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FORAMINIFERA IN NEARSHORE SEDIMENTS OF THE EASTERN BAY OF ISLANDS, NORTHERN NEW ZEALAND

by Bruce W. Hayward
New Zealand Geological Survey, PO Box 30368, Lower Hutt

SUMMARY

Foraminiferal faunas have been analysed from eleven samples of surface sediment from a variety of near-shore environments in the eastern Bay of Islands. Intertidal fine sand in the middle and upper reaches of a small estuary has faunas with low diversity dominated by *Trochammina inflata* (76-94%). Faunas from the beach, subtidal *Zostera* flats and clean sand (intertidal - 3 m depth) in sheltered Urupukapuka Bay are dominated by *Elphidium charlottensis* (40-50%) with subordinate *E. oceanicum, E. simplex, E. novozealandicum* and *Quinqueloculina seminula* (over 3% each). *E. charlottensis, E. novozealandicum* and *Q. seminula* (14-15% each) are dominant in low-tidal sand on a cockle beach in Otehei Bay.

Gravelly sand from the subtidal portion of a lagoon has faunas dominated by *E. charlottensis, Pileolina zealandica, Notorotalia olsoni, Q. seminula* and *E. novozealandicum* (over 7% each). Sandy shell gravel in the relatively exposed Albert Channel (c. 7 m depth) has faunas with a high diversity, dominated by *P. zealandica* (10-20%) with subordinate *Cibicides marlboroughensis, E. novozealandicum* and diverse miliolaceans, discorbids and glabratellids. The fauna of a muddy fine sand in a basin (12 m depth) in Rawhiti Inlet is dominated by *P. zealandica* and *E. charlottensis* (14-16% each) with subordinate *Q. seminula* and diverse miliolaceans and discorbaceans.

Most of these nearshore samples contain no planktic foraminifera but 0.3-2.3% of the faunas in the more open-water Albert Channel and Rawhiti Inlet are planktic.

INTRODUCTION

Sediment samples were collected from a variety of inshore localities (intertidal to 12 m depth) during the Offshore Islands Research Group trip to Urupukapuka Island, eastern Bay of Islands in January 1980. The Bay of Islands is on the east coast of Northland, New Zealand at latitude 35°15'S and longitude 174°15'E (Fig. 1).

METHODS

Eleven samples (Fig. 1) were processed for foraminifera. Six of these

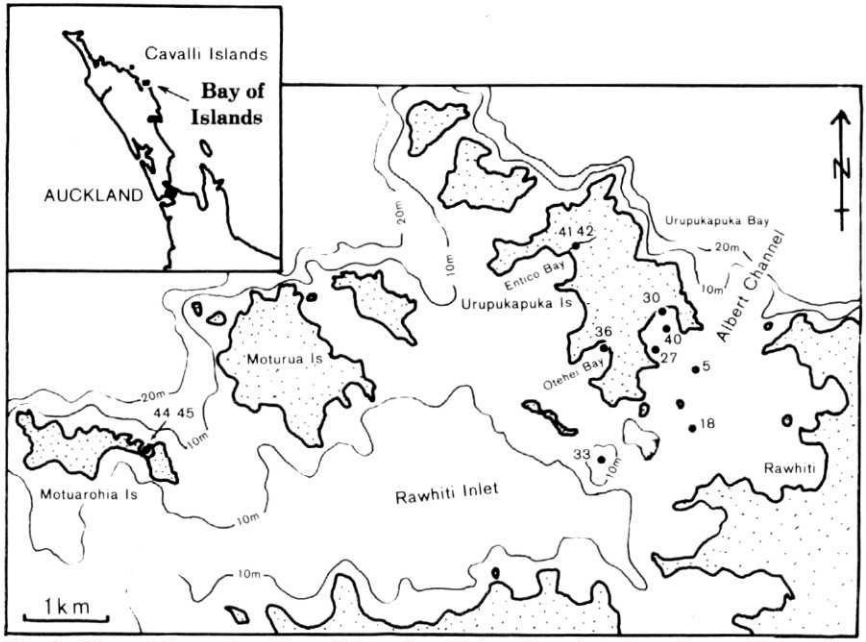

Fig. 1. Map of the eastern Bay of Islands with location of stations from which surface sediment samples were processed for foraminiferal studies.

(Stns 5, 18, 27, 33, 36, 40) were collected using a small dredge, hand-hauled from a 3.8 m aluminium dinghy with an 18 h.p. outboard motor. Under ideal conditions the dredge sampled an area of approximately 0.075 square metres to a depth of 6 cm (Hayward *et al.* 1981). The remaining five samples (30, 41, 42, 44, 45) were collected by hand and contained the upper 6 cm of sediment.

Each sample, comprising approximately 200 cc of sediment, was preserved in 10% ethanol. On return to the laboratory samples were stained with a solution of Rose Bengal (a stain for protoplasm, commonly used to identify living individuals) and analysed for grain size using sieves. Each sample was divided up using a microsplitter until the quantity of material left contained approximately 300 benthic foraminifera, which were then picked (together with the few planktics), mounted, identified and counted (Fig. 2, Appendix 1). A note was made of the number of stained (live) foraminifera, bearing in mind the apparent inaccuracies of such a method (Martin and Steinker 1973).

Station numbers 5-40 are those of Hayward *et al.* (1981) used in macrofaunal studies. All faunas and samples are held in the Micropaleontology Section of the New Zealand Geological Survey and have six figure catalogue numbers (e.g. F201805). Figured specimens have catalogue numbers prefixed by FP.

BENTHIC FORAMINIFERAL ASSOCIATIONS (Fig. 2)

The samples looked at were selected to be representative of some of the variety of near-shore and intertidal habitats and macrofaunal communities (Hayward *et al.* 1981) present in the area.

1. Small estuary

Two samples of muddy fine sand from the banks of the upper (stn 41) and middle (stn 42) reaches of a very small estuary at Entico Bay, Urupukapuka Island (Fig. 1), had faunas dominated by the agglutinated, trochospiral *Trochammina inflata* (Fig. 3a) comprising 94% and 76% of the foraminifera respectively. *Haplophragmoides* sp. is the only other taxon present in the upper estuary sample whereas eight other taxa, mostly *Elphidium* spp. are present in the middle estuary sample.

2. Pipi beach

One sample (stn 30) of clean, very coarse sand containing a macrofauna of pipi bivalves, *Mesodesma australe*, was looked at from

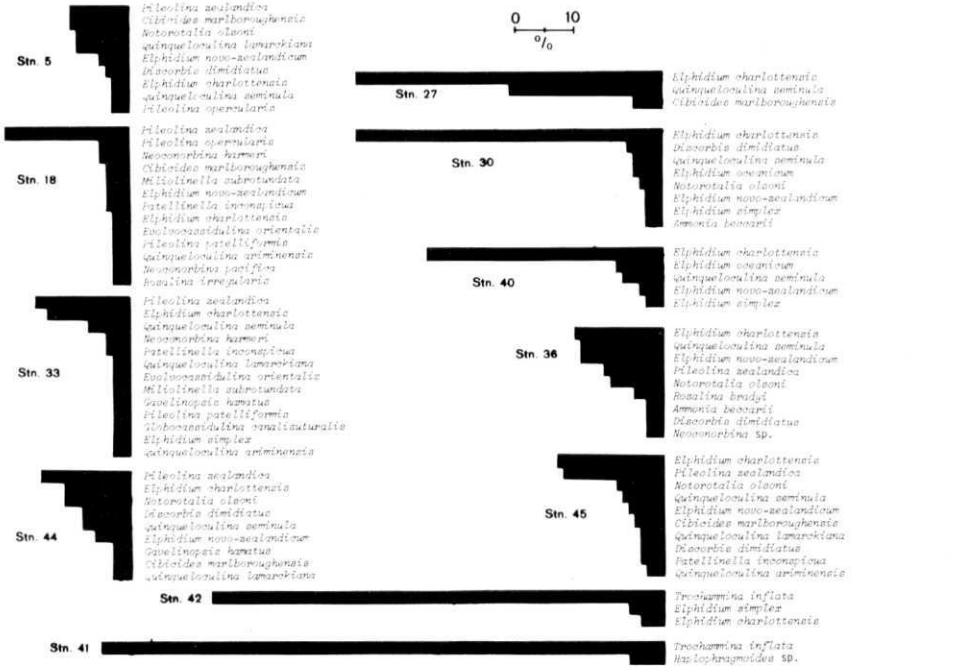

Fig. 2. Histograms of common benthic foraminiferal species (> 3%) to illustrate the differences in the gross composition of the faunas of the different stations.

the low tidal part of Urupukapuka Bay beach. The foraminiferal fauna is dominated by *Elphidium charlottensis* (52%) with subordinate *Discorbis dimidiatus, Quinqueloculina seminula* and *Elphidium oceanicum* (each 5-6%, Fig. 3b, c, f, g).

3. Cockle beach

One sample (stn 36) of slightly muddy medium sand, containing a macrofauna predominantly of cockles, *Austrovenus stuchburyi*, was looked at from the low tidal part of Otehei Bay beach. The foraminiferal fauna is dominated by *E. charlottensis, Q. seminula* and *Elphidium novozealandicum* (each 14-15%) with subordinate *Pileolina zealandica* and*Notorotalia olsoni* (each 9-10%, Fig. 3b, e, g, i, j).

4. Subtidal ***Zostera***

Most of the floor of the enclosed Urupukapuka Bay (0.5-3 m deep) is covered with a thick mat of seagrass, *Zostera muelleri*, growing in muddy fine sand. The foraminiferal fauna of the sediment (stn 40) is dominated by *E. charlottensis* (40%) with subordinate *Elphidium oceanicum, E. novozealandicum, E. simplex* and *Q. seminula* (Fig. 3b-e, g).

5. ***Zeacolpus-Zegalerus*** **community**

Clean, slightly shelly, medium to fine sand around the entrance to Urupukapuka Bay (1-3 m deep) has a macrofauna dominated by the gastropods *Zeacolpus pagoda* and *Zegalerus tenuis*. The foraminiferal fauna from one sample in this area (stn 27) is dominated by *E. charlottensis* (52%) with subordinate *Q. seminula* and *Cibicides marlboroughensis* (Fig. 3b, g, k).

6. ***Tawera*** **shellbed**

Clean shelly sand and sandy shell gravel covers the seafloor (2-8 m deep) in an area of moderate to high wave energy in Albert and "Poroporo" Channels. The macrofauna is dominated by the bivalve *Tawera spissa* which nestles on the seafloor forming a mat of dead and live shells. The foraminiferal fauna from one sample (stn 5) is dominated by *P. zealandica, C. marlboroughensis, N. olsoni* and *Quinqueloculina lamarckiana* (each 9-10%, Fig. 3h-k) with many subordinate taxa from the families Discorbidae, Glabratellidae, Elphidiidae and Miliolidae.

7. ***Corbula-Glycymeris*** **community**

Shelly and pebbly sand and sandy gravel over several areas of seafloor (1-7 m depth) with exposure to moderate wave energy around southern Urupukapuka Island has a macrofauna dominated by the bivalve *Corbula zelandica*. One sample (stn. 18, 7 m) of sandy gravel

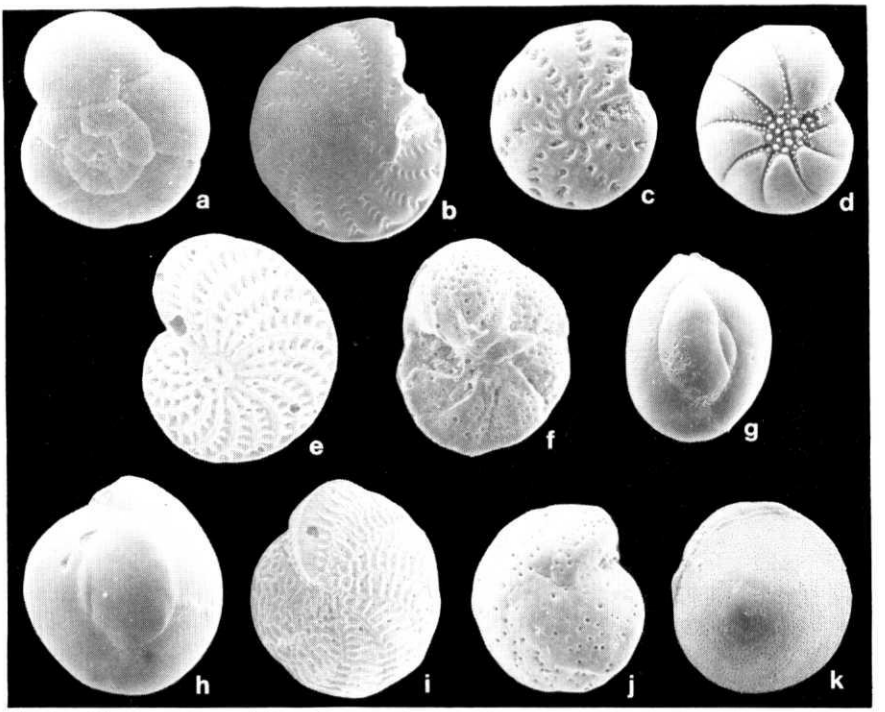

Fig. 3. Common foraminifera in near-shore sediment samples in the eastern Bay of Islands: a. *Trochammina inflata* (F201810, FP3032), × 45; b. *Elphidium charlottensis* (F201799, FP3033), × 50; c. *Elphidium oceanicum* (F201799, FP3034), × 75; d. *Elphidium simplex* (F201799, FP3035), × 75; e. *Elphidium novozealandicum* (F201805, FP3036), × 45; f. *Discorbis dimidiatus* (F201813, FP3037), × 40; g. *Quinqueloculina seminula* (F201796, FP3038), × 40; h. *Quinqueloculina lamarckiana* (F201774, FP3039), × 45; i. *Pileolina zealandica* (F201787, FP3040), × 75; j. *Notorotalia olsoni* (F201774, FP3041), × 50; k. *Cibicides marlboroughensis* (F201774, FP3042), × 75.

with the large dog cockle *Glycymeris laticostata* also common, was looked at. The foraminiferal fauna is dominated by *P. zealandica* (21%) and subordinate discorbaceans (*Pileolina opercularis, P. patelliformis, Neoconorbina harmeri, N. pacifica, Patellinella inconspicua, Rosalina irregularis*), miliolaceans (*Miliolinella subrotundata, Quinqueloculina ariminensis*), together with *C. marlboroughensis, E. novozealandicum, E. charlottensis* and *Evolvocassidulina orientalis* (all 3-5% each).

8. *Pleuromeris-Pectinaria* community

Muddy fine to medium sand in basins in Otehei Bay (2-4 m deep) and Rawhiti Inlet (5-15 m deep) contains macrofaunas dominated by the bivalve *Pleuromeris zelandica* and polychaete *Pectinaria australis*. The foraminiferal fauna from one sample (stn 33, 12m, Rawhiti Inlet) from

this community is dominated by *P. zealandica* and *E. charlottensis* (c. 20% each) with the subordinate taxa dominated by miliolaceans (*Q. seminula, Q. lamarckiana, Q. ariminensis. M. subrotundata*), discorbaceans (*N. harmeri, P. inconspicua, P. patelliformis, Gavelinopsis hamatus*) and cassidulinids (*E. orientalis, Globocassidulina canalisuturalis*).

9. Tidal lagoon

Several large tidal lagoons (0.5-1.5 m deep at low tide) with narrow openings to the sea occur on Motuarohia Island. Two samples (stns 44, 45) of gravelly medium sand from the subtidal portion of the largest of these lagoons have foraminiferal faunas dominated by *P. zealandica* and *E. charlottensis* (12-18% each), and *N. olsoni* (8-12%). Subdominants are *Quinqueloculina (Q. seminula, Q. lamarckiana, Q. ariminensis),* discorbids (*D. dimidiatus, G. hamatus*), *E. novozealandicum* and *C. marlboroughensis* (Fig. 3b, e-k).

PLANKTIC FORAMINIFERA

Planktic foraminifera are rare in the sediments of the rather enclosed eastern Bay of Islands. Virtually no planktics are present in samples from all the most sheltered situations - estuary, tidal lagoon, Otehei Bay and Urupukapuka Bay (stns 27, 30, 36, 40, 41, 42, 44, 45), although one juvenile of *Globigerina falconensis* was present in the pipi beach sample (stn 30). The three more exposed and deeper water samples from the Albert Channel and Rawhiti Inlet (stns 5, 18, 33) contain 0.3%, 2.3% and 1.6% planktic foraminifera respectively. The five taxa present are among the more common species living in waters around northern New Zealand today (Hayward 1979, Kustanowich 1963).

DIVERSITY

One simple measure of diversity is the Fisher α index (Murray 1973). A low value represents a low diversity whereas a value over 20 is a high diversity. The lowest diversities of the Bay of Islands' samples are from the upper estuary (α= 0.4) and middle estuary (α= 3).

Moderate diversities (α= 7-17, Appendix 1) are present in the faunas from all the shallower, more sheltered stations (+ 0.3 to 2 m depth, Otehei Bay, Urupukapuka Bay and tidal lagoon), whereas the highest diversities (α= 22-25) are present in the faunas from the three deepest, most exposed situations in Albert Channel and Rawhiti Inlet, where 58-64 species are present in faunal counts of 300 individuals.

DISCUSSION

The low diversity fauna dominated by one or more agglutinated taxa

Table 1. Data for stations in the eastern Bay of Islands, that were processed for foraminiferal studies.

Station	Depth	NZGS number	Sediment	Macrofauna/habitat
5	7 m	F201774	medium sandy gravel	*Tawera* shellbed
18	7 m	F201787	sandy fine gravel	*Corbula-Glycymeris*
27	2 m	F201796	medium-fine sand	*Zeacolpus-Zegalerus*
30	+0.3 m	F201799	gravelly very coarse sand	pipi beach
33	12 m	F201802	muddy fine sand	*Pleuromeris-Pectinaria*
36	+0.3 m	F201805	slightly muddy medium sand	cockle beach
40	2 m	F201809	muddy fine sand	subtidal *Zostera*
41	+1.7 m	F201810	slightly muddy fine sand	upper estuary
42	+1.5 m	F201811	slightly muddy very fine sand	middle estuary
44	0.5 m	F201813	gravelly medium sand	tidal lagoon
45	0.5 m	F201814	slightly gravelly medium sand	tidal lagoon

present in the Bay of Islands' estuarine samples is characteristic of similar hyposaline estuaries elsewhere in the world (Murray 1973, Boltovskoy and Wright 1976). The dominant taxon in these samples, *Trochammina inflata*, has a cosmopolitan distribution usually restricted to shallow, enclosed situations such as marshes, lagoons and estuaries.

Elphidium charlottensis (Fig. 3b) is the single dominant taxon (40-50%) in all three samples from the rather sheltered Urupukapuka Bay. Beaches and subtidal *Zostera* flats in similar sheltered bays around the Cavalli Islands also have foraminiferal faunas dominated by *E. charlottensis* (pers. obs.). Observations of the Bay of Islands' and Cavallis' samples indicate that two further species of *Elphidium* - *E. oceanicum* (Fig. 3c) and *E. simplex* (Fig. 3d) characteristically comprise 2-10% each of the faunas of sheltered beaches and subtidal *Zostera* flats. The rotaliid *Ammonia beccarii*, comprises 3% of both beach samples but is rare in other samples. This species has a cosmopolitan distribution and its occurrence in any number is characteristic of very shallow, often partly enclosed or hyposaline environments (Murray 1973, Gregory 1973).

A fourth species of *Elphidium* - *E. novozealandicum* (Fig. 3e), while present in sheltered situations with normal salinities, is more characteristic of higher energy environments usually in coarse sand or shell gravel, such as in the Albert Channel and tidal lagoon.

The diverse fauna of the sandy shell gravel of the Albert Channel (stns 5, 18) is dominated by a combination of *Pileolina zealandica* (Fig. 3i) *Cibicides marlboroughensis* (Fig. 3k) and numerous other

glabratellids, discorbids and miliolaceans. Identical faunas are also present in *Tawera* shellbeds in similar conditions in the Cavalli Passage (pers. obs.), inside the Cavalli Islands.

The foraminiferal fauna of the gravelly sand of the tidal lagoon is quite similar to that of the Albert Channel. The main difference being an increase in the numbers of *E. charlottensis* in the lagoonal environment.

Post-mortem transportation is obviously important in redistributing foraminiferal tests, especially in environments subject to strong wave and current action. It appears from the meagre data on stained ("live") foraminifera that this mixing has had little effect on the relative dominance of the abundant species but possibly results in higher diversity values.

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APPENDIX I -Census of picks of approximately 300 foraminifera from stations in the eastern Bay of Islands. Arabic numerals = % of benthic fauna; italic numerals = some "live" (stained) specimens; × = present, but fewer than 1%.

Station	5	18	27	30	33	36	40	41	42	44	45
Benthics:											
Ammobaculites exiguus Cushman & Bronnimann							x				
Gaudryina convexa (Karrer)	2	x	x	x			x			x	1
Haplophragmoides canariensis (d'Orbigny)		x									

Station	5	18	27	30	33	36	40	41	42	44	45
Haplophragmoides sp.								6			
Reophax euneta Jensen	*x*										
Textularia ensis Vella	x	x									
Textularia proxispira Vella	1	x									
Textularia sp.	x	x			x					x	
Trochammina bartrumi Hedley, Hurdle & Burdett	*1*	x		x					2	1	
Trochammina inflata (Montagu)								*94*	*76*		
Trochammina sorosa Parr	x	x					x			x	
Cyclogyra involvens (Reuss)				x	x				2	x	
Miliolinella labiosa schauinslandi (Rhumbler)			x	x		x				2	x
Miliolinella subrotundata (Montagu)	1	*4*	x	x	3	x	1			x	x
Miliolinella vigilax Vella			x	x	x	x	x				
Pyrgo anomala (Schlumberger)	x										
Pyrgo comata (Brady)		x									
Pyrgo depressa (d'Orbigny)											x
Pyrgo ezo Asano	x										
Quinqueloculina agglutinans d'Orbigny				x							
Quinqueloculina ariminensis d'Orbigny	2	3	1	1	3		2				3
Quinqueloculina bicornis (Walker & Jacob)		*1*									
Quinqueloculina colleenae Vella	x	*1*				x				x	x
Quinqueloculina lamarckiana d'Orbigny	9	1	2	x	3	2	x			3	4
Quinqueloculina lata Terquem		x									
Quinqueloculina parvaggluta Vella	*1*	x	x		x	1				x	x
Quinqueloculina patagonica d'Orbigny		x			1	x	2			1	x
Quinqueloculina seminula (Linnaeus)	*3*	*2*	*26*	5	7	*14*	7			8	7
Quinqueloculina suborbicularis d'Orbigny	1		x		x		x				x
Quinqueloculina tenagos Parker							2				
Quinqueloculina triangularis d'Orbigny	x	*1*			x	x	x			x	x
Quinqueloculina sp.				1							
Scutuloris hornibrooki Vella				x							
Spiroloculina angulata Cushman										x	
Spiroloculina disparilis Terquen					x						
Triloculina trigonula (Lamarck)		x		x							
Ammonia beccarii (Linnaeus)	x	x		3		3	1		2		1
Anomalinoides glabrata Cushman		x				x					
Anomalinoides spherica (Finlay)	x	x									
Astacolus australis (Chapman)											x
Astrononion novozealandicum Cushman & Edwards					x						
Bolivina cf. *arta* MacFadyen					x	x	x			x	

Station	5	18	27	30	33	36	40	41	42	44	45
Bolivina cacozela Vella	x				x	x	x			x	x
Bolivina pseudoplicata Heron-Allen & Earland					x						
Bolivina robusta Brady		x			x		x				
Bolivina spathulata (Williamson)	x			x	2		x				
Bolivina striatula Cushman				1	x						
Bolivina subexcavata Cushman & Wickenden		x			x		x				
Bulimina marginata d'Orbigny					x						x
Bulimina submarginata Parr	x				x						
Buliminoides madagascariensis (d'Orbigny)	1	*2*	x	x	2	x	x				x
Buliminoides williamsoniana (Brady)	x			x							
Cassidulina carinata Silvestri	1				2		1			x	
Cibicides corticatus Earland		x					x			x	
Cibicides marlboroughensis Vella	10	*4*	*5*	x	1		2			3	*5*
Cibicides refulgens Montfort			x								
Cibicides cf. *ungerianus* (d'Orbigny)	2	2	x	x						x	2
Cymbaloporetta bradyi (Cushman)						x				x	
Discorbis dimidiatus (Parker & Jones)	4		x	*6*	x	*3*				8	4
Dyocibicides biserialis Cushman & Valentine		x					x				
Ehrenbergina mestayeri Cushman	x										
Elphidium argenteum (Parr)			x	x		2	x			x	2
Elphidium charlottensis (Vella)	3	3	*52*	*52*	*14*	*15*	*40*		4	11	18
Elphidium novozealandicum Cushman	*5*	*4*	1	3	2	*14*	4			6	6
Elphidium oceanicum Cushman	x		1	5			8		2	x	
Elphidium simplex Cushman				3	3	2	3		6	x	x
Epistominella vitrea Parker	x										
Eponides repandus (Fichtel & Moll)		x									
Evolvocassidulina orientalis (Cushman)	*1*	*3*			3	x				1	
Fissurina evoluta McCulloch		x			x						
Fissurina lucida (Williamson)	x										
Fissurina cf. *marginata* (Montagu)					x						
Fissurina orbignyana Seguenza											x
Fissurina spp.		x									
Florilus flemingi (Vella)		x									
Fursenkoina schreibersiana (Czjzek)					x		x				
Gavelinopsis hamatus Vella	1	2	x	x	3	1	x			3	1
Gavelinopsis lobatulus (Parr)	x	2		x						x	
Globocassidulina canalisuturalis Eade	1	x			3		x			1	

Station	5	18	27	30	33	36	40	41	42	44	45
Globocassidulina minuta (Cushman)	x	*x*								x	
Guttulina irregularis (d'Orbigny)	x										
Gypsina vesicularis (Parker & Jones)										x	
Hanzawaia bertheloti (d'Orbigny)		x		x	x						
Hanzawaia subcomplanata (Parr)	x	1		x							
Hanzawaia sp.					x						
Lagena sp.							x				
Lagenosolenia sp.		x									
Laticarininia coronata (Heron-Allen & Earland)					x	x					
lenticulina gibba (d'Orbigny)				x		x					
Lenticulina tasmanica Parr	x										
Loxostomum karrerianum (Brady)	x									x	
Mychostomina revertens (Rhumbler)											x
Neoconorbina harmeri (Heron-Allen & Earland)	3	*5*		x	4	1	1			2	2
Neoconorbina pacifica Hofker	2	3		1	2	x	2			2	1
Neconorbina sp.		*x*	x	x	1	3	x			x	x
Notorotalia depressa Vella	2	x	x	1	x		x			2	2
Notorotalia olsoni Vella	*9*	1	x	4	2	*9*				11	8
Oolina melo d'Orbigny	x	x			x		x				
Patellina corrugata Williamson					x					x	
Patellinella inconspicua (Brady)	1	4	1	x	4	1	x			2	4
Pileolina calcarata (Heron-Allen & Earland)	2		x	x	1					x	1
Pileolina opercularis (d'Orbigny)	3	*5*			2	2	x		2		1
Pileolina patelliformis (Brady)	1	*3*	x	2	3	x	2			2	2
Pileolina radiata Vella	2		1		1						x
Pileolina zealandica Vella	10	*21*	2	1	*16*	*10*	2		2	15	17
Rosalina bradyi (Cushman)	2	1	1	2	2	*5*	1			2	1
Rosalina concinna (Brady)											x
Rosalina irregularis (Rhumbler)	x	*3*		x	1	x	x			1	x
Rosalina paupereques Vella	x	1			x						
Rosalina cf. *valvulata* d'Orbigny				x							
Rosalina vitrizea Hornibrook					x						
Sigmavirgulina tortuosa (Brady)						x	x				
Sigmoidella elegantissima (Parker & Jones)	x										
Sigmoidella kagaensis Cushman & Ozawa			x	x						x	
Sigmomorphina lacrimosa Vella	x										
Siphonina tubulosa Cushman					x						
Siphouvigerina vadescens (Cushman)		x			x						

Station	5	18	27	30	33	36	40	41	42	44	45
Sphaeroidina bulloides d'Orbigny		x									
Spirillina vivipara simulata McCulloch		x									
Trifarina gracilis (Vella)		x									
Trifarina sp.		x									
Virgulopsis turris (Heron-Allen & Earland)							x				
Planktics:											
Globigerina bulloides d'Orbigny		x			x						
Globigerina falconensis Blow	x	1		x	x						
Globigerinoides ruber (d'Orbigny)					x						
Globigerinoides trilobus (Reuss)		x									
Globorotalia inflata (d'Orbigny)		x			x						
Percentage planktics	0.3	2.3	0	0.2	1.6	0	0	0	0	0	0
Number of benthic species	60	64	30	39	58	35	46	2	9	49	42
Fisher α index	24	25	7	9	22	10	17	0.4	3	17	13
Percentage Textulariina	6	4	0.3	2	0.3	0	1.4	100	80	2	1
Percentage Miliolina	20	15	30	8	19	12	13	0	2	16	18
Percentage Rotaliina	74	81	70	90	81	79	86	0	18	82	81