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SOFT-BOTTOM BENTHIC FAUNAL ASSOCIATIONS OF TUTUKAKA HARBOUR, NORTHLAND, NEW ZEALAND

Part I Macrofauna
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SUMMARY

Benthic macrofaunas from thirty-five dredge samples of bottom sediments from Tutukaka Harbour, Northland, have been grouped into four faunal associations and two subassociations.

A *Chione - Nucula - Tellina (Macomona)* association occurs in the inner part of the harbour on intertidal and immediately subtidal muddy flats. In an adjacent channel area, at 2.2 - 2.5 m depth, a *Nucula - Tellina (Macomona) - Leptomya* subassociation occurs on shelly muddy fine sand. A *Theora* association occurs at 1 - 2 m depth in shallow subtidal muds and sandy muds at the head of Tutukaka Harbour. A *Corallina - Maoricolpus - Notomithrax* association occurs at 1 - 7 m depth in gravelly sands and gravelly muddy sands adjacent to rocky areas throughout the harbour. A *Gari - Myadora - Nucula* association occurs at 0.8 - 11 m depth in muddy fine sand and fine to medium sand throughout most of Tutukaka Harbour. An ascidian - *Gari* subassociation occurs at 7 - 12 m depth in fine to medium sand and gravelly sand in the outer part of the harbour.

Foraminifera (live plus dead) were studied from five of the samples. They contained a total of 164 species, eleven of which are first records for New Zealand.

Dominant foraminifera in the harbour are *Elphidium charlottensis, Quinqueloculina seminula* and *Rosalina irregularis*. The two shallowest and muddiest samples, near the head of the harbour, are dominated by *Elphidium* spp. *Bolivina striatula* and *Q. seminula*. Gravelly, muddy sand near rocks in the middle harbour is dominated by *Pileolina zealandica, Elphidium* spp. and miliolids. Slightly muddy, very fine sand in the outer part of the harbour has *Virgulopsis turris* dominant, which is accompanied by a very diverse fauna at 12 m depth in the harbour entrance.

INTRODUCTION

Tutukaka Harbour lies on the east coast of Northland, New Zealand (Fig. 1) at latitude 35°37'S and longitude 174°32'E. It forms a small indented embayment of approximately 150 hectares in a rugged, exposed greywacke coastline. A narrow mouth fringed by reefs shelters the harbour from onshore swells. Small coves in the outer and middle parts of the harbour have steeply sloping gravelly beaches while at the head of the harbour intertidal mudflats occur.

Several small streams flowing through scrub and farmland discharge into the harbour. A marked hydrological gradient is evident from murky, sediment-laden water at the head to cleaner, more oceanic water at the mouth.

A breakwater and marina were built at the head of the harbour in 1970, and the channel in the inner harbour is periodically dredged to facilitate passage of boats.

Fieldwork was carried out immediately prior to a trip by the Offshore Islands Research Group to the Poor Knights Islands in September 1980. Thirty-five dredge samples of bottom sediments were collected within the harbour at depths ranging from lower intertidal to 12 m.

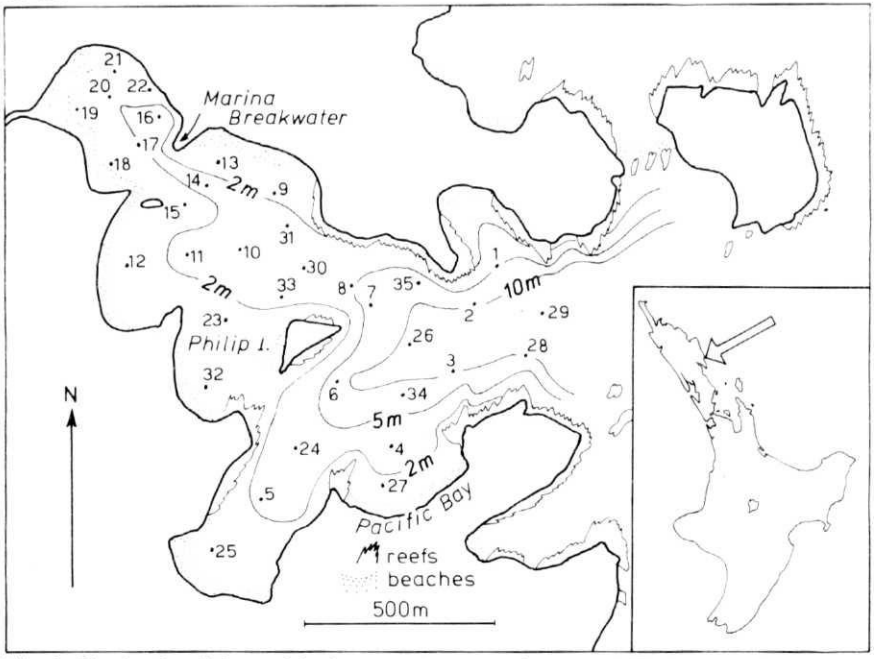

Fig. 1 Station localities and bathymetry (contours in metres). Bathymetry is adapted from Watkins (1974).

METHODS

Samples were collected by towing a small hand-hauled dredge behind an outboard-powered aluminium dinghy. The method is similar to that described by Grace and Whitten (1974) and subsequently used by Grace and Grace (1976), Grace and Hayward (1980), and Hayward, Grace and Brook (1981).

Under ideal conditions the dredge samples a surface area of approximately 0.075 square metres and recovers approximately 4 500 cc of sediment. However when coarse shelly or gravelly sediments are encountered a lower volume of sediment is generally recovered.

The approximate volume of each dredge sample was estimated and a descriptive sediment grainsize analysis was made. Sediment samples of approximately 200 cc volume each were obtained at stations 16, 23, 24, 28 and 31 for foraminiferal studies. The remaining sediment was then passed over a wire mesh sieve that retained all objects greater than 2 mm i.e. larger than very coarse sand size (Folk 1974). Live organisms retained in the sieve were identified and counted in the field and were then returned live to the harbour. Those organisms unable to be identified were preserved for laboratory identification.

Stations were located at the time of sampling using a sextant to measure horizontal angles between fixed points on the shore.

Spring Low Water depths (Fig. 1) have been taken from Watkins (1974, Map 25).

SEDIMENTS

Sediment analysis here is based on field interpretation and not on quantitive grain-size analysis. The nomenclature approximates that of Folk (1974, p.25-29). Sediment type for each station is given in Appendix 1 and distribution is shown in Fig. 2.

The beaches in the outer part of Tutukaka Harbour are of steeply sloping sandy gravel. In their lower part they grade through intertidal gravelly sand into subtidal sand and muddy sand. Beaches of the inner harbour (between Philip Island and the marina breakwater) comprise gravelly sand and generally have lower profiles. Muddy tidal flats, locally shelly or gravelly, occur behind and east-south-east of the marina breakwater. Within the marina subtidal sediments are muds with little or no sand. Outside the breakwater these pass into muddy fine sands, often with abundant land-derived plant material, which give way to clean fine and medium sands in a channel in the outer part of the harbour, and north-east of Pacific Bay, and coarsen towards the mouth of the harbour into gravelly sands. Adjacent to rocky areas in more sheltered parts of the harbour muddy fine sands grade into shelly, gravelly, muddy sand.

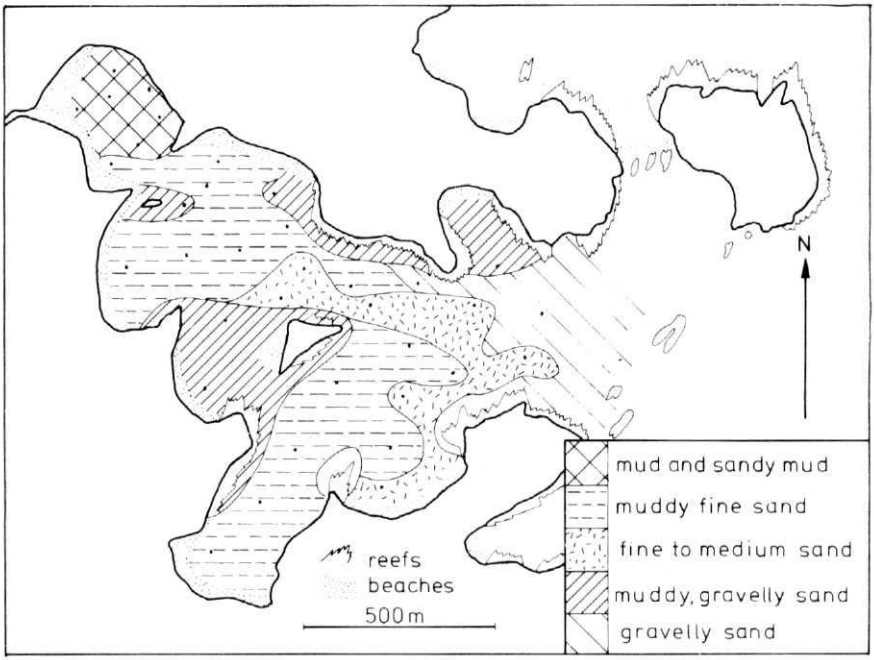

Fig. 2 Distribution of sediment types within Tutukaka Harbour, New Zealand.

PART I BENTHIC MACROFAUNAL ASSOCIATIONS

The identification of recurrent sets of taxa, or "associations" has here been made by intuitive, non-statistical analyses based partly on assocations recognised elsewhere. Macrofaunal associations are defined by the presence of one or more distinctive or abundant taxa, the term association being used in preference to community following Kauffman and Scott (1976).

Four macrofaunal associations and two subassociations are here recognised in the bottom sediments of Tutukaka Harbour (Fig. 3). Full census data is given in Appendix II.

1. *Chione - Nucula - Tellina (Macomona)* association

Stations: 13,18,19
Sediment type: muddy fine sand, gravelly sandy mud
Depth: Intertidal - 0.5 m

Characterising species:	Station
Chione stutchburyi	13, 18, 19
Nucula hartvigiana	13, 18, 19
Tellina (Macomona) liliana	13
Commonly associated species:	
Theora lubrica	18
Dosina zelandica	18

Dosina subrosea	13
Amalda australis	13
Pectinaria australis	13
Owenia fusiformis	13
Asychis sp.	18
Glycera sp.	13
Axiothella australis	13
Macropthalmus hirtipes	13, 18

This association occurs in the inner part of Tutukaka Harbour on intertidal and immediately subtidal muddy flats. It is characterised by the presence of the semi-infaunal suspension-feeding bivalve *Chione stutchburyi* along with the small infaunal deposit feeding bivalve *Nucula hartvigiana*. The deposit feeder *Tellina (Macomona) liliana* is less regular in occurrence. Species diversity within the association is lowest at the head of the harbour near the mouth of a freshwater stream. The highest diversity occurs on shallow subtidal flats on the eastern side of the harbour breakwater. Species densities are higher here also. Infaunal suspension- and deposit- feeding taxa predominate. Higher order feeders include the roving carnivorous gastropod *Amalda australis* and the scavenging crab *Macropthalmus hirtipes*.

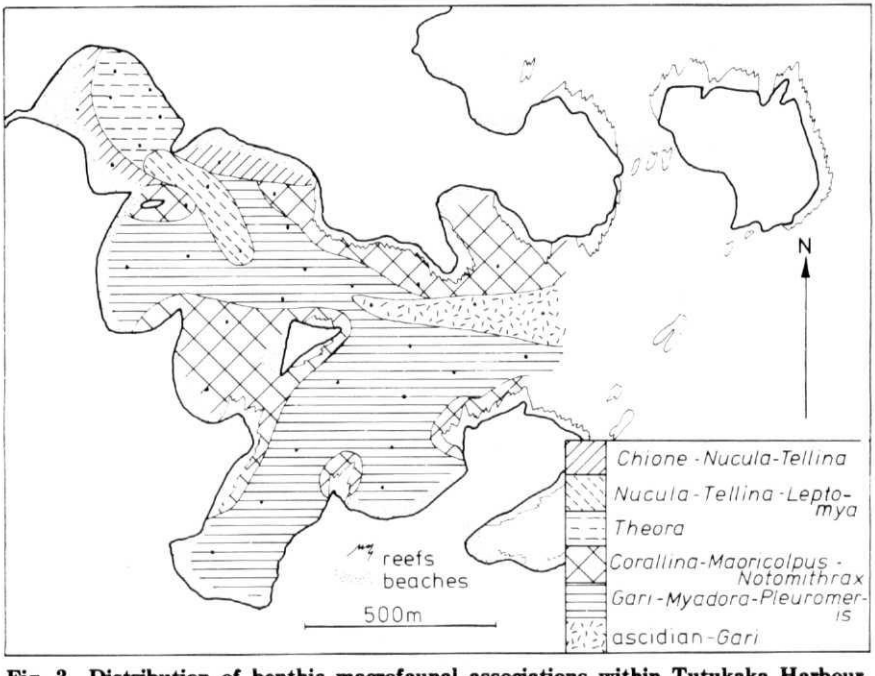

Fig. 3 Distribution of benthic macrofaunal associations within Tutukaka Harbour, northern New Zealand.

1a. *Nucula - Tellina (Macomona) - Leptomya* subassociation

Stations 10, 14
Sediment type: muddy fine sand, shelly muddy fine sand.
Depth: 2.2 - 2.5 m

Characterising species:	Station
Nucula hartvigiana	10, 14
Tellina (Macomona) liliana	10, 14
Leptomya retiara	10, 14
Commonly associated species:	
Theora lubrica	14
Pleuromeris zelandica	10
Struthiolaria vermis	14
Dosinia lambata	10
Venerupis largillierti	10
Owenia fusiformis	10
Pectinaria australis	10, 14
Glycera sp.	14
Lumbriconereis sphaerocephala	14
Macropthalmus hirtipes	14
Halicarcinus varius	14

This subassociation has many taxa in common with the *Chione - Nucula - Tellina (Macomona)* association and is not sufficiently distinct to warrant separation as a full 'association'. It differs however in the absence of living *Chione stutchburyi.* The *Nucula - Tellina (Macomona) - Leptomya* subassociation is defined by the presence of the three identifier taxa and an absence of living *Chione.* It occurs in slightly deeper water than the typical association, being found near the axis of a channel in the upper part of the harbour. Dead *Chione* valves at station 14 support an epifauna including the slipper limpet *Zegalerus tenuis,* the barnacle *Balanus trigonus,* and small membraniporiform bryozoan colonies. Many dead cockle valves here are encrusted by "*Lithothamnion*" paint. The shelly substrate favours the epifaunal scavenging crab *Halicarcinus varius.*

2. *Theora* association

Stations: 16, 17, 20, 21, 22
Sediment type: mud, sandy mud.
Depth: 1-2 m

Characterising species:	Station
Theora lubrica	16, 17, 20, 21, 22
Commonly associated species:	
Tellina (Macomona) liliana	20
Alpheus sp.	21, 22
Glycera sp.	17

The *Theora* association occurs in shallow subtidal muds and sandy muds inside the marina breakwater at the head of Tutukaka Harbour. It is defined by an abundance of the small semelid bivalve *Theora lubrica.* The association exhibits very low specific diversity although *Theora lubrica* occurs here in densities of up to 680 per square metre. The snapping shrimp (*Alpheus* sp.) is widespread in this association

although it occurs at low densities. The only other taxa recorded are juvenile *Tellina (Macomona) liliana* and the carnivorous polychaete *Glycera* sp.

3. *Corallina - Maoricolpus - Notomithrax* association.

Stations: 1, 9, 15, 23, 32, 35
Sediment type: gravelly muddy sand, gravelly sand
Depth: 1-7 m

Characterising species:	Station
Corallina officinalis	1, 9, 15, 23, 32, 35
Maoricolpus roseus	15, 23, 32, 35
Notomithrax minor	1, 9, 15, 32
Commonly associated species:	
Ischnochiton maorianus	1, 15, 23
Cominella adspersa	9, 23, 32, 35
Nucula hartvigiana	9, 15, 23, 32, 35
Gari stangeri	15, 23, 35
Tawera spissa	9, 15, 23, 35
Venerupis largillierti	9, 23, 35
Owenia fusiformis	1, 9, 15, 23, 32, 35
Terebellidae	9, 15, 23, 32, 35
Paguridae	1, 9, 15, 23, 35
Halicarcinus varius	15, 23, 32, 35

This association occurs in gravelly sediments adjacent to rocky areas throughout Tutukaka Harbour. It is defined by the presence of two or more of the characterising species. Rock clasts and dead shells provide attachment surfaces for a diverse epifauna including chitons *(Ischnochiton maorianus, Terenochiton inquinatus, Rhyssoplax stangeri,* and *Notoplax violacea),* limpets and slipper limpets *(Notoacmea helmsi, Maoricrypta monoxyla),* barnacles *(Elminius modestus),* anemones, and membraniporiform bryozoa. Crabs are common and include the masking crab *Notomithrax minor,* the small *Halicarcinus varius,* and hermit crabs. Gastropods include vagrant epifaunal carnivores and scavengers *(Marginella pygmaea, Neoguraleus lyallensis tenebrosus, Cominella adspersa* and *C. quoyana),* and the epifaunal/semi-infaunal suspension feeding turritellids *Maoricolpus roseus* and *Zeacolpus pagoda.*

Coralline turf *(Corallina officinalis)* is abundant, and many rock clasts are encrusted with "*Lithothamnion*" paint. Poorly developed rhodoliths occur at some stations.

Muddy sand amongst the gravel supports a diverse infauna including the suspension-feeding bivalves *Gari stangeri, Tawera spissa, Venerupis largillierti, Scalpomactra scalpellum;* and the deposit -feeding bivalves *Leptomya retiara, Nucula nitidula* and *Nucula hartvigiana.* The latter occurs at densities of up to 4 000 per square metre and is the numerically dominant taxon at several stations within this association.

4. *Gari - Myadora - Nucula* association

Stations: 3,4,5,6,8,11,12,24,25,26,27,28,30,31,33,34.
Sediment types: muddy fine sand, fine to medium sand.
Depth: 0.8 - 11 m

Characterising species:	Stations
Gari lineolata	3,4,8,11,12,24,26,27,30,31,33
Myadora striata	3,4,5,6,25,26,27,28,33,34
Nucula nitidula	3,4,5,6,8,11,12,24,25,26,27,30,
Commonly associated species:	
Nucula hartvigiana	4, 11, 12, 31, 33
Pleuromeris zelandica	4, 5, 11, 12, 25, 31
Scalpomactra scalpellum	3, 11, 24, 27, 31
Soletellina nitida	5, 8, 24
Tellina huttoni	26, 34
Cominella quoyana	3, 11, 12, 30, 31, 33, 34
Epitonium minora	3, 8, 30, 34
Pupa kirki	3, 12, 28, 30
Zeacolpus pagoda	4, 5, 24, 33, 34
Amalda novaezelandiae	8, 25, 26
Pectinaria australis	3, 4, 26, 27, 28, 30, 33
Owenia fusiformis	12, 28, 33
Axiothella australis	26, 30, 33, 34
Amphiura spp.	5, 8, 30, 34
Echinocardium cordatum	3, 12, 26, 28, 30, 31, 34
Balanoglossus australiensis	5, 24, 25, 28

The *Gari - Myadora - Nucula* association occurs throughout Tutukaka Harbour in subtidal, fine-grained, often muddy sediment. The association does not occur at the head of the harbour behind the breakwater, and adjacent to rocky areas it grades into the *Corallina - Maoricolpus - Notomithrax* association. The *Gari - Myadora-Nucula* association is somewhat loosely defined by the presence of two or more of the identifier taxa; *Gari lineolata*, *Myadora striata* and *Nucula nitidula*. Station 28 yielded only one of the identifier taxa, but has many species common to the *Gari-Myadora - Nucula* association. It may represent a transition in response to increasing depth, and more oceanic waters at the mouth of the harbour.

The *Gari-Myadora-Nucula* association is dominated by infaunal taxa. The small deposit-feeding bivalve *Nucula nitidula* is almost ubiquitous, occurring at densities of up to 700 per square metre. Other infaunal deposit feeders include the bivalves *Gari lineolata*, *Nucula hartvigiana* and *Tellina huttoni*, the spatangoid urchin *Echinocardium cordatum*, and the acorn worm *Balanoglossus australiensis*. Suspension feeders include the bivalves *Scalpomactra scalpellum*, *Myadora striata*, *M. boltoni*, *Pleuromeris zelandica* and *Thracia australica novozelandica;* and the epifaunal turritellid gastropod *Zeacolpus pagoda*. Deposit-feeding polychaete worms (e.g. *Owenia fusiformis*, *Pectinaria australis*, and *Axiothella australis*) are also common.

4a. Ascidian - *Gari* subassociation

Stations: 2,7,29
Sediment type: Fine to medium sand, gravelly medium sand
Depth: 7-12 m.

Commonly characterising species:	Station
ascidian	2, 7, 29
Gari stangeri	2, 7, 29
Associated species:	
Myadora striata	2, 29
Myadora boltoni	2
Nucula nitidula	2, 29
Scalpomactra scalpellum	7
Phenatoma rosea	2
Cylichna thetidis	29
Owenia fusiformis	2, 29
Edwardsia sp.	7
Echinocardium cordatum	7, 29
Balanoglossus australiensis	29

The ascidian - *Gari* subassociation is similar in faunal composition to the *Gari - Myadora - Nucula* association, but differs in the additional presence of abundant ascidians. It occurs in clean sand and gravelly sands in a channel in the outer part of Tutukaka Harbour.

The identifier ascidian occurs here in densities of up to 1 000 per square metre. It is a small (c. 1 cm diameter) semi-infaunal simple ascidian. Suspension feeding bivalves are common (e.g. *Gari stangeri, Myadora striata, Scalpomactra scalpellum)* as is the deposit-feeding polychaete *Owenia fusiformis*. The deposit feeders *Nucula nitidula, Echinocardium cordatum* and *Balanoglossus australiensis* also occur although not abundantly. The carnivorous gastropods *Phenatoma rosea* and *Cylichna thetidis* were not found outside the ascidian - *Gari* subassociation in Tutukaka Harbour.

COMPARISONS WITH OTHER AREAS

Three of the benthic faunal associations recognised in Tutukaka Harbour are known elsewhere around the New Zealand shelf (i.e. *Chione - Nucula - Tellina (Macomona)* association, *Theora* association, and ascidian - *Gari* subassociation). The other associations show similarities to previously described associations but are regarded as being sufficiently distinct to warrant separation.

The *Chione - Nucula - Tellina (Macomona)* association is common around northern New Zealand in sheltered areas such as harbours and estuaries. It occurs in intertidal to shallow fine sands and muddy fine sands. Several authors have documented this association e.g. Cassie and Michael (1968) and Grace (1972). It is very similar to the "*Chione* associations" of Oliver (1923) and Ralph and Yaldwyn (1956), differing only in the additional presence of common *Nucula hartvigiana.*

The *Nucula - Tellina (Macomona) - Leptomya* subassociation is a

variant of the above association and has not previously been described.

A possible correlative of the *Theora* association has been described. from mud in the Firth of Thames by Bioresearches Ltd. (1978). However the "*Theora* zone" of that report shows greater specific diversity than was found in this *Theora* association, and no values for specific densities of *T. lubrica* within the zone are given.

The *Corallina - Maoricolpus - Notomithrax* association has not been described elsewhere. It is similar in faunal composition to the *Maoricolpus - Nucula* association from the Manukau Harbour (Powell 1937), the *Atrina - Venerupis - Maoricolpus* association from Whangateau Harbour (Grace 1972) and the *Microcosmus - Notomithrax* association from the Manukau Harbour (Grange 1979).

The *Gari - Myadora - Nucula* association has not previously been recognised. It has faunal similarities with several other associations e.g. *Amphiura - Gari* association and *Scalpomactra - Maorimactra* association (McKnight 1969), *Myadora - Scalpomactra* association (Grace and Whitten 1974), and *Corbula - Pleuromeris* association and *Pupa - Pectinaria* association (Grace and Grace 1976).

The ascidian - *Gari* subassociation is recorded here for the first time. It is also known at 14-20 m water depth in South East Bay, Mayor Island, Bay of Plenty (F. Brook pers. obs.). Associated species at that locality include *Scalpomactra scalpellum, Gari hodgei, Cominella quoyana, Cylichna thetidis, Amalda australis, and Owenia fusiformis.*

DISCUSSION

The distribution of benthic faunal associations in Tutukaka Harbour cannot readily be attributed to any one physical factor. None of the associations is restricted to a particular sediment type and some associations have overlapping sediment tolerances.

The restriction of the *Chione - Nucula - Tellina (Macomona)* and *Theora* associations to the head of the harbour may be attributed to tolerance of several factors including lowered salinities, turbidity, wide temperature fluctuations (owing to daily exposure of tidal flats) and pollutants. The *Theora* association occupies what would appear to be a particularly inhospitable habitat within the Tutukaka marina. This is reflected by the very low specific diversity, although *Theora lubrica* occurs here at densities up to 680 per square metre. It is of interest to note that a single quantitative sample collected by R.V. Grace in soft mud in the Tutukuka marina in 1972 indicated a denisity of 1 820 *T. lubrica* per square metre. Thus this Japanese bivalve had locally reached very high population levels only a year after its apparent arrival in New Zealand (Climo 1976). It is not clear whether the lower densities observed in the present study are due to patchiness, or to a decline in population densities since 1972.

The *Gari - Myadora - Nucula* association occurs on both muddy and clean fine to medium sands, and is exclusively subtidal. It is a heterogeneous rather poorly defined association but cannot be adequately subdivided with the present data. It is apparent that several characteristic taxa (i.e. *Myadora striata, M. boltoni, Scalpomactra scalpellum, Gari lineolata, Pleuromeris zelandica, Tellina huttoni*) have similar environmental tolerances and thus specific distribution and abundance will be controlled by factors such as fecundity, larval dispersal, and predation. The *Gari - Myadora - Nucula* association appears to have a "loose" ecological structure. No taxon is consistently dominant, with distribution of the identifier organisms (with the exception of *Nucula nitidula*) being markedly patchy. However it is also possible that much of the apparent heterogeneity may be attributed to the small area of seafloor sampled at each dredge station.

The *Gari - Myadora - Nucula* association grades into the *Corallina Maoricolpus - Notomithrax* association adjacent to rocky areas. Several dredge stations show this transition (4,12,31,33). These stations include the identifier taxa of the *Gari - Myadora - Nucula* association but in addition have taxa common in the *Corallina - Maoricolpus - Notomithrax* association (e.g. *Corallina officionalis, Halicarcinus varius, Gari stangeri, Tawera spissa, Turbo smaragdus,* chitons). The bivalve *Atrina zelandica* was only dredged at the four transitional stations although diving observations show it to have a wider distribution within the harbour (F. Brook pers. obs.).

The ascidian - *Gari* subassociation is not known from muddy sediments and is apparently restricted to clean sand and gravelly sands. The ascidian is also known from a solitary specimen at station 33 off the north-west side of Philip Island.

Two species of the small deposit-feeding bivalve *Nucula* occur in Tutukaka Harbour. *Nucula hartvigiana* is found in all except the *Theora* association and the ascidian - *Gari* subassociation. It is most abundant in the inner harbour where it reaches densities of up to 4 000 per square metre. *Nucula nitidula* occurs only in the *Corallina - Maoricolpus - Notomithrax* association, the *Gari - Myadora - Nucula* association and the ascidian - *Gari* subassociation. It never reaches the same population densities here (up to 700 per square metre) as *N. hartvigiana* and is distributed throughout the inner and outer parts of the harbour.

The two species of *Nucula* occur together at several stations (4,11,12,31,33,35) and both tolerate a variety of substrate types. However the absence of *N. nitidula* from the *Chione - Nucula - Tellina (Macomona)* association and *Nucula - Tellina (Macomona) - Leptomya* association, coupled with the absence of *N. hartvigiana* from the ascidian - *Gari* subassociation are noteworthy. R.V. Grace (per. obs.)

has found that *N. hartvigiana* and *N. nitidula* generally occupy non-overlapping ranges in the south-western Firth of Thames, with *N. nitidula* being replaced shorewards by *N. hartvigiana**. Rainer (1969) describes a "harbour fine sand community" from Otago Harbour in which *Nucula nitidula* occurs with *Chione stutchburyi* and *Tellina (Macomona) liliana*. There *N. nitidula* apparently occupies the niche occupied by *N. hartvigiana* in the *Chione - Tellina (Macomona) - Nucula* association of northern New Zealand.

PART II FORAMINIFERA

Approximately 200 cc of sediment from the dredge hauls from five stations (Table 1) was processed in the laboratory for grain size distribution (sieved and weighed) and foraminiferal studies (washed over a 0.0625 mm sieve and concentrated by floating off with carbon tetrachloride). A bulk pick of 100 foraminifera (live plus dead) was made from the floated material to give a crude estimate of the gross composition of the fauna (Fig. 4). The remainder of the floated material was examined and specimens of additional taxa were picked to give a more complete list of the species present (Appendix III).

There is considerable variation in the faunas from the five stations (Fig. 4). There are several obvious trends between the faunas at the head of the harbour (stns. 16,31) and that at the entrance (stn. 28). Planktic foraminifera increase from an abundance of less than 1% of the total foraminiferal fauna inside the harbour to 4% at the entrance. Diversity of the benthic foraminiferal fauna is moderate inside the harbour (Fisher α index = 12-14) and very high at the entrance (Fisher α index = 26). The abundance of agglutinated foraminifera increases from less than 1% of the total fauna at the head of the harbour, to 3% in the middle of the harbour (stns. 23,24), and to 8% at the entrance.

Three species (*Elphidium charlottensis, Quinqueloculina seminula, Rosalina irregularis)* are abundant (over 3%) at all five stations and five others *(Bolivina striatula, Virgulopsis turris, Elphidium argenteum, E. oceanicum, E. simplex)* are abundant in over half the stations.

The two muddiest samples (stns. 16, 21, Table 1), both near the head of the harbour and closest to shore, are characterised by abundant *Elphidium (E. argenteum, E. charlottensis, E. simplex), Bolivina striatula, Rosalina irregularis* and *Ammonia beccarii* (each 4-15% of the fauna). The major difference between the two faunas is the abundance of *Quinqueloculina seminula* (20% in stn. 16, 6% in stn. 31).

* In northern New Zealand the two species can have non-overlapping or partially overlapping ranges. *Nucula hartvigiana* occurs in intertidal and shallow sub-tidal habitats (down to c. 10 m depth), while *N. nitidula* is found only sublittorally, extending from the immediate subtidal to 100 m water depth (Powell 1979).

Table 1. Station data for samples processed for foraminifera

Station	Depth	NZGS Number	Sediment	%planktics	index
16	2 m	F201839	very fine sandy mud	1	13
23	1 m	F201840	gravelly, muddy, medium sand	1	14
24	3 m	F201841	slightly muddy, very fine sand	1	13
28	10 m	F201842	slightly muddy, very fine sand	4	26
31	2.5 m	F201843	slightly gravelly, very fine sand	0	12

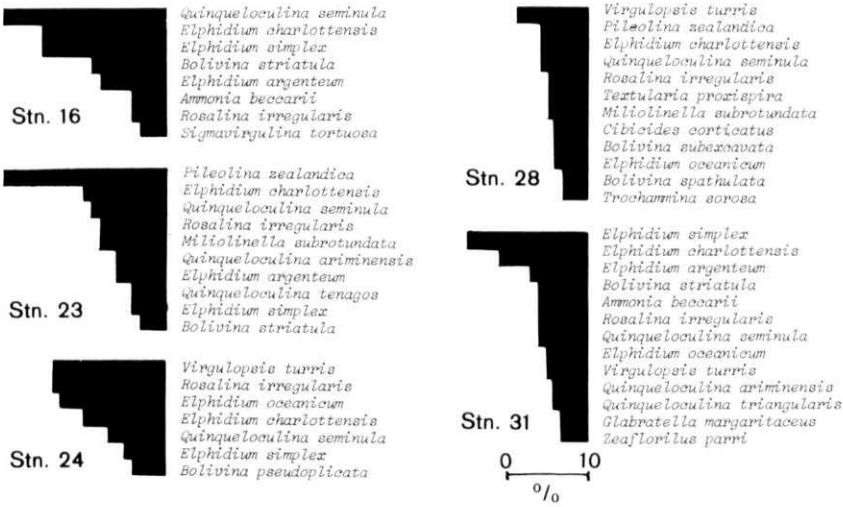

Fig. 4 Histograms of abundant benthic foraminiferal species (>3%) in each sample to illustrate the bulk composition of the fauna.

The sample (stn. 23) with the coarsest sediment (poorly sorted medium sand with 15% gravel and shells) situated in the channel inside Philip Island, has a fauna dominated by *Pileolina zealandica, Elphidium charlottensis, Quinqueloculina seminula, Q. ariminensis,* an assemblage characteristic of coarse sediment elsewhere around northern New Zealand (pers. obs.). The abundance (3-6%) of taxa *(Elphidium argenteum, E. simplex, Bolivina striatula)* more characteristic of sheltered or muddy sediments, distinguish this fauna from those of the strong current swept, shelly sands of the Cavalli Passage and Albert Channel (Hayward 1981, pers. obs.).

Slightly muddy, very fine sand in the outer part of the harbour (stns. 24,28) has faunas dominated by *Virgulopsis turris* (14%,19%) with

codominant *R. irregularis, E. charlottensis, E. oceanicum, Q. seminula* (1-19%) and *P. zealandica* (stn. 28 only). Station 24, well within the harbour contains predominantly taxa most abundant in sheltered and muddy environments (e.g. *Elphidium, Bolivina*), whereas station 28 at the harbour entrance in 12 m of water has an extremely diverse fauna containing a mixture of taxa, some characteristic of a sheltered harbour, others of clean sand from more exposed situations outside the harbour mouth. Faunas dominated by *V. turris* have not been previously recorded from New Zealand waters.

All nine species of planktic foraminifera recorded in the harbour sediments are common around northern New Zealand (Hayward 1979). Three species of *Globigerina (G. falconensis, G. quinqueloba* and *G. bulloides)* comprise over 90% of the planktic fauna in the samples studied. This is in marked contrast to the planktic faunas of more open-water, nearshore sediments around north-eastern New Zealand, where *Globorotalia inflata* and *G. falconensis* are the co-dominants and *G. bulloides* and *G. quinqueloba* are less than 10% each (Hayward 1979).

First Records of foraminifera from New Zealand Recent

One hundred and fifty-five species of benthic foraminifera are present in the five samples from Tutukaka Harbour (Appendix III). Eleven of these have not previously been recorded from the Recent New Zealand fauna:

1. *Nevillina coronata* (Millett) Fig.5a

Biloculina coronata Millett 1898, Journal of Royal Microscopical Society 1898:263, p.1, fig. 6a-c. This is an unusual miliolid with a radiate aperture. The genus was noted in the New Zealand Recent by Finlay and Marwick (1940, p.129) but this is the first specific record. It also occurs in other New Zealand shallow water Recent samples (pers. obs.) from the Cavalli Islands (F 201714, 715, 755) and Stewart Island (F 201111) but is unknown in the New Zealand fossil record.

2. *Discorbinella vitrevoluta* (Hornibrook) Fig. 5b

Rosalina vitrevoluta Hornibrook 1961, NZ Geological Survey Pal. Bulletin 34:102, pl.13, fig. 275-7. This species is known from the Miocene, Pliocene and Pleistocene of New Zealand. It appears to be quite common in shallow water sediments around present-day Northland (pers. obs.).

3. *Earltheeia clarionensis* McCulloch Fig. 5c

Earltheeia clarionensis McCulloch 1977, p.302, pl.114, fig. 12,13. This is a very distinctive, highly ornamented glabratellid, previously recorded only from the Pacific Coast of Mexico. The present record is of a single juvenile specimen, possibly carried down to New Zealand from a warmer locality in the south-west Pacific. It is the first New Zealand record of the genus, fossil or Recent.

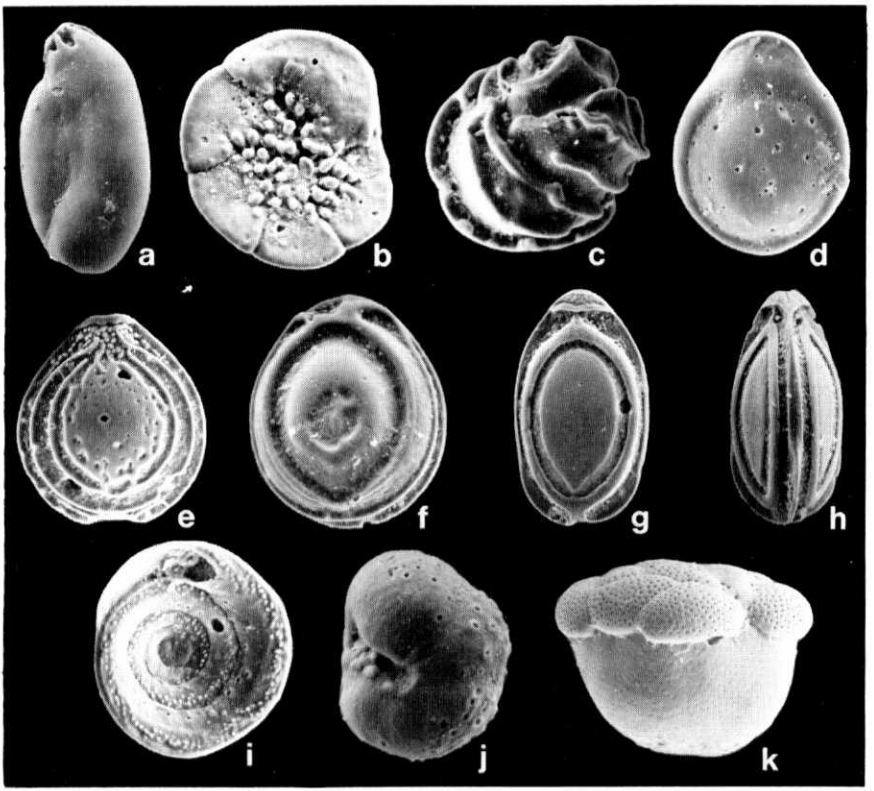

Fig. 5 Benthic foraminifera recorded for the first time from Recent New Zealand sediments:
a. *Nevillina coronata* (F 201840, FP 3051), juvenile x 30; b. *Discorbinella vitrevoluta* (F 201842, FP 3052) x 75; c. *Earltheeia clarionensis* (F 201843, FP 3053) x 150; d.*Fissurina claricurta* (F 201841, FP 3054) x 120; e. *Fissurina contusa* (F 201840, FP 3055) x 80; f. *Fissurina quadrirevertens* (F 201840, FP 3056) x 120; g. *Fissurina semi-alata* (F 201841, FP 3057) x 60; h. *Lagena trigono-orbignyana* (F 201842, FP 3058) x 60; i. *Mychostomina revertens* (F 201842, FP 3059) x 150; j. *Svratkina australiensis* (F 201842, FP 3060) x 120; k. *Tretomphalus planus* (F 201842, FP 3061) x 75.

4. *Fissurina claricurta* McCulloch Fig. 5d
Fissurina claricurta McCulloch 1977, p.25, pl.58, fig. 16. This species has probably been lumped with *F. lucida* in the past. It appears commonly in near-shore sediments around northern New Zealand (pers. obs.).
5. *Fissurina contusa* Parr Fig. 5e
Fissurina contusa Parr 1945, Proc. Royal Society of Victoria 56, p.203, pl.9, fig. 6. This species, described from Australian waters, is one of the most abundant *Fissurina* species in near-shore sediments around northern New Zealand.

6. *Fissurina quadrirevertens* (McCulloch) Fig. 5f
Lagenosolenia quadrirevertens McCulloch 1977, p.71, pl.62, fig. 24. This is a common species in near-shore sediments around northern New Zealand (pers. obs.).
7. *Fissurina semi-alata* (Balkwill and Millett) Fig. 5g
Lagena quadrata (Williamson) var. *semi-alata* Balkwill and Millett 1884, Journal of Microscopical Natural Sciences 3, p.81, pl.2, fig. 9. This species is moderately common around northern New Zealand (pers. obs.).
8. *Lagena trigono-orbignyana* Balkwill and Millett Fig. 5h
Lagena trigono-orbignyana Balkwill and Millett 1884, Journal of Microscopical Natural Sciences, 3, p.81, pl.3, fig. 10. A rare species known from New Zealand by this single specimen.
9. *Mychostomina revertens* (Rhumbler) Fig. 5i
Spirillina vivipara Ehrenberg var. *revertens* Rhumbler 1906, Zoologie Jahrb. 24, p.32, pl.2, fig. 8-10. Moderately rare in near-shore sediments around northern New Zealand. First record, fossil or Recent, of the genus from New Zealand.
10. *Svratkina australiensis* (Chapman, Parr and Collins) Fig. 5j
Discorbis tuberculata (Balkwill & Wright) var. *australiensis* Chapman, Parr and Collins 1934, Journal of the Royal Microscopical Society 38, p.563, pl.8, fig. 9. This distinctive species is moderatly rare around New Zealand today (pers. obs). The genus is also present in the New Zealand Miocene (pers. obs.).
11. *Tretomphalus planus* Cushman Fig. 5k
Tretomphalus bulloides (d'Orbigny) var. *plana* Cushman 1924, Carnegie Institute Publication No. 342, p.36, pl.10, fig. 8. This distinctive warm water Pacific species was probably carried to New Zealand on currents from the north as a pseudo-planktic embryonic form. Its nearest locality records are Fiji, Samoa and Taumotu Archipelago. The only other records of this genus in New Zealand are of one specimen from the Pleistocene and two from Recent sediments off Rakitu Island (pers. obs.)

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APPENDIX I. Station Data

Stn.	Depth[1] (m)	Sediment[2]	Sample Vol (cc)	No. of[3] taxa	Association[4]
1.	4.5	g,m,fs	1 350	7	Co
2.	7	fs	3 600	10	a*
3.	10	m,fs	4 050	16	G
4.	3	m,fs	1 350	16	G
5.	2.3	m,fs	1 800	8	G
6.	7	m,fs	1 350	4	G
7.	7	f-mds	4 050	8	a*
8.	5	m,fs	2 250	13	G
9.	1	g,m,s	4 500	18	Co
10.	2.5	m,fs	4 950	12	N*

11.	2.5	m,fs	4 050	10	G
12.	1	m,fs	3 150	15	G
13.	0.5	m,fs	4 950	11	C
14.	2.2	m,fs	4 950	17	N*
15.	1	g,m,fs	4 500	24	Co
16.	2	s,M	4 500	1	T
17.	2	s,M	4 050	2	T
18.	int.	m,fs	4 950	6	C
19.	int.	g,s,M	4 500	2	C
20.	1.8	M	2 700	2	T
21.	1.5	M	4 950	2	T
22.	1	M	4 050	2	T
23.	1	g,m,mds	4 500	30	Co
24.	3	m,fs	2 700	8	G
25.	0.8	m,fs	3 150	6	G
26.	11	m,fs	4 050	12	G
27.	1	fs	2 700	8	G
28.	10	m,fs	3 600	14	G
29.	12	g,mds	3 600	9	a*
30.	3	fs	4 500	20	G
31.	2.5	slg,m,fs	2 250	13	G
32.	1	**g,m,s**	4 950	24	Co
33.	2.2	mds	4 500	19	G
34.	7	fs	3 600	12	G
35.	7	g,S	4 500	31	Co

[1] int. = intertidal
[2] s = sand, M = mud, g s m = gravelly, sandy, muddy, slg = slightly gravelly, mds = medium sand, fs = fine sand.
[3] Taxa of fauna only have been summed, as listed in Appendix II.
[4] C = *Chione - Nucula - Tellina (Macomona)*, Co = *Corallina - Maoricolpus - Notomithrax*, G = *Gari - Myadora - Nucula*, N = *Nucula - Tellina (Macomona) - Leptomya*, T = *Theora*, a = ascidian - *Gari*, * = subassociation

APPENDIX II. Raw species counts. For each species, the station at which that species occurs is given, followed in brackets by the number of individuals occurring in the sample. Where no figures in brackets are given, information is qualitative only.

ALGAE	
Colpomenia sinuosa	32
Corallina officinalis	1, 4, 9, 15, 23, 31, 32, 35
Coralline "rhodoliths"	9, 23, 31
Green algae	14, 31
"*Lithothamnion*" paint	14, 23, 35
Red alga	35
ANGIOSPERMS	
Zostera sp.	23
ACTINIARIA	
Edwardsia sp.	7(2), 8(2), 26(1), 30(1), 34(1)
long thin attached anemone	32(2)
NEMERTEA - orange	32(1)
BRYOZOA - membraniporiform	14, 35
POLYCHAETA	
Armandia maculata	15(1)
Asychis sp.	18(7)

Axiothella australis	13(1), 26(1), 30(1), 33(1), 34(2)
Euchone sp.	33(1), 35(1)
Glycera sp.	9(1), 13(1), 14(1), 23(1), 32(3)
Lepidonotus sp.	23(1), 32(1)
Lumbriconereis sphaerocephala	14(1), 15(1)
Maldanidae	14(1), 23(1), 28(1)
Nereidae	32(1)
Orbinia papillosa	32(1)
Owenia fusiformis	2(5), 9(1), 10(1), 12(10), 13(3), 15(9), 23(12), 28(1), 29(10), 32(8), 33(4), 35(28)
Pectinaria australis	3(3), 4(3), 9(2), 10(1), 13(2), 14(2), 23(2), 26(2), 27(2), 30(1), 33(1)
Sigalion sp.	7(1), 27(1)
Stylaroides parmatus	23(1), 32(2)
Terebellidae	9(1), 15(1), 23(1), 32(22), 35(3)
Unidentified	4(3), 6(1), 10(2), 15(1), 26(1), 27(1), 28(1), 29(3), 30(2), 32(1), 35(4)
AMPHINEURA	
Acanthochitona zelandica	35(1)
Ischnochiton maorianus	1(1), 15(1), 23(4), 33(1)
Notoplax violacea	23(9)
Rhyssoplax stangeri	15(1), 35(2)
Terenochiton inquinatus	15(5), 35(3)
GASTROPODA	
Amalda australis	11(1), 13(2), 30(1)
Amalda novaezelandiae	8(1), 25(1), 26(1)
Antisolarium egenum	30(1), 34(1)
Bulla quoyi	9(1)
Cominella adspersa	3(1), 9(2), 11(1), 12(1), 23(4), 25(2), 30(2), 32(3), 33(1), 35(1)
C. quoyana	1(2), 3(1), 11(2), 12(1), 30(3), 31(1), 33(1), 35(3)
Cookia sulcata	23(1)
Cylichna thetidis	29(1)
Duplicaria tristis	2(1), 6(1), 8(1)
Epitonium minora	3(1), 8(2), 30(1), 34(1)
Maoricolpus roseus	15(4), 23(11), 32(5), 35(6)
Maoricrypta monoxyla	35(2)
Marginella pygmaea	23(3)
Neoguraleus sinclairi	8(1), 15(1), 31(2)
Neoguraleus lyallensis tenebrosus	23(1)
Notoacmea helmsi	35(3)
Phenatoma rosea	2(1)
Philine sp.	28(1)
Pupa kirki	3(5), 12(1), 28(3), 30(2)
Rissoina chathamensis	23(5)
Struthiolaria papulosa	3(1), 12(5), 15(1), 32(3)
S. vermis	14(1)
Tanea zelandica	28(1)
Turbo smaragdus	15(2), 23(1), 31(2)
Turbonilla (Chemitzia) sp.	8(1)
Xymene sp.	35(1)
Zeacolpus pagoda	4(1), 5(1), 24(1), 33(2), 34(7), 35(2)
Zegalerus tenuis	3(1), 4(3), 14(1), 33(1)

BIVALVIA	
Atrina zelandica	4(1), 12(1), 30(1), 33(1)
Bassina yatei	10(1), 34(1)
Chione stutchburyi	13(24), 18(1), 19(1)
Corbula zelandica	35(2)
Dosina zelandica	18(1)
Dosinia lambata	10(1)
D. subrosea	7(1), 11(1), 13(1), 24(1), 27(2), 33(2)
Felaniella zelandica	2(1), 23(3), 35(1)
Gari lineolata	3(2), 4(2), 8(3), 11(1), 12(1), 24(2), 26(3), 27(1), 30(2), 31(1), 33(8)
G. stangeri	2(3), 4(1), 7(1), 15(3), 23(4), 29(1), 33(4), 35(3)
Leptomya retiara	10(8), 14(2), 15(3), 32(1)
Maorimactra ordinaria	30(1)
Myadora boltoni	2(1), 3(1), 4(1), 8(1)
M. striata	2(2), 3(6), 4(4), 5(1), 6(1), 25(2), 26(7), 27(2), 28(1), 29(1), 33(2), 34(3), 35(1)
Nemocardium pulchellum	3(1)
Nucula hartvigiana	4(3), 9(c.300), 10(c.300), 11(10), 12(80), 13(c.80), 14(48), 15(c.150), 18(10), 19(1), 23(c.200), 31(8), 32(40), 33(2), 35(2)
N. nitidula	1(5), 2(3), 3(7), 4(18), 5(33), 6(5), 8(10), 11(48), 12(20), 24(10), 25(3), 26(1), 27(1), 29(8), 30(27), 31(7), 33(8), 34(2), 35(24)
Pleuromeris zelandica	4(1), 5(2), 9(20), 10(2), 11(1), 12(2), 15(2), 25(1), 31(2)
Scalpomactra scalpellum	3(1), 7(2), 9(1), 11(1), 24(1), 27(1), 31(2)
Soletellina nitida	5(1), 8(1), 24(1)
S. siliqua	13(1)
Tawera spissa	9(3), 10(1), 12(2), 15(1), 23(1), 33(2), 35(5)
Tellina (M.) liliana	4(1), 9(4), 10(5), 12(4), 13(5), 14(3)
T. huttoni	26(1), 34(1)
Theora lubrica	14(7), 16(15), 17(46), 18(5), 20(21), 21(15), 22(7)
Thracia australica novozelandica	8(1), 28(1)
Venericardia purpurata	35(1)
Venerupis largillierti	9(1), 10(1), 23(16), 30(1), 35(3)
Zearcopagia disculus	23(1), 35(3)
CIRRIPEDIA	
Balanus trigonus	14(1)
Eliminius modestus	15(2)
CUMACEA - unidentified	30(1)
ISOPODA	
Cirolana sp.	9(1), 32(1)
Unidentified	3(1)
AMPHIPODA - Unidentified	23(1)
NATANTIA - *Alpheus* sp.	21(1), 22(1), 32(2)
PAGURIDEA	
Unidentified hermits	1(1), 2(1), 3(1), 4(3), 8(1), 9(12), 10(1), 11(1), 14(1), 15(1), 23(3), 24(3), 26(9), 28(2), 30(3), 33(1), 34(2), 35(21)
BRACHYURA	
Halicarcinus varius	4(4), 12(1), 14(1), 15(3), 23(1), 28(1), 32(1), 35(10)

Macropthalmus hirtipes	13(2), 14(3), 18(1)
Notomithrax minor	1(1), 9(1), 15(1), 32(1)
OPHIUROIDEA	
Amphiura spp.	5(1), 8(2), 9(1), 15(1), 30(1), 34(1)
Axiagnathus squamatus	32(1), 35(1)
HOLOTHUROIDEA	
Trochodota sp.	7(1), 23(1), 28(1), 30(1), 32(2)
Unidentified	5(1), 26(1)
ECHINOIDEA	
Echinocardium cordatum	3(1), 7(1), 12(1), 26(1), 28(1), 29(1), 30(1), 31(1), 34(2)
HEMICHORDATA	
Balanoglossus australiensis	5(4), 24(1), 25(2), 28(1), 29(1)

APPENDIX III. Lists of foraminiferal species identified in sediment samples from stations 16, 23, 24, 28, 31, Tutukaka Harbour.

BENTHIC FORAMINIFERA

Suborder Textularina
Ammobaculites exiguus Cushman & Bronnimann 31
Gaudryina convexa (Karrer) 16, 23, 23, 24, 28
Haplophragmoides canariensis (d'Orbigny) 24, 28
Miliammina pelita Saunders 28
Reophax bacillaris Brady 16, 31
Reophax pseudodistans Cushman 16
Siphotextularia mestayerae Vella 16
Textularia ensis Vella 16, 24, 31
Textularia porrecta Brady 16
Textularia proxispira Vella 16, 23, 24, 28
Textularia torquata Parker 28
Textularia spp 23, 24, 28
Trochammina bartrami Hedley, Hurdle & Burdett 23, 28
Trochammina sorosa Parr 28
Trochamminita irregularis (d'Orbigny) 24
Suborder Miliolina
Cyclogyra involvens (Reuss) 16, 23, 24, 28, 31
Miliolinella labiosa schauinslandi (Rhumbler) 23, 28
Miliolinella subrotundata (Montagu) 16, 23, 24, 28, 31
Miliolinella vigilax Vella 28, 31
Nevillina coronata (Millett) 23
Pyrgo ezo Asano 28
Quinqueloculina agglutinans d'Orbigny 24, 28
Quinqueloculina ariminensis d'Orbigny 23, 24, 28, 31
Quinqueloculina bicostoides Vella 16, 23
Quinqueloculina cultrata (Brady) 16, 31
Quinqueloculina lamarckiana d'Orbigny 16, 23, 24, 28, 31
Quinqueloculina lata Terquem 24
Quinqueloculina parvaggluta Vella 23, 24, 28, 31
Quinqueloculina patagonica d'Orbigny 16, 23, 24, 28, 31
Quinqueloculina rebeccae Vella 28
Quinqueloculina seminula (Linnaeus) 16, 23, 24, 28, 31
Quinqueloculina suborbicularis d'Orbigny 24
Quinqueloculina tenagos Parker 16, 23, 24, 28, 31
Quinqueloculina triangularis d'Orbigny 23, 24, 28, 31

Siphonaperta crassa Vella 31
Spiroloculina disparilis Terquem 23, 28
Spiroloculina henbesti Petri 31
Spirosigmoilina tenuis (Czjzek) 16, 28
Triloculina trigonula (Lamarck) 28, 31
Wiesnerella auriculata (Egger) 28
Suborder Rotaliina
Ammonia beccarii (Linnaeus) 16, 23, 24, 28, 31
Anomalinoides glabrata Cushman 16, 28, 31
Aomalinoides spherica (Finlay) 16, 24, 28
Astacolus crepidulus (Fichtel & Moll) 28
Astrononion novozealandicum Cushman & Edwards 28
Bolivina cacozela Vella 28
Bolivina pseudoplicata Heron-Allen & Earland 16, 23, 24, 28, 31
Bolivina spathulata (Williamson) 16, 23, 24, 28, 31
Bolivina striatula Cushman 16, 23, 24, 28, 31
Bolivina subexcavata Cushman & Wickenden 16, 23, 24, 28, 31
Bucella frigida (Cushman) 28
Bulimina gibba Fornasini 16, 31
Bulimina marginata d'Orbigny 16, 28, 31
Bulimina submarginata Parr 24, 28
Buliminella elegantissima (d'Orbigny) 16, 28
Buliminoides madagascariensis (d'Orbigny) 23
Buliminoides williamsoniana (Brady) 23, 31
Cassidulina carinata Silvestri 23, 24, 28
Cibicides corticatus Earland 16, 23, 24, 28, 31
Cibicides marlboroughensis Vella 16, 23, 28
Cibicides cf. *ungerianus* (d'Orbigny) 24, 28
Cymbaloporetta bradyi (Cushman) 16, 23, 24, 28, 31
Dentalina communis d'Orbigny 28
Discorbinella timida Hornibrook 28
Discorbinella vitrevoluta (Hornibrook) 28, 31
Discorbis dimidiatus (Parker & Jones) 16, 23, 24, 28, 31
Dyocibicides biserialis Cushman & Valentine 16, 28
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