FAUNAL COMMUNITY STRUCTURE OF EIGHT SOFT SHORE, INTERTIDAL HABITATS IN THE MANUKAU HARBOUR

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SUMMARY: The effects of pollution (nutrient enrichment). and the presence of macrovegetation on the species diversity and density of large benthic fauna in the Manukau Harbour, Auckland, were studied by sampling eight soft shore, intertidal habitats. Pollution was found to reduce faunal density but to have only a slight effect on species diversity. The presence of dense meadows of the intertidal seaweed *Gracilaria secundata* var. *pseudoflagellifera* did not appear to affect the community structure of the underlying large benthic fauna greatly. However, species diversity of large benthic fauna was higher on both eelgrass *(Zostera muelleri)* flats and in mangrove *(Avicennia resinifera)* forests than in comparable nonvegetated habitats. Presence of mangroves also increased faunal density whereas eelgrass flats showed a slight decrease in density in relation to comparable nonvegetated habitats.

INTRODUCTION

A subtidal survey of benthic fauna in the Manukau Harbour was described by Powell (1937) who recognised two subtidal communities. One of the communities, typical of subtidal regions in the portions of the harbour east of Cornwallis and Big Bay, was associated with a variable substrate, and was dominated by *Maoricolpus roseus manukauensis* and *Nucula hartvigiana*. The other community confined to the outer basin of the harbour (west of Big Bay and Cornwallis) was associated with a fine iron sand substrate, and was dominated by *Arachnoides placenta*. The fauna and sediments of Karore Bank, an intertidal area near Auckland International Airport, were described by Michael (1966). Cassie and Michael (1968) reported on a multivariate analysis of the data collected in Michael's previous study. They found two clearly defined, negatively correlated communities characterised by *Chione stutchburyi* and *Macomona liliana,* and by *Halicarcinus cooki* and *Owenia fusiformis*. The former community was associated with coarse sediments and the latter with fine sediments.

Chapman and Ronaldson (1958) described some of the common animals associated with mangrove swamps and salt marshes of the Auckland region and recognised an *Amphibola-Helice* community. Anon (1976) examined the benthic fauna of Clarks Bay, on the southern shores of the Manukau Harbour, recognising five major zones: an *Amphibola* zone, a *Chione-Macomona* zone, a *Hemiplax* zone, and a zone of spring tide sandflats. Grange (1977), in a benthos-sediment study of the harbour, found that the proportion of deposit feeders in. creased with decreasing sediment grain size. A later study (Grange, 1979) characterised four subtidal, macro benthic species groups in the Manukau Harbour: a *Microcosmus* / *Notomithrax* community, a *H alicarcinus* / *Bugula* community, an *A malda* / *Myadora* community, and a *Fellaster* / *Pagurus* community.

Two measurements commonly used in studies of marine benthic fauna are density and species diversity. Density can be expressed as the number of individuals per unit area or volume whereas species diversity is usually held to encompass the number of species present in a sample and the abundance of individuals within each of the species. It is maximal when each individual represents a separate species and minimal when all individuals belong to the same species (Gray, 1974).

There is much controversy in the literature regarding the definition of species diversity, how to measure it, and what any differences in absolute values may indicate. However, in two recent exhaustive reviews by Gray (1974) and Peet (1974), it was suggested that certain species diversity indices, if used properly, could be of value in evaluating community structure.

In general, much of the criticism of diversity indices is related to attempts to compare the diversities of widely differing communities. The more similar a series of communities is, especially regarding their underlying species-individuals relationships, the better the rationale for comparing their species diversities.

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The present study examines a narrow segment of the Manukau Harbour soft shore intertidal fauna and attempts to consider the effects of pollution (nutrient enrichment) and the presence of macro-vegetation on species diversity and density of this faunal segment. Previous Manukau Harbour benthic invertebrate studies did not consider effects of these two factors on community structure.

MATERIALS AND METHODS

A total of eight habitats were sampled in the Manukau Harbour in the regions delineated in Figure 1. The number of stations located at each region depended upon habitat variety in the area and ranged from one to four.

At each station a 0.25 m^2 quadrat was dug to a depth of 10 cm and the fauna separated from sediments on a 6.25 mm mesh sieve. A 10 cm deep sample of substrate also was taken at each station and analysed by wet sieving and oven drying to determine the percentage of sand (particles between 0.0625 and 2.00 mm) and silt plus clay (particles less than 0.0625 mm).

The stations were placed in one of eight different habitats depending upon their tidal height, proximity to pollution sources, substrate characteristics, and type of vegetative cover. Stations east of a line between Ihumatao and Blockhouse Bay (see Fig. l) were defined as Upper Harbour stations and considered to be in close proximity to pollution sources (e.g. Mangere sewage oxidation ponds, Westfield industries). Stations west of this line were considered to be remote from pollution sources. Previous studies (Henriques, 1976 and 1977) had shown that sediments and to some extent waters east of this arbitrary line tend to be more nutrient enriched than those west of the line. If the substrate was less than or equal to 20 per cent silt plus clay on a dry weight basis then the station was considered sandy and if silt plus clay was greater

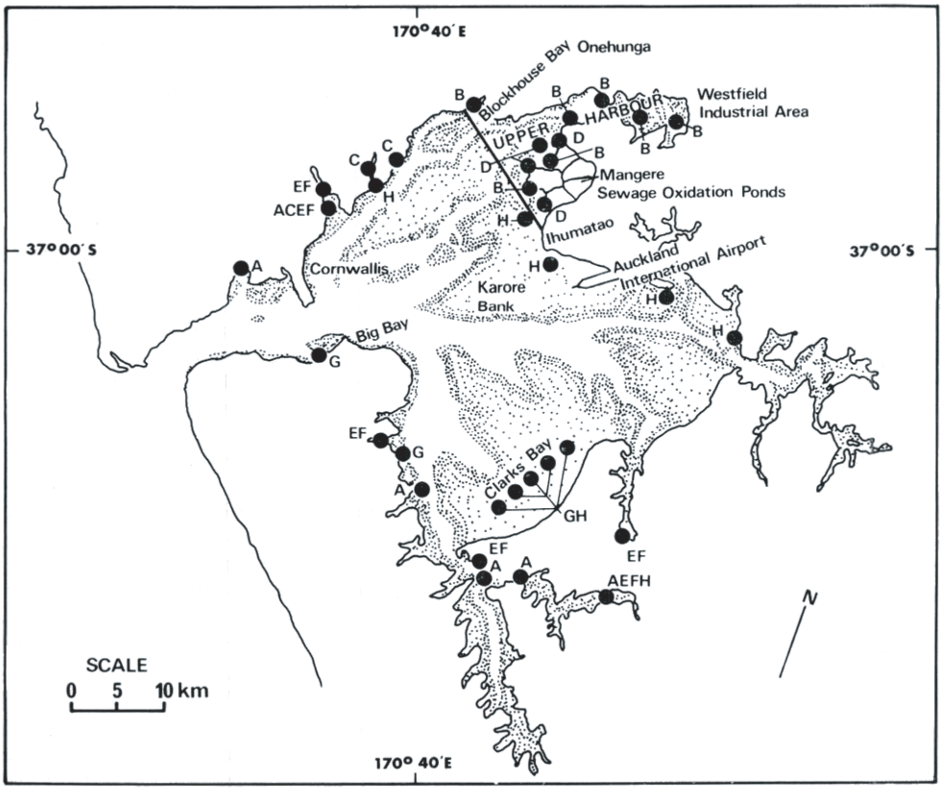

FIGURE 1. *Location of faunal sampling regions* (e). *Letters denote the habitats sampled in each region.*

than 20 per cent on a dry weight basis then the station was considered muddy.

Habitats A, B, C and D were each sampled in Spring 1972, Summer 1972/73, Summer 1973/74, and Winter 1975, habitats E and F were each sampled in Winter and Spring 1975, and habitats G and H were each sampled in Winter 1973, Summer 1974/75, and Winter and Spring 1975.

For each habitat, faunal density was assessed as the average number of large benthic fauna (those retained on the 6.25 mm mesh sieve) per 0.25 m^2. Rarefaction curves were drawn by the method described by Sanders (1968), and species diversity was calculated using the Shannon-Wiener formula as described by Gray (1974)

$$H^1 = -\sum_{i=1}^{s} p_i \log_2 p_i$$

where the probability of an individual belonging to species i is Pi and Pi is n_i/N where n_i is the number of individuals of the i-th species and N is the total number of individuals. This formula is sensitive to both the number of species and the evenness with which individuals are distributed among the species. Finally, evenness was calculated using Pielou's measure as described by Gray (1974)

$$J^1 = H^1/\log_2 S$$

where H^1 is the value obtained from the Shannon-Wiener formula, and S is the number of species.

TABLE 1. *Benthic fauna species list tabulating the percentage of stations at which each species was recorded for each of eight habitats (A -H).*

	A	B	C	D	E	F	G	H
AMPHINEURA								
Amaurochiton glaucus	0	0	0	0	0	0	40	21
BIVALVIA								
Amphidesma auslrale	12	0	14	0	0	0	7	14
Chione stutchburyi	88	71	100	100	14	62	47	86
Cras,vostrea glomerata	0	0	0	0	0	25	0	0
Cyclomactra ovala	38	14	29	60	0	0	27	0
Macomona liliana	50	43	71	100	14	12	100	100
Nucula hartvigiana	25	43	14	40	0	0	27	0
Soletellina siliqua	25	0	0	0	0	0	13	21
CRUSTACEA								
Alpheus sp.	0	0	43	20	0	12	7	0
A ustralomysis sp.	0	0	0	0	0	0	13	0
Elminius modestus	0	0	0	0	0	38	0	0
Helice crassa	62	71	86	80	100	100	60	14
Hemigrapsus crenulatus	12	14	14	0	0	12	27	0
Hemiplax hirtipes	25	0	14	20	14	25	0	0
Hymenicus cooki	0	14	29	40	0	12	73	36
Pagarus novaezelandiae	0	0	0	0	0	0	7	0
GASTROPODA								
Amphibola crenata	12	0	0	0	43	62	0	14
Cominella adspersa	12	0	0	20	0	0	7	0
Cominella glandiformis	62	71	100	80	43	38	93	93
Maoricolpus roseus	0	14	0	0	0	0	7	0
Micrelenchus huttoni	0	0	0	0	0	0	80	21
Xymene plebejus	12	14	0	0	0	12	53	14
Zeacumantus lutulentus	38	14	14	40	14	38	53	36
Zeacumantus subcarinatus	12	0	29	0	29	0	47	14
Zediloma subrostrata	38	43	86	40	29	25	33	43

TABLE 2. *Data for the eight faunal habitats (A-H). Upper Harbour (see Figure 1) habitats were considered close to pollution sources (e.g. Mangere sewage oxidation ponds, Westfield industries) whereas habitats in other regions of the harbour were considered remote from pollution sources.*

Habitat	Proximity to pollution sources	Substrate	Plant cover	Tidal height (m)	Total no. of stations sampled	Total no. of species	Density (no. of individuals per 0.25 m^2)	Information statistic (H^1)	Evenness measurement (J^1)
A	Remote	Mud	Nonvegetated	0.6-1.9	8	16	85	1.81	0.45
B	Close	Mud	Nonvegetated	0.6-1.5	7	12	45	2.10	0.58
C	Remote	Mud	Dense *Gracilaria*	1.1-1.6	7	14	72	2.05	0.54
D	Close	Mud	Dense *Gracilaria*	0.7-1.7	5	12	56	2.40	0.67
E	Remote	Mud	Nonvegetated	2.3-3.5	7	9	19	1.94	0.61
F	Remote	Mud	Dense *Avicennia*	2.6-3.7	8	14	48	2.85	0.75
G	Remote	Sand	Dense *Zostera*	1.1-3.2	15	21	80	2.71	0.62
H	Remote	Sand	Nonvegetated	1.1-3.2	14	14	101	1.81	0.48

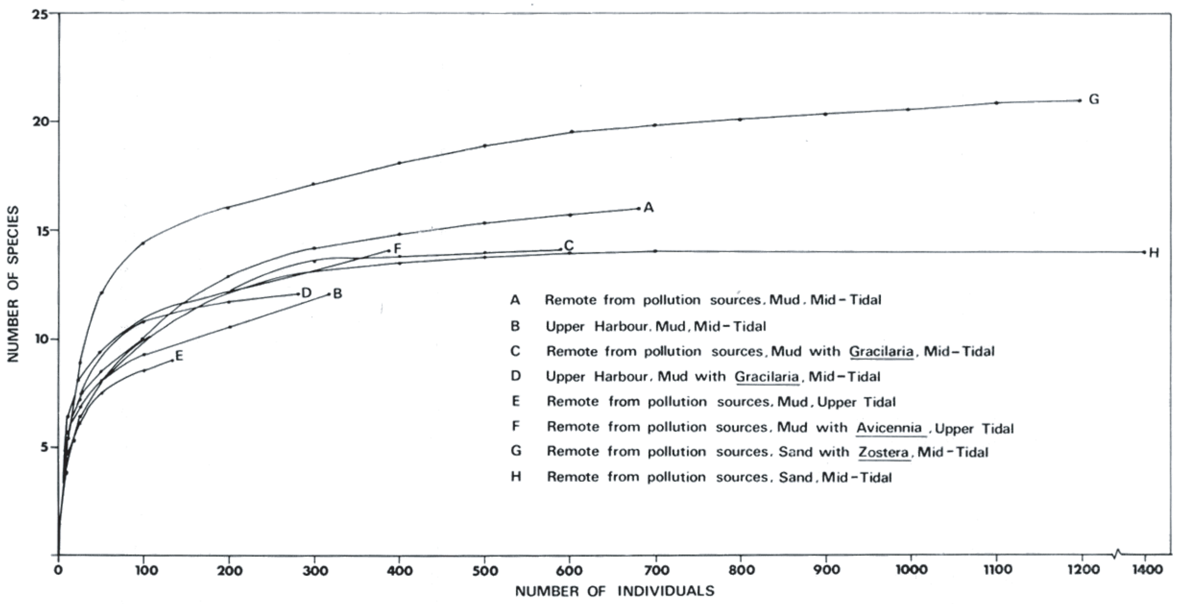

FIGURE 2. *Species diversity range of the large benthic fauna (those retained on a 6.25 mm mesh sieve) from eight Manukau Harbour intertidal habitats (A-H).*

RESULTS AND DISCUSSION

A species list for large, intertidal benthic fauna is presented in Table 1. Data related to the eight habitats are provided in Table 2 and species diversity rarefaction curves are depicted in Figure 2.

Effect of pollution

In comparing habitat A with B and habitat C with D, one can consider the effects of pollution on community structure. Habitats A and Bare muddy, mid-tidal, and nonvegetated, whereas habitats C and D are muddy, mid-tidal, and covered in dense *Gracilaria* meadows. Habitat A differs from B and habitat C differs from D in that A and C are remote from pollution sources whereas Band D are Upper Harbour habitats. All four habitats share the same prevalent species. Habitat B shows a reduction of four species from the comparable habitat remote from pollution sources and habitat C shows a reduction of two species from the comparable Upper Harbour habitat. Differences in species number are mostly due to rare species. Habitat A has a higher rarefaction curve than habitat B but since the curve for B has not levelled out it is possible that the curve for this habitat would rise further with an increase in sample size. The evenness measurement for habitat A is lower than that for habitat B and this has caused its information statistic to be lower. Habitat C has a higher rarefaction curve than does habitat D and both curves appear to have levelled out. However, habitat C has a lower evenness measurement than that for D and this has again caused a lower information statistic. Thus the pairs of habitats show conflicting results. The two Upper Harbour habitats have higher information statistics and evenness values but lower rarefaction curves than those for the comparable habitats remote from pollution sources.

These results are in contrast to those reported by Pearson (1975) who found that the rarefaction method and the information statistic both indicated a progressive simplification of the faunal complex when there was increasing organic pollution of the sediments. However, Pearson's results came from subtidal habitats rather than intertidal habitats and intertidal habitats tend to be harsher environmentally. Lappalainen and Kangas (1975) suggest that intertidal zones, due to their environmental instability, support physically controlled communities. They believe that in these communities any "natural changes in the environment (e.g., in temperature, salinity and sediment conditions) and external disturbances (e.g., pollution) are more likely to change the proportions of the rather well-adapted species of the community than to cause marked changes in the number of species."

Species diversity differences between habitats A and B and between habitats C and D are slight. Probably the most important aspect of the differences is the small reduction in species number in the Upper Harbour. However, density differences are important and hence support is given to the suggestion by Lappalainen and Kangas (1975) that in physically controlled communities pollution is more likely to change species proportions than species numbers. Reduced densities in the two Upper Harbour habitats studied are largely due to reductions in the number of juvenile *Chione*. In comparing habitats A and B, it is apparent that populations of *Macomona* are also reduced in the Upper Harbour in this type of nonvegetated, muddy habitat. However, in comparing habitats C and D, one sees that the *Gracilaria* meadow habitat in the Upper Harbour actually appears to support more *Macomona* than do *Gracilaria* meadows in other regions of the Harbour. The increase in the number of *Macomona,* however, is not as dramatic as the decrease in the number of *Chione*.

Reductions in the density of *Chione* in the Upper Harbour as well as reductions in numbers of species are probably related to one or a combination of the following factors: periodic discharge of toxic chemicals from Upper Harbour industries; variation in salinity caused by discharges of fresh water from the Mangere sewage oxidation ponds; habitat changes and smothering effects caused by excess silt and clay originating from initial dredging when the sewage ponds were constructed and from the continuous discharge from the ponds of small amounts of fine particles; and varying organic and inorganic nutrient introductions from the sewage oxidation ponds and Upper Harbour industries.

Effect of Gracilaria

In comparing habitat A with C and habitat B with D, one can consider the effect of the presence of *Gracilaria* on community structure. The data seem to indicate that *Gracilaria* meadows do not radically affect the community structure of the underlying large benthic fauna.

Effect of mangrove forest

In comparing habitat E with F, one can compare community structure in mangrove forests with community structure in a similar but nonvegetated habitat. Habitat E and F are equivalent in tidal height and substrate and both are remote from pollution sources; however, habitat E is bare of vegetation whereas F has a dense covering of mangroves. The habitats share the same prevalent species but the mangrove habitat has five additional species and not all of these are rare. The mangrove habitat's rarefaction curve occupies a higher position, its information statistic is higher, and its evenness measurement is higher than that for the comparable nonvegetated habitat. Hence the mangrove forest has a greater total number of species and a more even distribution of individuals among species than does the comparable nonvegetated habitat. In addition, density differences are pronounced between the two habitats, with the mangrove forest containing more than twice the number of individuals on an areal basis reflecting both a greater number of species and more individuals within each species.

Effect of eelgrass

In comparing habitat G with H, one can compare community structure in eelgrass flats with community structure in a similar but non vegetated habitat. Habitats G and H are remote from pollution sources, have a sandy substrate, and cover exactly the same tidal heights. They differ in that habitat G is covered by eelgrass whereas H is nonvegetated. The three most prevalent species in habitat Hare also prevalent in habitat G with by far the most prevalent species in both habitats being *Chione* and *Macomona*. Habitat H has more individuals of these two species on an areal basis than does habitat G. This difference is what causes habitat H, the non-vegetated habitat, to have a greater over-all density of individuals. The eelgrass flat has seven more species than the comparable nonvegetated habitat and many of these additional species are not rare e.g. *Micrelenchus huttoni).* The eelgrass habitat has a higher species diversity than the comparable nonvegetated habitat according to all three methods used in this study. Thus the eelgrass habitat has a greater total number of species and a more even distribution of individuals among species than does the comparable nonvegetated habitat.

Concluding remarks on the effect of vegetative cover

There is very little published work on the effect of vegetative cover on soft shore benthic community structure. In studying nuisance growths of benthic macro algae due to artificial nutrient enrichment, Perkins and Abbott (1972) reported that dense growths of *Viva* and *Enteromorpha* in the Clyde River Estuary in Scotland reduced oxygen levels in the substrate to such an extent that the dominant bivalves *Cerastoderma* and *Macoma* were killed. In a study in unpolluted waters, the macrofauna of eelgrass flats in Finland was examined by Lappalainen and Kangas (1975) who reported that animal species diversity was positively correlated with eelgrass biomass. They considered that this correlation occurred because of the increasing structural complexity of the habitat with increasing eelgrass biomass. Orth (1973) also reported that species diversity of benthic macrofauna (measured in terms of species richness, the information statistic, and evenness) was positively correlated with eelgrass biomass. In addition he noted that eelgrass meadows supported a higher density of infauna than any other benthic habitat in Chesapeake Bay, North America.

Unlike the nuisance growths of *Viva* and *Enteromorpha* reported by Perkins and Abbott (1972), *Gracilaria* meadows in the Manukau Harbour did not appear to affect greatly the underlying benthic fauna. The bivalves *Chione* and *Macomona* are quite numerous in *Gracilaria* meadows and the crab *Hymenicus cooki* frequently was observed on *Gracilaria* although not in great numbers; faunal diversity and density were reasonably similar in *Gracilaria* meadows and comparable non-vegetated habitats. Although vegetative cover normally increases species diversity, one still would not necessarily expect higher species diversities in *Gracilaria* meadows if the meadows are a man-induced phenomenon. If speciation were necessary to fill any additional niches provided by the *Gracilaria* meadows, this would be a slow process.

However, the hypothesis that vegetative cover increases species diversity is supported by findings in the mangrove swamps and eelgrass flats of the Manukau Harbour. In the mangrove forests, part of the increase in species richness is due to epifauna, such as *Elminius modestus* and *Crassostrea glomerata* which occur on trunks and pneumatophores. The epifauna of *Zostera* leaves are too small to be retained on the sieve used in the present study; however, despite this, the eelgrass flat habitat had seven more faunal species than did the comparable nonvegetated habitat. The ability of eelgrass flats to trap fine sediments (thus making the substrate more heterogeneous) as well as the existence of an intricate network of rhizomes, probably helps to make the eelgrass flat structurally complex and thus diverse.

The availability of a ready source of detritus may be the reason why the mangrove habitat contains more than double the number of large animals on an areal basis than does the comparable nonvegetated habitat. Density differences between the eelgrass habitat and the comparable nonvegetated habitat are harder to explain. The nonvegetated habitat's density of large animals is actually slightly greater than that of the eelgrass habitat in contrast to findings reported from Chesapeake Bay, North America by Orth (1973).

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