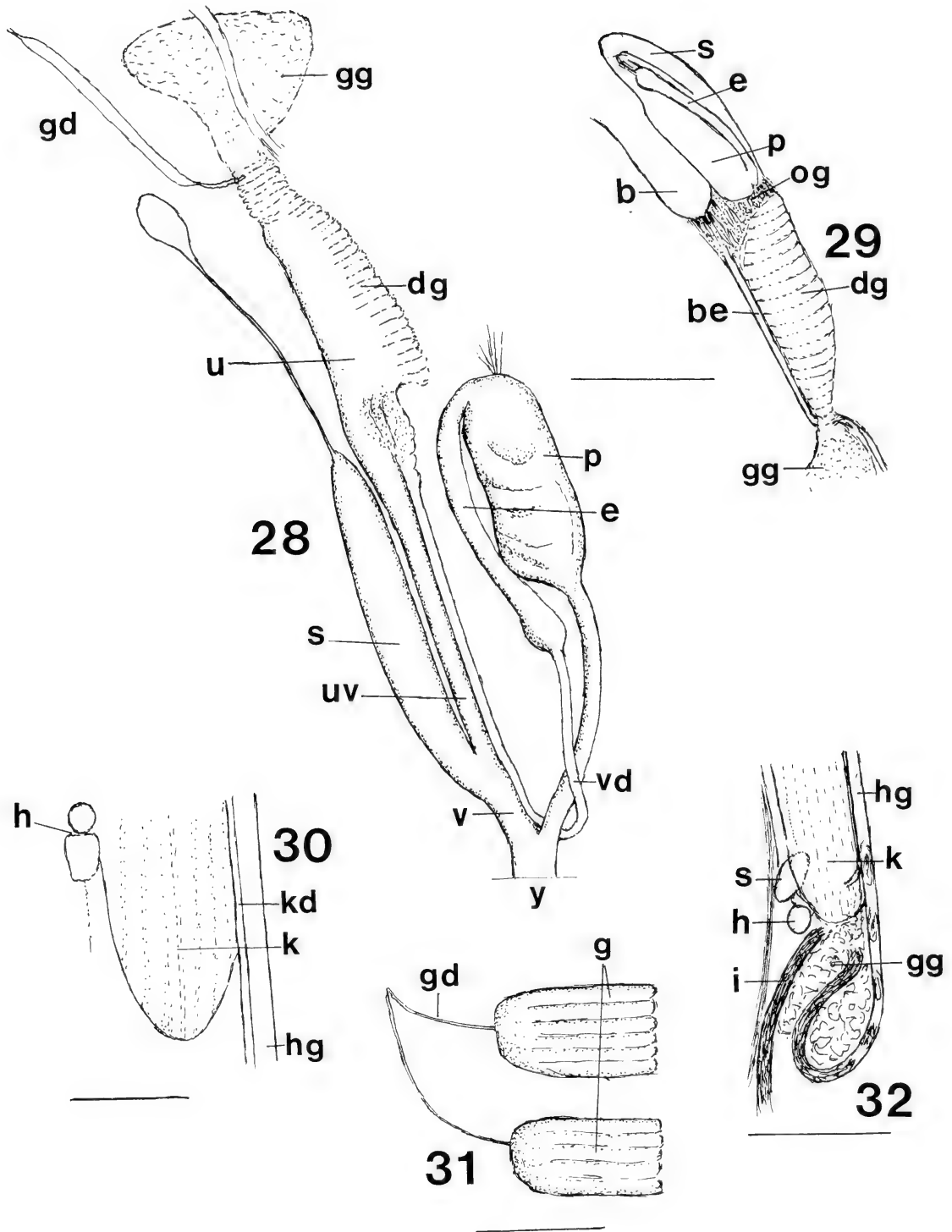
Charopa (Mocella) eta (Pfeiffer) Climo 1970:314; Powell 1979:310 (in part).
 “*Mocella*” n. sp. aff. *manawatawhia* Solem, Climo & Roscoe 1981:477.
 “*Mocella*” sp. 4 Goulstone 1983:21; 1990:25.

ETYMOLOGY: Derived from Maori, *kaitaka* is a fine cloak.

DESCRIPTION

Shell small, up to 2.8 mm x 1.4 mm, unicoloured, four whorls the last somewhat expanded, discoidal, spire flat or slightly depressed. Protoconch of 1.25 whorls with 9-10 spiral lirae which in the last quarter whorl are reticulated by up to 12 faint oblique radials (Figs 15, 16). Teleoconch with close axial ribs reticulated by strong microscopic spiral lirae. Interstices about one rib width with no discernible secondary axials but dominated by the spirals. First teleoconch whorl with about 105 axials, final whorl with 34 per mm. Ribs flexuous coming out of moderately deep suture and slightly protractive past the shoulder. Diameter of umbilicus a quarter to a third of maximum shell width. Colour, straw to white.

Animal with some stringy white pigmentation over stomach otherwise plain. Proximal section of penis a large lozenge-shaped compartment, reducing to a narrow tube in the distal section but widening briefly before it joins the vagina. Epiphallus of similar length to proximal section of penis which it enters at apex alongside retractor muscle. When animal retracted



Figs 28-32. Anatomy of *Climocella cavelliaformis* n. sp. Scale lines 28, 29, 32 = 0.5 mm; 30, 31 = 1 mm. Abbreviations as for Figs 18-21. 28. Reproductive system. 29. Part of reproductive system and buccal mass *in situ*. 30. Kidney. 31. Hermaphroditic gland. 32. Position of heart.

this whole complex lies like a squashed inverted “s” with proximal end of penis facing atrium. Vagina short leading to a wide oviduct about 1 mm long by 0.5 mm wide. Spermathecal duct about half oviduct width and a little longer before it reduces to the slender tube which is short (less than the length of the thickened section) and straight leading to the comparatively large receptacle (0.5 mm) which rests on proximal end of spermoviduct. Hermaphroditic glands (Fig. 42) are substantial organs filling much of cross section of digestive gland and a lower thickened section of its duct is long (1.25 mm) and straight. Kidney with two lobes of equal size (Fig. 41).

REMARKS

Dissections based on two animals from the type locality. In Auckland this snail will readily be identified on its close fine ribbing and secondary radials on the protoconch but in the central North Island identification may not be so easy as there is a very similar looking snail assignable to *Climocella* without the fine secondary radials on the protoconch (Mayhill 1994:51). A specimen from Mercer (Figs 15, 16) had these secondary radials somewhat reduced. Both *C. manawatawhia* and the unnamed species from Te Pahi (Goulstone *et al.* 1993) also have a similar shell but the former has a very complex penial structure (Climo 1973) and both seem restricted in range. At the type locality *C. kaitaka* lives in the same space as *C. akarana* and they are easily separated. In the damp, gloomy conditions which prevail here the shells of *C. kaitaka* are pale and delicate with an expanded final whorl. Shells from less protected areas, and limestone populations such as at Kawhia where they are abundant, have a final whorl which is narrower. In these less protected sites the shell and ribs are more robust and it can be harder to identify. In such conditions the shell is mostly white. In a fossil deposit at Mangere the shells appear larger and protoconchs seem to lack those secondary oblique radials.

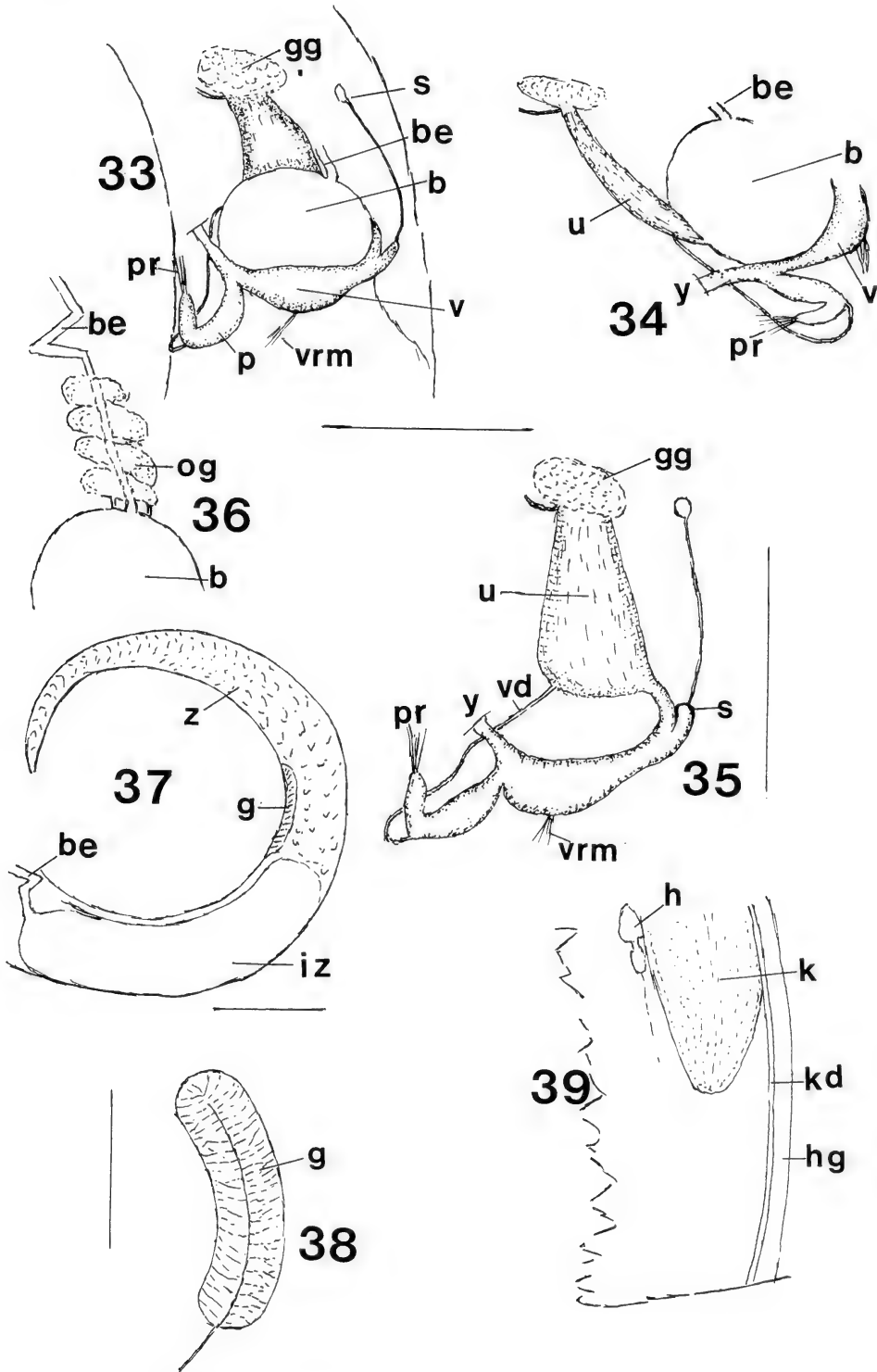
TYPE LOCALITY: Manukau City, Clevedon, Twilight Rd., Royal Forest and Bird Protection Society Reserve, “Ngaheretuku”, under a large kahikatea. R11 898669.

HOLOTYPE: Auckland Museum AK72709, 2.65 mm x 1.45 mm, J.F.G. 1/10/85.

PARATYPES: All from type locality. AK72710 (8), J.F.G. 1/10/85. NMNZ M.125009 (8) J.F.G. 1/12/94.

OTHER MATERIAL EXAMINED

Auckland: Mt. Wellington lava fields R11, A.W.B. Powell 31/10/26, AK85664; Mt. Wellington crater, B.F.H. 14/3/87, M.99539; East Tamaki archaeological excav., Regional Arch. Unit 29/10/87, M.97451; Mangere Mountain R11 762709, J.F.G. 1976, AK96618; Rangitoto Is. R11 765867, J.F.G. 26/9/76, AK96631; Mangere Oxidation Ponds R11 664673, J.F.G. 6/2/95, AK96743. **Auckland North:** Brynderwyn, P.M. 1/9/84, M.82808; Dome Valley R09 552363, J.F.G. 5/9/82, AK85654. **Auckland South:** Patumahoe, Hunter Res. R12 737443, J.F.G. 1/9/95, AK96652; Papakura, Maketu Pa R12 869497, J.F.G. 8/10/88, AK96726; Red Hills, Gibbs Cres. R12 862573, J.F.G. 8/9/86, AK85658; Red Hills Sc. Res. R12 865571, J.F.G. 7/9/86, AK85665; Raveithorpe Sc. Res. R12 848466, J.F.G. 31/7/88, AK85659; Bombay, Mt. William Res. S12 904409, J.F.G. 1/5/84, AK96736, B.F.H. 1/10/83, M.78946; Omana Regional Park S11 911783, J.F.G. 1/2/85, AK96738. **Coromandel Peninsula:** Mill



Figs 33-39. Anatomy of *Climocella haurakiensis*. Scale lines 33, 34, 35, 36, 38 = 0.5 mm; 37, 39 = 1 mm. Abbreviations as for Figs 18-21. 33. Reproductive system, top view *in situ*. 34. Reproductive system, side view *in situ*. 35. Reproductive system. 36. Salivary gland. 37. Position of hermaphroditic gland. 38. Hermaphroditic gland. 39. Kidney.

Creek T11 473766, J.F.G. 1/3/83, AK96739; Kauri Grove Track, kahikatea T11 382812, J.F.G. 1/1/78, AK96744; Matapaua Bay T10 609019, 10 m, P.M. 1/3/94; Hot Water Beach T11 618754, 25 m, P.M. 1/5/81. **Gulf Islands:** Waiheke S11, G. Sadler, AK95055; between Oneroa & Palm Beach, Waiheke S11, 1/1/33, AK96691; Little Barrier S08, A.E. Brookes, AK85652. **Hunua Ranges:** Duders Bush S11 943738, J.F.G. 11/3/90, AK96088; Whakatiwai, Workmans Track S12 542133, J.F.G. 23/1/92, AK96622; Hunua Gorge R12 887563, J.F.G. 1/8/84, AK96634; Mangatangi, rimu S12067510, J.F.G. 1/12/85, AK96637; Patumahoe, Hunter Res. R12 737443, J.F.G. 1/9/95, AK96652; Wairoa Dam S12 987528, J.F.G. 1/8/79, AK96727; Mangatawhiri Dam S12 019523, J.F.G. 1/9/76, AK96728; 0.4 km S of Orere Pt. turnoff S11 088665, D.J.R. 1/1/79, M.103681; Waharau Regional Res., rata S12 125600, J.F.G. 1/10/83, AK96734; Cosseys Dam, rimu S12 974568, J.F.G. 1/3/83, AK96735; Wairoa Gorge, kahikatea S11 949615, J.F.G. 1/10/84, AK96737; Moumoukai Hill Rd., puriri S11 009630, J.F.G. 1/10/83, AK96740; Moumoukai - Waharau Track, rimu S11 013623, J.F.G. 2/11/86, AK85646; Mataitai State Forest S11652998, J.F.G. 1/1/90, AK96741. **Kawhia:** Kawaka Ridge, K. Brown 1/10/77, M.81852; limestone ledges E of Andersons Bluff, B.F.H. 22/10/77, M.57425; cave entrance, Andersons Bluff, B.F.H. 22/10/77, M.57596. **Mercury Islands:** Middle Is., A. Ballance 6/10/84, M.81598. Green Is. T10 650023, 5 m, P.M. 1/3/94; Stanley Is. T10 683031, 80 m, P.M. 1/3/94. **Mercer:** just N alongside the railway line, B.F.H. 24/9/78, M.69257. **Ngaruawahia:** Hakarimata Track, B.F.H. 30/1/78, M.72387. **North Shore:** Muriel Fisher Res. R11 626865, rimu, J.F.G. 16/1/94, AK87680. **Port Waikato:** R13, H.J. Finlay, AK85655; Limestone Downs Station, N.Douglas 13/2/81, M.77916; Waikaretu, Mannerings Farm, B.F.H. 17/12/77, M.68429, M.58258; a variety of sites, Hamilton Junior Naturalists Club 1970-73 per S. Easterbrook-Smith, M.45846. **Raglan:** Karioi Peak, B.F.H. 4/1/77, M.55220. **Waitakere Ranges:** Huia Q11, L. Fitzgerald 5/3/72, AK85680; Cascades, 22/9/67, M.32917; Fairy Falls Q11 492756, J.F.G. 1/9/82, AK96729 Kakamatua, macrocarpa R11 518617, J.F.G. 1/7/82, AK96730; Woodlands, F.M.C. 22/9/67, M.37113; Titirangi, Atkinson Res. R11 581716, AK96731; Huia Dam, rimu Q11 484695, J.F.G. 1/1/83, AK96732; Whatipu consolidated dunes, R.K. Dell, M.25034; Korekore Pa Hill, Muriwai Q11, A.W.B. Powell 1925, AK85649. **Waiuku:** R12, Rev. W.H. Webster, AK85656; Waipipi Sc. Res., P.R. Jamieson 24/1/75, M.88506 Harveys Bush, F.M.C. & N. Douglas 15/2/81, M.82419; Crispes Bush, B.F. Elliott M.88631, F.M.C. & D.J.R. 16/2/81, M.45798, M.45890, M.77808.

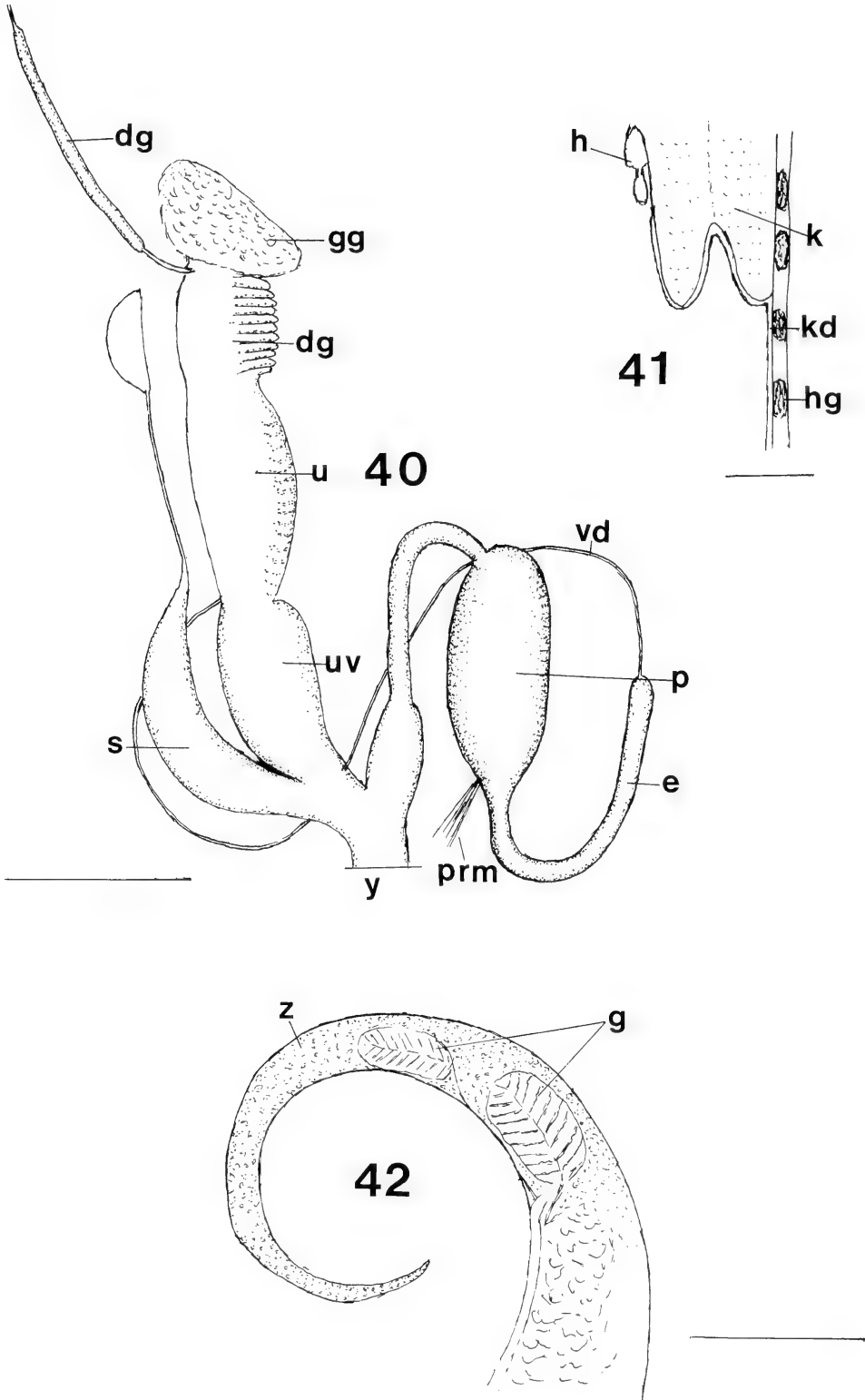
DISTRIBUTION AND HABITAT

C. kaitaka is not prominent on Great Barrier Island or the Coromandel Peninsula but is common on the Auckland Isthmus. In a list of species arranged in descending frequency of occurrence in South Auckland (Goulstone 1990) it was 15th out of more than a hundred, not far below *C. akarana*. It shows no particular preference for an undisturbed situation, but is particularly abundant in the West Coast limestone from Waitomo to Port Waikato. *C. kaitaka* seems at home in a wide range of habitat from very moist (type locality) to very dry (scoria craters of Mangere Mountain and Mt. Wellington). At many locations *C. kaitaka* and *C. akarana* are sympatric.

Climocella rata n. sp. Figs 8, 9, 17, 43-49, 50

"*Mocella*" sp. 1 Goulstone 1983:20; 1990:25; 1991:6,9 (in part).

ETYMOLOGY: Northern rata *Metrosideros robusta* is a prominent tree at the type locality.



Figs 40-42. Anatomy of *Climocella kaitaka* n. sp. Scale line = 1 mm. Abbreviations as for Figs 18-21. 40. Reproductive system. 41. Kidney. 42. Hermaphroditic gland.

DESCRIPTION

Shell small, up to 3 mm x 1.8 mm, with 3.75 whorls, subdiscoidal, spire flat, in side view outline somewhat squarish. Protoconch, 1.5 whorls with 9-10 spiral lirae cutting off sharply at teleoconch (Fig. 17). Teleoconch with primary axials strongly based, slightly sinuous, fairly sharp at their apex. Interstices, twice at most the width of the ribs, with finer radials reticulated by prominent fine spiral lirae (these spirals also going over major ribs), very noticeable near suture. First teleoconch whorl with 75 axial ribs and last whorl has 22 per mm. Diameter of umbilicus one quarter of maximum shell width. Colour consisting of broad indistinct brown bands on a light brown background, more obvious on final whorl. Juveniles display only indistinct dark blotches on a light brown background and definite colour bands seem restricted to final whorl of an adult shell.

Animal distinguished by a broad area of black pigmentation starting at mantle collar and extending nearly to tip of kidney then reducing towards the hindgut (Fig. 47). This pigmentation bisected by pulmonary artery. Penis consisting of a thickened proximal section and a shorter, narrower distal section. Epiphallus, about two-thirds length of penis, bulbous where vas deferens joins, entering penis apically close to retractor muscle. Vas deferens a reasonably substantial tube. Vagina short and bulbous. Free oviduct about same length as thick proximal section of penis. Spermathecal duct at point of origin with vagina about same width as oviduct but it reduces in a short distance to a thick tube, then a very slender one about level with the distal end of the spermoviduct. Spermoviduct in a mature snail is large round thin walled and clear, with prostatic gland around the edge. In a young adult, presumably before ovulation (Figs 48, 49) spermoviduct collapsed into a thin envelope with prostatic gland along thickened edge. Albumen gland in older snail cigar shaped and bent back onto spermoviduct. Thickened portion of hermaphroditic duct long (about half length of total duct) thicker at distal end and tapering at the proximal. Hermaphroditic glands with two uneven separate segments, which are themselves composed of fused segments (Fig. 46). Two long salivary glands wrapped around first portion of oesophagus (Fig. 45). Kidney bilobed, rectal lobe reduced.

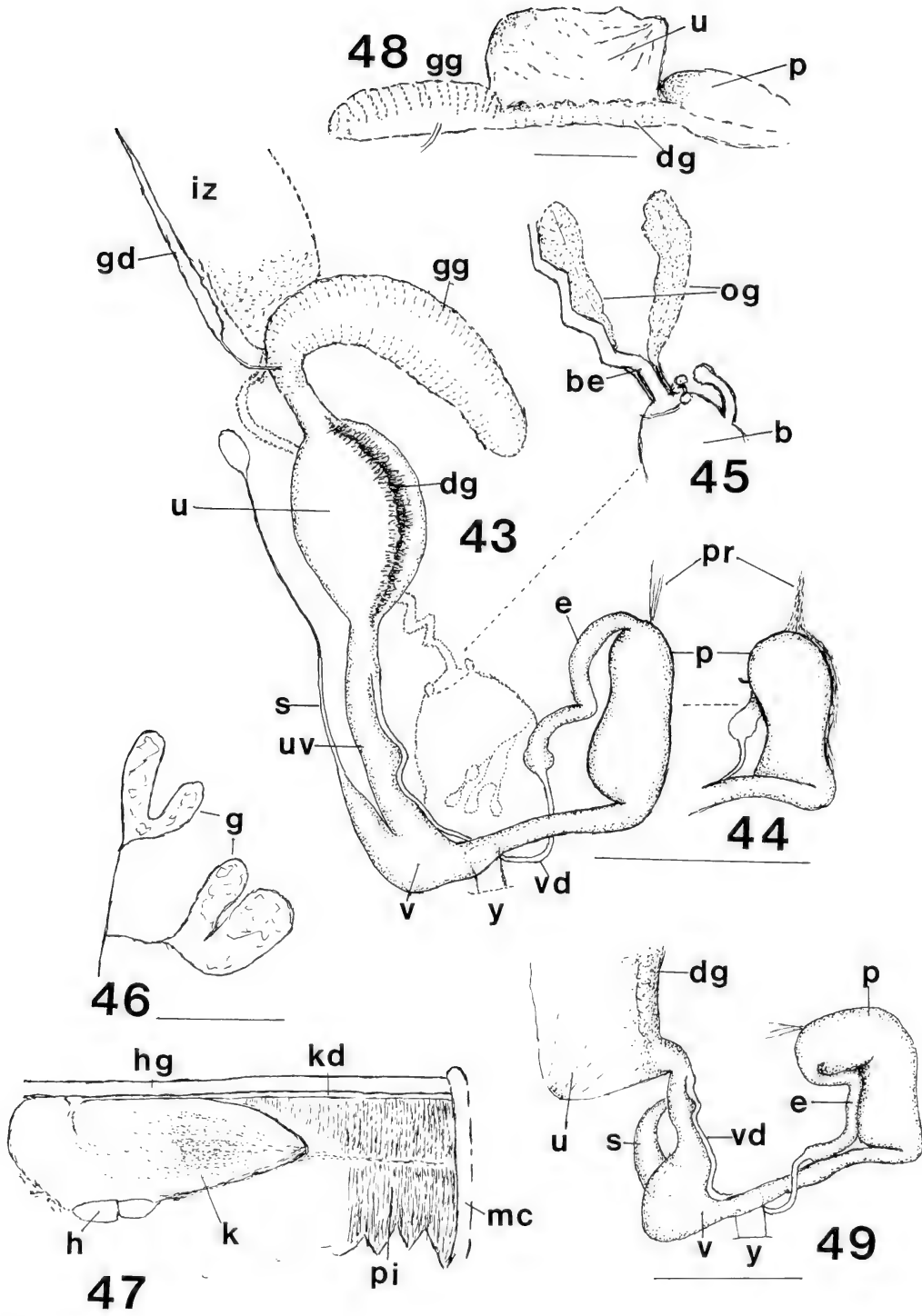
REMARKS

Dissections based on three specimens from the type locality. *C. rata* and *C. haurakiensis* are difficult to separate on shell details yet the anatomy of the animals are remarkably different. In shell characters colour is the most obvious difference but shape can also help in separation of the two species. *C. rata* has a shell with a flat to slightly depressed spire whereas in *C. haurakiensis* it is flat to slightly raised. Black pigmentation on the roof of the pallial cavity also defines *C. rata*. The shape and texture of the spermoviduct of *C. rata* suggests a link to *C. maculata* as does the structure of the hermaphroditic gland and the blotchy colour-pattern of the shell.

TYPE LOCALITY: Hunua Ranges, Whakatiwai Regional Park, the private road leading up the ridge near its summit (c. 160 m). The bush was well cut over with old dead trunks in evidence and the live material was taken under the largest trees left, northern rata S12 118552.

HOLOTYPE: Auckland Museum AK72713, 3 mm x 1.7 mm, J.F.G. 11/5/95.

PARATYPES: All from the type locality. AK72714 (7), J.F.G. 11/5/95, NMNZ M.125010 (5), J.F.G. 1/1/90.



Figs 43-49. Anatomy of *Climocella rata* n. sp. Scale lines 43, 44, 45, 47 = 1 mm; 46, 48, 49 = 0.5 mm. Abbreviations as for Figs 18-21. 43. Reproductive system. 44. Penis *in situ* in retracted state. 45. Posterior end of buccal mass and salivary glands. 46. Hermaphroditic gland. 47. Pallial cavity. 48. Spermoviduct in a young adult. 49. Terminal genitalia in a young adult.

OTHER MATERIAL EXAMINED

Coromandel Peninsula: Otama Forest Park T10 545912, 80 m, P.M.; Waitara Rd. T10 555917, 60 m, P.M. 1/3/94; Wharekaho Beach T11 549868, J.F.G. 1/1/77, AK96725; Kauri Grove Track, kahikatea T11 382812, J.F.G. 1/1/78, AK96722; Mill Creek, fern under cliff T11 473766, J.F.G. 1/7/83, AK96715; Kauaeranga Valley, rimu T12 459542, J.F.G. 1/1/79, AK96714 Kopu - Hikuai, S.H.25a, 3.7 km from Kopu end, B.F.H. 5/11/77, M.72365; Paeroa Waihi Hwy. T13 532169, B.F.H. 5/11/77, M.57564. **Great Barrier Island:** Whangaparapara, tawa S09 264501, J.F.G. 12/1/81, AK96724, 1/4/51, M.79251; Kaitoke swamp edge, tawa & nikau S09 286495, J.F.G. 11/1/81, AK96723; Harataonga Scenic Res. T08 308555, J.F.G. 25/3/90, AK96720. **Hapuakohe Range:** Te Hoe, Mangatea Rd., astelia S13 181110, B.F.H. 7/10/78, M.63494. **Hunua Ranges:** Waharau Regional Park, rata S12 125600, AK96716; 0.4 km S of Orere Pt. turnoff S11 088665, D.J.R. 1/1/79, M.103681; Clevedon, Ness Valley, A.G. Beu 8/4/61, M.32160. **Kaimai:** Matamata - Tauranga Rd., rest area at top of range, B.F.H. 2/1/77, M.51900. **Waiheke Island:** P. Anderson 1/4/88, M.96604.

DISTRIBUTION AND HABITAT

The live material at the type locality was found in a dark position in rata (*Metrosideros robusta*) litter and specimens a little further north at Waharau were also found under rata. Several specimens found in the Hapuakohe Range by B. Hazelwood (M.63494) were living under astelia. This was the only species examined in this group to have dark pigmentation over the pallial cavity although all the rest of the animal was pale coloured. Solem (1983: 34) correlates dark body colour with semi-arboreal snails but this particular pigmentation would never show as the shell of *C. rata* is opaque. Very little exploration above ground level for snails has been done around Auckland (Goulstone 1992) but *C. rata* could easily be living in arboreal situations.

DISCUSSION

The overall similarity in shell characters has required anatomical details to reinforce species recognition in *Climocella*. The *Climocella* coloured shells exhibit anatomical similarities though each is clearly different in detail. The species with the unicoloured shells are diverse in their anatomy and quite removed from the coloured shell species. Climo (1973) mentioned the complex penial structure of the Three Kings *C. manawatawhia* (Powell) as compared with *M. eta* (Pfeiffer) sensu Suter 1913. *C. kaitaka*, which has been thought of as a very close relative of *C. manawatawhia* (Climo 1981B:477) has a very simple penial structure. *C. kaitaka* does have more affinity with a similar looking shell from Te Paki in the Far North (Climo 1970:351 fig. C) but *C. haurakiensis* is very different again. The Auckland region has been an obvious centre to start investigating the group because two species have been so common. It seems inevitable that species at present in this holding group will find closer natural affinities in other genera, but I have not explored these options in this paper. I have looked at every shell available for the Auckland area and ended with only about six specimens which did not fit comfortably in the above groups. There has not been that body of hybrid material, defying separation, which seemed a possibility when I started the project. There is another concentration of as yet undescribed *Climocella* in the central North Island (Goulstone unpubl.) Taxonomic treatment of this central North Island material must await further dissection of live material before it can be presented. On evidence to hand, none of the species seem to be particularly threatened, but habitat loss or modification is a threat and

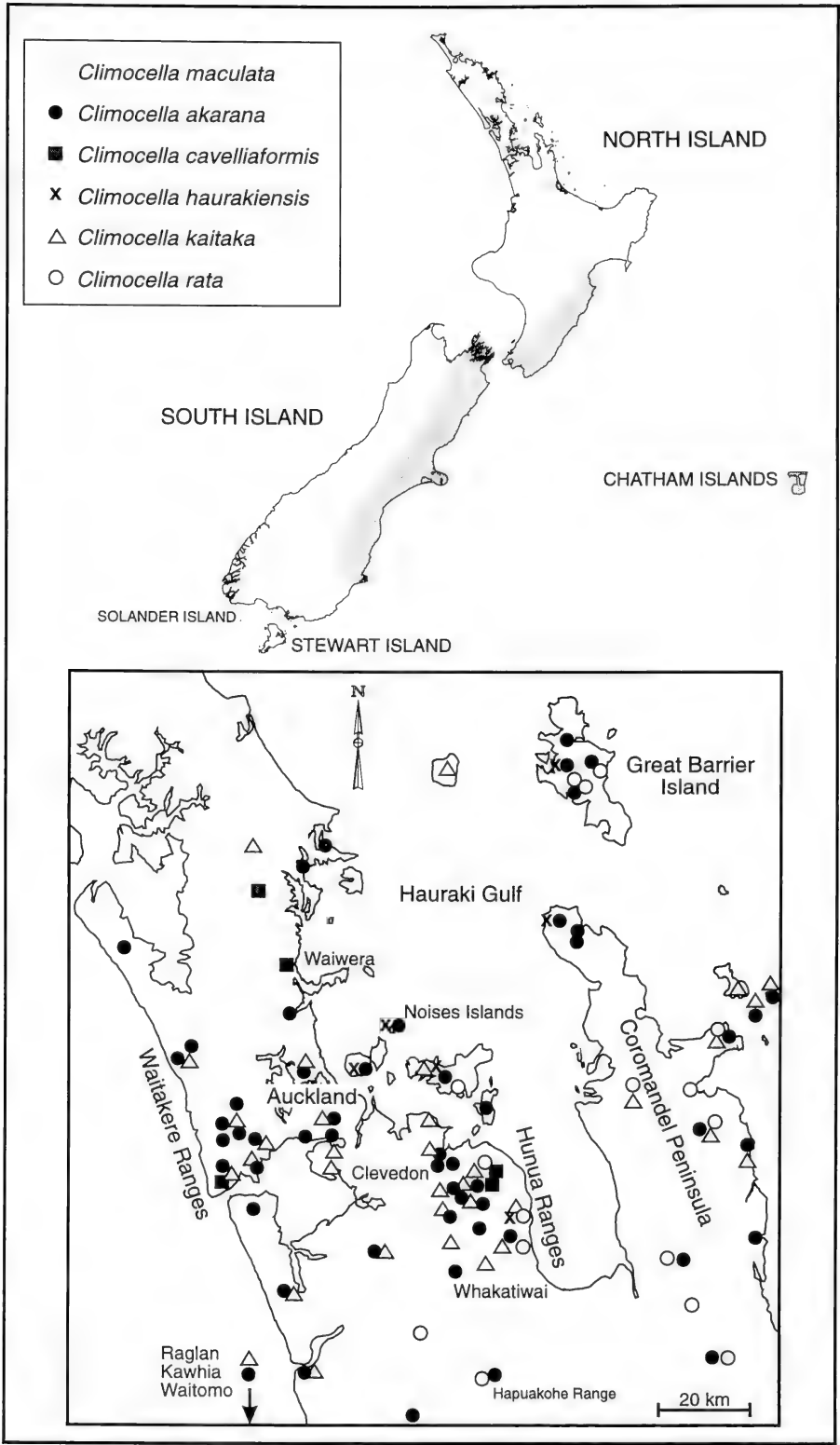


Fig. 50. Distribution of *Climocella* species in the Auckland region and of *C. maculata*.

both *C. cavelliaformis* and *C. haurakiensis*, with the smallest range, are probably dependant on only three or four well protected reserves.

Acknowledgements. Bruce Hazelwood has helped me at all stages of this paper with a lot of discussion and accompanied me on several field trips. Gary Barker, as referee, was very constructive. Dr Frank Climo gave me some *C. maculata* for dissection and together with Karin Mahlfeld has been very helpful. Both Pauline Mayhill and Dave Roscoe sent me specimens from their collection for appraisal. Bruce Marshall of the Museum of New Zealand kindly allowed me the use of that collection and has given me much good taxonomic advice. Dr Hugh Grenfell produced the map, Dr Bruce Hayward has been supportive and Con and Margaret Morley started the paper off by taking me over to the Noises in their yacht *Speedwell* to get live *C. haurakiensis*.

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Date of Publication

The nominal year of publication, as noted on the journal cover, title page, and on the heading of this paper, is 1995, but the actual year of publication is 1996. See Volume 33 for the exact date of publication.

ISOPODS OF FOUR SEaweEDS IN THE BAY OF ISLANDS, NEW ZEALAND

A. BRETT STEPHENSON AND JENNY RILEY

Abstract. Isopods of the subtidal macroalgae *Carpophyllum angustifolium*, *C. maschalocarpum*, *Xiphophora chondrophylla* and *Plocamium costatum* are described from the Bay of Islands, New Zealand. Isopod diversity is greatest on the carpophyllums but their communities, while stable, differ in composition because of the number of strongly host/habitat specific species. The isopods *Amphoroidea longipes* and *Dynamenella cordiforaminalis* characterise *Carpophyllum angustifolium*, whereas the isopods *Amphoroidea media* and *Dynamenoides decima* are specific to *Carpophyllum maschalocarpum*. *Dynamenella huttoni* was the codominant species on both *Plocamium costatum* and *Xiphophora chondrophylla*, while *Scutuloidea maculata* was common on all the seaweeds and had highest abundance on the three exposed seaweeds (*Plocamium costatum*, *Xiphophora chondrophylla* and *Carpophyllum angustifolium*). Exposure and substrate appear to play a part in the habitat preferences of isopod epifaunas.

Subtidal seaweed cover of rocky shores provides important habitats for the development of animal faunas. The contributing factors that shape ecology, including impacts on faunal density, species diversity and community interrelationships, are crudely understood (Morton & Miller 1968). Shoreline ecological studies that include strong reporting of crustacean groups (especially amphipods and isopods) are particularly lacking, even though seaweeds have high densities of these groups and are favourite habitats for collectors and taxonomists. It may be that difficulties in taxonomy alone are a sufficient deterrent. Comment on swimming faunas can also be avoided through the justification that mobility displaces these animals in such a way that they are non-participants of the seaweed fauna.

While Hurley & Jansen (1977) review the taxonomy and distribution of sphaeromatid isopods in the New Zealand region, based on accumulated national collections, their accompanying station lists (derived from those collections) are vague in gaining any ecological appreciation of seaweed/isopod relationships. The foundation to an ecological perspective of this group (Jansen 1971) considers frequency and distribution of 10 isopod species in relation to habitats in varying degrees of exposure. Although this introduces new information linking isopod habitat preference with individual algal species, its restriction to the Sphaeromatidae excludes reporting on other families which are common in seaweed communities. In working with mobile epifauna of brown seaweeds, Taylor & Cole (1994) included isopods, but some of their data are presented without identification to species.

We report on isopods in seaweeds from two stations in the Bay of Islands, New Zealand, over fifteen months. We recognise eight regularly occurring isopod species from three brown seaweeds (*Carpophyllum angustifolium*, *C. maschalocarpum*, *Xiphophora chondrophylla*) and one red seaweed (*Plocamium costatum*).

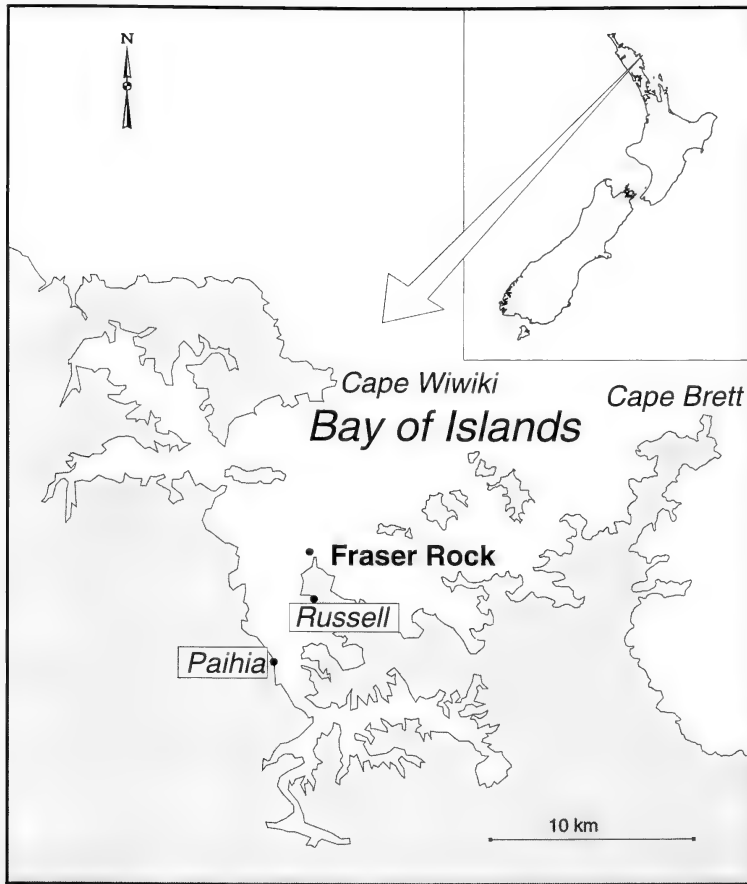


Fig. 1. Locality of Fraser Rock sampling stations, Bay of Islands.

METHODS

Three dominant seaweeds, *Carpophyllum angustifolium* Agardh, 1877, *Xiphophora chondrophylla* (Turner, 1819) and *Plocamium costatum* Agardh, 1841, were gathered from a small rock (35°14.5' S, 174°07.0' E) adjacent to Fraser Rock, Bay of Islands (Fig. 1). This is part of the Tapeka Point reef system and is close to NZOI Stn.981 for which Barnard (1972) reports the gammarid amphipods from seaweed. Because of the underwater profile this rock is exposed to swell and waves regularly throughout the year even though it is partially enclosed by coastline and outer islands. A fourth seaweed *Carpophyllum maschalocarpum* (Turner 1819) was collected from a shallow water, sheltered site c. 200 m SE along the Fraser Rock platform. These sites were sampled on five occasions at intervals (weather dependent) between July 1991 and September 1992.

Seaweeds were collected and the species kept isolated. Samples were gathered by hand, at low tide, by freeing each plant from its holdfast and rapidly transferring it to a large (450 x 850 mm) plastic holding bag. This method was sufficient to entrap mobile animals including shrimps, clingfish and pipefish. About 5 kg wet weight of bulk sample (including drip water) was collected for each seaweed type. Samples were taken ashore and processed immediately.

Wet plants were removed individually and vigorously shaken into another plastic bag of the same dimensions. Animals were decanted from the accumulated drip water and fixed in buffered 3% formaldehyde/glutaraldehyde mix. Plants of the earliest sampling period were examined subsequently for isopods that had not detached, but the process was unwarranted. Putting plants into formalin fixative to dislodge epifaunas (Taylor & Cole 1994)

was not found to be as reliable. Isopods, especially *Batedotea elongata* and *Amphoroidea* spp., which attach strongly to the thallus (using opposing grip and suction techniques) were found to die *in situ* rather than to swim away.

Some time later, isopods were separated from the bulk sample, identified and measured with the aid of a stereo-microscope. Voucher specimens are retained within the collections of the Auckland Museum. In identifying the relationships of association between isopods and seaweed environments a detrended correspondence analysis, DECORANA (Ter Braak 1985) was applied to the data.

RESULTS

The isopod fauna of seaweeds at the Tapeka site contains at least 22 species (Appendix 1), but deficiencies are recognised in the taxonomy of New Zealand species of the genera *Astacilla*, *Limnoria*, *Paranthuria* and *Scutuloidea*. A predominance of seaweed isopods, however, are from the Sphaeromatidae, a feature that is expected because of their well known general distribution in littoral-sublittoral zones. In several instances a species was recorded only once and/or in numbers fewer than 10 (eg. *Dynamenella condita*, *D. insula*, *D. mortenseni*); these are not treated further as they have little impact on the community structure. In addition, we have set aside *Limnoria* sp. which is normally an excavator or burrower of the stipe and holdfast of *Carpophyllum*. Its reporting therefore, as thallus epifauna is accidental. In effect only eight isopod species, *Amphoroidea longipes*, *A. media*, *Batedotea elongata*, *Dynamenella cordiforaminalis*, *D. huttoni*, *Dynamenoides decima*, *Paranthuria* sp. and *Scutuloidea maculata* occur consistently.

SEAWEED ASSOCIATIONS

A detrended correspondence analysis (DECORANA), using the programme CANOCO (Te Braak 1985), was used to summarise the data for the eight principal species. A two dimensional plot of the analysis is given in Fig. 2. Two clear groups emerge; one consisting of the seaweed *Carpophyllum maschalocarpum* and the other containing the three seaweeds *Xiphophora chondrophylla*, *Plocamium costatum* and *Carpophyllum angustifolium*. These two groups also correspond to a difference in exposure – *Carpophyllum maschalocarpum* is from a sheltered site and the other three are from exposed sites. Within the group of three seaweeds there is an additional split of *Carpophyllum angustifolium* from the other two. It is interesting to note that the two carpophyllums are the least similar.

Plocamium costatum

The *Plocamium* association (Fig. 2) shows a grouping influenced by *Dynamenella huttoni*, *Amphoroidea longipes*, *Scutuloidea maculata* and *Dynamenella cordiforaminalis*. The dominant species was *Scutuloidea maculata*, which showed a peak in abundance in the March 1992 sample. *Dynamenella huttoni* was the subdominant species (Fig. 3) and also showed a peak abundance in the March 1992 sample, but not in the numbers shown by *Scutuloidea maculata*. Six other species were recorded here but in numbers less than 10 for the entire sampling period. The sample for March 1992 gives the greatest abundance, both in numbers and species diversity (Appendix 1).

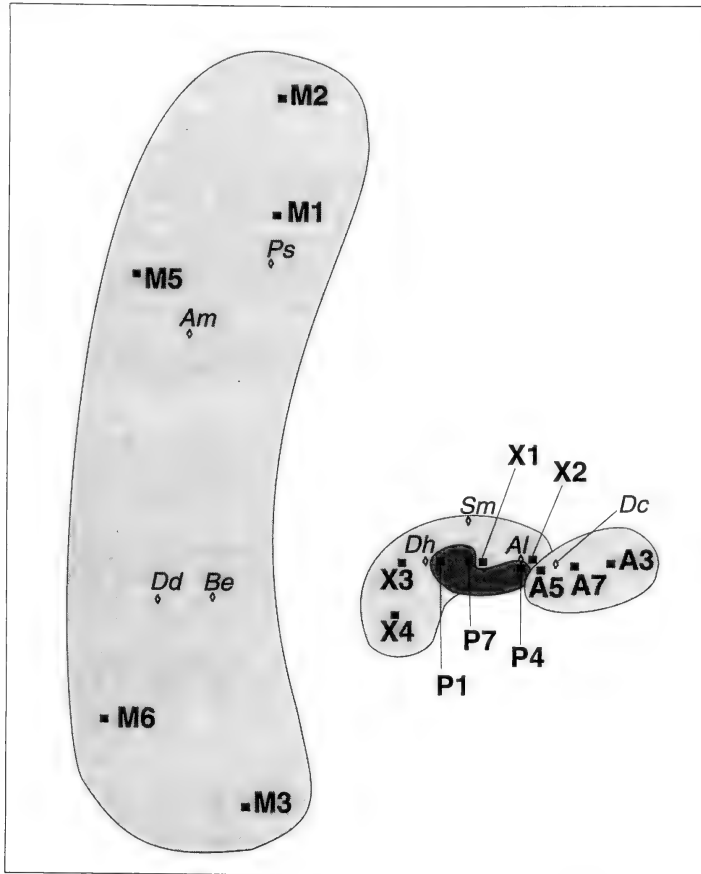


Fig. 2. A two-dimensional detrended correspondence analysis (DECORANA) plot of the principal isopod species on four seaweed substrates. A = *Carpophyllum angustifolium*, M = *Carpophyllum maschalocarpum*, X = *Xiphophora chondrophylla*, P = *Plocamium costatum*, Al = *Amphoroidea longipes*, Am = *Amphoroidea media*, Be = *Batedotea elongatus*, Dc = *Dynamenella cordiforaminalis*, Dd = *Dynamenoides decima*, Dh = *Dynamenella huttoni*, Ps = *Paranthura* sp., Sm = *Scutuloidea maculata*. Numbers 1 - 7 beside the letters A, M, X and P indicate sampling times as shown in Appendix 1.

Xiphophora chondrophylla

The *Xiphophora* association (Fig. 2) is influenced by *Dynamenella huttoni*, *Scutuloidea maculata* and *Amphoroidea longipes*. Two species *Scutuloidea maculata* and *Dynamenella huttoni* were codominant for all samples with *Amphoroidea longipes* also present in significant numbers (Fig. 3). Peak abundances again occurred in the March 1992 sample for these three species. Five other species were recorded, with two of those in numbers less than 10. The March 1992 sample again gives the greatest species diversity and specimen numbers (Appendix 1).

Carpophyllum angustifolium

The *C. angustifolium* association (Fig. 2) is strongly influenced by *Dynamenella cordiforaminalis*, *Scutuloidea maculata* and *Amphoroidea longipes*. The dominant species was *Scutuloidea maculata* which had a high abundance in the April 1992 sample and was common in the other samples. *Dynamenella cordiforaminalis* was the subdominant species

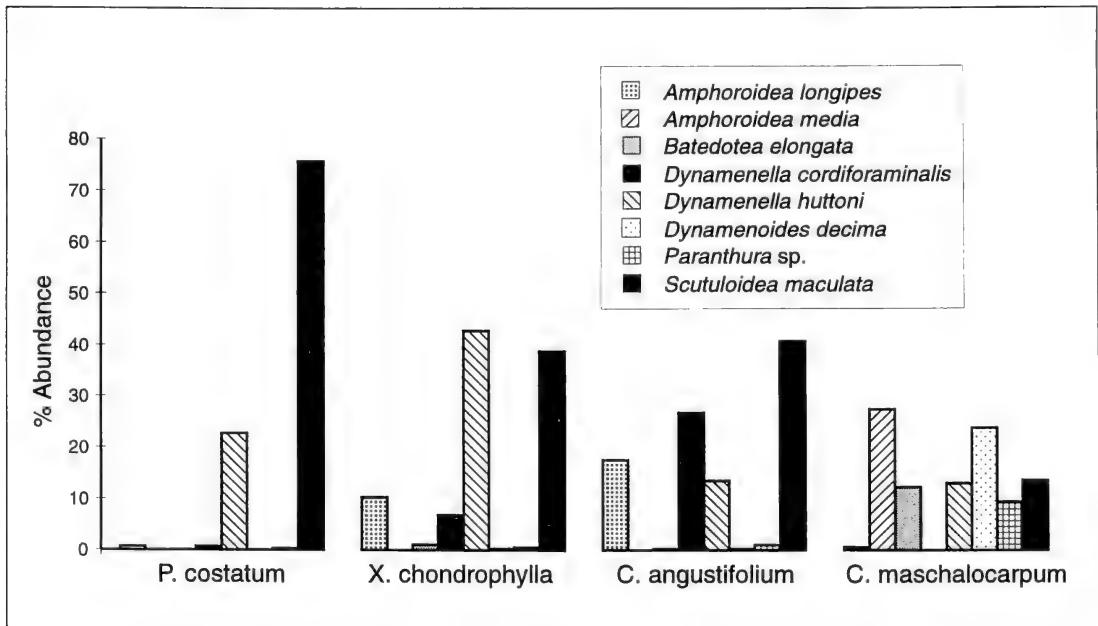


Fig. 3. Percentage abundance of principal isopod species from accumulated totals of samplings, over fifteen months, segregated by seaweed type.

(Fig. 3) with *Amphoroidea longipes* and *Dynamenella huttoni* also occurring regularly in the samples. The highest abundance and species diversity (14 species) was recorded in this seaweed, however several species were present in numbers less than 20. The sample from April 1992 gives the highest specimen numbers and greatest species diversity.

Carpophyllum maschalocarpum

The *C. maschalocarpum* association (Fig. 2) differs from the other three associations being influenced by a different group of species consisting of *Paranthura sp.*, *Amphoroidea media*, *Dynamenoides decima* and *Batedotea elongata*. The dominant species was *Amphoroidea media* which had a peak abundance in the August 1991 sample. The subdominant species was *Dynamenoides decima*, with *Scutuloidea maculata*, *Dynamenella huttoni*, *Batedotea elongata* and *Paranthura sp.* also commonly occurring (Fig. 3). Only in this seaweed did we record *Amphoroidea media*, *Dynamenoides decima* and *Paranthura sp.* in significant numbers. *Dynamenella cordiforaminalis*, which was present on the other three seaweed species, was absent on this seaweed. The sample from August 1991 has the highest species diversity and specimen numbers, closely followed by the July 1991 sample (Appendix 1).

SPECIES

Two groups of species clustering are evident in Fig. 2 with eight species of isopod consistently appearing. One group associated with *Carpophyllum maschalocarpum* from the sheltered site, consists of *Paranthura sp.*, *Amphoroidea media*, *Dynamenoides decima* and *Batedotea elongata*. The other group associated with the three seaweeds from the exposed

sites consists of *Dynamenella cordiforaminalis*, *Amphoroidea longipes*, *Dynamenella huttoni* and *Scutuloidea maculata*. *Scutuloidea maculata* and *Dynamenella huttoni* are cosmopolitan in their habitat range. Both are abundant on all four seaweed species and are often the dominant or subdominant species in the exposed seaweeds. *Amphoroidea media* is confined to *Carpophyllum maschalocarpum*, with *Dynamenoides decima*, *Batedotea elongata* and *Paranthura* sp. also largely confined to this seaweed. *Dynamenella cordiforaminalis* is absent from it. We also provide additional evidence of preferences; *Amphoroidea longipes*, along with *Dynamenella cordiforaminalis*, are largely confined to *Carpophyllum angustifolium*. However, the implications of such results are limited without information on the epifaunal contributions from other animal groups; we note that residual collections from *Plocamium costatum* are high in amphipods after isopod extraction.

When a detrended correspondence analysis (DECORANA) is applied to isopod species in relation to algal environments (Fig. 2) significant community clusters are distinguished. Although the pattern and intensity of sampling have not been comprehensive, the data do not give strong evidence of seasonal, numerical or faunal change to a community for each seaweed type. However the isopods show a discrete community structure and species diversity is maintained between the seaweeds at all times.

DISCUSSION

Notwithstanding the very important role of the water column in animal distribution patterns (Cummings *et al.* 1995) the isopod communities of subtidal seaweeds show substantially more structure than a random aggregation of species in transit from an adjacent water mass. Individual seaweed types seemingly provide a physical shelter, microclimate and food source for isopod communities. The results of our work extend the knowledge of isopods (Jansen 1971, Arrontes & Anadon 1990) and other mobile epifaunas generally (Taylor & Cole 1994), and support the contention that at least some species have individual habitat preferences amongst the seaweed types. In Jansen (1971), where we can make direct comparisons, the results are remarkably consistent. The more cosmopolitan habitat range for species like *Dynamenella huttoni* and *Scutuloidea maculata* agrees with the findings of Jansen (1971). Contrary to claims that no idoteid species occurs north of Wellington (Poore & Lew Ton 1993), *Batedotea elongata* is well represented in the epifauna of *Carpophyllum maschalocarpum* at Tapeka. Moreover, records in collections of Auckland Museum show it (and other idoteids) to be widely established in shallow seaweed habitats throughout northern New Zealand. In the northern hemisphere at least some idoteids have been shown (Arrontes & Anadon 1990) to occur specifically with particular macro algae including *Laminaria ochroleuca* and *Corallina elongata*. Further work with local species could be significant.

In the data arranged by correspondence analysis, the sheltered *Carpophyllum maschalocarpum* environment can be clearly distinguished from *C. angustifolium*, *Xiphophora* and *Plocamium* clusters. If habitat selection was merely a function of shoreline exposure then we might expect the communities of isopods on the carpophyllums to be very distinct, and those of the other seaweed types to match *Carpophyllum angustifolium*. This is not entirely the case. Wave action and substrate are acknowledged by Jansen (1971) to influence distribution, but on intertidal rocky shores, adults and juveniles had significant vertical separation as a direct result of exposure. The less extreme climatic conditions and a means to avoid wave action (shelter between the fronds) might be sufficient to explain why the epifaunas of subtidal environments are not arranged directly according to exposure.

While Taylor & Cole (1994) show that most seaweeds in their study had distinct epifaunas and that algal morphologies play a part in community sizes, they are less explicit on isopod

relationships but note in particular that “*Amphoroidea longipes* characterised *Ecklonia radiata*”. This example suggests the need for caution in interpreting the finer distinctions of habitat preferences without a knowledge of opportunities by way of other macro algae or algae and substrates in combination. Their suggestion, that wide-bladed thallus construction may provide for preferential settlement of dorso-ventrally flattened isopods as against the tubular ones (cf. *Batedotea elongata*), is not considered by our investigation, though the carpophyllums and strap-like *Xiphophora chondrophylla* communities contained both types. A relationship between density and species diversity in a community (Fig. 3) deserves further exploration but contributions from other infaunal groups need also to be considered.

There appears to be a lack of seasonal influence on seaweed epifaunas. The situation for isopods can be clarified at least to the extent that Jansen (1971) notes that extended breeding and overlapping developmental stages occur throughout the year. While we do not report on size or brood condition, the collections generally reflect a range of stages at all times, but we cannot exclude distribution shifts between adults and juveniles of any one generation. Seasonality may also be reflected through a species compositional change to the community; though this is not evident in our results shown through DECORANA analysis.

In summary, we conclude that the species of subtidal algae support distinct epifaunal communities which, for isopods, have some non-overlapping components. For the algae we have studied this is greatest between two non-contiguous species of *Carpophyllum* and we believe that exposure and substrate play a part in habitat preferences of these epifaunas.

Acknowledgements. We wish to thank our colleague Bruce Hayward for analysing our data using DECORANA and for his comments on the draft manuscript. Jill Kenny and Hugh Grenfell read the draft manuscript and suggested improvements.

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Appendix I. Numbers of isopods recorded from four seaweeds at various times, July 1991 to September 1992.

	Jul-91	Aug-91	Nov-91	Mar-92	Apr-92	Jul-92	Sep-92	TOTAL
<i>Plocamium costatum</i>	P1			P4			P7	
<i>Amphoroidea longipes</i>	1	-	-	3	-	-	0	4
<i>Deto bucculenta</i>	0	-	-	1	-	-	0	1
<i>Dynamenella cordiforaminalis</i>	0	-	-	8	-	-	0	8
<i>Dynamenella hirsuta</i>	0	-	-	0	-	-	2	2
<i>Dynamenella huttoni</i>	34	-	-	69	-	-	15	118
<i>Paranthura</i> sp.	0	-	-	0	-	-	1	1
<i>Scutuloidea maculata</i>	50	-	-	333	-	-	123	506
<i>Scutuloidea</i> sp.	0	-	-	6	-	-	0	6
TOTAL	85	-	-	420	-	-	141	
<i>Xiphophora chondrophylla</i>	X1	X2	X3	X4				
<i>Amphoroidea longipes</i>	7	14	1	45	-	-	-	67
<i>Chitonopsis spatulifrons</i>	1	0	0	0	-	-	-	1
<i>Batedotea elongata</i>	0	0	0	14	-	-	-	14
<i>Dynamenella cordiforaminalis</i>	0	15	7	2	-	-	-	24
<i>Dynamenella huttoni</i>	16	24	51	120	-	-	-	211
<i>Dynamenoides decima</i>	0	0	0	2	-	-	-	2
<i>Paranthura</i> sp.	0	0	0	6	-	-	-	6
<i>Scutuloidea maculata</i>	30	55	0	170	-	-	-	255
TOTAL	54	108	59	359	-	-	-	
<i>Carpophyllum angustifolium</i>		A2	A3		A5		A7	
<i>Amphoroidea longipes</i>	-	17	64	-	83	-	38	202
<i>Astacilla</i> sp.	-	0	0	-	2	-	0	2
<i>Batedotea elongata</i>	-	0	0	-	1	-	0	1
<i>Dynamenella cordiforaminalis</i>	-	6	101	-	85	-	161	353
<i>Dynamenella huttoni</i>	-	12	60	-	37	-	43	152
<i>Dynamenella insula</i>	-	0	0	-	6	-	0	6
<i>Dynamenella mortenseni</i>	-	0	0	-	0	-	3	3
<i>Dynamenoides decima</i>	-	0	0	-	1	-	0	1
<i>Jaeropsis palliseri</i>	-	0	0	-	8	-	5	13
<i>Limnoria</i> sp.	-	3	4	-	28	-	27	62
<i>Munna neozelanica</i>	-	0	0	-	6	-	0	6
<i>Munna schauinslandi</i>	-	0	1	-	0	-	0	1
<i>Paranthura</i> sp.	-	0	0	-	7	-	10	17
<i>Scutuloidea maculata</i>	-	67	31	-	250	-	124	472
TOTAL	-	105	261	-	514	-	411	
<i>Carpophyllum maschalocarpum</i>	M1	M2	M3		M5	M6		
<i>Amphoroidea longipes</i>	7	0	0	-	-	0	-	7
<i>Amphoroidea media</i>	55	105	1	-	85	17	-	263
<i>Astacilla</i> sp.	0	3	0	-	0	0	-	3
<i>Batedotea elongata</i>	8	25	13	-	13	9	-	68
<i>Dynamenella huttoni</i>	10	70	20	-	0	0	-	100
<i>Dynamenoides decima</i>	6	0	17	-	59	27	-	109
<i>Limnoria</i> sp.	0	3	0	-	0	0	-	3
<i>Paranthura</i> sp.	65	17	0	-	25	0	-	107
<i>Scutuloidea maculata</i>	82	109	0	-	0	0	-	191
TOTAL	233	332	51	-	182	53	-	

RECORDS CONCERNING BIOLOGICAL CONTROL OF INSECT PESTS BY NEUROPTEROIDEA (INSECTA) IN NEW ZEALAND

K.A.J. WISE

Abstract. This review, for the period 1890-1990, lists and discusses records concerning control of insect pests by neuropteroid predators in three parts: imported Raphidioptera (Snakeflies) and Neuroptera (Lacewings); non-endemic Neuroptera; endemic Neuroptera. All of many purposeful importations of neuropteroid predators to New Zealand from the 1890s to the 1970s were unsuccessful and were discontinued. The emphasis has changed to observations on self-introduced or accidentally introduced species, particularly three from Australia and one from Europe.

A possible effect of non-specific predators is the loss of native insect species in the groups they attack. Two instances indicate that established introduced species could affect native species. Concerning the endemic insect fauna, both imported and introduced predators could be considered as pests.

Information on members of the Superorder Neuropteroidea as predators of insect pests is reviewed. Of the three Orders accepted for the Superorder, Raphidioptera (Snakeflies) do not occur naturally in New Zealand, Neuroptera (Lacewings) are the main group considered here and Megaloptera (aquatic Alderflies, Dobsonflies) are not involved.

This review covers references in the period 1890-1990 and is in three parts. Not all references to lacewings as predators, amongst the multitude of papers dealing with insect pests, may have been found but it is believed that most are included and certainly sufficient to illustrate what has happened during a century.

I. LIST OF IMPORTED NEUROPTEROIDS

This is a list of references to importations of Neuropteroidea, namely Raphidioptera and Neuroptera, into New Zealand for insect pest control. Complementary to records compiled by the author, results of biological control work done at Cawthron Institute, Nelson, from 1921 (Gourlay 1930) and in a series of symposium papers by Miller, Clark & Dumbleton (1936) have been useful sources. More recently, a booklet on imported invertebrates (Cameron *et al.* 1987) and a book on biological control (Cameron *et al.* 1989) have been especially useful references, particularly as they include information from Department of Scientific and Industrial Research files (which contain the Cawthron Institute biological control records). However, in the latest publication above, the information is separated according to host insects in different chapters by different authors (Thomas 1989, on Aphids; Charles 1989, on Mealybugs; Zondag & Nuttall 1989, on Pine Adelgid; and others). The present list presents the Neuroptera references together and includes other records and further information.

The genera and species imported are listed and the insects they are recorded as being brought in to control are given in square brackets on the same line. References to the

importation of each are listed underneath, and at the end of each reference the source country and the year of importation (where known) are given in square brackets, so that the reason for grouping the references under a particular name can easily be seen.

The list contains both named and unnamed species which have been imported to control introduced insect pests. The imported species are listed using present-day nomenclature, which is particularly noticeable in the Chrysopidae and the revised list for this family by Brooks & Barnard (1990) is followed, as is the update for the genus *Chrysoperla* by Brooks (1994).

The pest insects are given both as particular species and as groups, as follows.

Aphids. Hemiptera: Homoptera: Aphididae

A large number of introduced species are mainly pests on crops, vegetables, fruit trees and garden flower plants. The Spruce Aphid, *Elatobium abietinum* (Walker, 1849) is a pest of introduced spruce trees.

Codling Moth. Lepidoptera: Tortricidae: *Cydia pomonella* Linnaeus, 1759

Codling Moth (or Codlin Moth) is a pest of apples.

Grass Grub. Coleoptera: Scarabaeidae: Melolonthinae: *Costelytra zealandica* (White, 1846)

Grass Grub is a pasture pest and also attacks many other plants including roots of trees.

Mealybugs. Hemiptera: Homoptera: Pseudococcidae

Many introduced and endemic species are pests on a wide range of plants especially fruit trees, grape-vines and ornamental plants.

Passion Vine Hopper. Hemiptera: Homoptera: Ricaniidae: *Scolypopa australis* (Walker, 1851)

The Passion Vine Hopper is very common in New Zealand and is recorded as a pest of passion fruit vines, kiwi fruit and ornamentals by Hill & Steven (1989).

Pine Adelgid. Hemiptera: Homoptera: Adelgidae: *Pineus laevis* (Maskell, 1885).

The Pine Adelgid (also known as Pine Twig Chermes and Pine Woolly Aphid) is a pest of introduced pine. Miller & Clark (1935) recorded this species as *Pineus (Chermes) pini* and noted “*Pineus pini* is often popularly known as the “White blight” of pine trees...”. “Pine Adelgid” was used by Cameron et al (1987: 16). Synonymy for this species was listed by Wise (1977).

Order RAPHIIDOPTERA

This Order does not occur naturally in New Zealand.

Family RAPHIDIIDAE

Raphidia sp.

[Codling Moth]

- Raphidia* sp.: Wight, 1890 (June), N.Z. Farmer 10: 206. [U.S.A.].
Raphidia sp.: Riley & Howard, 1890, Insect life 3(2): 43. [U.S.A.].
Raphidia : Wight, 1891 (February), N.Z. Farmer 11: 52.
Raphidia : Wight, 1891 (April), N.Z. Farmer 11: 140. [1890].
Raphidia sp.: Anon., 1891 (October), N.Z. Farmer 11: 414. [U.S.A., 1891].
Raphidia sp.: Riley & Howard, 1892 (June), Insect life 4(9,10): 339. [U.S.A.].
Raphidia sp.: Clausen, 1962, Entomophagous insects, 594. [U.S.A., 1890].
Raphidia sp.: Cameron *et al.*, 1987, DSIR Bull. No. 242: 22. [U.S.A., 1890].

Wight (1890 June) recorded that *Raphidia* specimens were then received in New Zealand. Riley & Howard (1890 Sept.) recorded that *Raphidia* had been collected and sent to New Zealand for Codling Moth control, and had arrived safely according to Wight (1890). Wight (1891a, b) recorded that Mr Koebele [of North America] sent specimens of *Raphidia*, and in the second article stated that they were sent "Last April...", presumably April, 1890. Wight (1891c) stated that he had sent *Raphidia* specimens from Auckland to Australia but no date is given. An unsigned article (Anonymous 1891) fully recorded a second visit by Koebele in 1891 and the release of predators; a figure of a *Raphidia* larva was included. Riley & Howard (1892) mentioned attempts to introduce *Raphidia* specimens carried from U.S.A. to New Zealand as recorded by Anon. (1891).

The above records indicate an introduction of *Raphidia* sp. from U.S.A. by June 1890 and another by October 1891. Clausen (1962) and Cameron *et al.* (1987) noted only the 1890 introduction.

Order NEUROPTERA

Family CONIOPTERYGIDAE

Conwentzia psociformis (Curtis, 1834)

[Aphids]

- Conwentzia psociformis* : Dumbleton, 1936, N.Z. J. Sci. Tech. 18 (7): 590. [1924].
Conwentzia psociformis : Clausen, 1962, Entomophagous insects, 606. [England, 1924].
Conwentzia psociformis : Cameron *et al.*, 1987, DSIR Bull. No. 242: 14. [England, 1924].
Conwentzia psociformis : Thomas, 1989, CAB Tech. Comm. No. 10: 61 (Table 11.1), 63. [North America, 1924].

Kimmins & Wise (1962) noted this species as introduced and not established, but Meinander (1972, 1990) recorded it in New Zealand. Dumbleton (1936) had stated that the species was not known to have established. Thomas (1989) noted that *Conwentzia psociformis* had been sent from North America by A. Koebele in 1924, but this species was originally European. Meinander (1972) recorded it as first intercepted in U.S.A. from European specimens in 1954. Consequently the validity of named sources or species for the 1924 specimens is in question.

Family HEMEROBIIDAE

Symphorobius barberi (Banks, 1903)

[Aphids, Mealybugs]

- Symphorobius barberi* : Dumbleton, 1936, N.Z. J. Sci. Tech. 18 (7): 589.

Symphorobius barberi : Cameron *et al.*, 1987, DSIR Bull. No. 242: 14, 17. [? U.S.A.].

Symphorobius barberi : Thomas, 1989, CAB Tech. Comm. No.10: 61 (Table 11.1), [error for *Symphorobius*]. [? N. America].

Symphorobius barberi : Thomas, 1989, CAB Tech. Comm. No.10: 63. [? U.S.A.].

Symphorobius barberi : Charles, 1989, CAB Tech. Comm. No.10: 232 (Table 39.4) [Chrysopidae in error]. [U.S.A., 1925].

Symphorobius californicus Banks, 1911

[Aphids, Mealybugs]

Symphorobius californicus : Dumbleton, 1936, N.Z. J. Sci. Tech. 18 (7): 589.

Symphorobius californicus : Cameron *et al.*, 1987, DSIR Bull. No. 242:14, 17. [? U.S.A.].

Symphorobius californicus : Thomas, 1989, CAB Tech. Comm. No.10: 61 (Table 11.1) [in error for *Symphorobius*]. [? N. America].

Symphorobius californicus : Thomas, 1989, CAB Tech. Comm. No.10: 63. [? U.S.A.].

Symphorobius californicus : Charles, 1989, CAB Tech. Comm. No.10: 232 (Table 39.4) [Chrysopidae in error]. [U.S.A., 1925].

Symphorobius sp.

[Mealybugs]

Symphorobius sp.: Charles, 1989, CAB Tech. Comm. No.10: 232 (Table 39.4). [U.S.A., 1925, 1926].

Hemerobius stigma Stephens, 1836

[Pine Adelgid]

Hemerobius stigma : Miller & Clark, 1935, N.Z. J. Sci. Tech. 16: 305-306. [England].

Hemerobius stigma : Clausen, 1978, U.S. Dep. Agric., Agric. Handb.No. 480: 50. [England, 1932].

Hemerobius stigma : Cameron *et al.*, 1987, DSIR Bull. No. 242: 16. [England, 1932].

Hemerobius stigma : Zondag & Nuttall, 1989, CAB Tech. Comm. No.10: 296. [U.K., 1932].

Clausen (1962) mentioned *Hemerobius* introduced into New Zealand for control of Chermidae (now Adelgidae) attacking forest trees.

Family CHRYSOPIDAE

U.S.A., Europe - before 1904

Chrysopa sp.

[Aphids]

Chrysopa sp.: Anon., 1891, (October), N.Z. Farmer 11: 414. [U.S.A., 1891].

In an unsigned article (Anonymous 1891) it is recorded that Mr Koebele brought some specimens, of a *Chrysopa* useful against Aphids, on his then recent second visit to New Zealand.

Charles (1989: 231) accepted a record by Broun (1898) for *Chrysopa* sp. feeding on Mealybugs, even though it was seven years after a possible introduction of Chrysopids by Koebele in 1891 (Anonymous 1891). Broun actually referred to a figure of *Chrysopa* provided earlier by Kirk (1895: 158 [not 198]), which appears to be the source of Broun's use of "*Chrysopa*", but Kirk's figures were from a Californian publication and not intended as a record of importation. Broun recorded larvae of lace-winged flies feeding on Aphids, and adults feeding on Mealybugs. Wise (1993) did not accept Broun's *Chrysopa* but took his species to be *Micromus tasmaniae* which is the common Lacewing in New Zealand and is an active aphid predator. Further consideration on Broun's mealybug predator may be required but it is not likely to have been a species of Chrysopidae.

Chrysopa perla Linnaeus, 1758

[? Aphids]

Chrysopa perla Schneider: Hutton, 1904, Index faunae Novae Zealandiae, 354. [Europe].

In a "List of Naturalised Animals", Hutton included this species, as introduced from Europe. The list was made up of "... animals introduced, either intentionally or unintentionally, by human agencies, and have become so well established that they may be considered as part of the fauna.", (Hutton 1904: 347). The species name had been received (Hutton Preface iii, iv) in a general list from F. W. Hilgendorf, who was Lecturer in Biology (from 1899), Canterbury Agricultural College at Lincoln, Canterbury, in the South Island of New Zealand. As introduced Chrysopids have never become established in this country the species may have been the common Hemerobiid *Micromus tasmaniae*. It is tempting to suggest that it was the European Hemerobiid *Wesmaelius subnebulosus*, which is now one of the three species predatory on Aphids on crops on the Canterbury Plains. However, the earliest collection of *W. subnebulosus*, known to the present author, is 1920 (see below, Part II).

U.S.A., Canada, Pakistan - 1922-1972

Chrysopa oculata Say, 1849

[Aphids]

Chrysoperla oculata: Thomas, 1989, CAB Tech. Comm. No.10: 60 (Table 11.1), 61. [U.S.A., 1925, 1926].

This must be one of the two *Chrysopa* species referred to by Clausen (1978: 50) as imported from North America in 1926 for aphid control.

Chrysopa sp.

[Aphids, Pine Adelgid]

Chrysopa sp.: Gourlay, [1926], N.Z. State For. Serv. News Letter, 13-17. [Canada, 1925].

Chrysopa sp. 2: Thomas, 1989, CAB Tech. Comm. No. 10: 60 (Table 11.1), 62. [Canada, 1925, 1927].

Gourlay ([1926]) described the introduction of 1910 *Chrysopa* sp. specimens from Canada, with the assistance of A. Gibson, Dept. of Agriculture, Victoria, British Columbia, which arrived in New Zealand on 7 December 1925 and in Nelson on 9 December. Some were released immediately in Nelson, others sent to control Aphids on oak trees in Christchurch and others retained for breeding. Rearing was done successfully on Aphids in general and, also, on "Pine aphid" and "Spruce aphid", until the following February. Gourlay's article must have been completed in 1926 [not 1925 as listed (Miller 1956)]. A comment by Gourlay, that the species overwintered under the bark of forest trees, suggests that this may have been the species later described as *Chrysopa downesi* by Smith (1932) [see below]. Tillyard (1926b:12) recorded that 1900 hibernating adults of an undetermined Canadian species of Chrysopidae had been received for the control of Aphids in general with the aid of A. Gibson and W. Downes. This must be the *Chrysopa* sp. 2 of Thomas (1989) received in 1925. Thomas also recorded a second lot received in 1927.

Clausen (1962) mentioned *Chrysopa* spp. introduced into New Zealand for control of Aphids and Chermids on pine, which may include this entity. Zondag & Nuttall (1989: 296) stated that there is no record by New Zealand authors of an importation of two species of *Chrysopa* [for control of *Pineus laevis*] from North America in 1926, as reported by Clausen (1978) in a section on "Pine Aphid". However, *Chrysoperla plorabunda* and *Chrysopa oculata* were both imported from the U.S.A. that year for aphid control and obviously Clausen was referring to those.

Chrysopa nigricornis Burmeister, 1839

[Aphids]

Chrysopa nigricornis : Thomas, 1989, CAB Tech. Comm. No.10: 60 (Table 11.1), 62. [U.S.A., 1972].

Chrysoperla plorabunda (Fitch, 1855)

[Aphids]

Chrysopa carnea : Valentine, 1975, Proc. 28th N.Z. Weed & Pest Control Conf., 195. [U.S.A.].

Chrysopa carnea : Thomas, 1977, Proc. 30th N.Z. Weed & Pest Control Conf., 182.

Chrysoperla carnea : Cameron *et al.*, 1987, DSIR Bull. No. 242: 14. [U.S.A., 1968, 1970].

Chrysoperla plorabunda : Cameron *et al.*, 1987, DSIR Bull. No. 242: 14. [U.S.A., 1925].

Chrysoperla plorabunda : Thomas, 1989, CAB Tech. Comm. No.10: 60 (Table 11.1), 61. [U.S.A., 1922, 1925, 1926].

Chrysoperla carnea : Thomas, 1989, CAB Tech. Comm. No.10: 60 (Table 11.1), 62. [U.S.A., 1968, 1970].

Gourlay (1930: 9) had listed importations of *Chrysopa* spp. against Aphids between 1921 and 1929, Dumbleton (1936: 590) recorded *Chrysopa* spp. imported from North America for aphid control from 1922 onwards, and Cameron *et al.* (1987: 14) recorded the same for 1922, but there is no record of any species other than *plorabunda* for that year.

Valentine (1975) recorded that *Chrysopa carnea*, from U.S.A., had not established but suggested a different strain may have a better chance. Thomas (1977) listed *Chrysopa carnea* as one of the insect species introduced against Aphids in the 1968-1976 period.

This must be one of the two *Chrysopa* species referred to by Clausen (1978: 50) as imported from North America in 1926 for aphid control.

Charles (1989: 231) noted *californica* Coquillett, 1890 as a synonym and made reference to it (1989: 233), but there is no indication that specimens were introduced under that name. Brooks (1994) confirmed the synonymy with *Chrysoperla plorabunda*.

Brooks (1994) has placed specimens from North America (Nearctic) in *Chrysoperla plorabunda*, so previous records of *C. carnea* from U.S.A. are now included here.

Chrysoperla downesi (Smith, 1932)

[Pine Adelgid]

Chrysopa downesi Smith, 1932, Ann. Ent. Soc. America 25: 591-595.[Canada, 1927].

Chrysopa sp. (3): Thomas, 1989, CAB Tech. Comm. No. 10: 60 (Table 11.1), 62. [Canada, 1927].

Smith (1932) described this new species, noted it was the species introduced into New Zealand and mentioned that Mr Downes had advised that this species overwintered as adults under the loose bark of pine trees. It is consequently here taken to be the *Chrysopa* sp. 3 of Thomas (1989). This species of *Chrysopa* spp. was received from Downes in October 1927 and subsequently released as next generation larvae onto pine trees amongst Pine Adelgid populations, presumably in March, April, May 1928 (not 1927). This entity is confirmed as a separate species in *Chrysoperla* by Brooks (1994).

Chrysoperla carnea (Stephens, 1836)

[Aphids]

Chrysoperla carnea : Thomas, 1989, CAB Tech. Comm. No.10: 60 (Table 11.1), 62. [Pakistan, 1969].

Thomas (1977) listed *Chrysopa carnea* as one of the insect species introduced against Aphids in the 1968-1976 period.

Brooks (1994) has retained specimens from Europe to China (Palearctic) as *Chrysoperla carnea*, which is followed here, although another species is recorded from Pakistan.

*Australia - 1921-1969***Chrysopa** sp.**[Aphids]**

Chrysopa sp. (1) : Thomas, 1989, CAB Tech. Comm. No.10: 60 (Table 11.1), 61. [Australia, 1921].

There is no indication as to whether this is the same as the following 1921 importation or not. Thomas (1989) thought this was the first introduction of Chrysopids. Gourlay (1930: 9) had listed *Chrysopa* spp. as imported against Aphids between 1921 and 1929.

Chrysopa sp.**[Mealybugs]**

Chrysopa sp. : Charles, 1989, CAB Tech. Comm. No.10: 231. [Australia, 1921].

Charles' suggestion (1989: 230), that *Chrysopa* spp. imported from Australia for mealybug control were *C. ramburi*, possibly includes this importation, but it is not known if it is the same species or importation as Thomas (1989) recorded for Aphids.

Chrysopa sp.**[Mealybugs]**

Chrysopa sp. : Charles 1989, CAB Tech. Comm. No.10: 230 (Text + Table 39.3). [Australia, 1928].

The suggestion by Charles (1989: 230), that *Chrysopa* spp. imported from Australia for mealybug control were *C. ramburi*, would possibly include this importation.

Plesiochrysa ramburi (Schneider, 1851)**[Aphids, Mealybugs]**

Chrysopa ramburi : Dumbleton, 1936, N.Z. J. Sci. Tech. 18 (7): 589.

Chrysopa ramburi : Cameron *et al.*, 1987, DSIR Bull. No. 242: 17. [? Australia].

Chrysopa ramburi : Thomas, 1989, CAB Tech. Comm. No.10: 60 (Table 11.1), 62. [U.S.A., 1928].

Chrysopa ramburi : Charles, 1989, CAB Tech. Comm. No.10: 230 (Table 39.3 + text), 231. [U.S.A. ex Australia, 1928].

Charles (1989: 230) intimated that all shipments of *Chrysopa* spp. from Australia for mealybug control were *C. ramburi*. Clausen (1962) mentioned *Chrysopa* spp. introduced into New Zealand for control of aphid and mealybug pests, which may include this species.

Chrysopa sp.**[Passion Vine Hopper]**

Chrysopa sp. : Cameron *et al.*, 1987, DSIR Bull. No. 242: 17. [Australia, 1965].

Hill & Steven (1989: 242) described the introduction of a chrysopid species from Australia and subsequent releases of larvae and adults, based on the work and results of R. A. Cumber.

Chrysopa spp.**[Aphids]**

Chrysopa sp. : Cameron *et al.*, 1987, DSIR Bull. No. 242:14. [Australia, 1969].

Chrysopa spp. (4, 5, 6) : Thomas, 1989, CAB Tech. Comm. No.10: 60 (Table 11.1). [Australia, 1969].

Chrysopa spp. : Thomas, 1989, CAB Tech. Comm. No.10: 62. [Australia, 1969].

Family ITHONIDAE

Ithone fusca Newman, 1838**[Grass Grub]***Ithone fusca* : Tillyard, [1926], Proc. Pan-Pacific Sci. Congr. Australia, 1923 1: 389. [Australia].*Ithone fusca* : Miller, 1936, N.Z. J. Sci. Tech. 18 (7): 592. [Australia, 1921-22].*Ithone fusca* : Dumbleton, 1942, N.Z. J. Sci. Tech. (A) 23 (6): 311. [Australia, 1921].*Ithone fusca* : Cameron *et al.*, 1987, DSIR Bull. No. 242: 7. [Australia, 1921].*Ithone fusca* : Cameron & Wigley, 1989, CAB Tech. Comm. No.10: 11. [Australia].

This species was earlier thought to be a predator on other soil fauna (Tillyard [1926]) but this idea has since been discredited (New 1986). Tillyard noted the failure of this species to acclimatise and Miller (1936) recorded the introduction as unsuccessful.

RESULTS

The importations recorded above are summarised in Table 1. All the records show that not one of the purposefully imported species of Raphidioptera and Neuroptera has been established in New Zealand, despite many attempts during more than 80 years. As recorded by various authors in Cameron *et al.* (1989), specimens were sometimes dead on arrival or were never released but, in other cases, species released were never recovered after the season of liberation.

II. INDIGENOUS NEUROPTERA IN NEW ZEALAND

Non-endemic species of New Zealand Neuroptera are listed and references given for information on control of insect pests. Pests are as in Part I except for the following.

Aphids.

The Aphids group here includes *Eriosoma lanigerum* (Hausmann, 1802), Family Pemphigidae, a pest of apple trees, which is still commonly known as the Woolly Apple Aphid.

Mites. Acarina: Tetranychidae

Phytophagous mite pests in orchards have been recorded as hosts.

Pittosporum Triozid. Hemiptera: Homoptera: Triozidae: *Trioza vitreoradiata* (Maskell, 1879)

This is included here as it can be a pest on New Zealand ornamental and hedge *Pittosporum* species, and represents a different host group from the others. Synonymy was listed by Wise (1977), but Family status has since been accepted for the previous Subfamily. The species has been commonly known as the Pittosporum Psyllid. One of the true Psyllids, *Psylla albizziae* (Ferris & Klyver, 1932), Family Psyllidae, has also been recorded as a host.

Table 1. Summary of importations of neuropteroid predators.

Year	Source	Species	Host	Comments
1890	U.S.A.	<i>Raphidia</i> sp.	Codling Moth	
1891	U.S.A.	<i>Raphidia</i> sp.	Codling Moth	
	U.S.A.	<i>Chrysopa</i> sp.	Aphids	
1904	Europe	<i>Chrysopa perla</i>	? Aphids	Or earlier
1921	Australia	<i>Chrysopa</i> sp.	Aphids	{ ? 1 importation or 2
	Australia	<i>Chrysopa</i> sp.	Mealybugs	
	Australia	<i>Ithone fusca</i>	Grass Grub	
1922	U.S.A.	<i>Chrysoperla plorabunda</i>	Aphids	
1924	England	<i>Conwentzia psociformis</i>	Aphids	
1925	U.S.A.	<i>Chrysoperla plorabunda</i>	Aphids	
	U.S.A.	<i>Chrysopa oculata</i>	Aphids	
	U.S.A.	<i>Sympherobius barberi</i>	Aphids, Mealybugs	
	U.S.A.	<i>Sympherobius californicus</i>	Aphids, Mealybugs	
	U.S.A.	<i>Sympherobius</i> sp.	Mealybugs	
	Canada	<i>Chrysopa</i> sp.	Aphids, Pine Adelgid	
1926	U.S.A.	<i>Sympherobius</i> sp.	Mealybugs	
	U.S.A.	<i>Chrysoperla plorabunda</i>	Aphids	
	U.S.A.	<i>Chrysopa oculata</i>	Aphids	
1927	Canada	<i>Chrysopa</i> sp.	Aphids, Pine Adelgid	
	Canada	<i>Chrysoperla downesi</i>	Pine Adelgid	
1928	Australia	<i>Chrysopa</i> sp.	Mealybugs	
	Australia	<i>Plesiochrysa ramburi</i>	Aphids, Mealybugs	
	U.S.A. ex Australia	<i>Plesiochrysa ramburi</i>	Aphids, Mealybugs	Colony established in U.S.A.
1932	England	<i>Hemerobius stigma</i>	Pine Adelgid	
1965	Australia	<i>Chrysopa</i> sp.	Passion Vine Hopper	
1968	U.S.A.	<i>Chrysoperla plorabunda</i>	Aphids	As <i>carnea</i>
1969	Australia	<i>Chrysopa</i> spp.	Aphids	
	Pakistan	<i>Chrysoperla carnea</i>	Aphids	
1970	U.S.A.	<i>Chrysoperla plorabunda</i>	Aphids	As <i>carnea</i>
1972	U.S.A.	<i>Chrysopa nigricornis</i>	Aphids	

Scale Insects. Hemiptera: Homoptera: Eriococcidae

Little mention has been made of predation on Scale Insects.

Tomato Fruitworm. Lepidoptera: Noctuidae: *Helicoverpa armigera conferta* Walker, 1857

Predation on this pest has been suggested.

Order NEUROPTERA

Family CONIOPTERYGIDAE

Cryptoscenea australiensis (Enderlein, 1906)

Cryptoscenea australiensis : Collyer, 1964, N.Z. J. Agric. Res. 7 (4): 558.

Cryptoscenea australiensis : Valentine, 1964, N.Z. J. Sci. Rev. 22 (2): 16.

Cryptoscenea australiensis : Valentine, 1967, N.Z. J. Sci. 10 (4): 1147.

Cryptoscenea australiensis : Collyer & van Geldermalsen, 1975, N.Z. J. Zool. 2: 128.

Cryptoscenea australiensis : Charles, 1981, N.Z. J. Zool. 8: 292.

Cryptoscenea australiensis : Charles 1989, CAB Tech. Comm. No.10: 227.

A colony of this species was discovered in 1959-60 (Kimmins & Wise 1962) and found to be predatory on Mealybugs which were later described as a new endemic species (*Trionymus wisei* Williams & de Boer, 1973). Valentine (1964) listed it as predatory on Mealybugs. The species has also been found feeding on Mites (Collyer 1964). Valentine (1967) recorded larval predation by this species mainly on eggs of Mealybugs (Pseudococcidae) and of Scale Insects (Eriococcidae) from his own observations. It was found feeding on Mealybugs on apple trees (Collyer & van Geldermalsen 1975). Charles (1981) recorded it in vineyards. Both adults and larvae are active predators of mealybugs.

Heteroconis ornata Enderlein, 1905

Heteroconis ornata : Wise, 1988, Rec. Auckland Inst. Mus. 25: 181.

Heteroconis ornata : Wise, 1991, Rec. Auckland Inst. Mus. 28: 214.

Wise (1988, 1991) recorded the occurrence of this Australian species in two separate areas of Auckland in 1988-90. This species may have the same potential as the previous one.

Family HEMEROBIIDAE

Micromus tasmaniae (Walker, 1860)

Micromus tasmaniae : Myers, 1921, N.Z. J. Agric. 23: 158.

Micromus tasmaniae : Miller, 1925, N.Z. State For. Serv. Bull. No. 2: 26.

Micromus tasmaniae : Gourlay, 1930, N.Z.D.S.I.R. Bull. No. 22: 9.

Micromus tasmaniae : Dumbleton, 1932, N.Z. J. Sci. Tech. 13 (4): 218.

Micromus tasmaniae : Clark, 1932, N.Z. J. Sci. Tech. 13 (4): 236.

Micromus tasmaniae : Miller & Clark, 1935, N.Z. J. Sci. Tech. 16: 305.

Micromus tasmaniae : Miller, 1935, Garden pests New Zealand, 34.

Micromus tasmaniae : Miller, 1944, Garden pests New Zealand (2nd. ed.), 36-37.

Micromus tasmaniae : Carter, 1949, N.Z. J. Sci. Tech. (B) 31 (2): 40, 41.

Micromus tasmaniae : Rawlings, 1953, Forest Res. Notes 1(8): 14.

Micromus tasmaniae : Valentine, 1964, N.Z. Sci. Rev. 22 (2): 16.

Micromus tasmaniae : Valentine, 1967, N.Z. J. Sci. 10 (4): 1148.

Micromus tasmaniae : Collyer & van Geldermalsen, 1975, N.Z. J. Zool. 2: 128-129.

Micromus tasmaniae : Thomas, 1977, Proc. 30th. Weed & Pest Control Conf., 183.

Austromicromus tasmaniae : Syrett & Penman, 1980, Proc. 33rd. Weed & Pest Control Conf., 52-54.

Micromus tasmaniae : Syrett & Penman, 1981, N.Z. J. Zool. 8: 281-283.

Micromus tasmaniae : Charles, 1981, N.Z. J. Zool. 8: 292.

Micromus tasmaniae : Cameron *et al.*, 1983, N.Z. J. Exper. Agric. 11: 344.

Micromus tasmaniae : Early, 1984, New Zealand pest and beneficial insects, 306.

Micromus tasmaniae : Cameron & Valentine, 1985, N.Z. J. Agric. Res. 28: 551.

Micromus tasmaniae : Farrell & Stufkens, 1988, N.Z. J. Zool. 15: 501.

Micromus tasmaniae : Thomas, 1989, CAB Tech. Comm. No. 10: 57.

Micromus tasmaniae : Cameron & Walker, 1989, CAB Tech. Comm. No. 10: 3.

Micromus tasmaniae : Walker, G.P., & Cameron, 1989, CAB Tech. Comm. No. 10: 33.

Micromus tasmaniae : Cameron, 1989, CAB Tech. Comm. No. 10: 88.

Micromus tasmaniae : Stufkens & Farrell, 1989, CAB Tech. Comm. No. 10: 105.

Micromus tasmaniae : Walker, J.T.S., 1989, CAB Tech. Comm. No. 10: 197.

Micromus tasmaniae : Charles, 1989, CAB Tech. Comm. No. 10: 227.

Micromus tasmaniae : Farrell & Stufkens, 1990, Bull. Ent. Res. 80: 381.

This Australian species has long been established in New Zealand (Wise 1993). Myers (1921) recorded it as feeding on pest Aphids. Miller (1925) recorded it as a predator of Spruce Aphid and Dumbleton (1932) had reared it from larvae attacking Spruce Aphid. Clark (1932) and Miller & Clark (1935) recorded the species as one of three predators of Pine Adelgid, and Rawlings (1953) listed it. Miller (1935, 1944) recorded it as a predator of Mealybugs but Charles (1989) was unable to confirm this for New Zealand (only for Australia). It was recorded by Carter (1949) as a predator of Pittosporum Psyllid. Hilson (1964) recorded *Micromus tasmaniae* as feeding on Aphids and other insects on crops, and considered biological control. Valentine (1964) listed it as predatory on Aphids, Woolly Apple Aphid and Mealybugs. Valentine (1967) recorded this species on Woolly Apple Aphid, Spruce Aphid and other Aphids, Pine Adelgid, Mealybugs and the Pittosporum Psyllid, mostly from earlier records. Collyer & van Geldermalsen (1975) recorded *M. tasmaniae* as present with Mealybugs and feeding on Woolly Apple Aphid and other Aphids on apple trees; later J. T. S. Walker (1989) noted their record of this aphid predator. Charles (1981) mentioned the species as a general predator on grapevines. Early (1984) recorded it as a predator of both Aphids and Mealybugs.

Thomas (1977) had noted *Micromus tasmaniae* as common against Aphids on lucerne. Syrett & Penman dealt with this species as a predator of Aphids on lucerne and reported (1980) that it had a higher resistance to the insecticide tested than the pest Aphid. They (Syrett & Penman 1981) also recorded physiological research which indicated that low threshold temperature tolerance of *M. tasmaniae* may relate to early seasonal appearance. Subsequently, it is recorded (Cameron *et al.* 1983, Cameron & Walker 1989, Walker & Cameron 1989) as an aphid predator in lucerne crops capable of responding to early season aphid increases, as the predator best synchronised with lucerne Aphids and, perhaps, the most effective of all the aphid predators.

Cameron & Valentine (1985) noted the presence of *Micromus tasmaniae* amongst larvae of a Lepidopteran pest, the Tomato Fruitworm, but not predation, although Cameron (1989) considered it to be predatory. The species is recorded as an aphid predator on cereal crops and grasses (Farrell & Stufkens 1988, 1990, Stufkens & Farrell 1989), and as a general predator of Aphids (Thomas 1989: 57).

Drepanacra binocula (Newman, 1838)

Drepanacra binocula : Gourlay, 1930, N.Z.D.S.I.R. Bull. No. 22: 9.

Drepanacra binocula : Dumbleton, 1932, N.Z. J. Sci. Tech. 13 (4): 218.

Drepanacra binocula : Miller & Clark, 1935, N.Z. J. Sci. Tech. 16: 305.

Drepanacra binocular : Carter, 1949, N.Z. J. Sci. Tech. (B) 31 (2): 40, 41 (in error for *binocula*).

- Drepanacra binocula* : Rawlings, 1953, Forest Res. Notes 1 (8): 14.
Drepanacra binocula : Valentine, 1964, N.Z. Sci. Rev. 22 (2): 16.
Drepanacra binocula : Valentine, 1967, N.Z. J. Sci. 10 (4): 1148.
Drepanacra binocula : Collyer & van Geldermalsen, 1975, N.Z. J. Zool. 2: 129.
Drepanacra binocula : Harrison, 1976, New Zealand insect pests, 71.
Drepanacra binocula : Thomas, 1977, Proc. 30th. Weed & Pest Control Conf., 183.
Drepanacra binocula : Somerfield, 1984, New Zealand pest and beneficial insects, 85.
Drepanacra binocula : Walker, J.T.S., 1989, CAB Tech. Comm. No.10: 197.

This is another long established Australian species. Gourlay (1930) listed Psyllids as hosts. Dumbleton (1932) reared *Drepanacra binocula* from larvae attacking Spruce Aphid. Miller & Clark (1935) included this species as a predator of Pine Adelgid. It was recorded by Carter (1949) as the most abundant predator of Pittosporum Psyllid. Miller & Clark (1935) included this species as one of the three predators of Pine Adelgid and it was listed by Rawlings (1953). *Drepanacra binocula* is now presumed to be the species referred to by Clark (1932) as *Protobiella zelandica* (see Part III below). Valentine (1964) listed it as predatory on Aphids including Woolly Apple Aphid. *Drepanacra binocula* was mentioned by Hilson (1964) in his study of *Micromus tasmaniae*. Valentine (1967) recorded the species on Aphids including Spruce Aphid and one endemic species (*Neophyllaphis totarae* Cottier, 1953), on Pine Adelgid, the Pittosporum Triozid and a Psyllid, from earlier records and his own observations. Collyer & van Geldermalsen (1975) recorded it as predatory on Woolly Apple Aphid and other Aphids on apple trees. Harrison (1976) noted this as an important predator of Pittosporum Triozid and Somerfield (1984) also recorded it on this host. It was noted by Thomas (1977) as rare on Aphids in lucerne.

Wesmaelius subnebulosus (Stephens, 1836)

- Boriomyia maorica* : Carter, 1949, N.Z. J. Sci. Tech. (B) 31 (2): 40, 41.
Boriomyia maorica : Valentine, 1967, N.Z. J. Sci. 10 (4): 1148.

This species was first described in New Zealand as an endemic but later recognised as a common European species (Wise 1973). A specimen collected in Dunedin, N.Z., in 1920, was designated the type of *Boriomyia maorica* by Tillyard (1923).

Three larvae were recorded by Carter (1949) from field work done 1942-45 and there are two adults, in collections known to the present author, labelled as bred from larvae feeding on Pittosporum Psyllids in 1942 and 1943 by M. W. Carter. *Boriomyia maorica* was mentioned by Hilson (1964) in his study of *Micromus tasmaniae*. Valentine (1967) recorded the species predatory on Pittosporum Psyllid, from the earlier record by Carter. There are also specimens of this neuropteran collected from lucerne crops in Canterbury, South I., N.Z., in 1978, 1984 and 1985.

Psectra nakaharai New, 1988

- Symphorobius* group : Wise, 1973, N. Z. Ent. 5 (2): 183.
Psectra nakaharai : Wise, 1988, Rec Auckland Inst. Mus. 25: 182.

An Australian species considered to be associated with *Acacia* in New Zealand and not known as a predator of pests.

III. ENDEMIC NEW ZEALAND NEUROPTERA

Family BEROETHIDAE

Protobiella zelandica Tillyard, 1923

Protobiella zelandica : Gourlay, 1930, N.Z.D.S.I.R. Bull. No. 22: 9.

Protobiella zelandica : Clark, 1932, N.Z. J. Sci. Tech. 13: 236.

Protobiella zelandica : Rawlings, 1953, Forest Res. Notes 1 (8): 14.

Protobiella zelandica : Valentine, 1967, N.Z. J. Sci. 10 (4): 1147 (in error for *zelandica*).

Gourlay (1930) listed *Chermes pini* (now *Pineus laevis*) as the host for *Protobiella zelandica*, probably from the work of A. F. Clark, and Clark (1932) recorded *P. zelandica* amongst three predators of Pine Adelgid on pine. The species was subsequently listed by Rawlings (1953), and Valentine (1967) also recorded it as predatory on Pine Adelgid, from earlier records. It was mentioned as the Family Beroethidae by Zondag & Nuttall (1989).

Wise (1992) has not accepted Clark's record as there is no evidence that Clark saw Beroethid adult lacewings, no relevant specimens of the one species in New Zealand have been found in collections and the larva has still not been described. In fact, Miller & Clark (1935) also recorded three predators of Pine Adelgid but *Protobiella zelandica* was replaced by *Drepanacra binocula*, which is now taken to be a correction. Records after 1935 were based on the earlier error.

DISCUSSION

The many importations of predatory Neuropteroids to control insect pests, as shown in the records listed above (Part I), were not successful. Importation of Snakeflies (Raphidioptera) was tried only in the late 1800s and was not continued. Importations of Lacewings (Neuroptera) against Mealybugs were continued from the 1890s until the late 1920s and against Aphids until 1972. Others were to control Grass Grub in the 1920s, Pine Adelgids in the 1920s-30s, and Passion Vine Hopper in the 1960s.

Although there are records of established Neuroptera as predators of pests (Part II), mainly since the 1920s, there appears to have been a later awareness, possibly since the 1960s, of self-established (considered by Wise 1991 to be indigenous) and/or accidentally introduced species as useful predators. These are mainly species of the Family Hemerobiidae from Australia, with one from Europe, and a species of Coniopterygidae from Australia.

The one case of an endemic species recorded as a predator on insect pests (Part III) is considered to be false.

Amongst all the records of imported predatory Neuropteroids there is no mention of any effect they would have on the endemic fauna, if established. This would appear to be in contradiction to the principles of host specificity often applied rigorously to the introduction of parasites.

The successful introduction of such non-specific predators could mean the loss of native insect species, particularly of Aphids and Mealybugs. Further, such an effect on endemics could already be happening with self-introduced indigenous species or accidentally introduced species. An indication that this can occur was shown by the discovery (Kimmins & Wise 1962) of an Australian species of Coniopterygidae feeding on a colony of a then undescribed endemic species of Mealybugs. Another is the record by Valentine (1967) of an endemic species of Aphids as a host for an Australian species of Hemerobiidae.

It is suggested that introduced and imported predatory Lacewings should be considered, not as beneficial insects, but as pests in regard to the safety of the endemic insect fauna.

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