SOFT BOTTOM MACROFAUNA, FORAMINIFERA AND SEDIMENTS OFF THE CHICKENS ISLANDS, NORTHERN NEW ZEALAND

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SUMMARY

The benthic macrobiota, foraminifera (Protozoa) and sediments were studied from 15 dredge samples taken from a 1 km² area of sea bed (5-53 m depth), south of Lady Alice Island in the Chickens Group, northern New Zealand. Four macrofaunal and three foraminiferal microfaunal associations or subassociations were recognised.

An infaunal bivalve Venericardia purpurata-Corbula zelandica-Talabrica bellula association occurs in shallow gravel and a Gari stangeri-Felaniella zelandica bivalve association occurs in somewhat deeper (28 m) coarse sand. An association of the molluscs Pupa kirki-Pleuromeris zelandica-Myadora striata is widespread in medium-fine sand at 11-45 m. The distribution of these three macrobenthic associations corresponds with that of the foraminiferal association dominated by Pileolina zelandica-Elphidium charlottensis-Quinqueloculina spp. A subassociation of this shallow foraminiferal assemblage is dominated by Discorbis dimidiatus and occurs in the head of South Cove at 5 m depth.

A macrofauna association characterised by the bivalves Nemocardium pulchellum-Notocallista multistriata and a foraminiferal association characterised by Bulimina submarginata-Evolvocassidulina orientalis occur on a gently sloping shelf below 50 m depth in slightly muddy fine sand. The shallow and the deep associations are separated by a zone (between 35 and 45 m) with faunas dominated by a mixture of their characterising species.

INTRODUCTION

Field work was undertaken during the Offshore Islands Research Group trip to the Chickens Islands, New Year 1981—1982. The Chickens Islands are situated in the outer Hauraki Gulf, 10-15 km east of Whangarei Heads on the eastern side of Northland Peninsula (Fig. 1). The 15 dredge stations on which this paper is based were located on the south side of Lady Alice Island and spread over an area of 1 km² of sea floor, at depths of 5-53 m (Fig. 1, Appendix 1). Bathymetry of the study
area is based on depths measured in the field and adjusted to mean low water spring tide level.

Fig. 1. Upper. Location of study area, south side of Lady Alice Island, Chickens Islands, east of North Auckland.
Lower. Bathymetry (in metres) and station locations.

**METHODS**

Samples were collected using a small dredge (capacity 4.5 litres), described by Grace and Whitten (1974), hand-hauled from a 3.8 m aluminium dinghy with an 18 horsepower outboard motor. Under ideal conditions the dredge sampled an area of 0.075 m² of sea floor to a depth of 6 cm.
Upon retrieval, the volume of each sample was estimated and approximately 200 ml was removed for sediment analysis and foraminiferal studies. The rest of the sample was passed over a sieve with 2 mm openings and live organisms retained on it were sorted fresh, identified and counted (Appendix II). Stations were located using a sextant to measure horizontal angles between fixed points on the shore. Depths were measured using a lead-weighted line.

Sediment retained for laboratory work was analysed for grain size using sieves, and prepared for microfaunal studies by washing out the mud (finer than 0.0625 mm) and concentrating the foraminiferal tests (by floating off with carbon tetrachloride). A bulk pick of 100 benthic foraminifera was made from a split of the floated material to give a crude quantitative estimate of the fauna. No attempt was made to distinguish live from dead tests. The remaining float from sample 6 was examined and specimens of additional taxa were picked to give a more complete list of the rarer species present (Appendix II).

BATHYMETRY (FIG. 1)

Off the south coast of Lady Alice Island, the sea floor drops away quite rapidly to depths of 35-40 m, flattening out to form an extensive 50-60 m deep shelf, which slopes very gently to the east. The main coastal feature is South Cove, the floor of which slopes gently seaward down to 20 m before dropping away more rapidly in the vicinity of the mouth.

SEDIMENTS

Grain size terminology follows Folk (1968, p. 26-30). Sediment type at each station is listed in Appendix I and their distribution shown in Fig. 2a.

The southern shores of Lady Alice are fringed almost continuously by a 1-30 m wide intertidal rock platform. Below low tide mark this passes into a 10-50 m wide belt of sandy greywacke, cobble and pebble gravel (e.g. stn. 15). This gravel is flanked by patches of shell gravel (stn. 14) and coarse sand (stn. 9) and grades rapidly into fine to medium sand that covers most of the study area.

The floor of the shallow inner portion of South Cove is composed of moderately sorted to well-sorted medium sand, whereas moderately sorted to moderately well-sorted fine sand covers all the rest of the area. Coarse shell is patchily distributed throughout these medium and fine sands (Fig. 2b) comprising 0.1-5% of the sediment in South Cove and 0.3-3% of the sediment of the steeper submarine slopes and southern shelf.

Mud distribution is less patchy (Fig. 2c). The fine sand below 50 m
depth on the southern shelf has 3-5% mud content and a tongue of mud (1-3%) extends up to 25 m depth into the mouth of South Cove. All the shallows (less than 25 m) and steeper slopes on either side of the mouth of South Cove are covered in clean sand with less than 0.5% mud. The distribution of mud presumably relates to the energy of local bottom currents that may sweep along the southern coast of Lady Alice Island and possibly swing into South Cove, allowing a tongue of slightly muddy sediment to accumulate in the mouth.

**LIVE MACROFAUNA**

In analysing the benthic biota (Appendix II) we have attempted to recognise recurrent sets of taxa, or ‘associations’ by an intuitive, non-
statistical approach based partly on associations recognised elsewhere. The associations are named after the dominant and most characteristic taxa.

We have recognised and mapped the distribution of 4 associations in the study area (Fig. 3).

1. *Venericardia purpurata-Corbula zelandica-Talabrica bellula* association.
   Stations: 14, 15
   Sediment: sandy pebble or shell gravel
   Depth: 12 to 16 m
   Wave energy: moderate to moderately high
   Characterising species: *Venericardia purpurata* (14,15), *Corbula zelandica* (15)

   This association occurs in the shelly and pebbly gravels that fringe the intertidal and subtidal reefs around the moderately exposed mouth of South Cove. The characterising bivalve infauna of the sandy matrix is not abundant with *Venericardia purpurata* having the greatest densities and low but persistent densities of *Corbula zelandica* and *Talabrica bellula*.

   The coarse shell and gravel substrate provides ample attachment surfaces for the chitons *Ischnochiton*, *Notoplax* and *Rhyssoplax* and vermetid gastropod *Stephopoma*, and a favourable habitat for other epifauna such as hermit crabs, isopods, ophiuroids, the crabs *Elamena producta* and *Notomithrax minor* and sucker fish *Trachelochismus pinnulatus*.

2. *Gari stangeri-Felaniella zelandica* association
   Station: 9
   Sediment: shelly coarse sand
   Depth: 28 m
   Wave energy: moderate to low
   Characterising species: *Gari stangeri* (9), *Felaniella zelandica* (9).
   Common associated species: *Otionella* sp. (9), *Sphenotrochus ralphae* (9), *Cominella quoyana* (9).

   This association occurs in the only coarse sand sampled, near the base of a very steep submarine slope off Moki Rock. The most common infaunal bivalves are the two characterising species, whereas the most abundant taxon is the domed, bristly, disc-shaped, sand-dwelling bryozoan *Otionella* which occurs at a density of 350 per square metre (Fig. 4a).

3. *Pupa kirki - Pleuromeris zelandica - Myadora striata* association
   Stations: 3, 4, 10, 11, 13
   Marginal stations: 2, 5, 12
   Sediment: slightly muddy to slightly shelly or clean fine sand
Depth: 11-45 m  
Wave energy: moderate to low  
Common associated species: *Otionella* sp. (4, 10, 11, 12), *Euchone* sp. (3, 4, 5, 11), *Amalda novaezelandiae* (2, 3, 4, 5, 10, 11, 13), *Cominella adspersa* (3, 11), *Epitonium minora* (3, 11), *Spectamen verum* (3, 4, 10), *Nucula nitidula* (3, 4).

This association occurs in the fine sand substrate shallower than 45 m that covers much of the floor of South Cove and the submarine slope along the south side of Lady Alice Island. The substrate contains less than 2% mud and in all cases, except marginal stations 2 and 12, has less than 5% gravel size shell component.

The gastropod *Pupa kirki* is present in moderate density in all but the marginal stations, reaching densities up to 200 per square metre. Equally common and almost as abundant is another gastropod *Amalda novaezelandiae*. The most abundant infaunal bivalves are the characterising species *Pleuromeris zelandica* and *Myadora striata*, together with *Nucula nitidula*. In common with association 2, the bryozoan *Otionella* reaches high densities in some stations here (e.g. 500 per square metre in stn. 10).

![Benthic macrofaunal associations](image-url)

**Fig. 3.** Distribution of benthic macrofaunal associations, south of Lady Alice Island.

4. *Nemocardium pulchellum-Notocallista multistriata*

Stations: 6, 7, 8  
Marginal stations: 5, 12  
Sediment: slightly muddy, slightly shelly, fine sand  
Depth: 42-53 m  
Wave energy: low  
Characterising species: *Nemocardium pulchellum* (5, 6, 8), *Notocallista multistriata* (6, 7 12).
Common associated species: Otionella sp. (6, 7, 12), Aglaophamus macroura (5, 7), Pectinaria australis (5, 6, 7, 8), Acteon spp. (5, 6), Cuspidaria tralli (8), Divaricella huttoniana (7), Myadora antipodum (6), Pontophilus australis (6, 8), ophiuroids (7, 12).

This association occurs in the slightly muddy (3-5%), slightly shelly (3-8%) fine sand, deeper than 42 m on the gentle, lower submarine slopes and southern shelf in the study area.

A number of infaunal bivalves only occur in this deeper water association and these include the characterising species Nemocardium pulchellum and Notocallista multistriata, as well as Cuspidaria, Divaricella, Myadora antipodum and Thracia australica. Numerically the most abundant taxa are the bryozoan Otionella and polychaete Pectinaria australis. Also restricted to this association are the polychaetes Aglaophamus macroura, Aphrodita, cirratulids, sipunculids, terebellids, gastropods Acteon spp., Muricopsis octogonus, Microvoluta marginata and shrimp Pontophilus australis.

5. Ungrouped

Station 1 (5 m depth, medium sand), at the head of South Cove, was devoid of living biota, apart from a solitary unidentified polychaete, and could therefore not be grouped with any association.

Comparisons with other areas

All 4 associations are similar to some of those previously recognised in other study areas, and appear to have similar environmental settings.

The Venericardia-Corbula-Talabrica association is remarkably similar to the Corbula zelandica association recognised in the eastern Bay of Islands (Hayward et al. 1981) which could easily have been also named Corbula-Talabrica-Venericardia as these three bivalves had the highest community scores there. Like the Chickens' association, that in the Bay of Islands occurs at shallow depths with moderate wave energy in coarse sediments, often gravel, with a low mud content.

The Gari-Felaniella association has previously been recognised at Rakitu Island (Hayward et al. 1982) where, like the Chickens, it occurs in areas of moderate to low wave energy close to shore, usually in medium to coarse sand. At Rakitu it occurs at depths of 1.5 to 23.5 m, making the Chickens sample, at 28 m slightly deeper than previously recorded.

The Pupa-Pleuromeris-Myadora association is similar in overall composition, but not exactly equatable, to associations recognised in similar environments at several other localities in northern New Zealand. It is probably closest to the Pupa kirki-Pectinaria australis association that occurs in medium to fine sand at 5 to 15 m depth off Great Mercury Island (Grace and Grace 1976) although the Chickens association lacks Pectinaria, and the Great Mercury one lacks Pleuromeris. Other quite similar associations are the Pleuromeris...
*Pectinaria australis* of muddy very fine to medium sand at 2 to 12 m in the eastern Bay of Islands (Hayward et al. 1981), the *Selenaria* (= *Otionella*)-*Zeacolpus* subassociation of slightly muddy medium to coarse sand at 30 to 51 m off Rakitu Island (Hayward et al. 1982), the *Myadora boltoni*-*Scalpomactra scalpellum* of medium to fine sand at 5 to 15 m off Slipper Island (Grace and Whitten 1974) and the uncharacterised association in fine to medium sand at 10-37 m off Cuvier Island (Hayward and Grace 1981).

The *Nemocardium-Notocallista* association is close enough in composition to be equated with the *Nemocardium pulchellum* association that occurs in very fine to fine sand at 30-40 m off the Cavalli Islands (Grace and Hayward 1980) and the *Cuspidaria-
Amphiura-Notocallista association of muddy fine to slightly muddy medium sand at 40-69 m off Rakitu Island (Hayward et al. 1982).

FORAMINIFERAL MICROFAUNA (LIVE PLUS DEAD)

Planktics
As with other areas, the percentage of planktic foraminifera increases with distance from shore and with increasing depth (Fig. 5a). Inside South Cove, at depths less than 20 m, planktics comprise less than 5%. On the steep submarine slopes at 20-40 m they comprise 1 to 10% and in the slightly muddy fine sand on the southern shelf reach 19-25% of the foraminiferal fauna. Taxonomically the planktic foraminiferal fauna is dominated by Globigerina falconensis with subdominant G. quinqueloba and Globorotalia inflata which is typical of nearshore localities in the warmer parts of the transitional zone (Hayward 1983).

Benthic associations
Benthic foraminiferal associations have been recognised intuitively based on the dominants in each sample and on associations recognised elsewhere. We recognise two associations and one subassociation in the study area (Fig. 6a).

Although post-mortem redistribution of foraminiferal shells by currents and waves obviously occurs, it does not appear to have been so severe in the study area as to obliterate the apparently original live distribution patterns. There is little evidence in samples of winnowing out of smaller tests or of unusually high abrasion of any particular group of species.

Fig. 5. a. Distribution and relative abundance of planktic foraminifera (percentage of total foraminiferal fauna). b. Distribution of Fisher alpha index values for diversity of benthic foraminifera.
Fig. 6. a. Distribution of benthic foraminiferal associations and subassociation, south of Lady Alice Island. b-c. Distribution and abundance (percentage of benthic foraminifera) of; b. Suborder Textularina and c. Suborder Miliolina.

Percentage abundances in stations are given in brackets. Dominant species are illustrated in Fig. 7.

1. *Pileolina zealandica-Elphidium charlottensis-Quinqueloculina* spp. association

Stations: 2, 3, 4, 9, 11, 13, 14, 15
Sediment: slightly muddy or shelly fine, medium or coarse sand or gravel
Depth: 11-31 m
Wave energy: moderately low to moderately high
Characterising species: *Pileolina zealandica* (12-33%), *Elphidium charlottensis* (6-29%), *Quinqueloculina semifusa* (2-20%), *Quinqueloculina triangularis* (2-11%)
Common associated species: *Patellinella inconspicua* (1-6%), *Notorotaliaolsoni* (1-7%), *Gavelinopsis hamatus* (0-8%), *Discorbis dimidiatus* (0-5%), *Miliolinella subrotundata* (0-7%), *Buliminoides williamsoniana* (0-4%), *Cibicides marlboroughensis* (0-3%).

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This association (together with its subassociation) occupies all the sea floor in the study area that is shallower than 35 m. It seems to be almost independent of substrate type, although all sediments contain little mud (0-1.5%) and are a highly varied mixture of sand grains and coarse shell. Thus the substrate is suited to both epifaunal (e.g. Pileolina, Discorbis) and infaunal (e.g. Elphidium, Quinqueloculina) foraminifera.

In all samples, except stn. 13 (where E. charlottensis dominates) P. zealandica is the most abundant foraminifera. The second most abundant is E. charlottensis in fine-medium sand and Q. seminula and Q. triangularis in coarse sand or gravel.

1A. Discorbis dimidiatus subassociation

Station: 1
Sediment: medium sand
Depth: 5 m
Wave energy: moderate
Characterising species: Discorbis dimidiatus (21%), Pileolina zealandica (14%), Elphidium charlottensis (11%), Quinqueloculina seminula (11%).
Common associated species: Rosalina bradyi (6%), Cibicides cf. lobatulus (4%), Elphidium novozealandicum (4%), Miliolinella subrotundata (4%).

This subassociation of the P. zealandica-E. charlottensis-Quinqueloculina association occurs in the shallowest station, at the head of South Cove. It is distinguished by the dominance of the epifaunal species D. dimidiatus. The sample is very well-sorted medium sand which provides little in the way of clasts for the D. dimidiatus to cling to and it seems probable that few actually live on this substrate and most are derived from the shallow seaweed-covered gravel and subtidal reefs that almost encircle the station. Other epifaunal members of the fauna (e.g. Cibicides, Rosalina) probably also come from the surrounding hard substrates.

2. Bulimina submarginata-Evolvocassidulina orientalis association

Stations: 6, 7, 8
Sediment: slightly muddy, slightly shelly fine sand
Depth: 52-53 m
Wave energy: low
Characterising species: Bulimina submarginata (12-17%), Evolvocassidulina orientalis (6-9%)
Common associated species: Textularia ensis (4-8%), Elphidium charlottensis (0-7%), Hanzawaia bertheloti (3-5%), Bulimina marginata (1-7%), Quinqueloculina triangularis (1-5%), Gavelinopsis hamatus (0-4%), Anomaloides sphera (1-4%), Textularia proxispira (2-5%), Globocassidulina canalisuturata (2-4%), Notorotalia olsoni (1-6%), Epistominella vitrea (1-2%).

This association occurs on the southern shelf at depths in excess of 50 m. The greater percentage of mud (3-5%) has been noted elsewhere (Hayward 1982a) to suit the species that dominate this association (i.e. B. submarginata, E. orientalis), as well as some of the other common
Fig. 7. Dominant benthic foraminifers in sediments, south of Lady Alice Island. a. Pileolina zelandica (FP 3504); b. Elphidium charlottensis (FP 3503); c. Quinqueloculina seminula (FP 3178); d. Quinqueloculina triangularis (FP 3181); e. Discorbis dimidiatus (FP 3164); f. Notorotalia olsoni (FP 3179); g. Patellinella inconspicua (FP 3505); h. Gavelinopsis hamatus (FP 3203); i. Bulimina submarginata (FP 3196); j. Evolvocassidulina orientalis (FP 3204); k. Textularia ensis (FP 3199). FP numbers are catalogue numbers of N.Z. Geological Survey. Bar scale is 0.1 mm long.
species (e.g. B. marginata, G. canalisuturata). The abundance of epifaunal foraminifera is very low (less than 10%) compared with the shallower faunas. Whereas some of the common taxa in shallower depths are also common here (e.g. E. charlottensis, O. triangularis, G. hamatus, N. olsoni), many others are more characteristic of this association (e.g. T. ensis, T. proxispira, H. bertheloti, A. spherica, E. vitrea).

3. Marginal stations between the two associations

Stations: 5, 10, 12
Sediment: clean to slightly muddy, slightly shelly, fine sand
Depth: 42-45 m
Wave energy: low
Common species: Notorotalia olsoni (4-11%), Pileolina zealandica (7-8%), Bulimina submarginata (2-7%), Bulimina marginata (3-6%), Textularia ensis (2-10%), Gaudryina convexa (0-9%), Quinqueloculina seminula (4-7%), Quinqueloculina triangularis (5-6%), Gavelinopsis hamatus (1-7%), Patelinella inconspicua (2-8%), Elphidium charlottensis (2-4%).

These stations occur towards the foot of the steep submarine slope, between 40-50 m depth, in a zone between the two recognised associations. Their faunas are mostly dominated by a mixture of the dominating species of the two associations and show a well-developed overlap between them.

The only distinctive element in their faunas is the high percentage of N. olsoni (Fig. 8a) which appears to have its greatest abundances (4-11%) in a broad zone encompassing the deeper stations of association 1 (deeper than 25 m) through to the inshore stations of association 2 (stns. 6, 7).

Comparisons with other areas

These two associations and one subassociation are very similar in character to foraminiferal associations recognised elsewhere in similar environments.

The P. zealandica-E. charlottensis-Quinqueloculina association is remarkably similar to faunas recorded: at 0-12 m depth in a variety of mixed substrates in the eastern Bay of Islands (Hayward 1981); at 15-37 m depth in medium sand off Cuvier Island (Hayward and Grace 1981); and at 1-40 m depth in a wide variety of, usually partly shelly, substrates (associations A2, B2, B3) around the Cavalli Islands (Hayward 1982a). The Cavalli Island faunas tend to differ from those at the Chickens in the consistent subdominance of Cibicides marlboroughensis, which is virtually absent from the present study area.

The D. dimidiatus subassociation fauna is most similar to those at 6-10 m depth in fine sand off Cuvier Island (Hayward and Grace 1981), at 4-10 m depth in shelly sand off Little Barrièr Island (Hayward 1982b)
and the *D. dimidiatus-Elphidium novozealandicum-P. zealandica* subassociation at 2-28 m in shelly sand at the Cavalli Islands (Hayward 1982a).

The *B. submarginata-E. orientalis* association can be equated with the *Cassidulina carinata-B. submarginata-Globocassidulina canalisuturata* association which occurs in slightly muddy sand at 29-41 m off the Cavalli Islands (Hayward 1982a), although the dominant cassidulinid is different. This association appears to be widespread east of northern New Zealand in slightly muddy, fine to medium sand at mid shelf depths (e.g. 25-60 m, outer Hauraki Gulf - Thompson 1975; 40-80 m, east of Great Barrier - pers. obs.).

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**Fig. 8.** Distribution and abundance (percentage of benthic foraminifera) of: a. *Pileolina zealandica*; b. *Elphidium charlottensis*; c. *Quinqueloculina seminula* and *Q. triangularis*; d. *Notorotalia olsoni*. 

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Distribution of suborders (Fig. 6b, c)

Modern foraminifera belong to three suborders, distinguished by the composition of the shell, and the abundance of each is often used in fossil faunas as an indication of the paleoenvironment. These Chickens faunas have 56-85% Rotaliina. The porcelaneous Miliolina range from 6-15% on the southern shelf up to 32-38% in the shallow gravel. Their greatest abundances here appear to correlate with clean, coarse sediments in shallow depths. On the other hand, the agglutinated Textularina range from 0-3% in South Cove to 9-17% on the southern shelf and appear to be independent of substrate type.

Diversity (Fig. 5b)

The simplest measure of species diversity is the Fisher alpha index (Murray 1973). In the study area alpha ranges between 10 and 30, with the lowest diversities in the clean sand at 5-20 m in South Cove and the highest diversities (25-30) near the foot of the steep submarine slope (40-55 m) in the overlap zone between the two associations. Fisher alpha index values of around 30 are among the highest recorded anywhere in the world and certainly from such shallow depths. Similar high diversities have been recorded at corresponding depths around the Cavalli Islands (Hayward 1982a) and are thought to reflect northeastern New Zealand’s location at the southern limit of the range of many subtropical taxa and the northern limit of the range of temperate taxa.

DISCUSSION

Both the macrobenthic and the foraminiferal benthic faunas have two widely distributed associations and one or two less-widely distributed shallow water associations or subassociations. In both cases the extensive shallower associations (i.e. Pupa-Pleuromeris-Myadora and Pileolina-Elphidium-Quinqueloculina) and the extensive deeper associations (i.e. Nemocardium-Notocallista and Bulimina-Evolvocassidulina) have very similar distributions and are separated by a zone of overlap at about 35-45 m depth. However the two shallowest macrobenthic associations do not have equivalent counterparts in the foraminiferal faunas.

A similar pattern of coincident distribution of macrobenthic and benthic foraminiferal associations has been shown around the Cavalli Islands (Hayward 1982a), especially in the deeper water, fine-grained sediment.

How real are the faunal associations?

The faunal associations, as recognised here, are combinations of dominant taxa (and often rarer ones as well) that consistently occur
together, either over a considerable expanse in the study area or have been recognised in other areas. The recognition of an association does not imply that the characterising species always necessarily occur together, either in the study area or elsewhere.

An examination of the contoured maps of absolute abundance of some of the dominant macrobenthos (Fig. 4) and of relative abundance of some of the dominant foraminifera (Fig. 8, 9) suggests that the distribution of each species is independently determined by its own specific set of physical and perhaps biotic variables. Few of the species (with the exception of *B. submarginata* and *E. orientalis*) appear to have exactly overlapping contoured abundances. However faunal associations are recognisable where the optimal abundances of several dominant taxa overlap over a significantly large area.
In areas where there are no abrupt changes in the environmental variables that control the distribution of species one can expect zones, as occurs at the Chickens, where one association grades into another. Nevertheless, a number of the dominant species consistently have a significant proportion of their optimum abundance distributions overlapping in several of the areas studied (see comparisons with other areas) and it seems useful to recognise these associations for they appear to occur in similar environmental settings. Recognition of associations seems to be a valuable way of synthesising the data and finding recurring groups of species that presumably have closely similar environmental requirements.

This does not mean that a study of the distribution patterns of individual taxa does not also have its merits. For example, within the *Pileolina-Elphidium-Quinqueloculina* association, it is obvious that the abundance of *Quinqueloculina* (Fig. 8c) is strongly correlated with clean sediments (less than 0.5% mud) and an abundance of gravel size clasts, and that *E. charlottensis* (Fig. 8b) is seemingly independent of mud content but is most abundant in well-sorted sand with few gravel size clasts. Similarly *Notorotalia olsoni* (Fig. 8d) and *Otionella* sp. (Fig. 4a) have their greatest abundances on the lower slopes at 25-55 m depth, especially where the sediments are clean.

ACKNOWLEDGEMENTS

We are grateful to all those on the O.I.R.G. trip to the Chickens Islands that assisted in hauling up the dredge or sorting out the live macrobenthos. Fred Brook kindly identified some of the more obscure molluscs and corals and together with Bob Hoskins and Hugh Morgans reviewed the manuscript and suggested improvements. The SEM photographs are the masterpieces of Barry Burt and Sue Bishop.

REFERENCES


**APPENDIX I. Station Data.**

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<td>sl M, sl Sh, f. sand</td>
<td>3 200</td>
<td>12</td>
<td>N</td>
<td>B F201923</td>
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<tr>
<td>9</td>
<td>28</td>
<td>shelly c. sand</td>
<td>2 800</td>
<td>16</td>
<td>G</td>
<td>P F201924</td>
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<td>10</td>
<td>43</td>
<td>f. sand</td>
<td>2 800</td>
<td>14</td>
<td>P</td>
<td>(P,B) F201925</td>
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<tr>
<td>11</td>
<td>31</td>
<td>f. sand</td>
<td>1 200</td>
<td>9</td>
<td>P</td>
<td>P F201926</td>
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<td>12</td>
<td>42</td>
<td>sl Sh, f. sand</td>
<td>1 200</td>
<td>12</td>
<td>(P,N)</td>
<td>(P,B) F201927</td>
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<td>13</td>
<td>11</td>
<td>sl Sh, f. sand</td>
<td>3 200</td>
<td>6</td>
<td>P</td>
<td>P F201928</td>
</tr>
<tr>
<td>14</td>
<td>12</td>
<td>S, Sh gravel</td>
<td>2 000</td>
<td>20</td>
<td>V</td>
<td>P F201929</td>
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<tr>
<td>15</td>
<td>15.5</td>
<td>S, p. gravel</td>
<td>1 600</td>
<td>19</td>
<td>V</td>
<td>P F201930</td>
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1. sl = slightly, M = muddy, S = sandy, Sh = shelly, f. = fine, m. = medium, c. = coarse, p. = pebble.
2. live macrobenthos analysis only.
F = foraminiferal association - B = Bulimina - Evolvocassidulina, D = Discorbis subassociation, P = Pileolina - Elphidium - Quinqueloculina
() = marginal.

**APPENDIX II. Macrofaunal counts from Chickens Islands dredge stations.** For each taxon, the stations at which it occurs is given, followed in brackets by the number of individuals occurring live in the sample.

**ALGAE**
*Corallina officinalis* 2

**FORAMINIFERA**
*Liebusella soldanii* 9(1),12(1)

**BRYOZOA**
*Otionella sp.* 4(6),6(4),7(3),9(17),10(24),11(4),12(7)
unidentified 8(1),14(1)
**COELENTERATA**
*Sphenotrochus ralphae* 9(1),14(1)

**POLYCHAETA**
*Aglaphamus macroura* 5(1),7(1)
*Aphrodita* sp. 7(1)
*Euchone* sp. 3(2),4(5),5(2),11(1),14(1)
*Hyalinoecia* sp. 7(2),9(1)
*Lepidonotus* sp. 15(2)
*Lumbriconereis* sp. 8(2),10(1)
*Pectinaria australis* 5(8),6(4),7(2),8(3)
Cirratulidae 8(2)
Maldanidae 2(5),3(1),7(7),8(1),10(2),11(1)
Sipunculidae 8(1)
Terebellidae 7(1)
unidentified 1(1),3(10),4(50),5(15),6(13),7(1),8(7),9(4),10(5),11(1),12(9),13(2),14(8),15(24)

**NEMERTEA**
cream 9(1)
orange 2(1),4(1),6(1),8(1),9(1)
white 3(1)

**AMPHINEURA**
*Ischnochiton maorianus* 14(6),15(6)
*Notoplax* sp. 15(2)
*Rhyssoplax stangeri* 14(21),15(38)

**GASTROPODA**
*Acteon cratericulatus* 6(2)
*Acteon hancocki* 5(1)
*Amalda novaezelandiae* 2(1),3(11),4(10),5(2),10(1),11(3),13(1),14(1)
*Antimelatoma buchanani maorum* 4(1)
*Antisolarium egenum* 3(1)
*Balcis bulbula* 11(1)
*Chelidonura aureopunctata* 4(1)
*Cominella adspersa* 3(3),11(1)
*Cominella quoyana* 2(1),3(3),4(6),5(2),9(2),11(2),12(2),13(1),14(4),15(6)
*Cylichna thetidis* 4(1),6(1)
*Duplicaria tristis* 2(2)
*Epitonium minora* 3(1),11(1)
*Microvoluta marginata* 5(1)
*Muricopsis octogonus* 8(1)
*Philine* sp. 4(1),5(1)
*Proxiuber australis* 9(1),14(1)
*Pupa kirki* 3(12),4(7),5(6),10(9),11(7),12(1),13(2)
*Scrinium neozelanicum* 15(1)
*Spectamen tryphenense* 12(1)
*Spectamen verum* 3(1),4(1),9(1),10(1)
*Stephopoma roseum* 14(1)
*Struthiola furcata* 4(1),14(1)
*Tomopleura albula* 4(1),14(1)
*Zaccolus pagoda* 12(3),13(1)
*Zegalerus tenuis* 6(1)
BIVALVIA
Corbula zelandica
Cuspidaria raillii
Divaricella huttoniana
Felaniella zelandica
Gari stangeri
Myadora antipodum
Myadora striata
Nemocardium pulchellum
Notocallista multistriata
Nucula nitidula
Pleuromeris zelandica
Talabrica bellula
Thracia australica novozelandica
Venericardia purpurata

CRUSTACEA
Alpheus sp.
Amphipoda
Cumacea
Elamena producta
hermit crabs
Isopoda
Notomithrax minor
Paranthura sp.
Pontophilus australis
Tanaidacea

ECHINODERMATA
Astropecten polyacanthus
ophiuroid unidentified
Trochodota sp.

PISCES
Trachelochismus pinnulatus

APPENDIX III. Foraminiferal microfaunas from Chickens Islands dredge stations. For each taxon, the stations at which it occurs is given, followed in brackets by its percentage of the benthic foraminiferal fauna. No percentage reading indicates less than 1%. For each planktic species, the percentage of the total foraminiferal fauna is given in brackets.

BENTHICS

Suborder Textularina
Gandryina convexa (Karrer) 2(1),3(1),6(2),7(1),8(1),9(5),10(9),12(2),14(1),15(1)
Haplophragmoides canariensis (d’Orbigny) 6
Haplophragmoides canariensis Heron-Allen
& Earland 6(1),7(1),8(1)
Reophax sp. 15(1)
Siphotextularia aperturalis (Cushman) 6,12(1)
S. blacki Vella 6(1),8(1)
Textularia ensis Vella
T. horrida Egger
T. proxispira Vella
Textularia sp.
Trochammina bartrami Hedley,
   Hurdle & Burdett
T. sorosa Parr

Suborder Miliolina
Cyclogyra involvens (Reuss)
Miliolinella schauinslandi (Rhumbler)
M. subrotundata (Montagu)
M. vigilax Vella
Miliolinella sp.
Pyrgo anomala (Schlumberger)
P. depressa (d’Orbigny)
Quinqueloculina agglutinans
Q. arminensis d’Orbigny
Q. colleeae Vella
Q. cooki Vella
Q. delicatula Vella
Q. lamarckiana d’Orbigny
Q. aff. lata Terquem
Q. parvaggluta Vella
Q. patagonica d’Orbigny
Q. rebecca Vella
Q. seminula (Linnaeus)
Q. suborbicularis d’Orbigny
Q. triangularis d’Orbigny
‘Siphonaperta’ n.sp.
Spiroloculina aff. angulata Cushman
S. disparitis Terquem
Triloculina tricarinata d’Orbigny
T. trigonula (Lamarck)

Suborder Rotaliina
Amphicoryna separans (Brady)
Anomalinoides spherica (Finlay)
Anomalina sp.
Astacolus australis (Chapman)
A. crepidulus (Fichtel & Moll)
A. neolatus Vella
Astrononion novozealandicum
   Cushman & Edwards
Bolivina cacozea Vella
B. compacta Sidebottom
B. pseudoplicata Heron-Allen &
   Earland
B. robusta Brady
B. spatulata (Williamson)
B. spinescens Cushman

3(1),5(2),6(4),7(4),8(8),9(3),10(3),12(10)
6
6(5),7(2),8(2),10(3)
5(6),6(3),7(2),9(1),10(3),11(1),14(1)
14(1)
5(1)
4(1),6
10(1),15(1)
12(2),14(7),15(3)
9(1),14(1)
4(4),14(1)
6
6
6(1),12(1)
5(1),8(1),11(1),12(1)
2(2),7(1),8(1),10(1),14(1)
5(2),6(1),8(3),10(2),12(2)
1(3),2(2),6(1),15(1)
2(1),4(1),12(1),13(3)
3(1),10(2),13(1),14(2)
1(1),2(1),4(1),5(2),7(1),10(1),14(1)
10(1),12(2)
1(11),2(12),3(8),4(2),5(4),6(3),7(3),8(2),9(15),10(7),
11(10),12(6),13(20),14(11),15(17)
6(1)
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15(1)
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10(1)
6,12(1),14(1)
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5(1)
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5(1)
9(1)
4(1),6,13(1)
3(1),14(2)
5(1)
1(1),4(2),6(2),7(1),8(2),9(1),11(1),12(2)
5(1),6(1),7(1)

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B. striatula Cushman
B. subexcavata Cushman & Wickenden
Bulimina gibba Fornasini
B. marginata d'Orbigny
B. submarginata Parr
Buliminoides williamsoniana (Brady)
Cancris maoricus Finlay
Cassidulina carinata Silvestri
C. laevigata d'Orbigny
Chilostomella ovooidea Reuss
Cibicides cf. lobatulus (Walker & Jacob)
C. marlboroughensis Vella
C. temperata Vella
Cymballoporetta bradyi (Cushman)
Dentalina communis d'Orbigny
Discorbis dimidiatus (Jones & Parker)
Dyocibicides sp.
Elphidium advenum depressulum Cushman
E. charlottensis (Vella)
E. novozealandicum Cushman
E. aff. oceanicum Cushman
Elphidium sp.
Epistominella cf. cassidulinoides
Hornibrook
E. vitrea Parker
Evolvocassidulina orientalis (Cushman)
Fissurina baccata (Heron-Allen & Earland)
F. contusa Parr
F. laevigata Reuss
F. lucida (Williamson)
F. marginata (Montagu)
F. orbignyana Seguenza
F. quadrivrevertens McCulloch
F. cf. striolata (Sidebottom)
Fissurina spp.
Fursenkoina schreibersiana Czjzek
Gavelinopsis hamatus Vella
G. lobatulus (Parr)
Glabratella margaritaceus (Earland)
Globocassidulina canalisuturata Eade
G. minuta (Cushman)
Guttulina bartschi Cushman & Ozawa
G. yabei Cushman & Ozawa
Gypsinia vesicularis (Parker & Jones)
Hanzawaia bertheloti (d'Orbigny)
H. complanata (Sidebottom)
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<td>Haynesina depressulus (Walker &amp; Jacob)</td>
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<td>Hoeglundina elegans (d’Orbigny)</td>
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<td>L. crenata Parker &amp; Jones</td>
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Sigmavirgulina tortuosa (Brady)  7(1),11(1),14(1)
Sigmoidella elegantissima (Parker & Jones)  6(1),14(1)
Sigmomorphina cf. disparilis  McCulloch  6(1)
Siphouviergerina interrupta (Brady)  6
S. vadescens (Cushman)  3(1),5(2),6(1),11(2),12(2),14(1)
Sphaeroidina bulloides d'Orbigny  6(2),8(1),11(1)
Spirillina vivipara simulata McCulloch  4(1),6,14(1)
Suratkina australiensis (Chapman, Parr & Collins)  8(1)
Tretomphalus planus Cushman  6
Trifarina carinata bradyana (Cushman)  5(2),6(1),7(1),8(1),11(1),12(1)
Trifarina n.sp.  1(1),2(1),3(1),6(1),13(1)
Virgulopsis turris (Heron-Allen & Earland)  7(1)
Zeaflorilus flemingi (Vella)  6,8(1)

PLANKTICS

Globigerina bulloides d'Orbigny  6
G. falconensis Blow  3(1),4(4),5(17),6(12),7(10),8(14),9(2),10(1),12(4),  13(1),14(2),15(2)
G. quinqueloba Natland  3(1),4(2),5(3),6(6),7(5),8(3),9(1),10(1),13(2),14(1)
Globigerinella aequilateralis (Brady)  7(1)
Globigerinita glutinata (Egger)  4(1)
Globigerinoides ruber (d'Orbigny)  5(2),6(1),12(2)
G. sacculifer (Brady)  6
Globorotalia crassa Cushman & Stewart  7(1),12(1)
G. scitula (Brady)  5(1),7(2)
G. truncatulinoides (d'Orbigny)  6(1),7(1),10(1)
Neogloboquadrina dutertrei (d'Orbigny)  6(1),8(1),12(1)
Orbulina universa d'Orbigny  6,9(1)