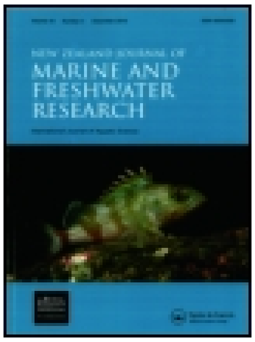

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Soft-bottom macrobenthic communities of Manukau Harbour, New Zealand

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A survey of the macrobenthos at 42 stations in the channels and subtidal sandflats in Manukau Harbour, Auckland, revealed four biotic associations; although referred to as communities, they are not equivalent to Peterson-type communities since they are not particularly discrete and there is some overlap in species composition. The similarity in species between stations was measured by percentage similarity coefficients using Jaccard's coefficient for presence-absence data and Czekanowski's coefficient for log-transformed quantitative data. Stations were grouped in dendrograms by group-average sorting which allowed re-arrangement of the similarity matrices into trellis diagrams.

Dominant species in each of the four groups of stations were ranked by calculating a 'community score' for each, based on its abundance, fidelity, and bioindex value within the group. Each of the four groups was found to support a unique group of species and these are considered as representing four communities. Two indicator species in each community were identified from the highest community scores: Group 1, the *Microcosmus/Notomithrax* community — associated with a coarse sediment of dead bivalve shells and small rocks in shallow water. It has high species diversity indices; Group 2, the *Halicarcinus/Bugula* community — associated with a relatively coarse sediment of dead shells, grit, and little sand in deep water in the main channels; Group 3, the *Amalda/Myadora* community—associated with fine sand with mud or shell grit in shallow parts of the channels; and Group 4, the *Fellaster/Pagurus* community — associated with ironsand in shallow water in the outer harbour. It has low species diversity indices.

INTRODUCTION

A recent survey of the intertidal sandflats of Manukau Harbour has shown a close relationship between the deposit and suspension feeding infaunal invertebrates and the surface sediments (Grange 1977). Several environmental impact reports have described the intertidal communities of various portions of the eastern section of the harbour near Onehunga City (e.g., Ministry of Works & Development 1975, Beca, Carter, Hollings, & Ferner Ltd 1975). The intertidal ecology of the southern shore was described in a report on the suitability of the area as a site for cooling ponds for a thermal power station (Bio-researches Ltd 1976), and Henriques (1976) described the overall intertidal ecology and the distribution of algae, particularly the introduced *Gracilaria secundata,* in detail. There are no published data on the subtidal macrofauna apart from those reported from nine stations sampled in the main channels by Powell (1937).

A sampling programme was, therefore, initiated to delineate the present distribution of the subtidal species and to determine if they are associated into the communities identified by Powell (1937).

METHODS

Forty-two stations, ranging in depth from 1 m to 16 m below low tide, were sampled throughout the harbour during March 1977 (Fig. 1).

Strong currents, up to 2.25 $m.s^{-1}$ in the main channels (Heath *et al.* 1977) prevented use of a soft-sediment sampler (Grange & Anderson 1976) by divers or a grab; it was impossible to drop grabs vertically so they would trigger and sample adequately. Therefore, all samples were taken using a small naturalist's dredge covered with 1 mm mesh and fitted with large cutting blades to allow good penetration into the sediment. The dredge was towed for 4 min to collect more or less comparable samples at each station.

Stations were chosen to cover all the expected ranges in depth and sediment type from the channels and shallower sand flats. Each station was positioned using at least four bearings with a hand-bearing compass. Each haul was washed while in the dredge to remove all sediment finer than 1 mm diameter before the entire sample was preserved in 80% isopropyl alcohol. In the laboratory, all individuals were identified as far as possible to species level, counted, and an estimate made on whether they were juveniles, small adults, or adults. Sediment samples were not

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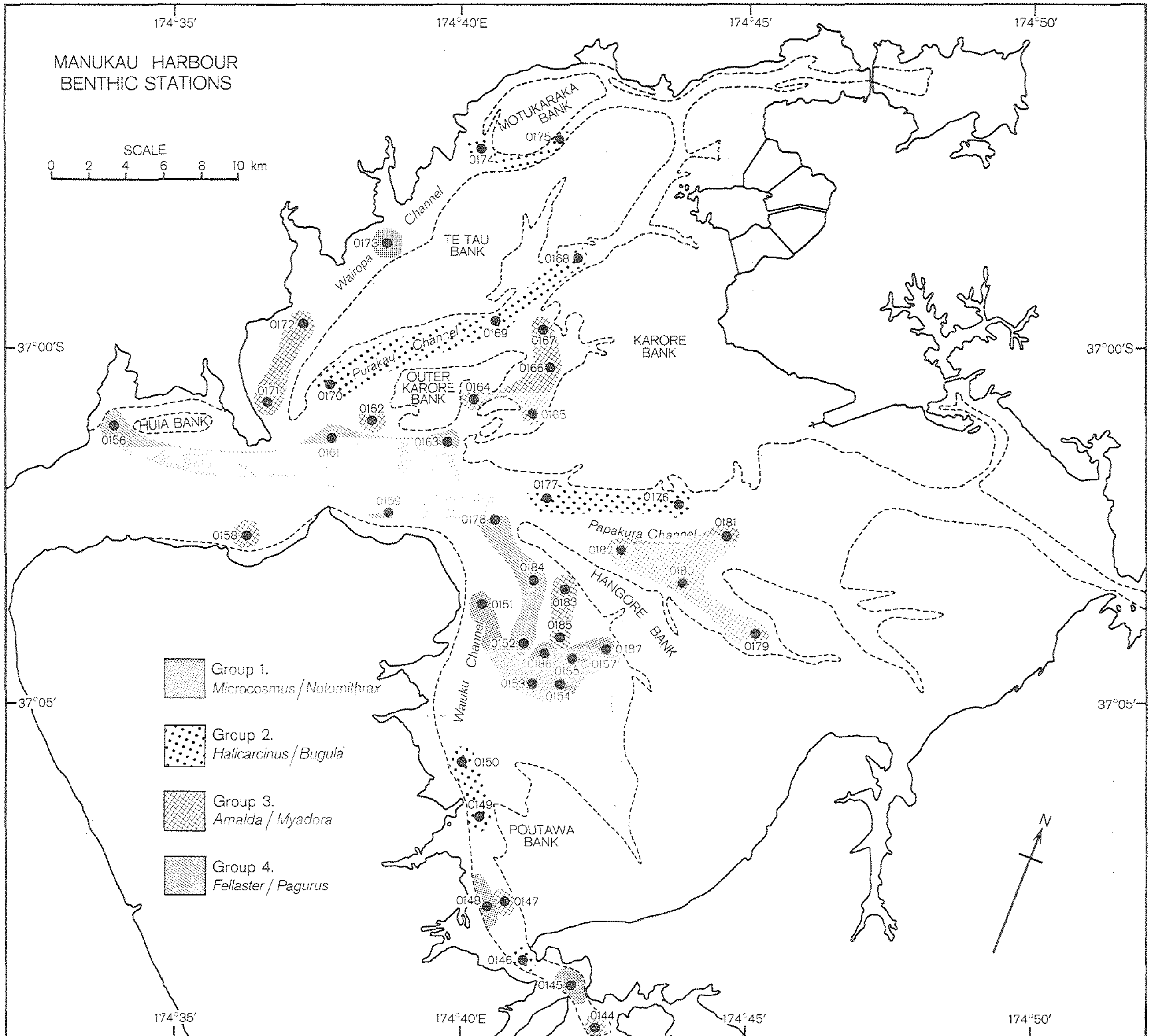


Fig. 1. Sampling stations and community distributions, Manukau Harbour, March 1977.

analysed in detail, but each dredge-haul with sediment was given a visual description before washing, and any cobbles, rocks, shell grit, dead shells, or ironsand recorded.

Species diversity indices were calculated for each station using the formula developed by Brillouin (1962),

$$H = N^{-1} \log_2 N!/N_1!\, N_2! \ldots N_s!$$

where N = total number of individuals, s = number of species, and N_1, N_2 = number of individuals in the first and second species, respectively, etc. This species diversity index was used because all individuals in the samples were identified and counted (McCloskey 1970).

Analyses of the species similarity between stations were made using both presence-absence data and numbers of individuals. Similarity coefficients (S) were calculated from presence-absence data using the coefficient of floral community developed by Jaccard (1902) and slightly modified by Sneath (1957) and Singleton & Skerman (1973). This is given by

$$S = [j/(a+b-j)]100$$

where a = number of species in the first station, b = number of species in the second station, and j = number of common species.

The station × station similarity matrices resulting from calculating the percentage similarity of every station with every other station were rearranged by group-average sorting (Lance & Williams 1967) to produce a hierarchical classification in the form of a dendrogram. The dendrogram was used to construct the sorted station × station similarity matrix into a trellis diagram in which stations with similar faunal compositions lay along the diagonal.

Two sets of dendrograms and trellis diagrams were constructed from the presence-absence data. One used all the species collected, except for those that occurred at only one station (i.e., 83 species) (method a); the other used only the most widespread species, i.e., the 40 species that occurred in over 10% of all stations (method b).

The similarity index used to compare stations using quantitative data was the Czekanowski coefficient (C_z) (Bray & Curtis 1957) after the original data had been log-transformed to decrease the importance of over-abundant species; i.e.,

$$C_z = 2W/(A+B)$$

where A = sum of species scores for sample A; B = sum of species scores for sample B, and W = sum of the smaller scores of each species in the two samples being compared.

Trellis diagrams were also constructed from the quantitative data to compare with the presence-absence results using three methods: the numbers of individuals of all species occurring in more than one station (method c); the numbers of individuals of the 40 most widespread species (method d); and the percentage of each species in a sample by number, using only the 40 most widespread species (method e).

Each method produced a slightly different trellis diagram although the same main four groups of stations were evident in each instance, with only a few station differences between groups depending on the method used. Each station was finally assigned to a specific group by the number of times it occurred in a group using the five different methods.

With these four groups of stations identified, the species associated with each were divided into dominant, sub-dominant, and secondary. Dominant species were defined as those in 50% or more of all stations in a group and with a 'community score' (see below) greater than 25% of the total possible community score. Those with a community score less than 25% of the total possible were defined as sub-dominant. Those species which were not common enough to occur in over 50% of the stations in any group, but had more than 50% of their total distribution in a single group, were defined as secondary if they occurred at four or more stations throughout the harbour. This excluded all rare species.

Community Score

The dominant species in each station group were ranked according to their importance to identify unique or indicator species in each community. This was done by developing the concept of 'community score' to rank the dominant species in each group objectively, concentrating on uniqueness, based on three criteria:

(i) The percentage of stations in the group at which the species was collected. This is the first value to be calculated and must be greater than or equal to 50%.

(ii) The bioindex value, obtained by ranking the 10 most abundant species at each station within the group. Ten points are given to the species numerically most abundant, 9 for the second most abundant species, and so on until the 10th species is given 1 point. The points are summed for each species for all stations in the group, to give the bioindex value (McCloskey 1970, Lowry 1975). This method compares relative species abundance, independent of sample size.

(iii) The proportion of the species' total distribution that occurs in the group, i.e., the species fidelity (McCloskey 1970), or degree to which a species is restricted to that group.

When nominating dominant species in a group or community, more emphasis should be given to those species which are unique to that community than to ubiquitous species that may be abundant in other communities as well, since they describe the community more succinctly.

The community score (C.S.) then is defined as the sum of the percentage distribution and bioindex values, multiplied by the fidelity factor,

$$C.S. = (A+B)C$$

where A = percentage of stations in the group at which the species was collected, B = bioindex value, and C = fidelity.

Bioindex values in each group depend on the number of stations in the group so that the community scores cannot be compared between groups. However, a total possible community score (T.P.C.S.) may be calculated for each group, e.g., for a group of eight stations;

(a) A species may occur at all eight stations, i.e., 100% distribution.

(b) This species may be the most abundant at all stations, i.e., bioindex value = 80.

(c) This species may only occur at these eight stations, i.e., fidelity = 1.0

$$\therefore \text{T.P.C.S.} = (100 + 80)\,1.0 = 180$$

The community score for each species, when expressed as a percentage of the T.P.C.S., allows species rankings and dominance to be compared between groups, and gives a level at which dominant and sub-dominant species may be decided for all groups. Thus, in the present data, all species with a community score greater than 25% T.P.C.S. were defined as dominant, the rest as sub-dominant. Each community is named from its two most dominant or 'indicator species'.

Since values can be compared between groups, regardless of the number of stations in each group, the community score also provides a method of checking the validity of groups produced by the trellis diagrams. If two groups have very similar ranks of dominant and sub-dominant species, they probably represent different facies of the one community, rather than two separate communities.

This was found in a recent community analysis of the zooplankton in Hawke Bay (J. M. Bradford, N.Z.O.I., pers. comm.) where a coastal faunal group was found at a large number of stations, represented by three sub-groups, separated by various environmental factors. In each sub-group there were a small number of unique species.

RESULTS

In all, 126 species were collected from the 42 stations, with an average of 16 species and 87 individuals at each station. The most widespread species was the introduced alga, *Gracilaria secundata,* which was collected at 31 stations, followed by the polychaete *Owenia fusiformis* (28 stns), a small crab, *Halicarcinus varius* (27 stns) and a gastropod, *Amalda australis* (27 stns) (Table 1). Plants of *G. secundata* which appeared healthy and growing were attached to shells and small stones at depths

Table 1. Species present in Manukau Harbour subtidal benthos, March 1977, and number of stations where collected

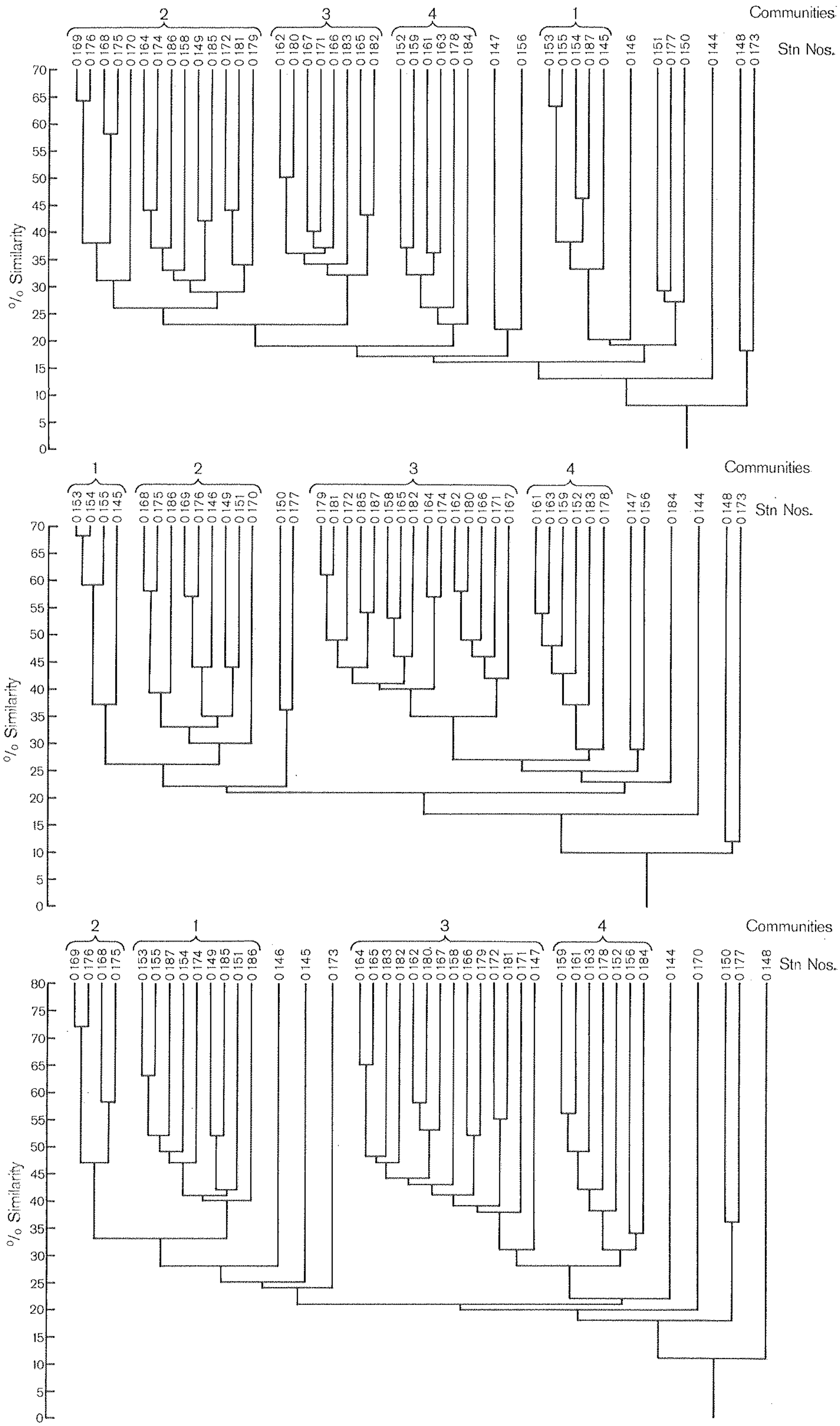
Species	No. of Stns
ALGAE	
Gracilaria secundata	31
Unidentified 2	3
Dictyota ocellata	1
Unidentified 1	1
PORIFERA	
Halicondria moorei	8
Callyspongia ramosa	5
Microciona coccinea	2
Polymastia granulosa	2
Spongia reticulata	1
Tethya aurantiacum	1
Ancorina alata	1
HYDROIDA	
Amphisbetia bispinosa	2
Unidentified 1	2
Plumularia setacea	1
ACTINARIA	
Actinothoe albocincta	10
Anthopleura aureoradiata	2
Unidentified 1	1
POLYCLADIDA	
Leptoplana sp	3
POLYCHAETA	
Owenia fusiformis	28
Axiothella sp.	17
Scolecolepides benhami	9
Glycera lamellipodia	9
Aglaophamus macroura	8
Platynereis australis	6
Goniada emerita	5
Pectinaria australis	4
Haploscoloplos cylindrifer	3
Lepidonotus polychroma	2
Glycera americana	2
Unidentified 1	2
Idanthyrsus pennatus	1
Pomatoceros caeruleus	1
Sabellaria kaiparaensis	1
Capitellethus sp	1
Unidentified 2	1
NEMERTEA	
Unidentified 1	1
CIRRIPEDIA	
Balanus decorus	2
CUMACEA	
Unidentified 1	2
Diastylis sp	1
MYSIDACEA	
Unidentified 1	14
OSTRACODA	
Cylasterope zelandica	1
ISOPODA	
Unidentified 1	2
Isocladus armatus	1
Unidentified 2	1
AMPHIPODA	
Unidentified 1	8
Unidentified 2	4
Unidentified 3	1
Unidentified 4	1
NATANTIA	
Pontophilus australis	24
Periclimenes yaldwyni	15
Palaemon affinis	3

Table 1 continued

Species	No. of Stns	Species	No. of Stns
ANOMURA		BIVALVIA	
Petrolisthes elongatus	12	*Myadora striata*	19
		Nucula hartvigiana	13
PAGURIDEA		*Soletellina siliqua*	7
Pagurus sp	20	*Dosinia subrosea*	7
		Perna canaliculus	6
BRACHYURA		*Paphirus largillierti*	4
Halicarcinus varius	27	*Arthritica bifurca*	4
Notomithrax minor	17	*Macomona liliana*	3
Macrophthalmus hirtipes	8	*Myadora boltoni*	3
Liocarcinus corrugatus	4	*Ostrea lutaria*	2
Ovalipes punctatus	3	*Zenatia acinaces*	2
Halicarcinus whitei	2	*Pecten novaezelandiae*	2
Notomithrax peronii	2	*Modiolarca impacta*	1
c.f. *Pinnotheres* sp	2	*Felaniella zelandica*	1
Pilumnus novaezelandiae	1	*Cyclomactra ovata*	1
Hemigrapsus crenulatus	1	*Tawera spissa*	1
		Myadora subrostrata	1
POLYPLACOPHORA		*Theora lubrica*	1
Terenochiton inquinatus	4	*Thracia vitrea*	1
Acanthochitona zelandica	4	SCAPHOPODA	
		Fissidentalium zelandicum	2
GASTROPODA		ASTEROIDEA	
Amalda australis	27	*Coscinasterias calamaria*	12
Maoricolpus roseus manaukauensis	23	*Patiriella regularis*	4
Zegaleurus tenuis	20	OPHIUROIDEA	
Cominella adspersa	17	*Amphiura* sp	6
Pervicacia tristis	10	*Amphiura rosea*	5
Sigapatella novaezelandiae	5	ECHINOIDEA	
Philine powelli	5	*Fellaster zelandiae*	9
Zethalia zelandica	4	POLYZOA	
Xymene plebeius	3	*Bugula neritina*	7
Buccinulum lineum	3	*Zoobotryon pellucida*	6
Trochus tiaratus	2	*Watersipora cucullata*	4
Zeacumantus lutulentus	2	Unidentified 1	1
Diloma subrostrata	2	ASCIDIACEA	
Neoguraleus manukauensis	2	*Microcosmus kura*	5
Cominella glandiformis	1	*Styela plicata*	4
Micrelenchus huttoni	1	*Cnemidocarpa bicornuta*	1
Buccinulum heteromorphum	1	HEMICHORDATA	
Trichosirius inornatus	1	*Balanoglossus australiensis*	4
Epitonium minora	1	PISCES	
Alcithoe arabica	1	*Rhombosolea plebeia*	2
Xymene ambiguus	1	*Trypterigium varium*	1
Struthiolaria vermis	1	*Dellichthys morelandi*	1
Struthiolaria papulosa	1	Unidentified 1	1
Maoricrypta monoxyla	1		

down to 10 m, although Henriques (1976) asserts that this species is essentially intertidal, and never covered by more than about 4 m of water at high tide. Large masses of drift plants were found throughout the harbour. Some of the individuals collected at the deeper stations may have been carried there by currents and may not survive for long. However, the species has been included in the analyses wherever it was found still obviously alive.

The dendrograms drawn from the group-average sorting of the similarity coefficients calculated by all five methods (Fig. 2) show approximately the same four station groups (I-IV) recognised by a core of recurrent stations. Designations of station groupings were made from the trellis diagrams of the original similarity coefficients (Fig. 3). Each station group is formed by obvious clusters which are outlined in bold lines. In both the dendrograms and trellis diagrams there are stations which have low affinities with the above four groups. These stations were generally not the same in each method, so probably had attributes of more than one group; rather than being used to form new groups, they were assigned to an established group by averaging all the similarity coefficients in each group. The largest value determined the group into which they were placed. Two stations, 0 150 and 0 177, had low affinities with all groups using four of the five methods. Although


Communities
2 3 4 1
Stn Nos.
O169 O176 O168 O175 O170 O164 O174 O186 O158 O149 O185 O172 O181 O179 O162 O180 O167 O171 O166 O183 O165 O182 O152 O159 O161 O163 O178 O184 O147 O156 O153 O155 O154 O187 O145 O146 O151 O177 O150 O144 O148 O173
% Similarity
Communities
1 2 3 4
Stn Nos.
O153 O154 O155 O145 O168 O175 O186 O169 O176 O146 O149 O151 O170 O150 O177 O179 O181 O172 O185 O187 O158 O165 O182 O164 O174 O162 O180 O166 O171 O167 O161 O163 O159 O152 O183 O178 O147 O156 O184 O144 O148 O173
% Similarity
Communities
2 1 3 4
Stn Nos.
O169 O176 O168 O175 O153 O155 O187 O154 O174 O149 O185 O151 O186 O146 O145 O173 O164 O165 O183 O182 O162 O180 O167 O158 O166 O179 O172 O181 O171 O147 O159 O161 O163 O178 O152 O156 O184 O144 O170 O150 O177 O148
% Similarity

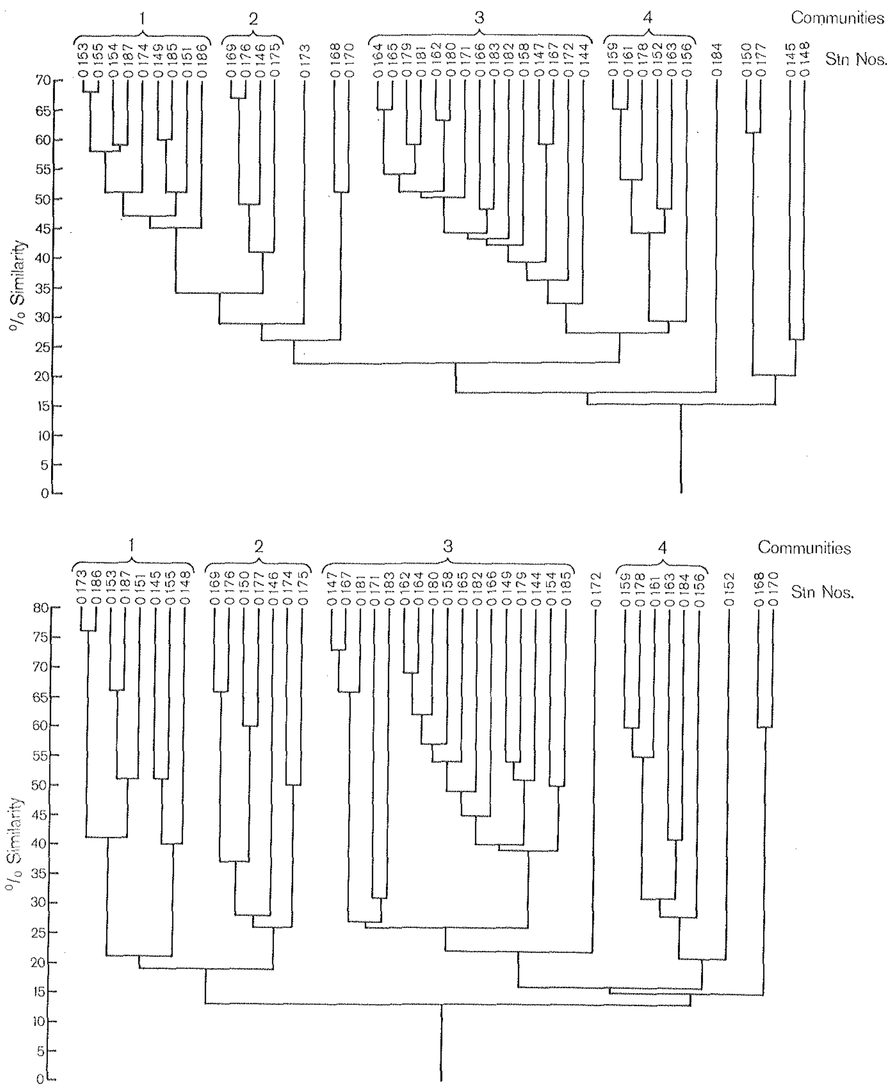


Fig. 2. Dendrograms of station similarities produced by group-average sorting, Manukau Harbour: (*opposite*) (a) Jaccard coefficient, presence-absence: 83 species; (b) Jaccard coefficient, presence-absence; 40 most widespread species; (c) Czekanowski coefficient, numbers of individuals; 83 species; (*above*) (d) Czekanowski coefficient, numbers of individuals; 40 most widespread species; (e) Czekanowski coefficient, percentage numbers of individuals; 40 most widespread species.

they occasionally had high affinities with each other (63% in method (d)), neither had a unique fauna. For this reason they were regarded as intermediate between Groups I and II.

There is considerable species overlap between Groups I and II, shown by the shaded areas between these groups in the trellis diagrams (Figs 3a–e). Each station was finally assigned to the group into which it was most frequently placed according to each method (Table 2). Using all methods, most stations fall obviously into one of the groups except Stns 0 149, 0 174, 0 177, and 0 185. These were placed in one of the four groups only after comparing their depths, sediments, species diversities, and positions within the harbour. (The stations in each group, along with their physical and biological attributes are compared in Table 3 and the geographical positions of each are shown in Fig. 1.)

Since the stations allocated to each group have similar attributes in species composition and diversity,

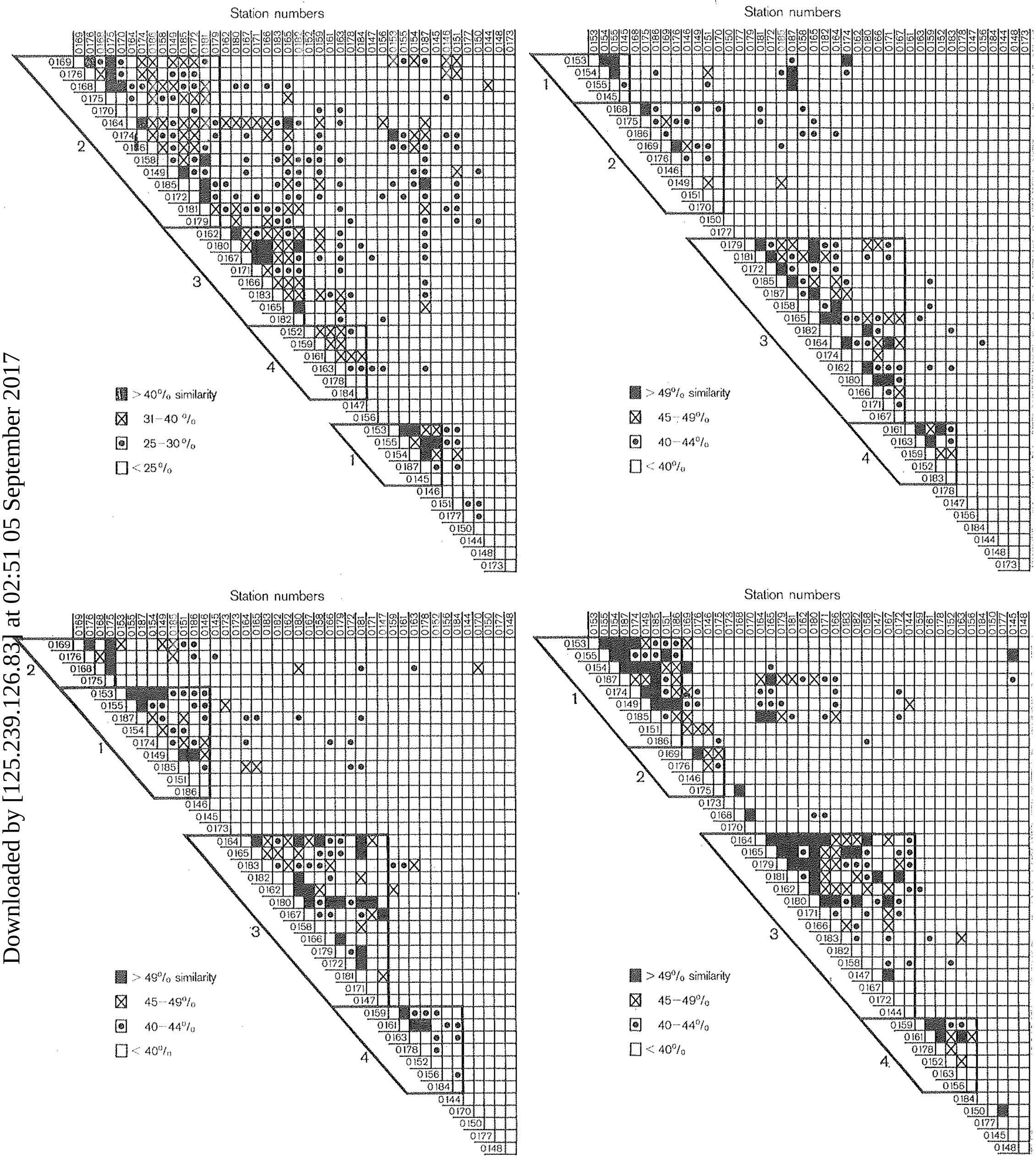
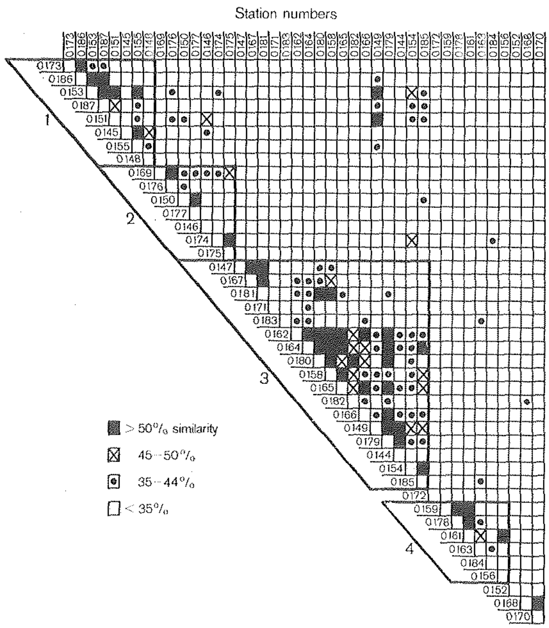


Fig. 3. Trellis diagrams showing station groupings, drawn from the dendrograms, Manukau Harbour: (*above*) (a) Jaccard coefficient; 83 spp.; (b) Jaccard coefficient; 40 most widespread species; (c) Czekanowski coefficient; 83 spp.: (d) Czekanowski coefficient; 40 most widespread species; (*opposite*) (e) Czekanowski coefficient (percentage numbers); 40 most widespread species.



as well as similar physical characteristics such as depth and sediment type, the four groups produced by group-average sorting are regarded as reflecting reality.

GROUP 1 — *Microcosmus/Notomithrax* COMMUNITY

This group consists of nine shallow water stations in the central part of the harbour with a coarse sediment composed of dead bivalve shells and small rocks. It has the highest average species diversity index and contains the most diverse station of all, 0 154 (Table 3).

The characteristic species are dominated by the simple ascidian *Microcosmus kura* and the brachyuran *Notomithrax minor* (Table 4). These two species are not dominant in any other group, so they are used as the indicator species to name this diverse community. The coarse sediment, dead shells, and rocks provide attachment for sessile epifaunal suspension feeders, and this community is the only one which supports ascidians such as *Microcosmus kura* and *Styela plicata* and the large sponges *Callispongia ramosa* and *Halicondria moorei*. At the same time, the coarse sediment precludes large numbers of infaunal species, which are restricted to the polychaetes *Owenia fusiformis* and *Axiothella* sp. (both of which tend to be ubiquitous throughout the harbour) and the bivalve *Paphirus largillierti*. There is a large proportion of mobile epifaunal carnivores such as the asteroid *Coscinasterias calamaria* and the brachyurans *Notomithrax minor* and *Halicarcinus varius*. Microscopic and encrusting algae on the dead shells support populations of the grazing chitons *Terenochiton inquinatus* and *Acanthochitona zelandica*, and the shells themselves provide attachment for the suspension feeding sessile gastropod *Zegaleurus tenuis*.

This community appears to be equivalent to the *Maoricolpus/Nucula* association of Powell (1937) which also contained *Zegaleurus* and *Terenochiton* as sub-dominants and *Acanthochitona, Halicarcinus* and *Notomithrax* (=*Paramithrax*) as secondary elements. Powell's association differed from the present material in the absence of sponges, ascidians, and the polychaste *Owenia fusiformis*. *Maoricolpus roseus manukauensis*, although an abundant species in Group I, was not used to name the community as done in previous harbour surveys (e.g., Powell 1937, Grace 1966) because it was not a dominant species (Table 4). It was not considered as an indicator since it is also a sub-dominant species in Group II. A similar example was found in a community study in Otago Harbour (Rainer, in press) where *Maoricolpus roseus* is abundant but occurs with many different species, rather than in a single association. The co-dominant species named in Powell's (1937) association, *Nucula hartvigiana*, was found at many stations throughout the harbour, but did not occur at over 50% of any stations in any one group. It was, therefore, not included in the community score analyses.

GROUP 2 — *Halicarcinus/Bugula* COMMUNITY

This group contains 10 stations, restricted to deep water in the main channels; the shallowest station was 7 m. The sediment is relatively coarse with dead shells and shell grit, and very little sand; possibly sand has been removed by tidal scour.

The species characteristic of this community tend to occur in other communities as well. The two most dominant indicator species are the brachyuran *Halicarcinus varius* and the polyzoan *Bugula neritina* (Table 5).

Apart from the attached *Bugula neritina, Zoobotryon pellucida, Gracilaria secundata*, and the slow-moving *Maoricolpus roseus manukauensis*, this community is characterised by mobile epifauna (mainly crustaceans) and a small, unidentified amphipod which is restricted to the stations in deeper water, most of which occur in this group. This community has no parallel in the associations described by Powell (1937), although the dominance of *Maoricolpus* and *Halicarcinus* suggests that it would have been included in his *Maoricolpus/Nucula* association, particularly since his stations ranged from 5 to 22 m. Neither *Bugula* nor *Gracilaria* was recorded by Powell (1937), probably because neither species was present in abundance in the harbour at that time. *Gracilaria* may have been present, but only sparsely, before 1960. The building of the sewage oxidation ponds caused deposition of fine sediment in the area which provided a suitable habitat for *Gracilaria,* and the first dense meadows appeared in August 1960. The distribution of the species has increased considerably since September 1960 when the oxidation ponds began discharging rich nutrients (Henriques 1976). *Bugula* and *Zoobotryon* are fouling species and have probably spread with the increase of shipping in the harbour since 1937.

Group 3 — *Amalda/Myadora* Community

This group contains the largest number of stations (16), over 38% of all sampled, all in shallow parts of the channels in the central harbour. The sediment is largely medium to fine sand with mud or shell grit at some stations. The fauna is relatively diverse with large numbers of individuals in some samples.

The community is characterised by a large number of secondary species, most of which are infaunal, deposit-feeding polychaetes and bivalves (Table 6) although the indicator species are a carnivorous gastropod (*Amalda australis*) and a suspension feeding bivalve (*Myadora striata*). One of the dominants, *Gracilaria secundata,* is also dominant in Group II. *Amalda, Cominella,* and *Pagurus* are all active carnivores and their abundance in this community is probably a consequence of the large numbers and variety of prey organisms. The *Amalda/Myadora* community has no direct parallel with the associations recorded in the Manukau Harbour by Powell (1937), but he did record a *Baryspira* (=*Amalda*) *Pervicacia* community in shallow water on fine sand off the outer Auckland Harbour and sheltered coastal beaches. He concluded that it was essentially a benthic phase of a low-tidal, littoral community, a similar situation to that found at extreme low water on the large littoral sand flats of Manukau Harbour (pers. obs.). Most of the other genera recorded by Powell (1937) as living in his *Amalda/Pervicacia* community are also found in the present *Amalda/Myadora* community, e.g., *Amalda, Cominella, Amphiura, Owenia, Asterina* (= *Pateriella*), and *Myadora,* although the absence of *Pervicacia* in the present analysis (but its dominance in Group IV) suggests that the Manukau communities have slightly different faunal compositions from those in Auckland Harbour.

Group 4 — *Fellaster/Pagurus* Community

This is the smallest group, containing only seven stations restricted to shallow water in the outer harbour. The sediment is clean, well-sorted, fine sand with considerable ironsand. It is the least diverse of the four groups and is dominated by the flattened echinoid *Fellaster zelandiae,* the hermit crab *Pagurus* sp. and the gastropod *Pervicacia tristis* (Table 7). It is regarded as equivalent to the *Arachnoides* formation found in Manukau Harbour by Powell (1937) which was dominated by *Arachnoides* (=*Fellaster*), with *Pagurus* as a secondary species. The present community contains no secondary species. Powell regarded his formation as having a sparse fauna with a very poorly represented microfauna. The community does not extend for any distance inside the inner harbour, probably because *Fellaster* cannot tolerate low salinity (Grace 1966), and one may assume the same for the other species. A similar community, dominated by *Fellaster* and *Amalda,* has been reported from the main entrance channel to Whangateau Harbour by Grace (1966) who also regards it as rather impoverished. He lists only one other species, the chiton *Notoplax cuneata.*

Table 2. Assignation of each station in Manukau Harbour into one of four station groups by five methods (see Methods)

Stn no.	Group with each method (a)	(b)	(c)	(d)	(e)	Final Group
0 144	II	III	III	III	III	III
0 145	I	I	I	I	I	I
0 146	II	II	II	II	II	II
0 147	III	III	III	III	III	III
0 148	I	I	I	I	I	I
0 149	II	II	I	I	III	II
0 150	II	II	II	I	II	II
0 151	I	II	I	I	I	I
0 152	IV	IV	IV	IV	IV	IV
0 153	I	I	I	I	I	I
0 154	I	I	I	I	III	I
0 155	I	I	I	I	I	I
0 156	III	III	IV	IV	IV	IV
0 158	II	III	III	III	III	III
0 159	IV	IV	IV	IV	IV	IV
0 161	IV	IV	IV	IV	IV	IV
0 162	III	III	III	III	III	III
0 163	IV	IV	IV	IV	IV	IV
0 164	II	III	III	III	III	III
0 165	III	III	III	III	III	III
0 166	III	III	III	III	III	III
0 167	III	III	III	III	III	III
0 168	II	II	II	II	II	II
0 169	II	II	II	II	II	II
0 170	II	II	II	II	II	II
0 171	III	III	III	III	III	III
0 172	II	III	III	III	III	III
0 173	I	I	I	I	I	I
0 174	II	III	I	I	II	II
0 175	II	II	II	II	II	II
0 176	II	II	II	II	II	II
0 177	IV	I	II	I	II	II
0 178	IV	IV	IV	IV	IV	IV
0 179	II	III	III	III	III	III
0 180	III	III	III	III	III	III
0 181	II	III	III	III	III	III
0 182	III	III	III	III	III	III
0 183	III	IV	III	III	III	III
0 184	IV	IV	IV	IV	IV	IV
0 185	II	III	I	I	III	III
0 186	II	II	I	I	I	I
0 187	I	III	I	I	I	I

The deposit-feeding gastropod, *Zethalia zelandica,* listed as a sub-dominant species in the *Arachnoides* association (Powell 1937) was found at only four stations in the present survey (Table 1), only two of which are included in this group. It was not common enough, therefore, to be included as a characteristic species, whereas *Pervicacia* was not recorded at all in the *Arachnoides* formation (Powell 1937) but is a dominant species in the present analysis. This would suggest a slight shift in species composition in the outer Manukau Harbour over the last 40 years.

A community dominated by *Pagurus* has not been reported previously from a New Zealand harbour, although a single station (37 m deep) off the Mokau River mouth was reported to be characterised by an abundance of hermit crabs and an absence of infaunal bivalves or echinoderms (McKnight 1969). The hermit crabs at McKnight's station occupied shells of *Austrofusus, Amalda,* and *Struthiolaria,* and sponges, barnacles, hydroids, and *Coscinasterias* were also present (McKnight 1969). This would suggest the Mokau station is not equivalent to the present *Pagurus/Fellaster* community.

Table 3. Physical and biological characteristics of stations in Manukau Harbour

Stn no.	Group	Depth (m)	No. species	No. individs	Diversity (*H*)	Sediment
0 145	I	2	22	52	3.000	Coarse shell, small rocks
0 148	I	8	17	178	2.311	Dead shell, small rocks
0 151	I	2	18	102	3.317	Dead shell
0 153	I	1	28	199	3.315	Dead shell, coarse shell grit
0 154	I	1	23	113	3.768	Dead shell, coarse shell grit
0 155	I	2	23	95	3.216	Dead shell, coarse shell grit
0 173	I	9	8	68	1.275	Mud, dead shell
0 186	I	3	15	69	1.779	Dead shell
0 187	I	2	22	205	3.062	Dead shell, coarse shell grit
Mean		**3**	**20**	**120**	**2.783**	
0 146	II	10	18	66	2.970	Shell grit
0 149	II	12	18	117	2.523	Shell grit
0 150	II	10	10	22	2.320	Shell grit
0 168	II	15	12	63	2.297	Grey sand, shell grit
0 169	II	15	13	91	2.715	Dead shell, shell grit
0 170	II	16	14	77	2.256	Shell grit
0 174	II	10	25	159	2.825	Mud, sand, shell grit
0 175	II	7	9	26	2.355	Grey sand, shell grit
0 176	II	16	10	48	2.114	Shell grit, dead shell
0 177	II	10	10	22	2.320	Shell grit, dead shell
Mean		**12**	**14**	**69**	**2.469**	
0 144	III	8	7	157	0.541	Black mud
0 147	III	4	10	125	1.875	Fine grey sand, shell grit
0 158	III	4	19	36	2.983	Fine grey sand, shell grit
0 162	III	1	17	44	2.925	Grey sand, shell grit
0 164	III	1	18	110	2.872	Fine grey sand, shell grit
0 165	III	1	16	206	2.877	Fine grey sand
0 166	III	1	24	106	3.309	Fine grey sand, mud
0 167	III	1	12	46	2.222	Fine grey sand
0 171	III	1	18	71	2.762	Shell grit, dead shell
0 172	III	5	20	155	2.757	No sediment
0 179	III	2	16	71	2.612	Fine grey sand
0 180	III	2	17	78	2.993	Fine grey sand, shell grit
0 181	III	3	16	180	2.592	Fine grey sand
0 182	III	2	18	149	2.792	Grey sand, black mud
0 183	III	2	20	83	3.411	Fine grey sand
0 185	III	1	20	123	3.099	Grey sand, shell grit
Mean		**2**	**17**	**109**	**2.664**	
0 152	IV	1	13	25	2.664	Shell grit
0 156	IV	1	13	114	1.124	Fine grey sand, ironsand
0 159	IV	2	16	67	2.184	Fine grey sand, ironsand
0 161	IV	2	7	68	1.912	Shell grit
0 163	IV	2	13	53	2.871	Grey sand, ironsand
0 178	IV	2	7	18	1.835	Fine grey sand, shell grit
0 184	IV	2	6	13	1.741	Fine grey sand, ironsand
Mean		**2**	**11**	**51**	**2.047**	

Table 4. Faunal composition of Group I (*Microcosmus/Notomithrax* community), Manukau Hbr. (9 stns, total possible community score (T.P.C.S.) = 190 (see text). Dominant species (>25% T.P.C.S.) in bold type; sub-dominant species (<25% T.P.C.S.) in italic type. Secondary species: *Callyspongia ramosa, Halicondria moorei, Terenochiton imquinatus, Acanthochitona zelandica, Paphirus largillerti, Styela plicata*)

Species	Stns where found		Bioindex value	Fidelity	Community score	T.P.C.S.
	(no.)	(%)				(%)
Notomithrax minor	9	100	49	0.53	79.0	41.6
Petrolisthes elongatus	7	78	55	0.58	77.1	40.6
Halicarcinus varius	7	78	36	0.26	29.6	15.6
Owenia fusiformis	7	78	53	0.25	32.7	17.2
Maoricolpus roseus manukauensis	7	78	62	0.30	42.0	22.1
Coscinasterias calamaria	6	67	24	0.50	45.5	23.9
Periclimenes yaldwyni	5	56	24	0.33	26.4	13.9
Axiothella sp.	5	56	15	0.29	20.6	10.8
Zegaleurus tenuis	5	56	25	0.25	20.2	10.7
Microcosmus kura	5	56	27	1.00	83.0	43.7

Table 5. Faunal composition of Group II (*Halicarcinus/Bugula* community). Manukau Hbr. (10 stns, total possible community score (T.P.C.S.) = 200 (see text). Dominant species (>25% T.P.C.S.) in bold type; sub-dominant species in roman or italic type. Secondary species: *Platynereis australis, Zoobotryon pellucida*)

Species	Stns where found (no.)	(%)	Bioindex value	Fidelity	Community score	T.P.C.S. (%)
Gracilaria secundata	10	100	61	0.32	51.5	25.8
Halicarcinus varius	10	100	63	0.37	60.3	30.2
Maoricolpus roseus manukauensis	8	80	55	0.35	47.2	23.6
Pontophilus australis	7	70	52	0.29	35.4	17.7
Periclimenes yaldwyni	7	70	54	0.47	58.3	29.1
Bugula neritina	5	50	34	0.71	59.6	29.8
Amphipod 1.	5	50	28	0.62	48.4	24.2

Table 6. Faunal composition of Group III (*Amalda/Myadora* community), Manukau Hbr. (16 stns. total possible community score (T.P.C.S.) = 260 (see text). Dominant species (>25% T.P.C.S.) in bold type; sub-dominant species (<25% T.P.C.S.) in italic type. Secondary species: *Pectinaria australis, Scolecolepides benhami, Aglaophamus macroura, Goniada emerita, Glycera lamellipodia, Philine powelli, Nucula hartvigiana, Soletellina siliqua, Dosinia subrosea, Arthritica bifurca, Patiriella regularis, Amphiura rosea*)

Species	Stns where found (no.)	(%)	Bioindex value	Fidelity	Community score	T.P.C.S. (%)
Amalda australis	16	100	116	0.59	127.4	49.0
Owenia fusiformis	15	94	134	0.54	123.1	47.4
Gracilaria secundata	13	81	76	0.42	65.9	25.4
Myadora striata	13	81	101	0.68	123.8	47.6
Cominella adspersa	12	75	74	0.71	105.8	40.7
Pontophilus australis	11	69	65	0.46	61.6	23.7
Zegaleurus tenuis	10	62	53	0.50	57.5	22.1
Halicarcinus varius	9	56	39	0.35	33.2	12.8
Pagurus sp.	9	56	43	0.45	44.6	17.1
Axiothella sp.	9	56	49	0.53	55.6	21.4

Table 7. Faunal composition of Group IV (*Fellaster/Pagurus* community), Manukau Hbr. (7 stns, total possible community score (T.P.C.S.) = 170 (see text). Dominant species (>25% T.P.C.S.) in bold type; sub-dominant species (<25% T.P.C.S.) in italic type. Secondary species: none)

Species	Stns where found (no.)	(%)	Bioindex value	Fidelity	Community score	T.P.C.S. (%)
Pagurus sp.	7	100	63	0.35	57.0	33.6
Gracilaria secundata	6	86	51	0.19	26.0	15.3
Amalda australis	5	71	41	0.18	20.2	11.9
Pervicacia tristis	5	71	32	0.45	46.3	27.3
Fellaster zelandiae	5	71	42	0.56	63.3	37.2
Myadora striata	4	57	26	0.21	17.4	10.3

DISCUSSION

The 42 dredge samples taken throughout the Manukau Harbour have been analysed and sorted into 4 groups, each representing an assemblage of characteristic species, or a community. These semi-quantitative samples have been analysed using presence-absence and quantitative statistics, both of which have produced similar station groups. At some stations, the numbers of individuals of each species per unit area would have been difficult to count even if a grab had been used because of the presence of colonial species such as sponges and bryozoans. Although individual, massive sponge colonies may be counted as individuals, it is difficult to count the encrusting species, while the branching, fragile colonies of the fleshy polyzoan *Zoobotryon* are easily broken into smaller colonies during collecting and handling. A similar problem occurs with the algae, particularly *Gracilaria,* where the sampler may have collected large masses of drift plants. The dredge is assumed to have sampled the macrofauna as adequately as a grab would have done under the same tidal conditions.

Previous community analyses in New Zealand have relied largely on a visual interpretation of the station groups and characteristic species in each community (e.g., Powell 1937, Fleming 1950, Dell 1951, Hurley 1964, Grace 1966, McKnight 1969), rather than classifying stations with similar faunas using similarity coefficients and dendrograms. In Otago Harbour and Blueskin Bay, Rainer (in press) distinguished five soft-bottom communities using criteria of environmental stability which enabled samples with a similar species composition to be arranged together. However, no details of the methods used were reported. Knight (1974) defined benthic communities in the upper reaches of Lyttelton Harbour by correlating the species present with the sediment types and the sediment organic carbon, using Fager's recurrent species analysis and a discriminant function program. These methods have all given similar results to those obtained from the present survey and similar communities may be recognised throughout New Zealand (see reviews by McKnight 1969, Knight 1974).

The use of dendrograms to group stations containing similar species has been used by many workers (e.g., Field & McFarlane 1968, Field 1970, McCloskey 1970, Eagle 1973), and statistical tests using information content have been developed to separate the groups objectively and reveal indicator species (Field 1969). These tests (Field 1969, 1970) identify distinct classes in dendrograms, produced by group-average sorting of similarity coefficients. However, such dendrograms should not be used in this way as they merely represent the best way of re-arranging the similarity coefficients so that when the trellis diagram is drawn those stations with high values lie closest together along the diagonal. The dendrograms themselves are not the end-point of the analysis and statistical tests cannot be applied with meaningful results. In the present survey, no statistical methods were used to identify the station groups in the dendrograms. More emphasis was given to the station groupings shown by the sorted station × station trellis diagrams. Since the groups were not discrete, and since some stations were likely to have been on the boundaries of two or more groups with characteristics of each, it was considered more useful to average the results from the five methods rather than statistically separate the groups into rigid units. Within a harbour, communities respond to the environmental gradients of salinity, wave action, tidal currents, and substrate. These do not have boundaries which can be defined precisely since they continually move with tides and weather. The communities themselves are, therefore, unlikely to be discrete units with precise boundaries; rather they are likely to intergrade, and samples taken in some areas may appear anomalous if only one method of analysis is used. With the exception of Stn 0 156, stations in the present analysis which were included in different groups depending on the method used (Stns 0 149, 0 156, 0 174, 0 177, 0 185, and 0 186; Table 2), lie on the boundary between two different communities (Fig. 1) and have characteristics of each.

The fluctuating salinities, currents, and wave action in harbours are likely to favour populations of those species that are adapted to withstand such conditions. Since these will be more tolerant species, they are likely to live in a variety of habitats, some ranging further than others, thus preventing easy definition of discrete communities, each with its own set of unique species. A similar conclusion was reached in a community analysis of a Florida estuary (Bloom *et al.* 1972) where communities as abstractions from continua were considered more realistic than communities as discrete units. In this situation, many species will occur in more than one community. Examples in the present study are *Gracilaria, Owenia, Maoricolpus, Amalda,* and *Halicarcinus.* Less tolerant species such as *Fellaster* or those that require a particular substrate, such as the sponges, are restricted to a single community. Tolerant species should not be used to characterise any one community even though they may be visually dominant, such as the previously described *Maoricolpus* community.

The concept of community score relies on the biological attributes of grouped stations and offers an objective method of determining the relative dominance of species in each community, rather than merely describing species which occur together as does a 'species × species' similarity matrix. To test this belief, a 'species × species' similarity matrix was constructed from the data from Manukau Harbour. Since the results only reinforced the community score results — the same overall groups of species were identified, but the ubiquitous genera such as *Amalda, Gracilaria, Owenia,* and *Maoricolpus* tended to form a large anomalous group — the results are not presented here.

CONCLUSIONS

The main central area of Manukau Harbour contains four benthic communities, separated by species composition, depth, sediment, and possibly salinity. The inner harbour has three communities separated from each other by depth and, in the shallower areas, by sediment. The outer harbour community is separated from the inner communities by the narrow salinity tolerance of its dominant species.

The *Microcosmus/Notomithrax* community of the inner harbour occurs in shallow areas with very coarse sediment of shells and rocks. It contains almost all the sessile suspension feeders (sponges, ascidians, and barnacles) as well as many of the mobile carnivores and scavengers. It is the most diverse of the four communities, despite the absence of an abundant infauna. The remaining two communities in the inner harbour are separated by depth. The *Halicarcinus/Bugula* community, characterised by an abundance of mobile crustaceans, occurs where the depth is over 7 m, although most of the species present are not unique to this community. The strong tidal currents and associated scouring probably restrict colonisation to those species adapted to withstand the conditions, such as fast-moving crustaceans, or to the strongly attached species, such as *Bugula.* In the shallower parts of the channels, where the tidal currents are less severe, sand can settle amongst the shell grit giving a heterogeneous sediment which is available for colonisation by the large numbers of infaunal, deposit-feeding polychaetes and bivalves making up the diverse *Amalda/Myadora* community. In the outer parts of the channels this community grades into the outer harbour *Fellaster/Pagurus* community which has a low species diversity but a large overlap of species with the *Amalda/Myadora* community.

Overall, this survey of the Manukau Harbour has revealed very similar species distributions to those identified at a limited number of stations 40 years ago (Powell 1937). Differences in identification of the communities are largely nomenclatural, due to a different approach to naming associations using unique species rather than visually dominant species. Slight differences in dominance are probably due to the location of stations and methods of analysis, but the large increases in numbers of *Owenia fusiformis* and *Pervicacia tristis* and a decline in *Zethalia zelandica* during the last 40 years are regarded as real.

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