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## Macrobenthic community composition of six intertidal sandflats in Manukau Harbour, New Zealand

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**Abstract** Macrobenthic community structure was assessed on intertidal sandflats, a predominant feature of Manukau Harbour. Thirty-six replicate core samples were collected from each of six 9000 m<sup>2</sup> sites, during October 1987. The distribution of individuals amongst taxa was similar at the six sites, but the numerical dominance of the most common taxa changed appreciably from site to site. A shift from polychaete- to bivalve-dominated communities was apparent between sites. Examination of a hypothesised relationship between sediment grain size and trophic structure of the macrobenthos highlights the difficulties in using this relationship to monitor environmental change. Identification of core taxa by DECORANA ordination and TWINSpan classification is considered a useful mechanism in defining taxa likely to play major roles in influencing community structure and function.

**Keywords** Intertidal ecology; macrobenthic community structure; population densities; sandflats; Manukau Harbour; New Zealand

### INTRODUCTION

The soft-sediment communities of Manukau Harbour (37° 02'S, 174° 41'E), New Zealand, have been described by Powell (1937), Chapman & Ronaldson (1958), Cassie & Michael (1968), Cassie (1972), Grange (1977, 1979, 1982), Henriques (1980), Roper et al. (1988), and Thrush & Roper (1988). Most of these studies have consisted of synoptic surveys covering large areas of the harbour with well-spaced, but not intensively sampled, stations. Such broad surveys characterise large-scale differences between major habitat/community types and have allowed groups of abundant species to be identified. However, to have confidence in descriptions of community structure and population density estimates, more intensive sampling is required.

Intertidal sandflats constitute about 40% of the area of Manukau Harbour. To better understand how the macrofauna occupying these sandflats are distributed, we intensively sampled six sites located in different regions of the harbour (Fig. 1). Thrush et al. (1989) describe the spatial arrangement of some of the abundant bivalves and polychaetes at these sites. The present paper describes the macro-benthic communities, the variability in community structure between sites, and the densities of common taxa. The merit of the benthos-sediment relationship reported by Grange (1977) to monitor the biological effects of environmental change is also considered, with particular respect to sandflat communities.

### METHODS

Six sites, each 9000 m<sup>2</sup>, were established at about mid-tide level near: Auckland Airport (Site AA), Puhinui Spit (Site PS), Cape Horn (Site CH), Karaka Point (Site KP), Elletts Beach (Site EB), and Clarks Beach (Site CB) (Fig. 1). The sites were positioned in the main body of the harbour away from known point sources of pollution, except for Site CH which may be influenced by discharges from the Mangere Sewage Purification Works situated about 7 km away.

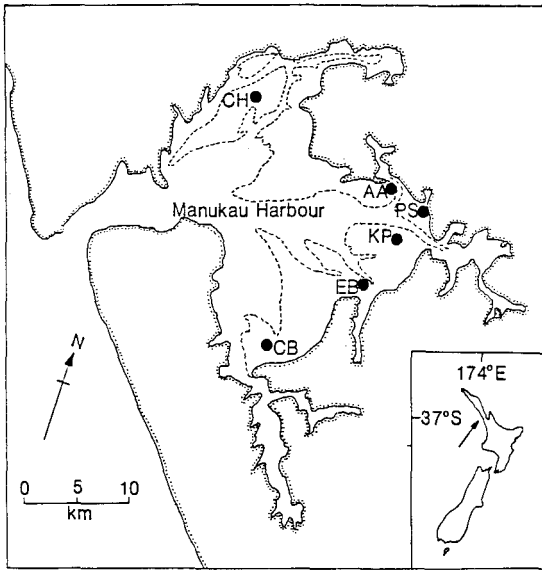


Fig. 1 Map of the Manukau Harbour showing the position of the six sample sites. Dotted line indicates area of sandflat exposed at spring low tide.

Each sampling site (either  $90 \times 100$  or  $50 \times 180$  m in configuration) was divided into 12 equal sectors ( $30 \text{ m} \times 25 \text{ m}$ ). From each sector three sediment cores (13 cm diam., 12 cm depth) were taken, giving a total of 36 cores per site. The positions of the three cores within each of the 12 sectors were obtained from randomly derived cartesian coordinates. Samples were collected in October 1987. After collection, samples were sieved ( $500 \mu\text{m}$  mesh) and the residue fixed in 5% formalin and 0.1% Rose Bengal, in sea water. Macrofauna were sorted, identified to the lowest possible/practicable taxonomic level, counted, and preserved in 70% alcohol.

Sediment grain size at each site was determined by the methods described in Folk (1968) on a composite of 12 evenly spaced samples (c. 25 m apart). Only the top 3 cm of sediment was sampled as this was considered to be the sedimentologically recent and active layer most likely to influence the distribution and abundance of benthos. Grange (1977) collected the top 2 cm of sediment in his study of Manukau sediment-benthos relationships.

Taxa were allocated to general feeding guilds (i.e., deposit feeders, suspension feeders, carnivores, grazers) principally following Grange (1977), with further information provided by Enquist (1949), Biernbaum (1979), Fauchald & Jumars (1979), Jones

(1983), and our personal observations. Although many of the taxa (e.g., *Owenia fusiformis*, *Aglaophamus macroura*) could be placed in more than one feeding guild, the most common classification or that used by Grange (1977) was adopted. Only a few taxa could not be placed in feeding groups. As these taxa consisted of only small animals, each represented by less than five individuals, we did not consider that omitting them from the analysis affected the validity of comparisons of trophic structure.

Curves of cumulative number of taxa versus sample size (i.e., number of cores) were derived for each site using a randomisation technique. Each core was assigned a number from 1 to 36. A FORTRAN 77 subroutine (RAN) was then used to generate 1000 random combinations of the core numbers for each sample size. For example, for sample size  $n = 4$  cores, some of the combinations drawn were (36, 21, 25, 3), (3, 7, 22, 4), and (17, 4, 35, 33). The total number of taxa in each combination was determined by comparing lists of taxa for the cores represented. For each sample size (i.e., 2, 4, 8, 12, 16, 20, 24 cores), results from the 1000 combinations were ranked and the median, and 5 and 95 percentiles were determined (see Zar 1987: 20–23). These results were then presented graphically (Fig. 2).

Similarities in community structure between sites were established using the ordination technique of detrended correspondence analysis (DECORANA, Hill 1979a) and the clustering technique of two-way indicator species analysis (TWINSPAN, Hill 1979b). Ordinations were based on the total number of individuals of each taxa recorded at each site, whereas classifications were based on total and median numbers. To reduce the influence of rare taxa on site positions in the ordination space their abundances were down-weighted using the DECORANA option:

$$A_{ij} + F_j (A_{\max}/5)$$

where  $A_{ij}$  is the abundance of taxon  $j$  in sample  $i$ ,  $F_j$  is the frequency of taxon  $j$ , and  $A_{\max}$  is the frequency of the commonest taxon.

The significance of differences between sites in the abundance of individual taxa, trophic groups, and number of individuals per core were established by non-parametric ANOVA (Kruskal-Wallis) and multiple comparison (Tukey's rank sum) tests. Multiple comparison tests were conducted only after a significant ( $P < 0.05$ ) ANOVA result was obtained. Estimates of the mean, variance, median, and

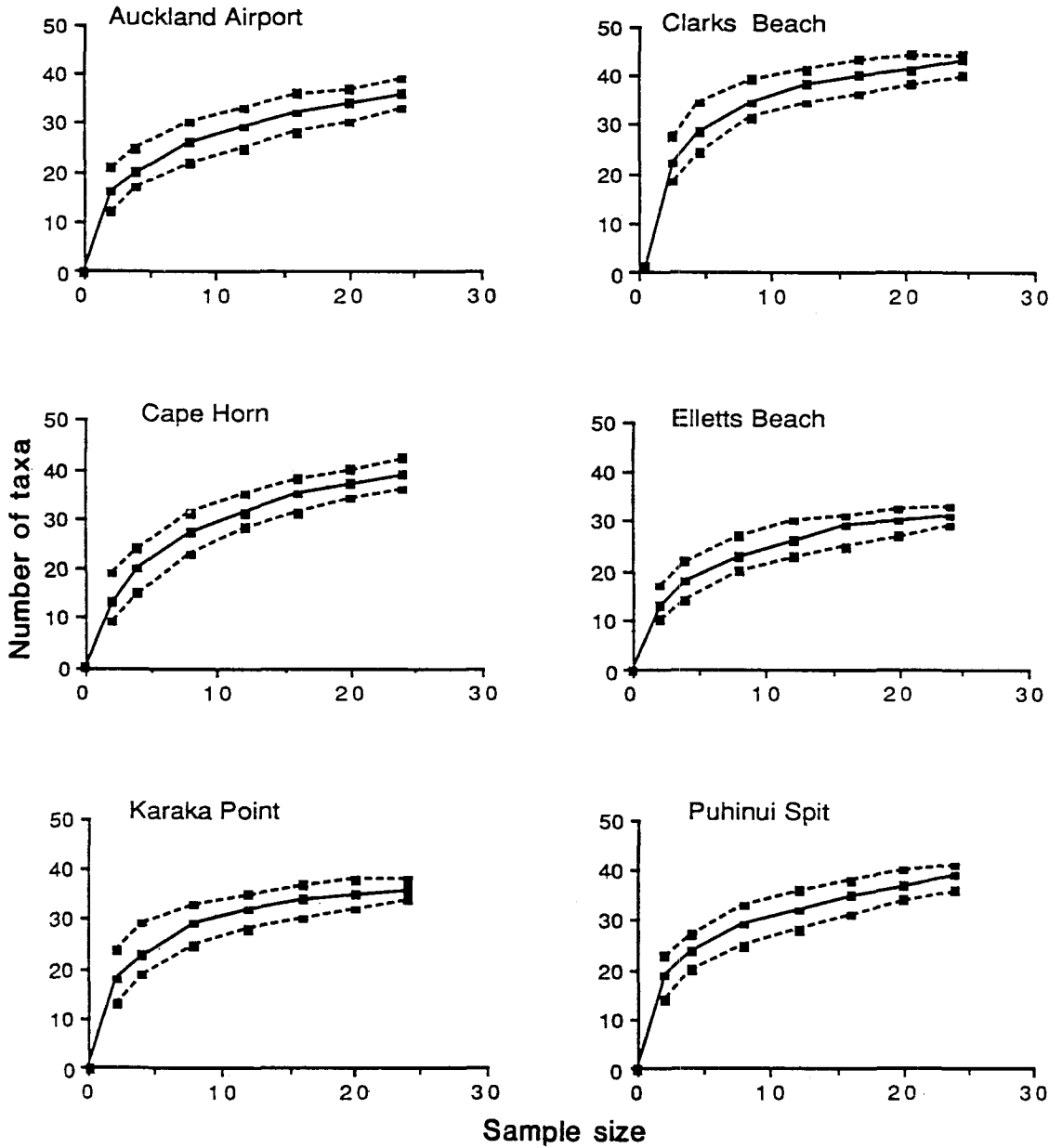


Fig. 2 Curves of cumulative number of taxa versus sample size for each site. Squares connected with a solid line represent the median number of taxa, based on 1000 random draws for each sample size, bounded by the 5 and 95 percentiles (squares connected by broken lines).

interquartile range for each taxon at each site can be obtained from the authors on request. Details of the statistical methods used can be found in Zar (1984) and SAS Institute (1987).

**RESULTS**

Nearsurface sediment at each site was predominantly fine sand (Table 1). At Sites CB and KP relatively large quantities of shell were also present. Sorting

coefficients (i.e., inclusive graphic standard deviations) for the composite samples were typical of moderately to very well sorted sediments suggesting low within-site variability in nearsurface sediment grain size. Small runnels on the surface of the sediment were apparent only at Site CH. Large biogenic structures (for example, crab burrows and faecal mounds) were not observed at any site, although disturbances generated by the feeding activities of eagle rays (*Myliobatis tenuicaudatus*) were observed at Sites AA and CH. These disturbances consisted of pits of about 20 cm deep and 30 cm diameter. Observations on the frequency and duration of these disturbances indicate that rays disrupted about 50% of the surface area of each site each month (authors' unpubl. data).

The efficiency of our sampling program in estimating the number of taxa present within each site was visually assessed using plots of cumulative number of taxa versus sample size. Because conclusions based on this approach can vary with sequence of data entry, a randomisation procedure was adopted (see Methods). Fig. 2 shows that, for each site, few new taxa were likely to be found in each additional core after 16–24 cores had been analysed. Thus a sample size of 36 was considered to provide a satisfactory description of these macrobenthic communities. Similar randomisation tests performed on numbers of individuals demonstrated that a sample size of 12 was sufficient to describe the density of most taxa at any given site (Hewitt et al. in press.).

The 216 samples collected from the six sites yielded 10 828 individuals from 95 taxa (Appendix 1). Most of the individuals (69%) belonged to one of eight species: the polychaete *Heteromastus filiformis* (27%), the bivalve *Tellina liliana* (11.6%), the polychaete *Magelona ?dakini* (8.4%), the bivalve *Nucula hartvigiana* (7.4%), the polychaete *Macroclymenella stewartensis* (5.1%), the bivalve

*Soletellina siliqua* (4%), the polychaete *Goniada emerita* (2.8%), and the amphipod *Proharpinia hurleyi* (2.7%). Although all eight species were found at every site, their relative abundance varied markedly (Fig. 3). Polychaetes tended to be more consistently abundant than bivalves or amphipods. *Heteromastus filiformis* was the most abundant species at all sites except Site AA. *Magelona ?dakini* was the only species represented in the 10 most abundant taxa at every site. *Goniada emerita*, despite representing only 2.8% of the total individuals collected in this study, was represented in the top 10 taxa rankings at five of the six sites.

Rank-abundance plots (Whittaker 1975) show that the most inequitable distribution of individuals occurred at Site CH, where *Heteromastus filiformis* accounted for over 50% of the total number of individuals (Fig. 4). In contrast, the community at Site CB demonstrated the most equitable distribution of individuals amongst taxa. No site showed a truncation of the rank-abundance curve indicating the absence of rare species. The highest number of taxa was recorded from Site CB (63), followed by Sites KP (50), CH (44), PS (43), AA (41), and EB (39). No pattern is apparent in the total number of taxa found at each site and their geographical proximity, with the two most southern sites, CB and EB, recording the highest and lowest total number of taxa, respectively. All sites recorded a substantially lower number of taxa than the overall total of 95 recorded in this study. Of the 95 taxa observed, 29 have not been reported previously in the ecological literature on Manukau Harbour (see Appendix 1). A further 26 taxa could not be identified sufficiently to allow comparison.

The 10 most abundant taxa collected from each site are listed in Table 2. Most of these taxa were abundant at only one or two sites, e.g., the bivalve *Chione stutchburyi*, the anemone *Anthopleura aureoradiata*, and the isopods *Exosphaeroma* spp.

**Table 1** Major sediment grain size fractions from the six sites. The gravel fraction in each sample was predominantly shell. Fine sands are characterised by a median phi of 2–3 units (Folk 1968).

	Site					
	AA	CB	CH	EB	KP	PS
% mud	1.7	2.8	4.2	4.0	6.1	0.4
% sand	96.7	91.1	93.3	95.9	88.1	99.0
% gravel	1.6	6.1	2.5	0.1	5.8	0.6
Median grain size (phi)	2.62	2.71	2.64	2.57	2.77	2.42
Inclusive graphic standard deviation	0.39	0.88	0.42	0.40	1.00	0.32

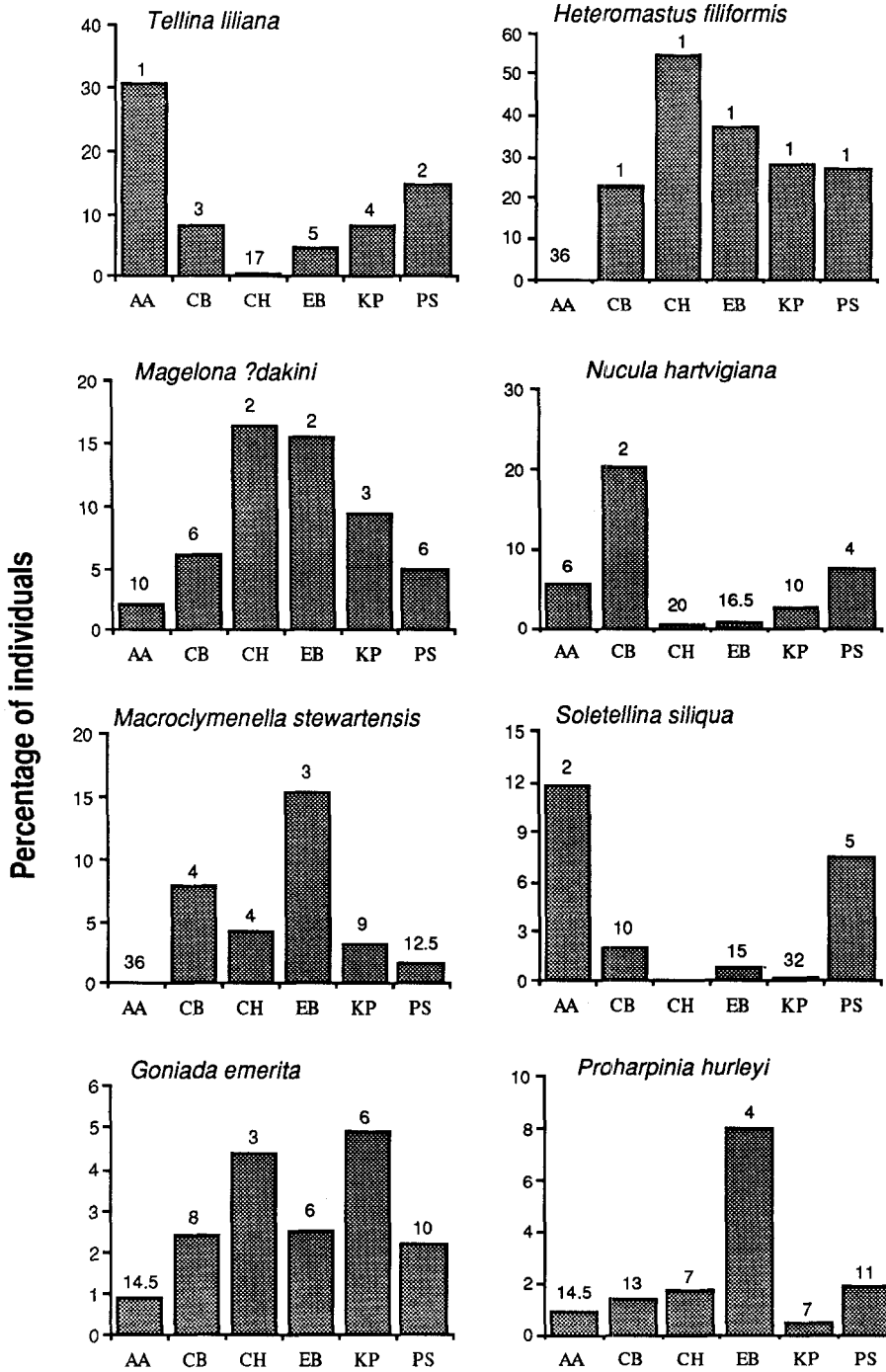


Fig. 3 Numerical dominance hierarchy plots for the eight most abundant species collected in Manukau Harbour. The abundance rank for each species at each site is indicated above the histogram block.

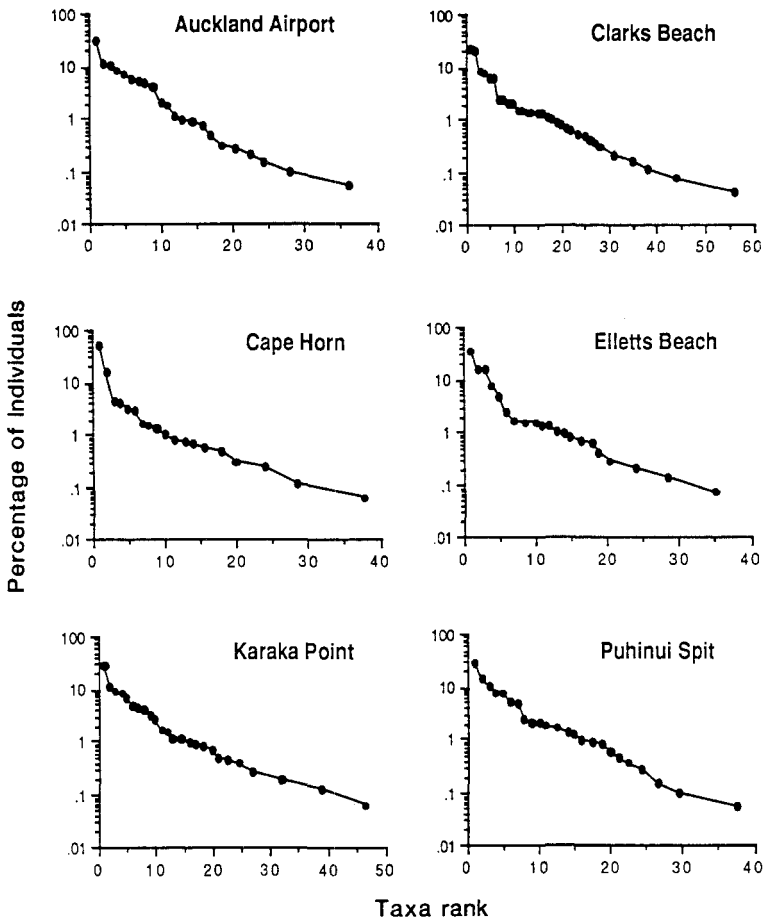


Fig. 4 Rank abundance diagrams showing the distribution of individuals amongst taxa for the six sites. Where taxa share ranks only one point is represented on the curve.

(principally *E. ?falcatum*) (Fig. 5). Highly significant differences in abundance were recorded over the six sites for all 27 taxa, except for the polychaete *Orbinia papillosa*. Sites with similar densities of a given taxon are denoted in Fig. 5. No consistent pattern in the grouping of sites was apparent. A pattern which emerges from the abundance of individual taxa at the different sites is the predominance of bivalves at Site AA (i.e., *Tellina liliana*, *Soletellina siliqua*, *Nucula harvigiana*, and *Chione stutchburyi*), whereas polychaetes common at the other sites (i.e., *Heteromastus filiformis*, *Goniada emerita*, *Magelona ?dakini*, and *Macroclymenella stewartensis*) were comparatively sparse. The converse of this pattern is apparent at Site CH (Fig. 6).

Significant variation between sites was apparent in the total number of individuals per core, with Site CB recording the highest density and Site EB the lowest (Fig. 5). When the taxa were grouped into feeding guilds, deposit feeders were found to account

for over 70% of the individuals at each site. The highest percentage of deposit feeders was found at Site EB; Sites AA and KP possessed the lowest (Fig. 7). The relatively high percentage of suspension feeders at Site AA was attributable to *Chione stutchburyi*. Grazers (e.g., the limpet *Notoacmea helmsi*) and carnivores (e.g., *Anthopleura aureoradiata*) were most abundant at Site KP (Fig. 5 and 7).

Variations in macrobenthic community structure between sites was further assessed by detrended correspondence analysis (DECORANA) (Fig. 8). One of the consequences of DECORANA is that taxa turnover occurs at a uniform rate along the ordination axes. About a 50% turnover in species composition occurs within 1 axis unit, whereas sites which differ by 4 or more units are not expected to share taxa (Gauch 1982: 155). No study site was sufficiently separated from the others in the ordination space to indicate a complete turnover of taxa. The

most dissimilar sites, AA and CH, were separated by about 2 axis units. Further interpretation of the ordination was achieved by TWINSpan, based on the total numbers of individuals at each site (Fig. 9a). This classification splits the sites into two groups, PS-AA and CB-CH-EB-KP, indicated by a rare phyllodocid polychaete (*Eteone near aurantiaca*). Another TWINSpan classification based on the median abundance of individuals (Fig. 9b) (i.e., considering only consistently abundant taxa) separated Site AA from the remaining sites at a higher level than Site PS. The first level split was indicated by *Chione stutchburyi*. The lower level split, which separates Site PS from the remaining four sites, was indicated by the amphipod *Waitangi brevirostris*.

Apart from producing an ordination of sites, DECORANA also produces an ordination of taxa (Fig. 10). The most ubiquitous taxa are plotted towards the centre of the cluster, and by superimposing the site ordination on to the taxa ordination, community composition at each site relative to the other sites can be assessed (Jongman et al. 1988). The approximately equal length of axes 1 and 2 indicates both are accounting for similar amounts of variability in taxa distribution/abundance and thus it is unlikely that taxa are distributed along the axes in relation to a simple physico-chemical gradient. The central positions within the ordination array of *Heteromastus filiformis*, *Magelona ?dakini*,

and *Goniada emerita* emphasise their abundance throughout the sites. The position of *Tellina liliana* indicates its importance to the communities at Sites AA and PS relative to the other sites; similarly, the position of the polychaete *Owenia fusiformis* indicates its importance to the communities at Sites KP and CB. Further analysis of taxa groupings is achieved with the TWINSpan classification of taxa. This defines clusters in the list of taxa which basically correspond to positions on Axis 1 of the ordination. The first TWINSpan split emphasises the difference between PS-AA and the other sites. The second divides these two clusters into groups of common and rare taxa, thus defining core and ephemeral taxa for the two site groups (i.e., AA-PS versus CB-CH-KP-EB). These groupings are superimposed as contours on the DECORANA taxa ordination (Fig. 10). Core species for Sites PS and AA were: the polychaetes *Aonides oxycephala*, *Nicon aestuarinensis*, *Platynereis australis*; the bivalves *Tellina liliana*, *Chione stutchburyi*, *Dosinia subrosea*, *Nucula hartvigiana*, *Soletellina siliqua*; the gastropods *Notoacmea helmsi*, *Diloma subrostrata*, *Micrelenchus tenebrosus*, *Cominella glandiformis*; the crustaceans *Waitangi brevirostris*, *Halicarcinus whitei*, *Exosphaeroma* spp., *Colurostylis lemorum*, *Paracallioppe novizealandiae*, Phoxocephalidae sp. 1; and the holothurian *Trochodota dendyi*. Core species for Sites CB, CH,

**Table 2** The 10 most abundant taxa collected from each site. Taxa are listed in order of decreasing abundance.

AA	CB	CH	EB	KP	PS
<i>Tellina liliana</i>	<i>Heteromastus filiformis</i>	<i>Heteromastus filiformis</i>	<i>Heteromastus filiformis</i>	<i>Heteromastus filiformis</i>	<i>Heteromastus filiformis</i>
<i>Soletellina siliqua</i>	<i>Nucula hartvigiana</i>	<i>Magelona ?dakini</i>	<i>Magelona ?dakini</i>	<i>Anthopleura aureoradiata</i>	<i>Tellina liliana</i>
<i>Chione stutchburyi</i>	<i>Tellina liliana</i>	<i>Goniada emerita</i>	<i>Macroclymenella stewartensis</i>	<i>Magelona ?dakini</i>	<i>Exosphaeroma</i> spp.
<i>Aonides oxycephala</i>	<i>Macroclymenella stewartensis</i>	<i>Macroclymenella stewartensis</i>	<i>Proharpinia hurleyi</i>	<i>Tellina liliana</i>	<i>Nucula hartvigiana</i>
<i>Colurostylis lemorum</i>	Ostracoda	Nemertinea	<i>Tellina liliana</i>	<i>Notoacmea helmsi</i>	<i>Soletellina siliqua</i>
<i>Nucula hartvigiana</i>	<i>Magelona ?dakini</i>	<i>Boccardia</i> spp.	<i>Goniada emerita</i>	<i>Goniada emerita</i>	<i>Magelona ?dakini</i>
<i>Notoacmea helmsi</i>	<i>Syllis</i> sp.	<i>Proharpinia hurleyi</i>	<i>Methalimedon</i> sp.	<i>Proharpinia hurleyi</i>	<i>Paracallioppe novizealandiae</i>
<i>Travisia olens</i>	<i>Goniada emerita</i>	<i>Orbinia papillosa</i>	Nemertinea	<i>Owenia fusiformis</i>	<i>Boccardia</i> spp.
<i>Waitangi brevirostris</i>	<i>Boccardia</i> spp.	<i>Arthritica bifurca</i>	<i>Aglaophamus macroura</i>	<i>Macroclymenella stewartensis</i>	<i>Trochodota dendyi</i>
<i>Magelona ?dakini</i>	<i>Soletellina siliqua</i>	<i>Colurostylis lemorum</i>	<i>Orbinia papillosa</i>	<i>Nucula hartvigiana</i>	<i>Goniada emerita</i>



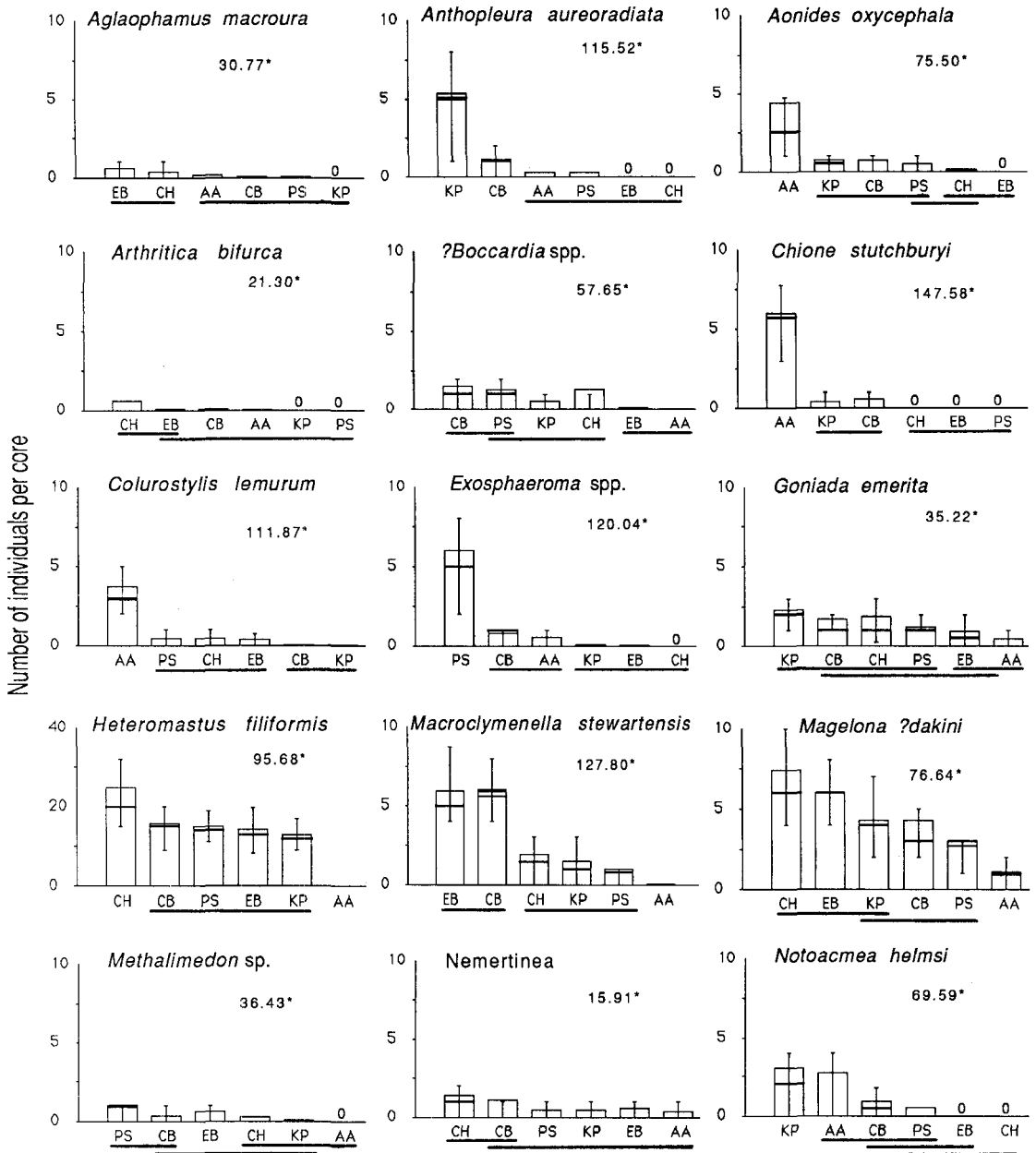


Fig. 5 Variation in abundance between sites of the 10 most abundant taxa collected at each site. Thin line tops to blocks represent means; thick lines, medians; and error bars, the interquartile range. 0 indicates sites at which no individuals were collected. Kruskal-Wallis test statistics are presented with significance at the 5% probability level indicated by \*. Sites which were not significantly different from each other (Tukey's test) are connected by underlining.

KP, and EB were: the polychaetes *Aquilaspio aucklandica*, *Glycera americana*, *Goniada emerita*, *Heteromastus filiformis*, *Magelona ?dakini*, *Macroclymenella stewartensis*, *Aglaophamus*

*macroura*, *?Boccardia* spp., *Cossura* sp., *Orbinia papillosa*, *Syllis* sp., *Phyllodoce* sp. 1; nemertean; nematodes; the crustaceans Ostracoda, *Methalimedon* sp., *Cirolana* aff. *woodjonesi*,

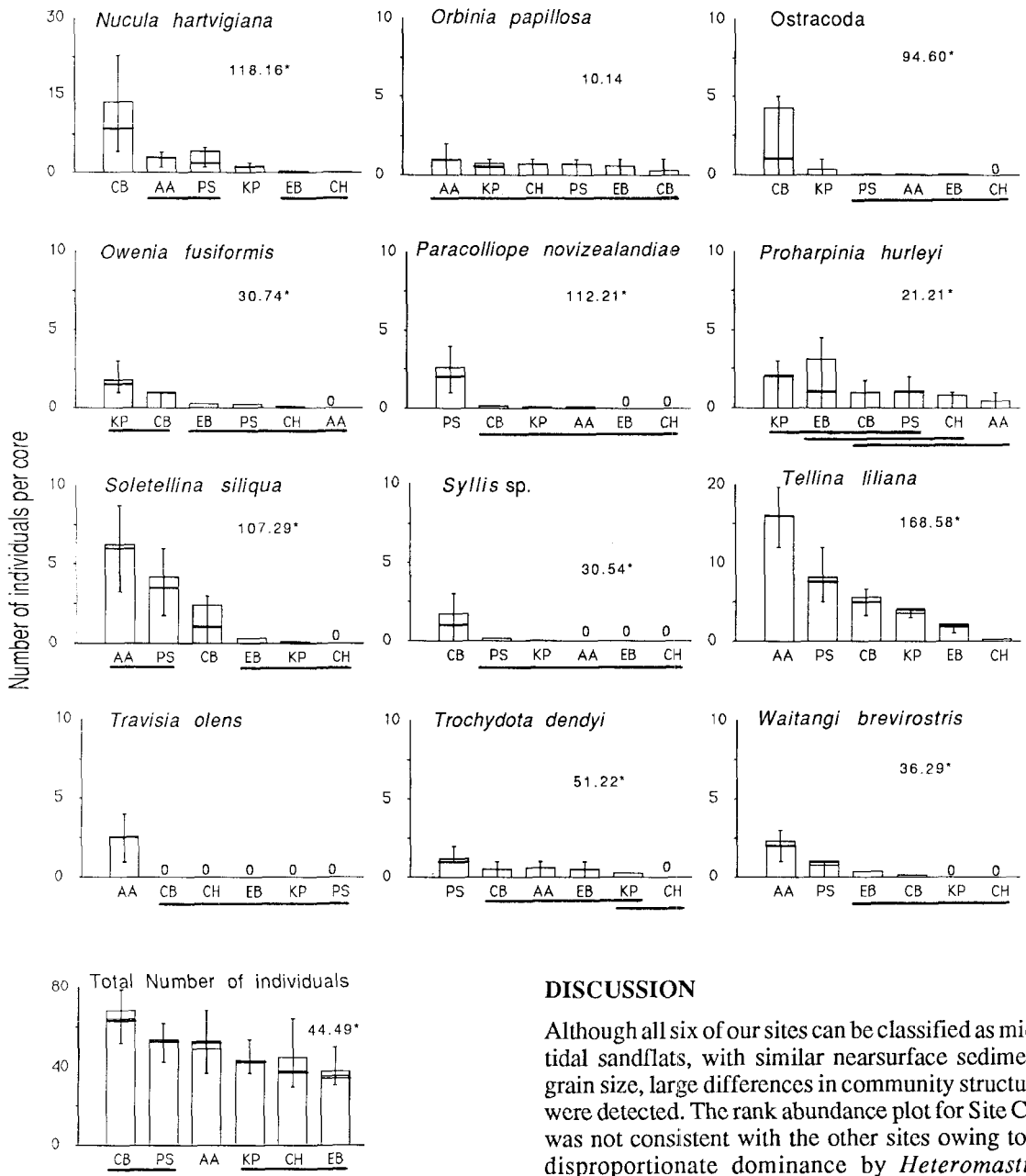


Fig. 5 (Continued)

*Proharpinia hurleyi*; the anemone *Anthopleura aureoradiata*; and the gastropods *Zeacumantus lutulentus* and *Xymene plebeius*. These groupings further emphasise the difference between polychaete- and bivalve-dominated sites illustrated in Fig. 6.

### DISCUSSION

Although all six of our sites can be classified as mid-tidal sandflats, with similar near-surface sediment grain size, large differences in community structure were detected. The rank abundance plot for Site CH was not consistent with the other sites owing to a disproportionate dominance by *Heteromastus filiformis*. A high density of capitellid polychaetes, like *Heteromastus filiformis*, frequently indicates an area exposed to disturbances which downgrade successional status, for example increased organic loading (Pearson & Rosenberg 1978). As Site CH is the closest site to the Mangere Sewage Treatment Plant it may contain organic detritus which these polychaetes find higher in quality than the organic detritus at other sites. However, Beukema & Cadée

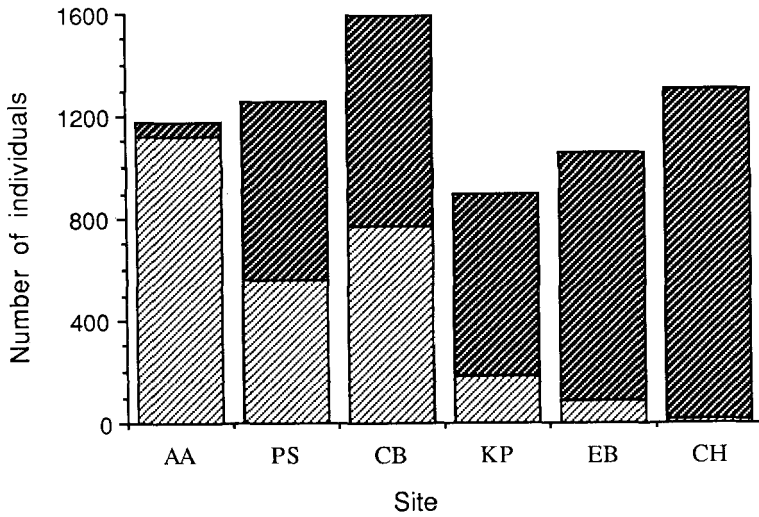


Fig. 6 Total number for each site of the four most dominant polychaetes (dark hatching) and bivalves (light hatching) collected at each site.

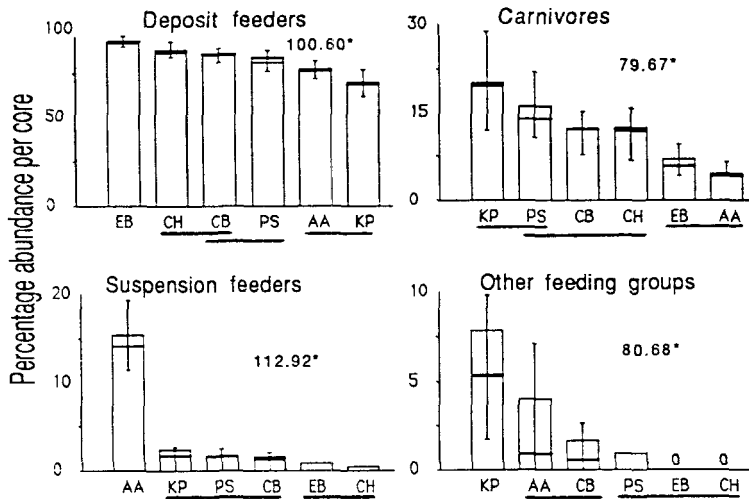


Fig. 7 Percentage abundance of different feeding guilds at the six sites. Legend as in Fig. 5.

(1986) point out that such a cause-and-effect relationship presupposes some food limitation which may not be the case in shallow and enriched waters of harbours like the Manukau.

None of the rank abundance plots (Fig. 4) was truncated indicating the absence of rare species. This contrasts with the results of a study of macrofaunal communities from the mudflats of the Manukau, where the absence of rare species was readily apparent in two contaminated mudflats (Roper et al. 1988).

Analysis of the density of common species demonstrated significant variations in abundance around the harbour. Most taxa were abundant at only

one or two sites. *Heteromastus filiformis* and *Tellina liliiana* were both abundant at all but one site (AA and CH, respectively). These were the two sites with the most distinctly different communities: Site AA was dominated by bivalves whereas Site CH was dominated by polychaetes. This dissimilarity between the two sites appears consistent, at least for one year (Table 3). The ordination of sites (Fig. 8) indicates that the differences in community composition between Sites AA and CH are extremes on a continuum passing through Sites PS and CB. As Sites AA and CH were the only sites markedly affected by feeding rays, these disturbances are unlikely to be responsible for the observed difference.

However, surface sediment turnover generated by ray feeding activity may be responsible for maintaining dominance patterns by providing some advantage to resident populations. Nevertheless, it is not possible from the data collected by this study to identify any single factor responsible for the switching between bivalve- and polychaete-dominated communities. Differences in environmental characteristics not addressed in this study may be important, whereas other biological interactions such as adult-larvae interactions (e.g., Woodin 1976), or bioturbation (e.g., Rhoads 1967) are also likely to be relevant. Studies designed to describe the processes important in defining the switching between these two community types would greatly improve our understanding of the ecology of these and similar ecosystems.

Apart from the major difference in community dominance apparent at Sites AA and CH, some individual taxa show marked affiliations with certain sites, e.g., *Aonides oxycephala* and *Chione stutchburyi* at Site AA, *Anthopleura aureoradiata* and *Notoacmea helmsi* at Site KP, *Exosphaeroma* spp. at Site PS, and *Nucula hartvigiana* at Site CB. Some of these affinities may be attributed to the environmental characteristics at each site. For example, *Anthopleura aureoradiata* and *Notoacmea helmsi* which live attached to cockles (*Chione stutchburyi*) were most abundant at Site KP where large numbers of empty cockle shells were found. Other affiliations were attributable to variations in recruitment, for example, a large proportion of the *Nucula hartvigiana* collected at Site CB during this survey were recently settled juveniles. However, reasons are not apparent for many of the affiliations. *Chione stutchburyi* was prevalent only at Site AA. This affinity does not appear to be related to its reported preference for medium to coarse sand (Morton & Miller 1973; Grange 1977) as all sites were composed predominantly of fine sand, and Site PS, the site with the coarsest sediment, yielded no *Chione*. A similar argument applies to *Aonides oxycephala*, also abundant at Site AA, which previously has been collected only from very fine muddy sediments within Manukau Harbour (authors' unpublished data). For many of the taxa (e.g., *Exosphaeroma ?falcatum*, *Colurostylis lemorum*, *Travisia olens*) information on habitat preference, recruitment patterns, species associations etc. are simply not available. Unravelling the complexities of these and other distribution patterns is beyond the scope of this study.

Attempts to compare results of our study with those of previously published work on Manukau

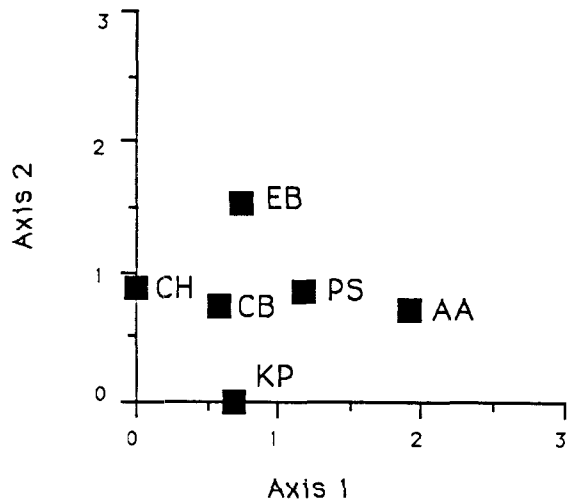


Fig. 8 DECORANA ordination of sites.

sandflats are hampered by the assortment of methods used. Important factors confounding comparisons between studies are differences in the size of sieve mesh used to separate macrofauna from the sediments, the number of samples collected within each sampling station/site, and the confused taxonomic status of many species (see Appendix 1). Of the 95 taxa observed in this study, only 40 could be confidently assigned to species previously recorded in the ecological literature for Manukau Harbour. An additional 26 may have been collected previously in the harbour, but their restricted classification (to at best genus by either us or others) prevents comparison.

Cassie & Michael (1968), defined a sand community dominated by *Chione stutchburyi* and *Macomona liliana* (= *Tellina liliana*) around Auckland airport which is consistent with our observations. Their methods involved collecting one sample (0.5 × 0.5 m, 6–10 cm depth) from each of 40 stations and extracting organisms from the sediment on a 2.5 mm mesh. Their results indicate that *Chione stutchburyi* and *Tellina liliana* were common in this area about 20 years ago. However, their mesh would have retained few of the small polychaetes, crustaceans, and bivalves recorded in our study. Hence any comparison of community structure is not possible. Similar difficulty arises when comparing our results with those of Henriques (1980), who used a 6.25 mm mesh. The disadvantages of using large-mesh sieves (> 2 mm) in macrofauna community studies have been noted by many workers

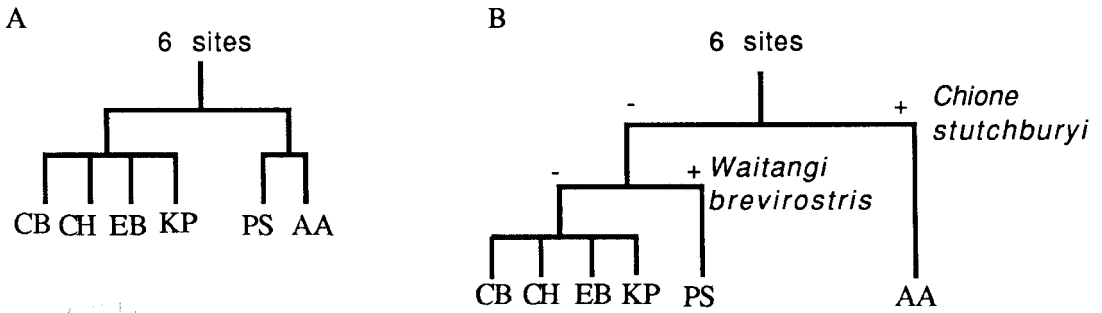


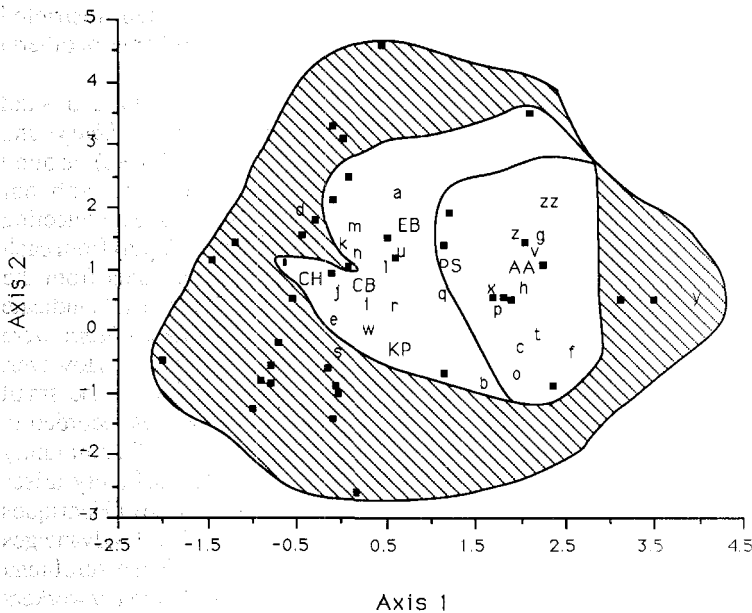
Fig. 9 TWINSpan classification of sites. Based on total number of individuals (A) and based on median number of individuals (B). Taxa indicating splits in classification are included.

(e.g., Gray 1981; Eleftheriou & Holme 1984). Data presented in Reish (1959), who passed five benthic samples through a series of 11 sieves, show that a 2.8 mm mesh retained only 4.2% of the polychaetes, 33.3% of the crustaceans, 34.6% of the nemerteans, and 37.5% of the molluscs collected with a 0.5 mm mesh. Large discrepancies have also been observed using fine-mesh sieves. For example, Lewis & Stoner (1981) found that only 55–77% of the total macrofauna collected with a 0.5 mm mesh was retained by a 1.0 mm mesh. The Baltic Marine

Biologists have standardised the mesh used in their studies at 1.0 mm (Dybern et al. 1976; Ankar et al. 1979) with the recommendation that a 0.5 mm mesh should be used in addition whenever possible. Eleftheriou & Holme (1984), in their review of macrofaunal techniques, suggest that a 0.5 mm mesh should be used.

Grange (1977) sampled 57 stations in Manukau Harbour by collecting one 0.1 m<sup>2</sup> × 10 cm deep slab of sediment and extracting biota on a 1 mm mesh sieve. Most of his stations (73%) were located in

Fig. 10 DECORANA ordination of taxa with site ordination positions superimposed. The 10 most abundant taxa recorded at each site are indicated by letters: a, *Aglaophamus macroura*; b, *Anthopleura aureoradiata*; c, *Aonides oxycephala*; d, *Arthritica bifurca*; e, ?*Boccardia* spp.; f, *Chione stutchburyi*; g, *Colurostylis lemurum*; h, *Exosphaeroma* spp.; i, *Goniada emerita*; j, *Heteromastus filiformis*; k, *Macroclymenella stewartensis*; l, *Magelona? dakini*; m, *Methalimedon* sp.; n, Nemertinea; o, *Notoacmea helmsi*; p, *Nucula hartvigiana*; q, *Orbinia papillosa*; r, *Ostracoda*; s, *Owenia fusiformis*; t, *Paracallioppe novizealandiae*; u, *Proharpinia hurleyi*; v, *Soletellina siliqua*; w, *Syllis* sp.; x, *Tellina liliana*; y, *Travisia olens*; z, *Trochodota dendyi*; zz, *Waitangi brevisirostris*. Other taxa are represented by ■.



Other taxa are represented by ■. TWINSpan classification of taxa and sites defines core taxa (unshaded) and ephemeral taxa (shaded for each site group).

areas of fine sand, the remainder were characterised by either medium (23%) or coarse (4%) sand. His Stns N630–N632 were in the vicinity of our Cape Horn site, Stns N620–N623 were adjacent to Karaka Point, Stns N617–N619 near to Puhinui Creek, and Stns N598–N602 were close to Clarks Beach. Grange (1977) recognised *Tellina liliana*, *Chione stutchburyi*, *Soletellina siliqua*, *Nucula hartvigiana*, *Anthopleura aureoradiata*, and *Owenia fusiformis* as widely distributed species throughout his sampling stations. All of these were collected in our sampling programme. However, only *Tellina liliana*, *Nucula hartvigiana*, and perhaps *Soletellina siliqua* could be considered widespread from our data. Of the species noted by Grange (1977), only *Nucula hartvigiana*, *Tellina liliana*, and *Soletellina siliqua* occupy central positions in the species ordination space (which indicates their ubiquity and abundance). Of the polychaetes which numerically dominated our sites *Macroclymenella stewartensis* was recorded by Grange (1977) at only two stations, whereas *Heteromastus filiformis* and *Magelona ?dakini* were not reported at all. The differences between our results and those of Grange (1977) will to some degree be related to the methods used (e.g., different sieve size) and the different habitats studied (e.g., medium versus fine grain sediments). They may also reflect some environmental change, such as a restriction in the distribution of Grange's "widespread species" (e.g., *Chione stutchburyi*, *Anthopleura aureoradiata*, and *Owenia fusiformis*). However, without time series data collected with consistent methods, it is not possible to be decisive when inferring differences and attributing environmental changes to such comparisons.

Based on the abundance of animals collected at sites with very different mean sediment grain size, Grange (1977) was able to relate grain size to animal abundance. His analysis indicated that the percentage of deposit feeders was inversely proportional to grain size. For example, he noted that the deposit feeding bivalves *Macomona liliana* (= *Tellina liliana*) and *Nucula hartvigiana* were most abundant in fine sand whereas suspension feeding bivalves (*Chione stutchburyi* and *Paphies australe*) were most abundant in sand of medium grain size. Sites which were anomalous with this relationship were considered to be undergoing a change in community structure or sediment characteristics. He concluded that identifying such unstable areas may be a useful method to monitor effects caused by environmental change. However, at our Airport site, *Tellina liliana*, *Chione stutchburyi*, and *Nucula hartvigiana* were

all abundant. This suggests that while these animals may show a preference for certain grain sizes a narrow selectivity is not indicated. Also attributing significance to anomalous site position on the percentage deposit feeder–grain size curve proposed by Grange (1977) may prove difficult owing to variation in community structure which is apparent between our study sites. For the range of median grain size of 2.42–2.77 phi we recorded a range in percentage deposit feeders of 69–93 from our sites. Moreover, the proposed percentage deposit feeder–grain size relationship follows a sigmoid curve where large changes in grain size result in very small change in percentage deposit feeders.

Further problems arise in allocating animals to trophic groups. Detailed study of some taxa has indicated that feeding behaviour is too variable to allow allocation to distinct groups. For example, Oliver et al. (1982) note that phoxocephalid amphipods are generally considered deposit feeders. However, their detailed observations made in United States, New Zealand, and Antarctica of phoxocephalids show them consuming settling invertebrate larvae and small juveniles. Oliver et al. (1982) considered this predation so important as to lead them to hypothesise a key functional role for these amphipods by influencing recruitment and early survival in a variety of soft bottom communities. Further examples of plasticity in feeding behaviour by soft sediment organisms are provided by Mauer et al. (1979) and Fauchald & Jumars (1979). In shallow and turbid environments, where surface sediments and associated diatom mats are frequently resuspended, differentiation between deposit feeders, suspension feeders, grazers, etc. are further confounded. Hence, the utility of general feeding groups in describing communities is questionable.

The results of our survey highlight the variability within sandflat macrobenthic community structure.

Table 3 Total number of the four most abundant polychaetes (*Heteromastus filiformis*, *Goniada emerita*, *Magelona ?dakini*, and *Macroclymenella stewartensis*) and bivalves (*Tellina liliana*, *Soletellina siliqua*, *Nucula hartvigiana*, and *Chione stutchburyi*) collected on three sampling occasions at Sites AA and CH. Totals are based on the number of individuals in 12 cores (i.e., the number of replicates collected after the first sampling occasion).

	Oct 1987		Dec 1987		Jun 1988	
	AA	CH	AA	CH	AA	CH
Polychaetes	13	431	16	518	38	422
Bivalves	375	5	280	44	242	72

Factors important in influencing variability in community structure are likely to be disturbance events (e.g., action of predators or storms) and spatio-temporal variation in patterns of recruitment. Such processes prevent communities developing to consistent and stable states except as an averaged condition over large spatial scales (Connell 1977; Sousa 1984). Consequently the method proposed by Grange (1977) may be appropriate only where very large changes in community structure need to be detected.

This study has described the macrobenthic invertebrate communities of the sandflats in Manukau Harbour. Although no site was completely different from another, community structure varied between the six sites. Sites AA and CH were the most dissimilar sites being numerically dominated by bivalves and polychaetes, respectively. Earlier descriptions of these sandflat communities provide a list of taxa very similar to that presented here. However, the intensity of the sampling carried out in this study allows a better estimate of variations in density of taxa, especially for the smaller macrobenthic taxa which were likely to have been ineffectively sampled in previous studies. Multivariate analysis identified the relationships between sites and taxa and defined core taxa for two site groups AA-PS and CB-CH-EB-KP.

The sandflats in Manukau Harbour are a dominant feature of the intertidal zone and the harbour in general, and it is likely that their invertebrate communities play an important role in the overall ecology of the harbour. They are also certain to be important in the feeding ecology of some commercially exploited fish species. The harbour borders Auckland city and consequently is exposed to a variety of anthropogenic disturbances (Gregory 1978; Grange 1979; Aggett & Simpson 1986; Fox et al. 1988; Glasby et al. 1988; Roper et al. 1988; Hume et al. in press). Despite this it is striking that details of the ecology of individual species are lacking and ecological processes controlling such communities are only very poorly understood.

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## Appendix 1 Taxa from Manukau Harbour sandflats. \* not previously reported in Harbour; nd, not determined.

## CNIDARIA

*Anthopleura aureoradiata*  
\*? *Edwardsia* sp.

## NEMERTINEA: nd

## NEMATODA: nd

## MOLLUSCA

## Polyplacophora

*Sypharochiton pelliserpentis*

## Gastropoda

*Amalda australis*  
*Amphibola crenata*  
*Cominella adpersa*  
*Cominella glandiformis*  
*Diloma subrostrata*  
*Micrelenchus tenebrosus*  
*Notoacmea helmsi*  
*Potamopyrgus* sp.  
*Xymene plebeius*  
*Zeacumantus lutulentus*

## Pelecypoda

*Arthritica bifurca*  
\* *Arthritica crassiformis*  
*Chione stutchburyi*  
\* *Dosinia maoriana*  
*Dosinia subrosea*  
? *Leptomya* sp.  
*Mactra ovata*  
*Nucula hartvigiana*  
*Soletellina siliqua*  
*Tellina liliana*  
*Zenatia acinaces*

## ECHIURA: \*nd

## ANNELIDA

## Oligochaeta nd

## Polychaeta

*Aglaophamus macroura*  
\* *Aonides oxycephala*  
*Aquilaspio aucklandica*  
\* *Aricidea*  
\* *Armandia maculata*  
\*? *Asychis theodori*  
*Axiothella* sp.  
\*? *Boccardia* spp.<sup>1</sup>  
*Capitella* spp.  
\* *Cossura* sp.  
\* *Eteone near aurantiaca*  
\* *Eupolyodontes* sp.  
*Glycera americana*  
*Goniada emerita*  
*Heteromastus filiformis*  
*Macroclymenella stewartensis*  
\* *Magelona ?dakini*<sup>2</sup>  
\* *Malacoseros* sp.

*Maldanidae* sp.1  
*Maldanidae* sp.2  
*Nicon aestuarinensis*  
*Notomastus zeylanicus*  
*Opheliidae* nd  
? *Opheliidae* nd  
*Orbinia papillosa*  
*Owenia fusiformis*  
*Pectinaria australis*  
\* *Phyllodoce* sp.1<sup>3</sup>  
\* *Phyllodoce* sp.2<sup>3</sup>  
*Platynereis australis*  
*Polychaeta* nd  
*Polynoidae* sp.1  
*Polynoidae* sp.2  
*Sabellidae* nd  
*Scolecopelides benhami*  
\* *Sphaerosyllis semiverrucosa*  
*Spionidae* nd.  
*Syllidae* sp.1  
*Syllidae* sp.2  
\* *Syllis* sp.  
*Terebellidae* nd  
*Travisia olens*

## ARTHROPODA

## Nebaliacea nd

## Ostracoda nd

## Mysidacea nd

## Cumacea

\* *Colurostylis lemurum*

## Isopoda

\* *Cirolana aff. woodjonesi*  
\* *Exosphaeroma ?falcatum*  
\* *Exosphaeroma chilensis*  
*Isocladus* spp.

## Amphipoda

*Amphipoda* 2  
*Amphipoda* 8  
*Amphipoda* 9  
\* *Eusiridae* nd.  
\* *Methalimdon* sp.  
\* *Paracallioppe novizealandiae*  
\* *Phoxocephalidae* sp.1  
*Proharpinia hurleyi*  
\* *Waitangi brevirostris*

## Decapoda

*Callianassa ?filholi*  
*Halicarcinus whitei*  
*Hemigrapsus crenulatus*  
\* *Heterosquilla* sp.  
*Paguridea* nd  
*Pontophilus australis*

## PHORONIDA: nd

## ECHINODERMATA

*Trochodota dendyi*

<sup>1</sup>not *B. polybranchia* as in Grange (1982). <sup>2</sup>specimens resemble *M. dakini* described by Jones (1978) in her revision of *M. papillicornis*. *M. papillicornis* has been reported in Manukau Harbour by Grange (1982). <sup>3</sup>not *P. castanea* as in Grange (1977).