Technical Report

Investigations and Monitoring Group

Sediments and macrobiota of the intertidal flats of inner Akaroa Harbour

Environment Canterbury
Your regional council

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Report U05/

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Executive summary

The sediments and macrobiota of intertidal flats in four areas of Akaroa Harbour were investigated. These were Barrys Bay, Duvauchelle, Robinsons Bay and Takamatua Bay. Ten sites were sampled, three in Barrys Bay, three in Duvauchelle, two in Robinsons Bay and two in Takamatua Bay. Sampling was undertaken in November/December 2003. Sediments were analysed to determine grain size, organic matter content and total nitrogen and total phosphorus content. All taxa present in the macrobiota samples were identified and counted and the size and wet weight of all the cockles and wedge shells were measured. The percent cover of the seagrass *Zostera* sp. in each of the macrobiota samples was recorded.

The sediment in Barrys Bay was 93-98% mud whereas in Duvauchelle, Robinsons Bay and Takamatua Bay the sediment was 73-96.5% sand. The sediment organic matter content over all sites ranged from 0.5 – 4.6%. There was no correlation of organic matter content with sediment grain size or with the percent cover of seagrass. The total nitrogen (TN) content of the sediment ranged from 800-2600mg/Kg and the total phosphorus (TP) content ranged from 390-830 mg/kg. The strong correlation between TN and TP, and the lack of correlation of TN and TP to sediment grain size indicates a common external source for these nutrients. The possible sources of TN and TP are the streams that drain into each bay and the populations of waterfowl that feed on the flats. An analysis based on the sediment characteristics of percent sand, percent silt, percent clay, percent organic matter and TN and TP concentrations, shows there are distinct differences in the sediment characteristics between bays.

One hundred and four taxa were identified, with the taxa present being typical of enclosed harbour flats in New Zealand and also common in New Zealand estuaries. Macrobiota density ranged from 77-1477 individuals/0.25m^2 (308-5908 individuals/m^2) and a total of 23,432 individuals were present in the samples. The macrobiota community present at sites within in a bay was more similar than it was to the community in each of the other bays. The community at all sites within in each bay was distinct from that in other bays. These differences result from differences in the presence and abundance of molluscs, polychaetes and crustaceans at the sites studied. The difference in the macrobiota community between sites within a bay and between sites in different bays is a reflection of differences in the suite of natural physical and biological factors affecting the flats in each bay.

Cockles and wedge shells made up most of the biological biomass in the sediments and are an important food source for wading birds, flounders and predatory molluscs. The abundance, biomass and size of cockles and wedge shells varied between both sites in a bay and sites in different bays. Differences between sites in the abundance and size of cockles, could, in part, be due to human harvesting of this species. The seagrass *Zostera* sp., which was present on each flat, is an important component of the biological community stabilising the sediment. It provides habitat and source of food for a range of organisms, including gastropod molluscs and crustaceans. The flats of Robinsons Bay are biologically the richest of the flats studied, based on the biological community including the density of seagrass and cockles.

The information obtained in this study supports the classification of these intertidal flats as Areas of Significant Natural Value in accordance with Schedule 1 of the Proposed Regional Coastal Environment Plan. To ensure that the sediments and macrobiota of these flats remain in a state as healthy as they are at present, any proposed developments, for example subdivision of land for housing or changes in land use in a catchment, should be thoroughly assessed with respect to likely impacts on the associated intertidal flat. In addition, if applications for resource consents for developments likely to impact on the intertidal flats are received, then consideration should be given to consent conditions which require the relevant monitoring of the sediment and macrobiota of the associated intertidal flat.

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1 Introduction

1.1 Akaroa Harbour

Akaroa Harbour is a long narrow inlet formed by the collapse of the seaward margin of the southern most crater of the volcanic complex that forms Banks Peninsula. The harbour is some 17 km long with the width ranging from 1.5 – 3.6 km. The outer harbour, orientated SSE, is 1.8 km wide at its heads. Some 5 km inland, its orientation changes to N-S and the harbour widens variously into embayments. In the inner harbour these embayments are Barrys Bay, Duvauchelle, Robinsons Bay and Takamatua Bay (Figure 1.1).

The shoreline of the harbour grades from the gently sloping intertidal flats between steep rocky headlands in the inner half of the harbour, through to rocky shores that increase in steepness to seaward, with rugged shores and high cliffs at the heads. It is the extensive, gently sloping intertidal flats of Barrys Bay, Duvauchelle, Robinsons Bay and Takamatua Bay that are the focus of this study (Figures 1.1 and 1.2).

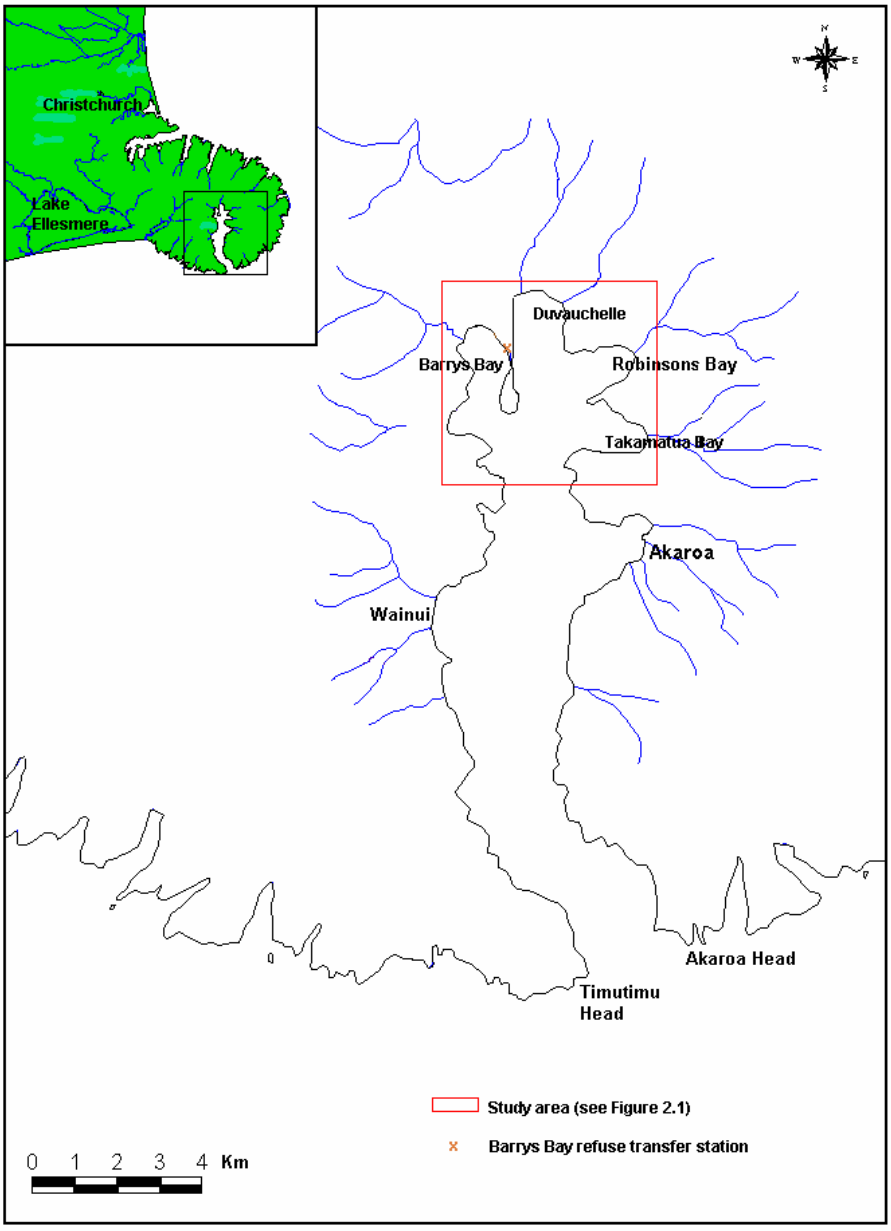

Figure 1.1 Akaroa Harbour: Location, streams, bays and the study area

Figure 1.2 **The intertidal study areas**

A – Barrys Bay B – Duvuachelle C – Robinsons Bay D – Takamatua Bay

1.2 The intertidal flats

The intertidal flats (hereafter often referred as the flats) in Barrys Bay, Duvauchelle, Robinsons Bay and Takamatua Bay are extensive. The approximate extent of the flats in each bay is:

Barrys Bay: ~ 1400 m along the shore and ~250 m seaward
Duvauchelle: ~1500 m along the shore and ~350 m seaward
Robinsons Bay: ~ 890 m along the shore and ~ 450 m seaward
Takamatua Bay: ~860 m along the shore and ~ 600 m seaward

Intertidal flats are highly productive areas, supporting a diversity and abundance of organisms that are adapted to cope with the natural environmental stressors that are present. In addition to the natural environmental stressors, these flats increasingly have the potential to be impacted by human activities. In inner Akaroa Harbour, there is an ever-increasing human presence with continually growing settlements. Associated with this increase are increases in the volumes of sewage that must be disposed of, and an increase in the area covered by impervious surfaces that generate increasing volumes of stormwater. Stormwater entering the inner bays is either a non-point discharge that flows into the streams that then flow into the sea or a point discharge directly into the sea. At low tide such a discharge would be directly to the flats. Stormwater flow can result in inputs of rubbish, sediments, pathogens, organic matter, chemical contaminants such as heavy metals and organic compounds and possibly nitrogen and phosphorus compounds (Morrisey, 1997; Vincent and Thomas, 1997). The increase in the number of permanent residents and tourist visitors to Akaroa Harbour has resulted in an increase in traffic on the roads, with the roads in the inner harbour bays just landward of the intertidal flats. Rainfall runoff from the roads would transport the ever-increasing amounts of road use associated contaminants, such as Zn and organic compounds, into the adjacent coastal waters or at low tide, onto the flats. Such road and stormwater runoff has the potential to:

- alter the sediment structure of the flats
- elevate sediment organic matter levels
- alter the redox regime of the sediments of the flats
- add organic compounds to the sediments of the flats
- add litter to the flats
- elevate the concentrations of metals (primarily Cd, Cu, Pb, Zn) in the sediments of the flats
- elevate the concentrations of N and P compounds in the sediments of the flats
- elevate the levels of oil and grease in the sediments of the flats
- alter the biological communities (presence/absence and abundance of taxa) of the flats

(Bolton-Ritchie, 2003; Smith, 1986).

To date, the intertidal flats of Barrys Bay, Duvauchelle, Robinsons Bay and Takamatua Bay have not been studied (i.e. nothing is know about the sediment structure of the mud flats and organisms that live there). This lack of information prompted the need for a study of these mud flats, especially in light of the increasing potential for human impacts.

1.3 Study objectives

This study of the intertidal flats of Barrys Bay, Duvauchelle, Robinsons Bay and Takamatua Bay aims to:

1. Quantify the present state of the sediments of the four flats in terms of grain size, organic matter content and total nitrogen and total phosphorus content.

2. Quantify the present macrobiota of the four flats.

3. Compare the flats in different bays, based on the sediment grain size, organic matter content, total nitrogen and total phosphorus content and the macrobiota.

Note: This study is not a baseline study for future monitoring; rather it will provide information that will assist with the development of any future intertidal monitoring programme that may be required.

2 Methods

2.1 Sampling sites

Samples were collected from the mid-low tide level on the intertidal flats of Barrys Bay, Duvauchelle, Robinsons Bay and Takamatua Bay. Sampling at this shore level follows the recommendation given in the Estuarine Environmental Assessment and Monitoring Protocol (Robertson *et al*., 2002). In total 10 sites were sampled, with 2 or 3 sites (depending on the alongshore length of the flat) sampled in each of the four bays (Figure 2.1). At each site an area 10 m by 10 m was marked out using tape measures. A GPS reading (Appendix I) was taken at the inner shore left corner (when looking out to sea) of each site. These readings establish the exact location of each site as shown on Figure 2.1.

2.2 Sample collection

Sampling was carried out on the 24-26th November and 17th and 22nd of December 2003.

At each site, the following samples were collected:

- macrobiota - four random 500mm x 500mm quadrat samples to a depth of 150mm (the % cover of the seagrass *Zostera* sp. in each quadrat was also recorded)
- grain size analysis - one random surface sediment sample
- organic matter content - three random surface sediment samples
- total nitrogen and total phosphorus– one random surface sediment sample.

2.3 Sample processing

The macrobiota samples were sieved through a 1 mm mesh and the material remaining on the sieve was preserved in 10% formalin in sea water. The samples were kept in the formalin for at least 24 hours, washed in fresh water and stored in 70% alcohol. The animals present were sorted from the debris, identified and counted. Organisms were identified, where possible, to species level using a wide range of reference literature (Knox, 1960; Day, 1967; Cooper, 1969; Barnard, 1972; Knox and Green, 1972a, 1972b; Rainer, 1973; Melrose, 1975;Day, 1977; Fauchald, 1977; Blake and

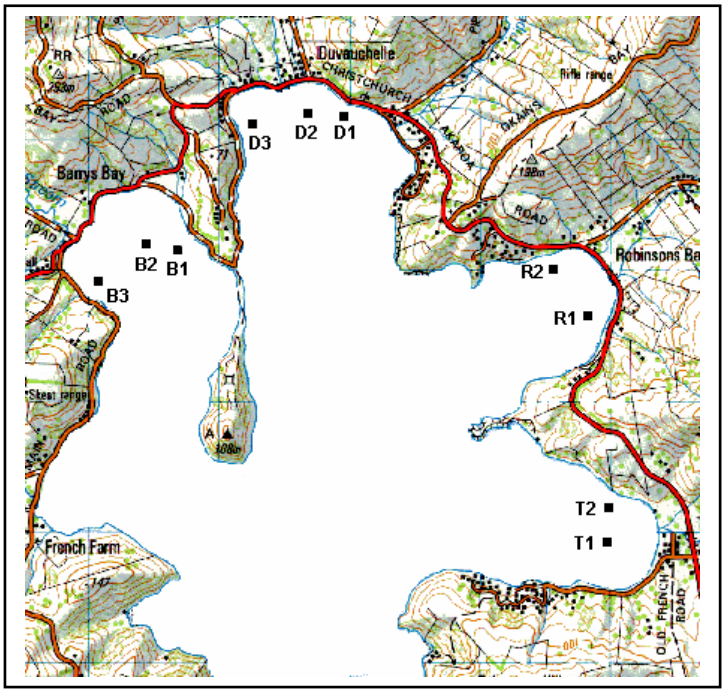

Figure 2.1 Location of sampling sites

Kudenov, 1978; Day and Hutchings, 1979; Powell, 1979; McLay 1988; Spencer and Willan, 1995; Glasby, 1984; Glasby and Read, 1998; Beesley *et al*., 2000; keys for New Zealand Lumbrinerid (Hilbig and Glasby), and Glyceridae (Glasby) polychaetes and keys to the polychaete families Cirratulidae and Paraonidae (provided by C. Glasby)). In addition, the size (length, width and height) and wet weight of *Astrovenus stuctchburyi* (cockle) and *Macomona lilliana* (wedge shell) individuals in each quadrat were measured.

The analyses to determine sediment grain size were carried out by staff from the Department of Geography, University of Canterbury. The analytical method used was based on that described in 'Analytical Sedimentology' (D.W Lewis and D McConchie, 1994). To measure the sediment organic matter content (OM), the APHA 2540 G method, modified to ignition temperature of 450 ºC was used (Environment Canterbury Laboratory). The sediment for the total nitrogen and total phosphorus analysis was first sieved through a 63ц nylon mesh (sample preparation EPA 3050B) with the sediment < 63 ц Kjeldahl digested following the ASTM D3590 B method (Environment Canterbury Laboratory).

2.4 Data analyses

Microsoft Excel 2000, SYSTAT (version 9) (SPSS, 1999) and the software package PRIMER (version 5) (Plymouth Routines in Multivariate Ecological Research, Clarke and Warwick, 1994) were used for the production of charts, box plots and all statistical analyses.

Multi Dimensional Scaling Ordination (MDS) was used to plot the relative similarity of all the biological samples (based on the presence and abundance of the macrobiota), and the relative similarity between sites (based on both sediment characteristics (% sand, % silt, % clay, OM, TN and TP) and the presence and abundance of the macrobiota).

To plot the relative similarity of all biological samples, the abundance data for each taxon was log(x+1) transformed. Using the Bray-Curtis similarity measure, a similarity matrix was then generated from the transformed data. To plot the relative similarity between sites using the macrobiota data, the average abundance (from the 4 quadrat samples) of each taxon was log(x+1) transformed. Using the Bray-Curtis similarity measure, a similarity matrix was then generated from the transformed data. To plot the relative similarity between sites using the sediment characteristics, the data for OM were transformed (square-root) while the % sand, % silt, % clay, TN and TP data were not. Using the Euclidean similarity measure a similarity matrix was then generated from these data. Non-metric MDS was then performed on each similarity matrix to produce a 2-dimensional ordination of either stations or sites. Interpretation of the MDS plots is based on the closeness of samples/sites on the plot. The closer the samples/sites are, the more similar they are with respect to the parameters used to generate the plot. For each plot a stress value is given. Stress (goodness-of-fit) is a measure of the accuracy of the 2-dimensional ordination of points on the MDS plot in representing the actual values in the similarity matrix (Clarke and Warwick, 1994). The stress values for the plots generated were 0.12 or less; i.e. they are a good representation of the values in the similarities matrices.

3 Results

3.1 Sediments

The sediment at all three sites (B1, B2, B3) in Barrys Bay comprised 93-98% silt/clay (Figure 3.1) and very little sand, i.e., it was very soft sediment and difficult to walk on. In Duvauchelle (D1, D2) and Takamatua Bay (T1, T2), the sediment was sand with the silt/clay content ranging from 20-27% and in Robinsons Bay the sediment was predominantly sand with a silt/clay content of 3.5-10%. Note: The raw data (percent in each phi class) for each site are presented in Appendix II.

The organic matter (OM) content over all sites ranged from 0.5 – 4.6% (Figure 3.2) with the largest range at a site being 2.6 – 4.6% at site B3. The highest OM content was at site B3, with the OM content at both sites in Takamatua Bay also being high. There was little difference in the OM content between sites B3, T1 and T2. The OM content at sites B3, T1 and T2 was higher than at sites B1, B2, D1, D2, D3, R1 and R2, with the OM content at site B2 being higher than at sites B1, D1, D2, D3, R1 and R2. The lowest OM content was at sites D1 and D2 in Duvauchelle.

The total nitrogen (TN) content ranged from 800-2600 mg/kg (Figure 3.3). The highest TN concentration of 2600 mg/kg occurred at site R1 where the sediment contained 900 mg/kg more TN than the sediment at other sites. The lowest TN concentration of 800 mg/kg occurred at site D1. In Takamatua Bay the concentration of TN was the same (1400 mg/kg) at both sites. In Robinsons Bay, Duvauchelle and Barrys Bay the concentration of TN varied between the sites within each bay.

The total phosphorus (TP) content ranged from 390-830 mg/kg (Figure 3.3). The highest TP concentration of 830 mg/kg occurred at site R1 where the sediment contained 180 mg/kg more TP than the sediment at other sites. The lowest TP concentration of 390 mg/kg occurred at site D1. In Takamatua Bay the concentration of TP was similar at both sites. In Robinsons Bay, Duvauchelle and Barrys Bay the concentration of TP varied between the sites within each bay. Over all sites there was a strong correlation (Pearson correlation coefficient of 0.889) between TN and TP. This is suggestive of a common source of these nutrients.

A multidimensional scaling analysis (MDS) of sites (Figure 3.4), based on the sediment characteristics of grain size (% sand, % silt % clay), OM and TN and TP concentrations, shows there are distinct differences in the sediment characteristics between bays. The sediments at the three sites in Duvauchelle are similar (close together on the MDS plot) as are the sediments at the two sites in Takamatua Bay. In Barrys Bay, the sediment is distinct from that in other bays and is different at each site in the bay (large separation distances on the MDS plot). The sediment in Robinsons Bay is also different at each site, with the sediment at site R2 more comparable to that at the sites in Duvauchelle and Takamatua Bay than to the R1 site.

3.2 The macrobiota

3.2.1 The biological community

One hundred and four taxa were identified and 23,432 individuals counted in the 39 macrobiota samples that were analysed. Unfortunately one sample from site D3 was not preserved and therefore could not be processed. The list of taxa and mean abundance (per 0.25 m^2) of each taxa at each site are presented in Appendix III. Of the 104 taxa, 13 taxa were represented by one individual, 52 taxa had 10 or fewer individuals and 52 taxa had more than 10 individuals. The number of taxa present in a 0.25 m^2 sample ranged from 8 (in sample D1a) to 46 (in sample R1b) and the number of individuals present in a sample ranged from 77 (in sample D1a) to 1477 (in sample R1a).

With four samples collected from each site, there was considerable variation in the number of taxa and individuals collected per sample at each site (Figure 3.5; Appendix IV). The highest variation in the number of taxa was in the samples from site R2 and the highest variation in the number of individuals was in the samples from site T1. At site D3, each sample contained the same number of taxa and there was only a small difference between samples in the number of individuals present.

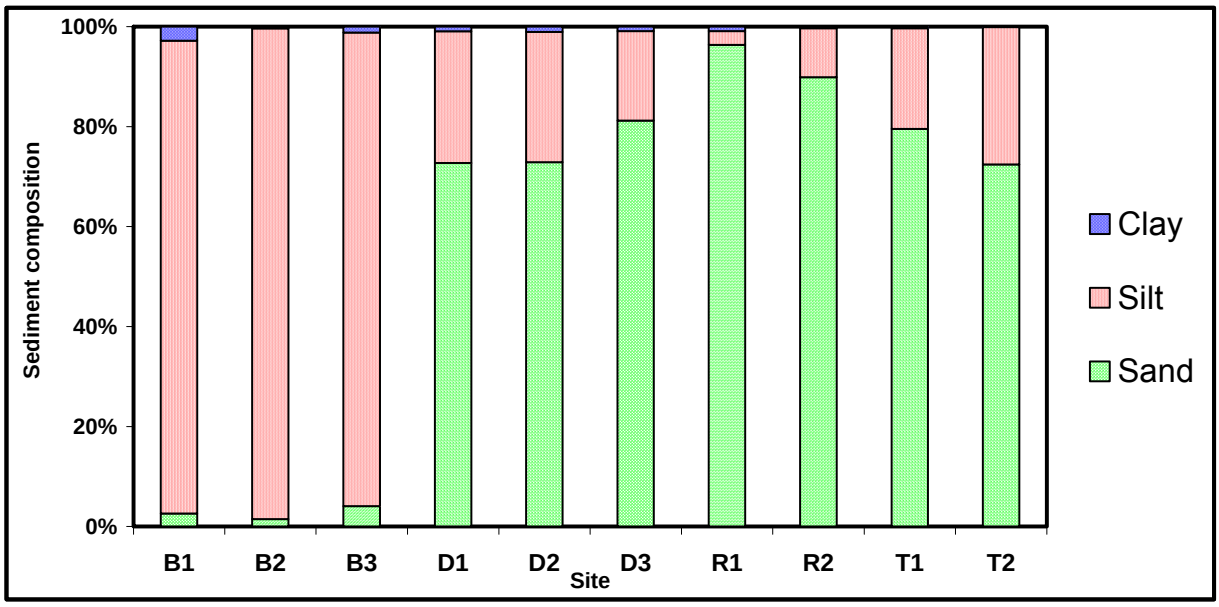

Figure 3.1 **Sediment particle size composition at each intertidal site in Akaroa Harbour**

Number of samples at each site = 1

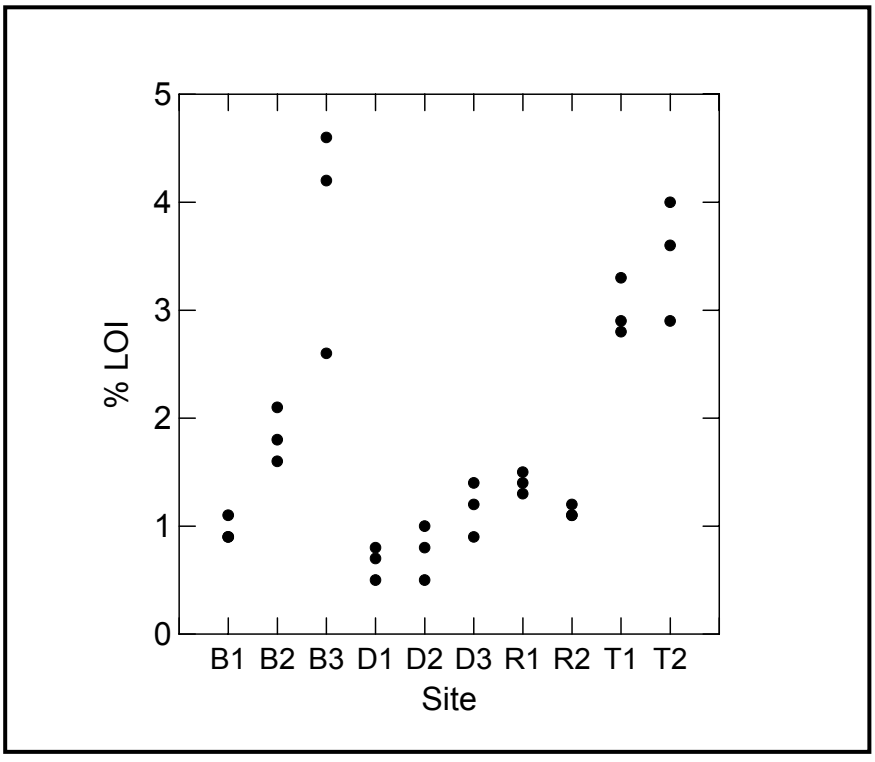

Figure 3.2 **Organic matter content (% LOI) at each intertidal site in Akaroa Harbour**

Number of samples at each site = 3
NOTE: horizontal bar = median, box = interquartile range, whisker ends = 5% and 95%iles

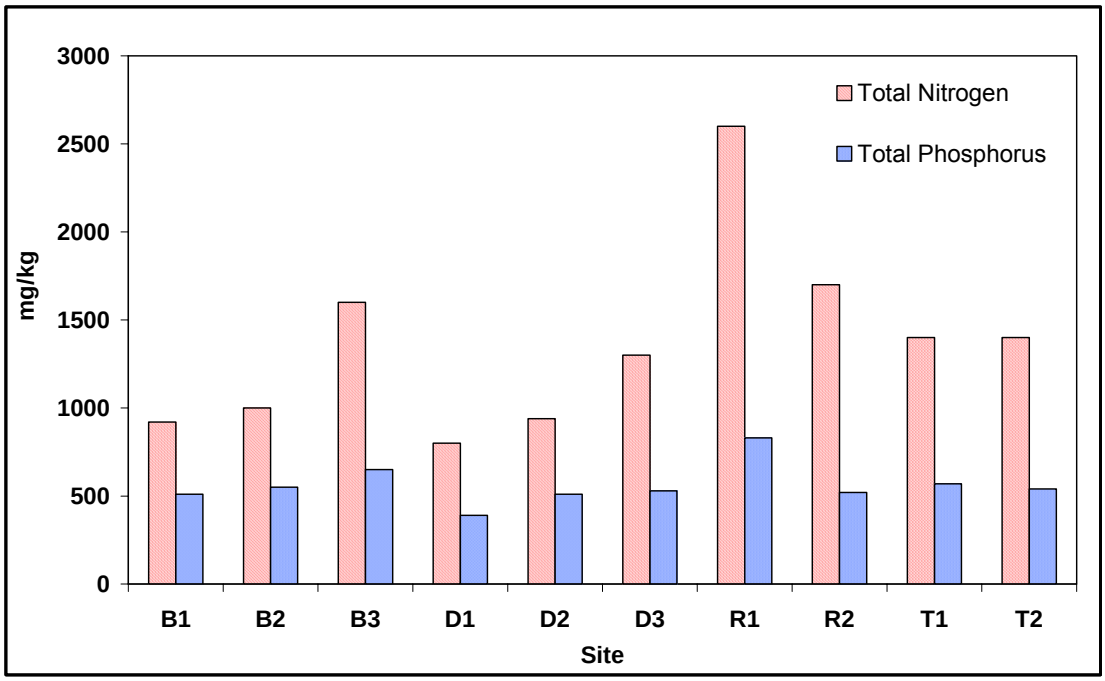

Figure 3.3 **Concentrations (mg/kg) of total nitrogen and total phosphorus in the sediment at each intertidal site in Akaroa Harbour**

Number of samples at each site = 1

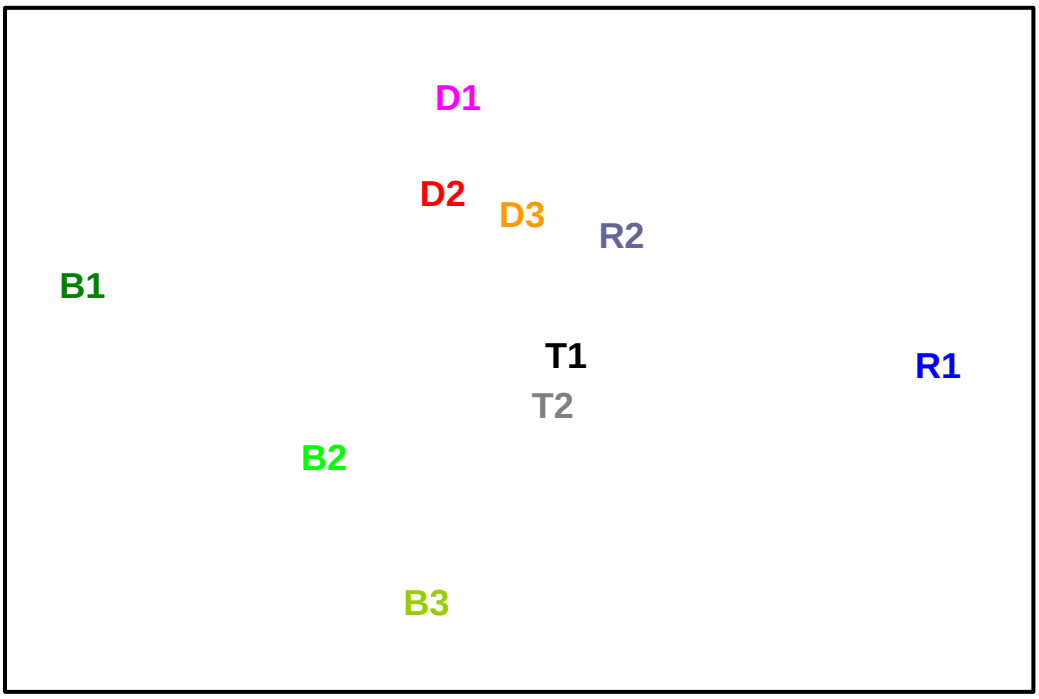

Figure 3.4 **MDS plot of sediment characteristics, at the intertidal sites in Akaroa Harbour (Stress = 0.05)**

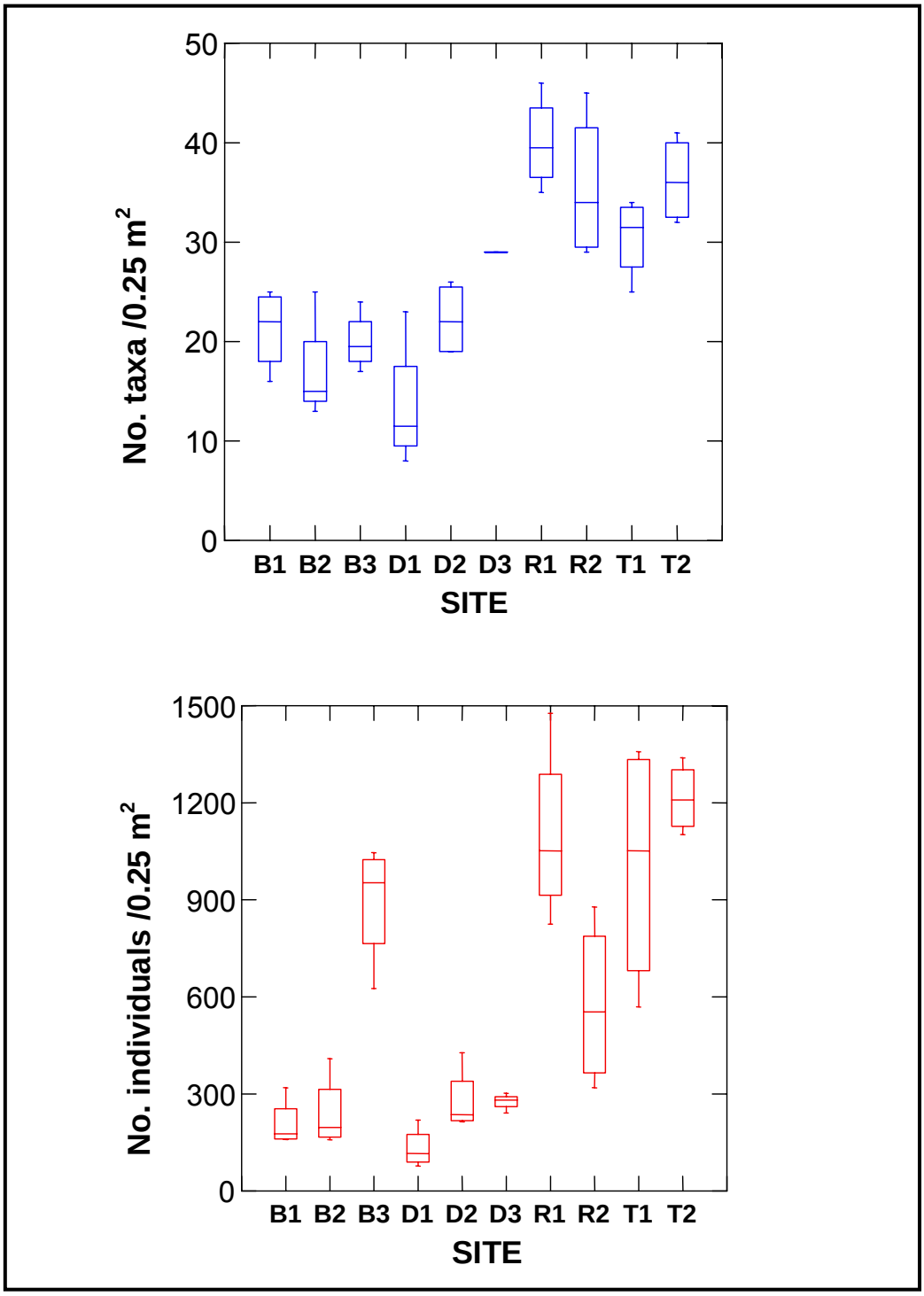

Figure 3.5 **Total number of taxa and individuals at each intertidal site in Akaroa Harbour**

Number of samples at each site = 4
NOTE: horizontal bar = median, box = interquartile range, whisker ends = 5% and 95%iles

Samples collected from the sites in Barrys Bay (B1, B2 and B3) and Duvuachelle (D1 and D2) contained fewer taxa than those collected from Robinsons Bay (R1 and R2) and Takamatua Bay (T1 and T2). This was also the case for the number of individuals, except at site B3 where there were many more individuals than at the other sites in Barrys Bay and Duvauchelle. The numbers of individuals present at site B3 is comparable to the numbers present at the sites in Robinsons Bay and Takamatua Bay.

The macrobiota at Barrys Bay site B3 differed to that at the other sites (B1 and B2) in this bay in that the samples contained more polychaete and crustacean individuals (Figure 3.6; Appendix IV). The number of polychaete individuals at B3 was comparable to that at the sites in Takamatua Bay. At the sites in Duvauchelle there were fewer total individuals, including fewer mollusc, polychaete and crustacean individuals and total taxa at site D1 than at sites D2 and D3. The abundances of mollusc, polychaetes and crustaceans and the number of total taxa at sites D1 and D2 were comparable. The samples from Robinsons Bay site R1 contained more mollusc and crustacean individuals than did samples from all other sites including site R2. In Takamatua Bay the samples from site T2 contained more mollusc and generally more crustacean individuals than the samples collected from T1.

The multidimensional scaling (MDS) plot of all biological samples (Figure 3.7) shows that at sites B1, B3, T1, T2 and R1 the macrobiota was very similar in each of the samples (that is, the four samples at each site are generally close together on the MDS plot). At each of sites B2, D1, D2, D3 and R2, one of the replicate samples differed somewhat from the other samples collected at the site. The MDS plot of the sites (Figure 3.8) shows that the macrobiota was very similar at sites T1 and T2 (in close proximity on the MDS plot) in Takamatua Bay. In each of the other bays the macrobiota at each site differed. However, in general, the macrobiota within each bay was more similar than it was to the macrobiota in each of the other bays (that is, on the MDS plot, sites in a bay were closer to each other than they were to sites in other bays).

3.2.2 Abundant taxa

3.2.2.1 Bivalves

The most abundant bivalve species were *Austrovenus stutchburyi* (cockles) and *Macomona liliana* (wedge shells). Both species were among the five most abundant taxa present in the samples. Where present, there were 1 (D3d) to 784 (R1a) cockles and 2 (D1d) to 56 (B1d) wedge shells per 0.25 m^2. There was considerable variability in the density of cockles and wedge shells per 0.25 m^2, between the four samples collected at each site (Figure 3.9). The highest variability in the density of cockles/0.25 m^2 was at R1 and the lowest variability was at D1, while the highest variability in the density of wedge shells/0.25 m^2 was at D3 and the lowest variability was at D1.

In Barrys Bay, Duvauchelle and Robinsons Bay there were differences in the density of cockles, between sites within each bay; there were more cockles at B2 than B1, more at D2 than D1 and more at R1 than R2. There were also differences in the density of cockles between sites in different bays. For example, there were more cockles at site T2 than at sites D1, D2 and D3 and more at site R1 than at any of the other sites. In Barrys Bay and Duvauchelle there were also differences in the density of wedge shells between sites within each bay; there were more at B1 than at B2 and B3, more at B2 than at B3 and more at D3 than at D2 and D1. As with cockles, there were also differences, in the density of wedge shells, between sites in different bays. For example, there were more wedge shells at T2 than at D1, D2 and B3.

The total wet weight (g) of each species at each site is presented graphically (Figures 3.10 and 3.11). The highest wet weight, of cockles was in samples from sites R1 and B2, and of wedge shells was in samples from site B1, T2 and T1 (1 sample only). At sites B1, B3, D1, D2, and T2 the wet weight of cockles and wedge shells was similar in each the four samples from a site. At sites B2, D3, R1, R2 and T1 there was considerable variability in the wet weight of these bivalves between the four samples from a site (Figures 3.10 and 3.11).

The size frequency data are only presented for sites where there were more than 120 cockles (Figure 3.12) and more than 75 wedge shells (Figure 3.13). The cockles at site B2 were generally larger than those from any other site. The difference in the size of individuals between sites, e.g. between sites B2 and R2, accounts for the disparity between the abundance of, and total wet weight of cockles.

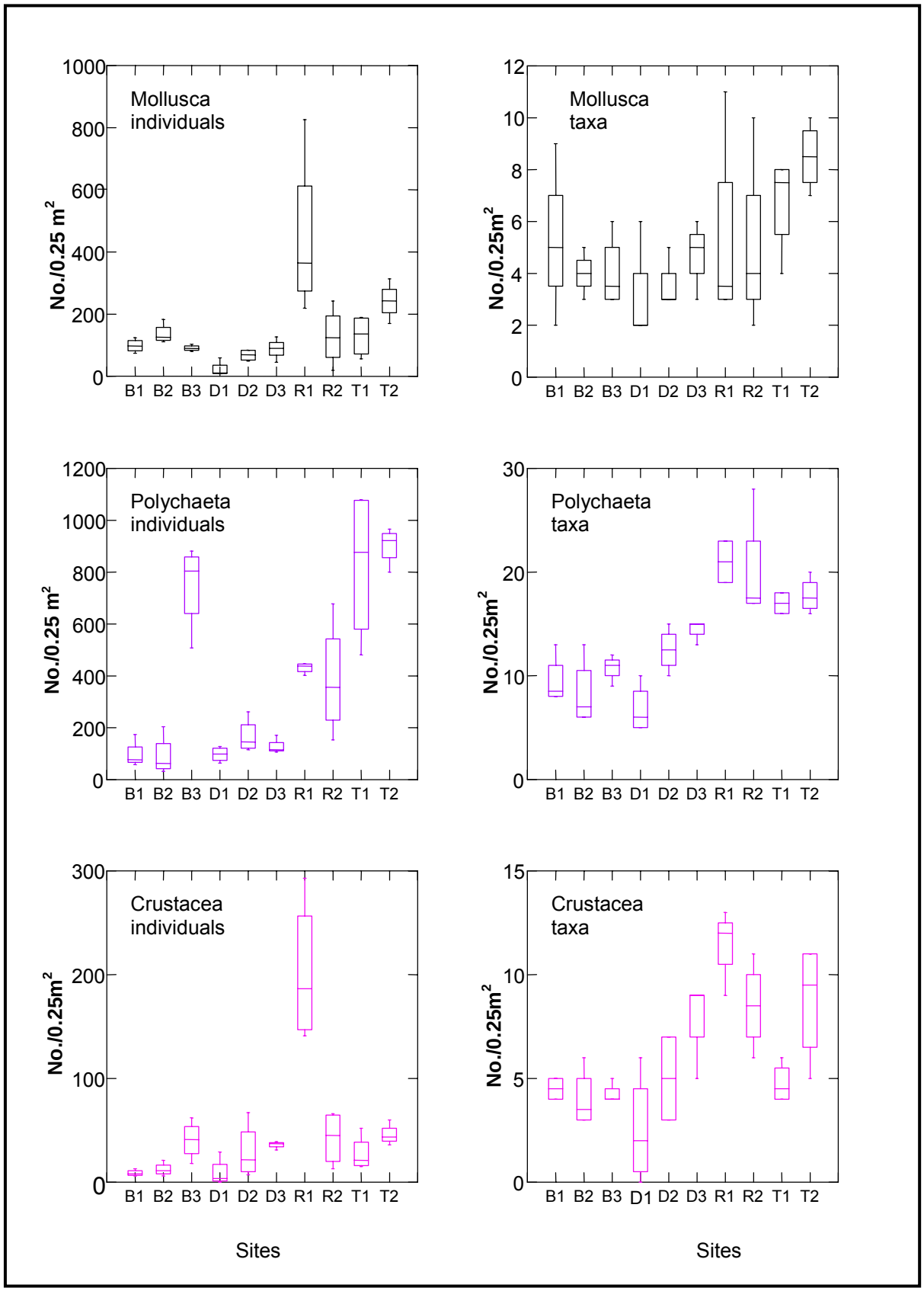

Figure 3.6 **Number of individuals and taxa of Mollusca, Polychaeta and Crustacea at each intertidal site in Akaroa Harbour** (Number of samples at each site = 4)

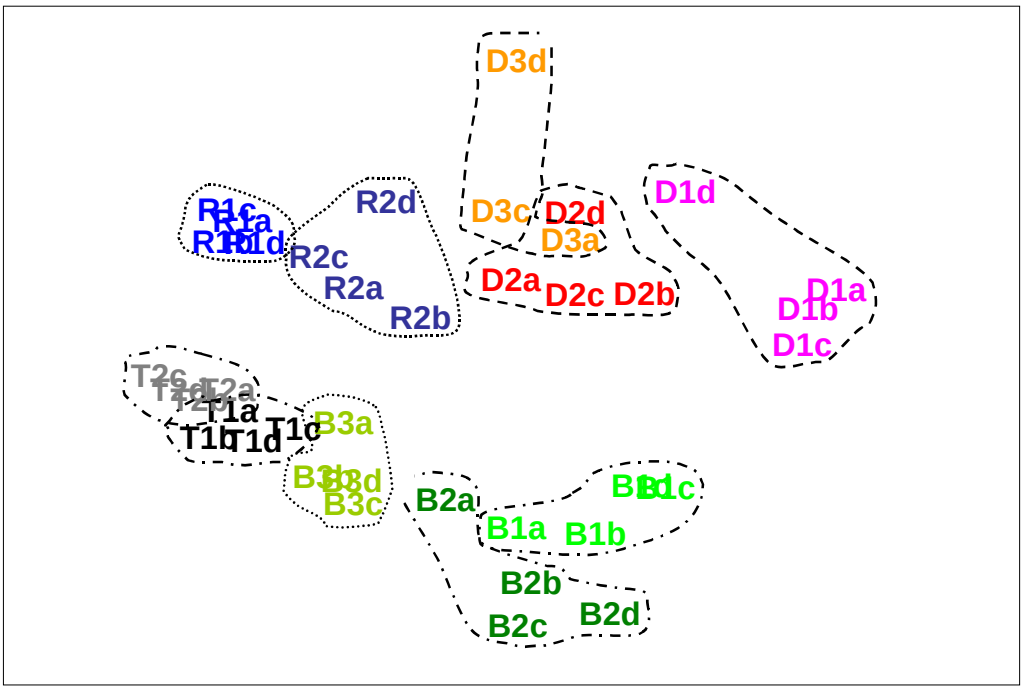

Figure 3.7 **MDS plot of the macrobiota in each sample from intertidal sites in Akaroa Harbour (Stress = 0.12)**

Note: All samples from one site are in the same colour and have been grouped using a black dotted line

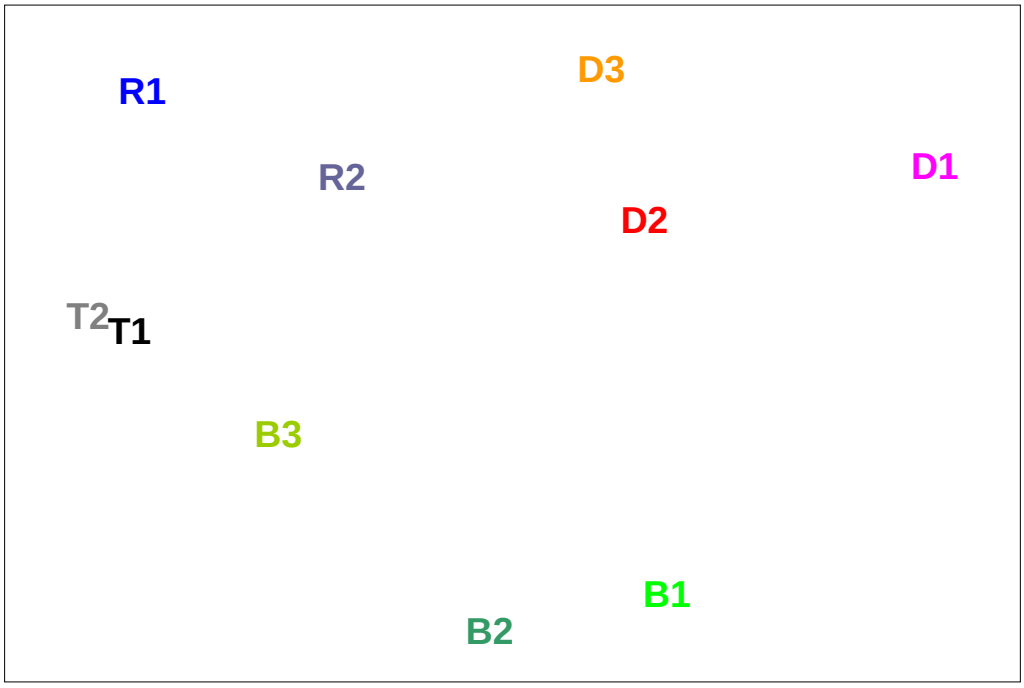

Figure 3.8 **MDS plot of the macrobiota (average of the samples) at each intertidal site in Akaroa Harbour (Stress = 0.08)**

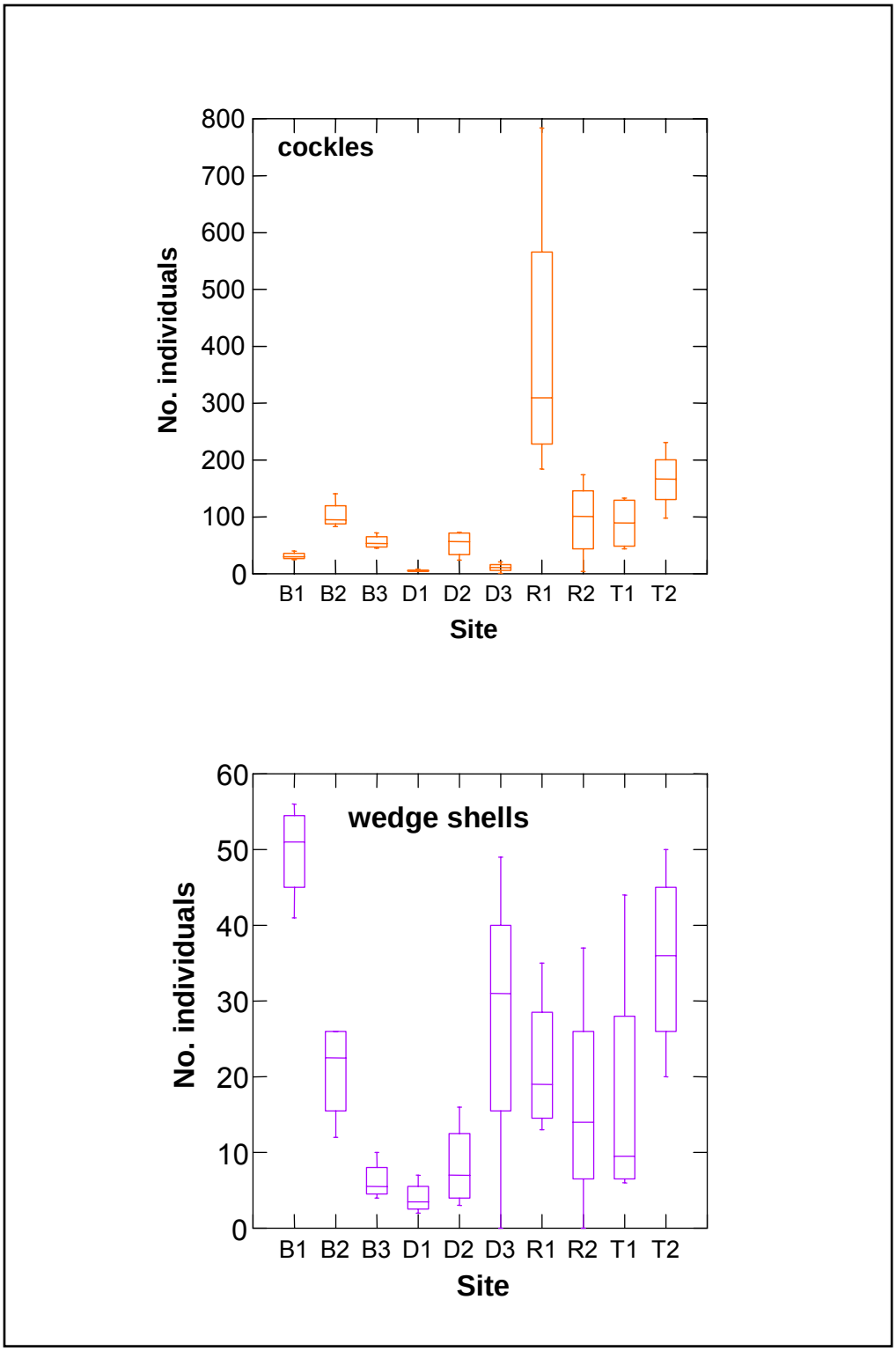

Figure 3.9 **Number of cockle and wedge shell individuals at each intertidal site in Akaroa Harbour**

Number of samples at each site = 4

NOTE: horizontal bar = median, box = interquartile range, whisker ends = 5% and 95%iles

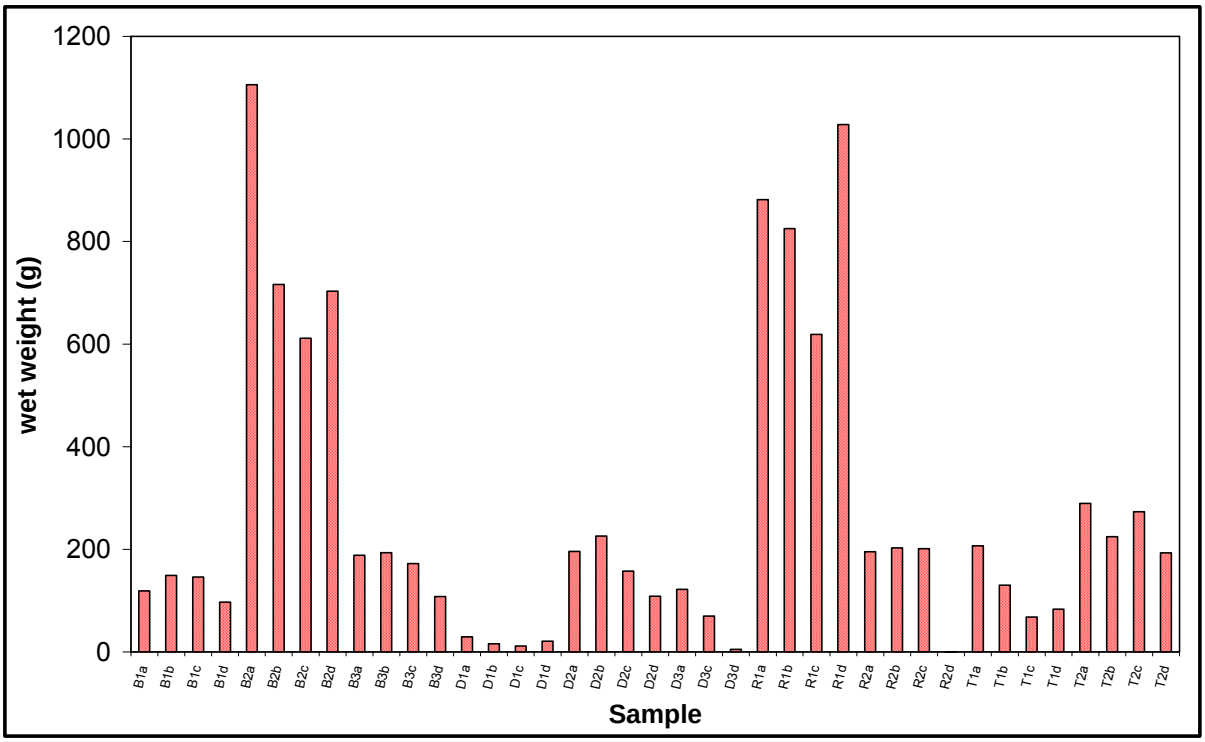

Figure 3.10 **Wet weight (g) of cockles in each sample at each intertidal site in Akaroa Harbour**

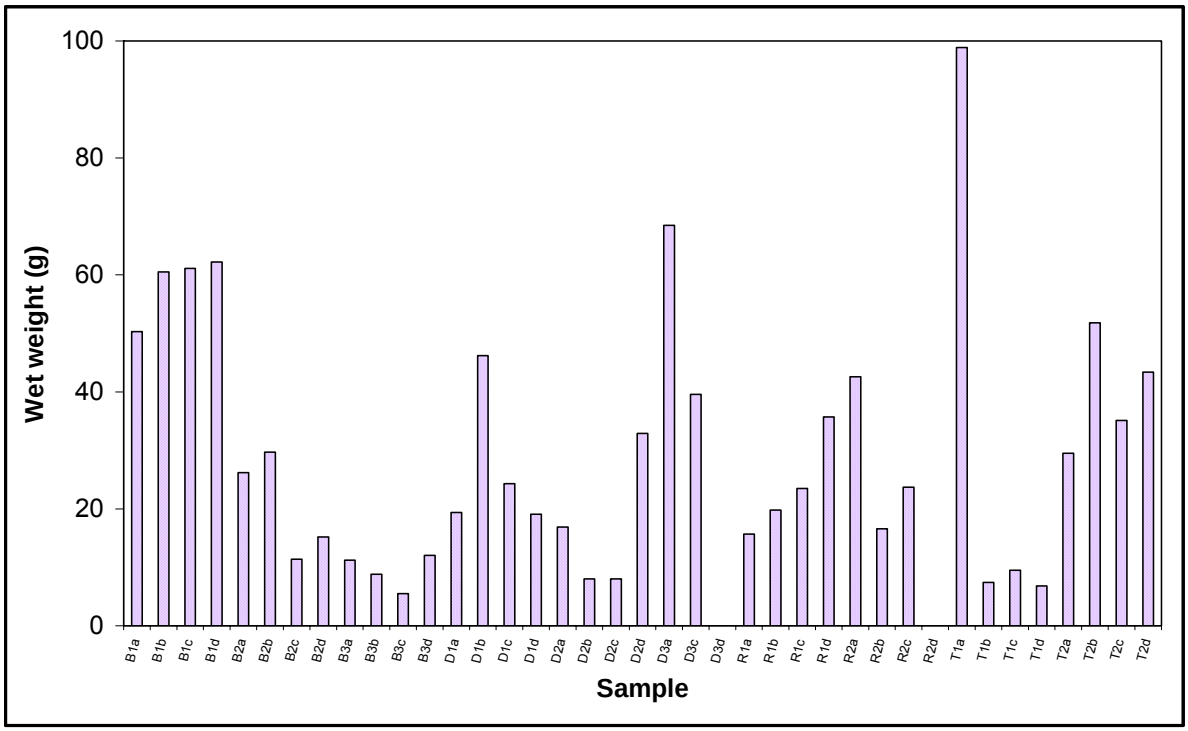

Figure 3.11 **Wet weight (g) of wedge shells in each sample at each intertidal site in Akaroa Harbour**

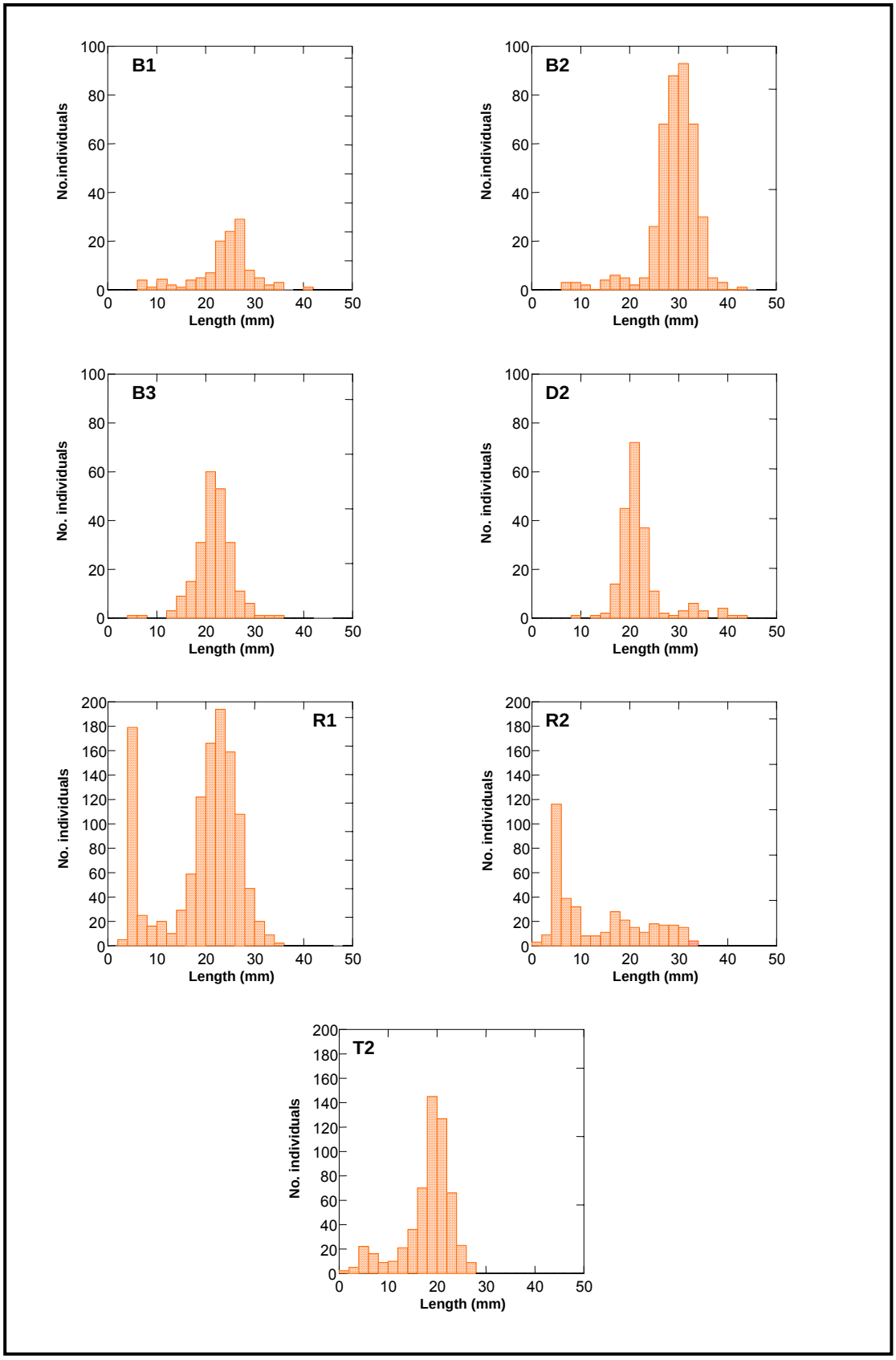

Figure 3.12: Size (length) frequency of cockles at seven intertidal sites in Akaroa Harbour

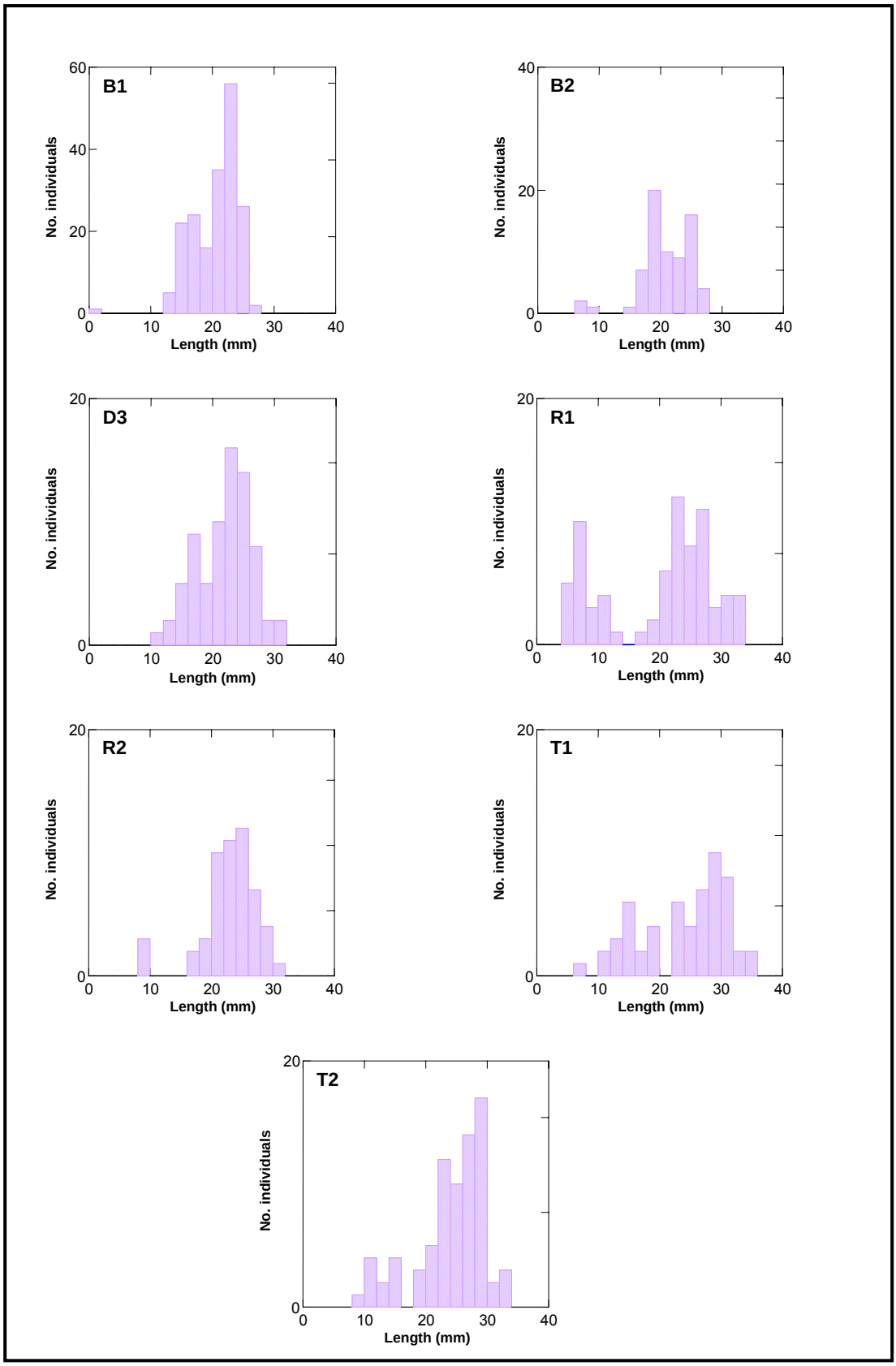

Figure 3.12 **Size (length) frequency of wedge shells at seven intertidal sites in Akaroa Harbour**

For both cockles and wedge shells, there were considerable differences in the size of individuals between sites. For example, at sites R1 and R2 a considerable number of the cockle individuals were smaller than 10 mm while at sites B3 and D2 almost all cockle individuals were larger than 10 mm.

3.2.2.2 Polychaetes

The most abundant taxon was the deposit feeding polychaete *Heteromastus filiformis,* with *Boccardia* spp. and *Monticellina* sp. among the five most abundant taxa.

Heteromastus filiformis was present in every sample at every site (Figure 3.14). The density of *H. filiformis* in samples from sites B3, T1 and T2 was greater (by more than at least 295 individuals) than that at all other sites. At site R1 there were 148-204 individuals/0.25 m^2 while at all other sites the samples contained fewer that 110 individuals/0.25 m^2. At sites B3 and T1 the number of individuals per 0.25 m^2 was very variable (371–735 at site B3 and 295–630 at site T1) with lower variability per 0.25 m^2 at site T2 (490–601 individuals).

The taxon *Boccardia* spp. includes two very similar species, *Boccardia syrtis* and *Boccardia acus.* Identification of these species requires the presence of the posterior end of the individual. However many individuals were broken, with few having an attached posterior end, making species identification difficult. *Boccardia syrtis* lives in a sand grain tube in sand and muddy sand, while *Boccardia acus* bores into mollusc shells, and in particular, cockle shells (Read, 1975). Live and dead cockle shells that were collected from Akaroa Harbour were infested with *Boccardia acus* with these polychaetes removed from the shell during sorting; in hindsight it was unfortunate that these individuals were not kept separate to aid in the differentiation of the species. For all sites, except R1 and R2, there appears to be a similarity in the pattern of abundances of *Boccardia* spp. (Figure 3.14) and cockles (Figure 3.9). This pattern suggests that many or all of the individuals present at these sites were *Boccardia acus.* The mismatch between cockle and *Boccardia* spp. abundances at site R1, is suggestive of a low infestation of cockles by *Boccardia acus.* At site R2, the mismatch could result from either a high infestation of live cockles by *Boccardia acus* or from the infestation of dead cockle shells by *Boccardia acus or* from an abundance of *Boccardia syrtis.*

The deposit feeding polychaete *Monticellina* sp. only occurred at sites B1, T1 and T2 and was most abundant at site T1 (Figure 3.14). This distribution suggests that this polychaete has very specific environmental requirements.

3.2.2.3 Crustaceans

The amphipod *Aora maculata*? was the most abundant crustacean and the sixth most abundant taxon. This amphipod was present in low numbers (< 23 individuals per 0.25 m^2) at all sites except R1 where 71-220 individuals per 0.25 m^2 were present (Figure 3.14).

The second most abundant crustacean was Amphipod sp.A. Amphipod sp.A was not present at site D1 and at sites B1 and B2 there were 2 or less individuals/0.25 m^2 (Figure 3.14). At each of the remaining sites there was considerable variability in the number of individuals present in each sample. However, the total number of individuals present per site (i.e. the total number in all samples from a site), except D2, was comparable.

The stalk-eyed mud crab *Macrophthalmus hirtipes* was the third most abundant crustacean. *M. hirtipes* was not present at sites D1 and D2 and at sites B2 and T1 there were 3 or less individuals/0.25 m^2 (Figure 3.14). At each of the remaining sites there was considerable variability in the number of individuals present per 0.25 m^2, with the total number of individuals present per site being quite different.

3.2.2.4 Seagrass

The seagrass *Zostera* sp. (Figure 3.15) was present at all sites and present in all but two samples (B1d and B3d) (Figure 3.16). The greatest cover of *Zostera* sp. was in the samples from site R1. The *Zostera* cover at sites B1, B2 and R1 was similar in each the four replicate samples. At all other sites there was considerable variability in *Zostera* cover between the samples collected at a site.

Coverage of the mid-low shore flat by *Zostera* sp. varied between sites within each bay. There was more *Zostera* sp. cover at B3 than at B1 and B2, more at D2 than D1, more at D3 than at D2 and D1, more at R1 than at R2 and more at T2 than at T1.

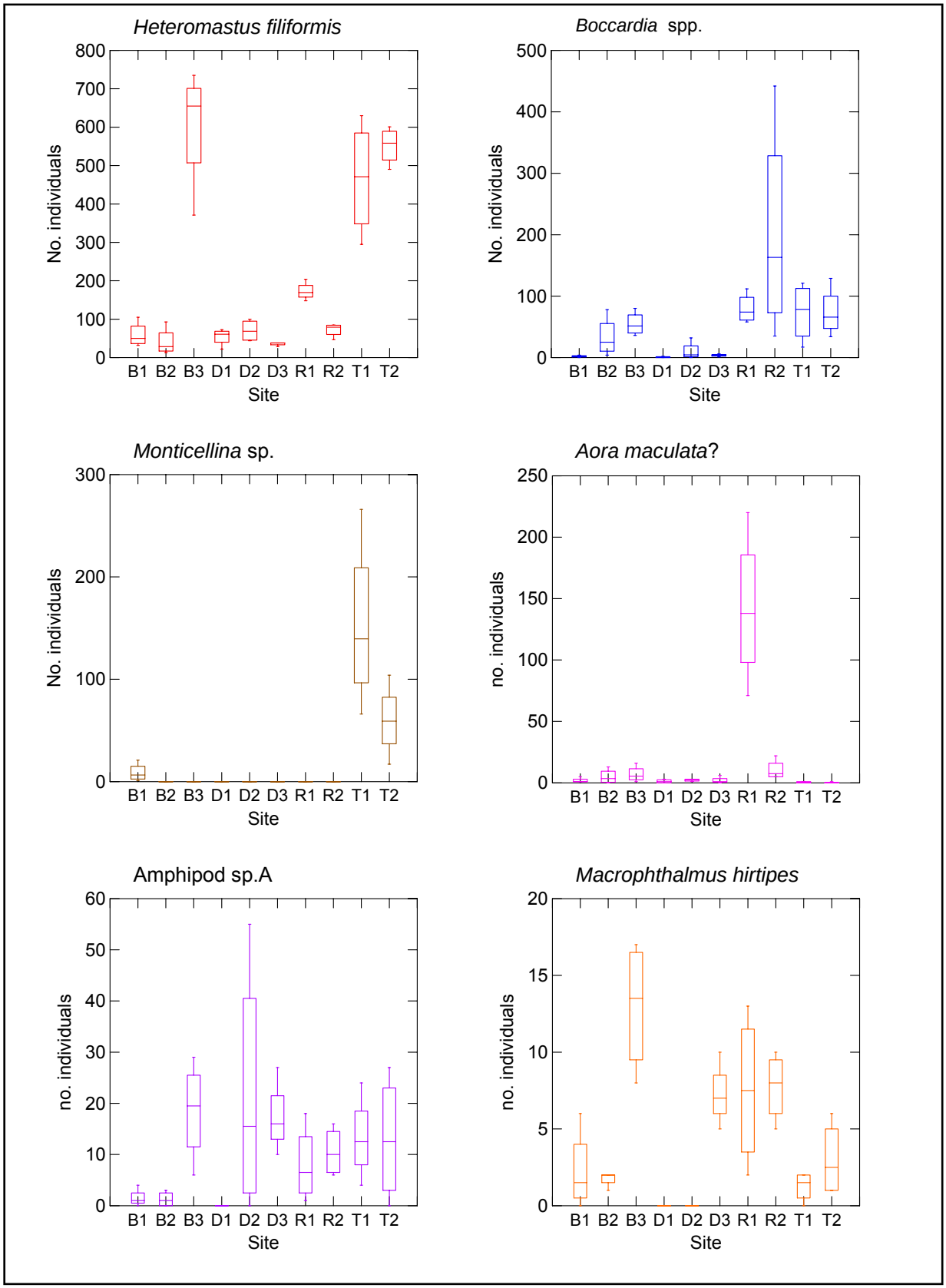

Figure 3.13 **Number of individuals of three polychaete and three arthropod taxa at each intertidal site in Akaroa Harbour** (Number of samples at each site = 4)

NOTE: horizontal bar = median, box = interquartile range, whisker ends = 5% and 95%iles

Figure 3.14 Zostera sp.

A – *Zostera* sp. on the intertidal flat in Robinsons Bay
B – close up of *Zostera* sp. and underlying cockle shells

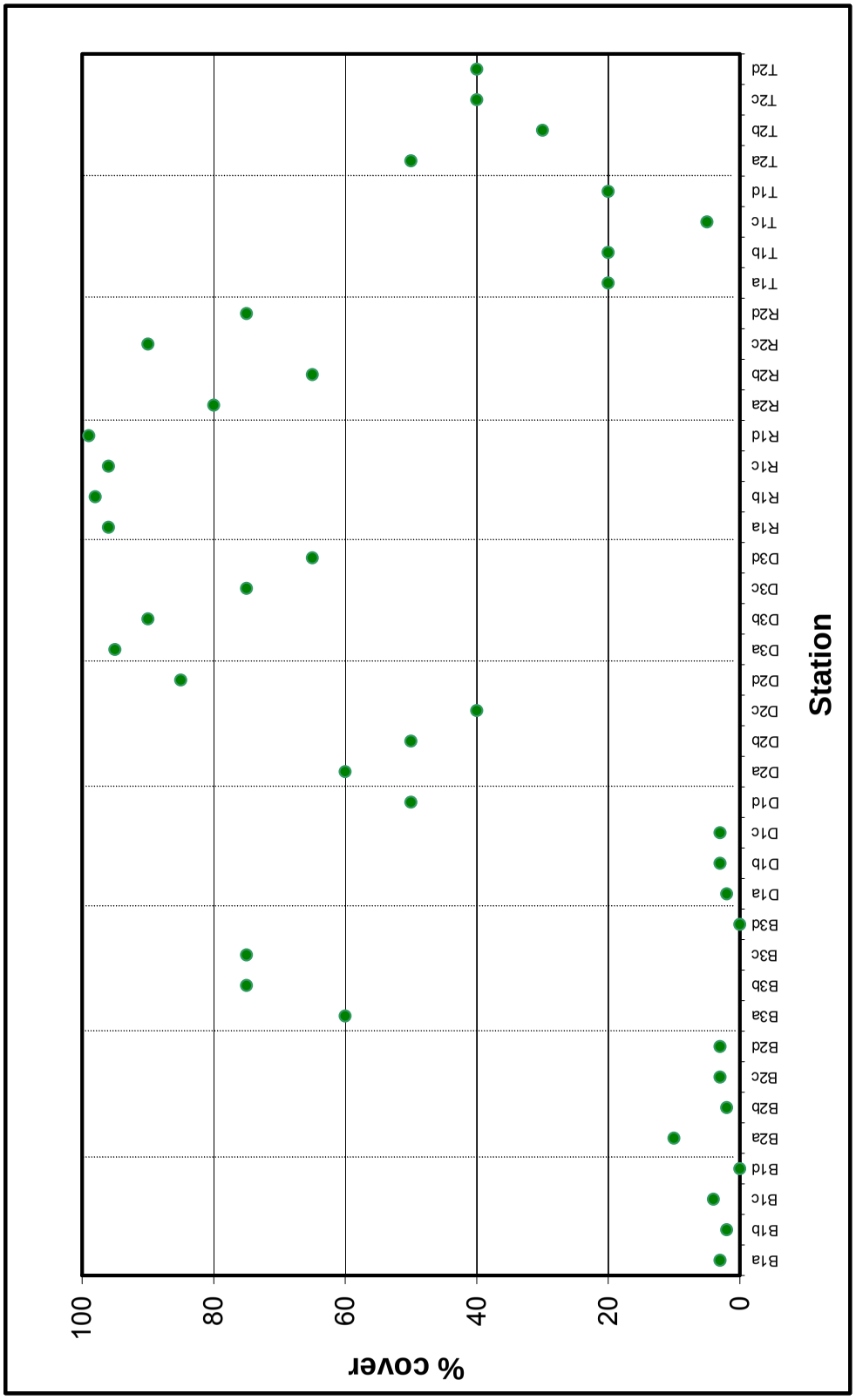

Figure 3.15 Zostera sp. cover (%) in each sample at each intertidal site in Akaroa Harbour

4 Discussion

The intertidal flats of Akaroa Harbour are classified as Areas of Significant Natural Value within Schedule 1 of the Proposed Regional Coastal Environment Plan (Environment Canterbury, 2003). For these flats this classification is based on one or more of the following values:

- Maori cultural values
- Protected areas
- Wetland, estuaries and coastal lagoons
- Marine mammals and birds
- Ecosystems, Flora and Fauna habitats

Such a classification is to assist in the management of activities, such as subdivision development, which are likely to have an adverse affect on an area of significant natural value. It is also to ensure the precautionary approach is applied when considering applications for resource consents where the effects are as yet unknown or little understood, or where the functioning of marine ecosystems is poorly understood. Prior to this study nothing was known about the habitats and marine ecosystem of the flats of Barrys Bay, Duvauchelle, Robinsons Bay and Takamatua Bay. This study goes some way in providing information on the habitats and marine ecosystem which is an insight into the existing natural values of four intertidal flats of inner Akaroa Harbour.

The sediment in Barrys Bay differed from that in the other bays in that it was almost entirely mud (93-98%); in the other bays sand (73-96.5%) dominated. This suggests that the flat in Barrys Bay is, of the four studied, the least exposed to wind-generated waves. Such waves entrain fine (i.e. silt and clay) sediment which then settles to the bottom in areas of least water movement. The predominantly sandy sediments of Duvauchelle, Robinsons Bay and Takamatua Bay indicate that in these bays the sediment is subjected to the natural entrainment and redistribution resulting from exposure to wind-generated waves. At 5-6 m depth in inner Akaroa Harbour the sediment is predominantly mud; this indicates that the wave and current regime in the inner harbour results in the deposition of fine sediment some distance from shore (Fenwick, 2004).

The organic matter content differed between sites, with no correlation of organic matter content with sediment grain size (% sand, % mud) or with percent cover of seagrass (a likely contributor of organic matter). Organic content is usually correlated to grain size. For example, in the subtidal sediments of Akaroa Harbour the muddy sediment contains 3.5-3.67% and the sandy sediment contains 2-2.6% organic matter (Fenwick, 2004) and in the subtidal sediments of Wellington Harbour the sandy sediment contains 1.4-3% and the muddy sediment contains 3.5-7.7 % organic matter (Goff, *et al.,* 1998; Haddon and Wear 1993; Wear and Anderlini, 1995). Compared to the Akaroa Harbour subtidal sediment values:

- the muddy sediment at sites B1 and B2 in Barrys Bay contained less, while that at site B3 in Barrys Bay contained more organic matter than would have been expected
- the sandy sediment at sites T1 and T2 in Takamatua Bay contained more while that at sites D1, D2 and D3 in Duvauchelle and R1 and R2 in Robinsons Bay contained less organic matter than would have been expected.

The higher organic content at B3 than at B1 and B2, suggests organic matter inputs in the vicinity of B3. This could originate from either the Barrys Bay stream or the dense seagrass beds in the vicinity or from a combination of both sources. The higher organic content at sites T1 and T2 than at sites D1, D2 and D3, where the grain sizes were comparable, indicates an input of organic matter at sites T1 and T2. This input could be from seagrass; however, there was a higher percentage cover of seagrass at D2 and D3 than at T1 and T2. Thus the difference in organic content between the Takamatua Bay and the Duvauchelle sites suggests another source, possibly the Takamatua Stream, which discharges into inner Takamatua Bay and, at all but high tide, flows across the flat.

The total nitrogen concentrations ranged from 800-2600 mg/kg. A TN concentration of 1300 mg/kg has been recorded in the subtidal sediments of inner Akaroa Harbour (Fenwick, 2004). Hence the TN concentrations at four intertidal sites were less than, while concentrations at sites B3 (1600 mg/kg), R2 (1700 mg/kg) and R1 (2600 mg/kg) were higher than the concentration in subtidal

sediment. The total phosphorus concentration ranged from 390-830 mg/kg. TP concentrations of 640-730 mg/kg have been recorded in the subtidal sediments of inner Akaroa Harbour (Fenwick, 2004). Hence the TP concentration at R1 (830 mg/kg) was higher, that at B1 comparable to, and the concentrations at all other sites were less than, the concentrations in subtidal sediment. The strong correlation between TN and TP, and the lack of correlation of TN and TP with sediment grain size indicates a common external source of these nutrients. The likely sources of TN and TP are the streams that drain into each bay and the populations of waterfowl that feed on the flats. Differences between bays could arise from differences in:

- stream flows
- nutrient inputs into the streams
- the waterfowl populations on the different flats.

A diversity and abundance of macrobiota are found on and in the flats of inner Akaroa Harbour. The taxa present are typical of enclosed harbour flats in New Zealand (Morton and Miller, 1968; Grange, 1977; Bolton, 1991) with many of the taxa present also common in New Zealand estuaries (Marsden, 2000; Robertson *et al,* 2002). The 104 taxa recorded in this study are many more than the 64 taxa recorded from the intertidal flats in Manukau Harbour (Grange, 1977) and the 74 taxa recorded from the intertidal flats of Shakespeare Bay in inner Queen Charlotte Sound (Bolton, 1991). From the Manukau, Shakespeare Bay and Akaroa Harbour intertidal flats, 30, 21 and 18 mollusc taxa, 19, 28 and 51 polychaete taxa and 8, 13 and 25 crustacean taxa respectively, were identified. These differences could result from differences in the:

- diversity of the habitat sampled
- sample size
- total volume of sediment sampled
- mesh size (for sieving samples)
- resolution of identifications; and possibly also to
- geographic differences.

In this study an area of 9.75 m^2 was sampled to a depth of 15 cm and sieved through a 1 mm mesh. In Manukau Harbour an area of 5.7 m^2 was sampled to a depth of 10 cm and sieved through a 1mm mesh. In Shakespeare Bay an area of 1.6 m^2 was sampled to a depth of 15 cm and sieved through a 0.5 mm mesh and an area of 1.7 m^2 was sampled to a depth of 10 cm and sieved through a 2.00 mm mesh. That is, differences in the total volume of sediment sampled and mesh size, could account for the differences between these three sites in the number of taxa recorded. The diversity of habitats sampled in Akaroa Harbour (mud, sand, percent seagrass cover) could also account for the higher number of taxa present in Akaroa Harbour than in these other areas. Seagrass provides habitat and is a food source for a range of organisms, including gastropod molluscs and crustaceans (Woods and Schiel, 1997). There is no record of seagrass from the intertidal flats of Manukau Harbour. However seagrass was present in some of the Shakespeare Bay samples.

The macrobiota densities varied from 77-1477 individuals/0.25 m^2 (308-5908 individuals/m^2). This is comparable to macrobiota densities at sites in the Avon-Heathcote Estuary/Ihutai (excluding sites adjacent to the Christchurch City oxidation ponds discharge) where 710-5535 individuals/m^2 have been recorded (Marsden, 2000). The macrobiota densities in the intertidal samples are lower than the 1283-15,432 individuals/m^2 present in the subtidal samples from this harbour (Fenwick, 2004).

At sites where the samples contained a high number of individuals (i.e. B3 (626-1046/0.25 m^2), R1 (825-1477/0.25 m^2), R2 (319-878/0.25 m^2), T1 (569-1358/0.25 m^2) and T2 (1102-1339/0.25 m^2)), one or two taxa were very abundant. The taxa most responsible for the high number of individuals differed between sites. At site B2 the polychaete *Heteromastus filiformis,* at site R1 the amphipod *Aora maculata*? and the bivalve mollusc *Austrovenus stutchburyi*, at site R2 the polychaete taxa *Boccardia* spp., and at sites T1 and T2 the polychaetes *Heteromastus filiformis* and *Monticellina* sp. were present in high numbers. These between-site differences in the abundant taxa, indicate that the macrobiota at each site are generally different from that at other sites even when the sites are in the same bay. These differences are evidenced by the relative positioning of sites on the MDS plot with sites from the same bay separated on the plot. However, on the MDS

plot sites in a bay are in closer proximity to each other than they are to sites in other bays. That is, the macrobiota present at sites within in a bay were more similar than they were to the macrobiota in each of the other bays. The difference in the macrobiota between sites in a bay and between sites in different bays is a reflection of differences in the suite of natural physical and biological factors affecting the flats in each bay. The physical factors include aspect, wave action, water currents, stream flows, inputs from the land (related to land use in the catchment), sediment grain size, sediment organic matter content and sediment TN and TP concentrations. The biological factors include inter and intra specific competition, predation, seagass cover and waterfowl populations. In addition the anthropogenic influences of cockle gathering and stormwater (from housing areas) and rainfall (from roads) runoff likely affect a range of physical and biological factors of the flats which in turn affects the distribution and abundance of the macrobiota.

The bivalve molluscs *Austrovenus stutchburyi* and *Macomona liliana* are an important part of the biological community of the intertidal flats in each bay. They make up most of the biomass in the sediments, and cockles in particular, are an important food source for wading birds, flounders and predatory molluscs. Cockles can live in mud and sandy sediment and burrow 2-4 cm deep into such sediment. Cockles, being indiscriminant suspension feeders, occur at the mid-lower shore level because they need to be covered by water for a considerable period of time to feed (Morton and Miller, 1968; Jones, 1983). Wedge shells live in firm sediment at the mid-low shore (Morton and Miller, 1968; Jones, 1983) and burrow to a depth of 15-20 cm in the sediment. They do not compete with cockles for space because these species occupy different depths in the sediment. Wedge shells are deposit feeders; this means that they do not need to be covered by water to feed.

The abundance, biomass and size of cockles and wedge shells varied both within and between bays. This reflects differences in the suite of natural physical and biological factors affecting the flats in each bay. However some of the differences in the abundance and size of cockles could also be due to the harvesting of this species by humans. For example, the larger cockles in the middle of Barrys Bay compared to sites in other bays may be due to the muddy sediment making cockle harvesting unpleasant and difficult, so that cockles in this bay are left to grow larger. Cockles are frequently harvested from Duvauchelle by both day-visitors and holiday-makers (local resident, Pers. Comm., November 2003), apparently reducing the density and total size of cockles in this bay. It is also likely that cockles are harvested from the intertidal flat in Robinsons Bay given its proximity to the highway.

The highest macrobiota densities and diversities were in Robinsons Bay and Takamatua Bay. The intertidal flat of Robinsons Bay had the greatest seagrass cover and the highest density of cockles. These results indicate that the intertidal flat of Robinsons Bay is the biologically richest of the four flats of Akaroa Harbour. However, all of the flats studied support a diversity and abundance of taxa. The information obtained in this study supports the classification of these intertidal flats as Areas of Significant Natural Value. To ensure that the sediments and macrobiota of these flats retain their present high ecological values any proposed developments, for example subdivision of land for housing or changes in rural land use in any of the contributing catchments should be thoroughly assessed with respect to likely impacts on the associated intertidal flat. If resource consents for such developments are to be given appropriate consideration, the AEE should contain information on the potential effects of the development on the sediments and macrobiota of the intertidal flat. If such resource consents are then granted, it may be advisable to include a condition requiring baseline sampling followed by routine monitoring of the sediment and macrobiota of the relevant intertidal flat.

As already described, there are differences in the macrobiota both within and between bays. The implication of this is that any biological monitoring to assess the long-term changes in the biological communities of the intertidal flats of Akaroa Harbour must include sites in each of the bays. This is entirely appropriate given that the factors likely to result in changes in the macrobiota are likely to be different in each bay given differences in:

- land use in the different stream catchments

- stream flows in the different catchments
- the number of houses, and hence stormwater runoff into the different bays
- the proximity of the road and hence rainfall runoff to the shore into the different bays.

5 Conclusions

The intertidal flats of Barrys Bay, Duvauchelle, Robinsons Bay and Takamatua Bay in inner Akaroa Harbour are extensive and are classified as Areas of Significant Natural Value in the Proposed Regional Coastal Environment Plan. The sediments and macrobiota of these intertidal flats were investigated here for the first time.

The sediments in Barrys Bay were predominantly mud while those in Duvauchelle, Takamatua Bay and Robinsons Bay were predominantly sand. The sediment organic matter content over all sites was low to moderate (i.e. 0.5 – 4.6%). The TN (800-2600 mg/Kg) and TP (390-830 mg/kg) concentrations were low to high when compared to Akaroa Harbour subtidal sediment concentrations. A multidimensional scaling plot of sites based on the sediment characteristics of % sand, % silt, % clay, OM and TN and TP concentrations, shows there are distinct differences in the sediment characteristics between bays.

One hundred and four taxa were present in the samples. The macrobiota present at sites within in a bay were more similar than they were to the macrobiota in each of the other bays. The macrobiota within in each bay were distinct from that in other bays. These differences result from differences in the presence and abundance of molluscs, polychaetes and crustaceans at the sites studied. The difference in the macrobiota within and between bays is a reflection of differences in the suite of natural physical and biological factors operating in each bay. With respect to the biological community, including the density of seagrass and cockles, the flats of Robinsons Bay are biologically the richest of those studied.

Given that these intertidal flats support a diversity and abundance of macrobiota with seagrass beds present on each flat, any proposed subdivision of land for housing or changes in land use in any catchment feeding these bays, should be assessed for potential impacts on the sediments and macrobiota of the associated flat. That is, the extensive flats of inner Akaroa Harbour need to be protected as much as possible from direct and indirect anthropogenic impacts that could have a detrimental impact on the sediments and macrobiota present. In addition in granting a resource consent in any contributing catchment consideration should be given to mudflat impacts including the possible need for conditions requiring relevant monitoring of the sediment and macrobiota of the associated intertidal flat.

6 Future investigations and monitoring

Any future marine ecosystem work on the intertidal flats of the bays of inner Akaroa Harbour should be for long-term monitoring. Monitoring should commence as soon as possible to establish baselines of natural variability. The monitoring programme must be designed to ensure that spatial and temporal impacts that are not due to natural variability can be detected. It is suggested that in the future there is routine monitoring to assess:

1. the density and size of cockles and wedge shells present in the flats in each bay
2. the % cover of *Zostera* sp. on the flats in each bay
3. the diversity and abundance of selected taxa (indicator organisms).

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Appendix I: Location of each site

Site Label	Easting	Northing
B1	2503687	5716147
B2	2503444	5716185
B3	2503074	5715905
D1	2504967	5717165
D2	2504688	5717194
D3	2504296	5717105
R1	2506825	5715632
R2	2506564	5715998
T1	2506971	5713914
T2	2506990	5714179

Appendix II: Sediment grain size (percent in each phi class) at each intertidal site in Akaroa harbour

phi	B1	B2	B3	D1	D2	D3	R1	R2	T1	T2
9.0	2.78	2.54	4.07	1.14	1.01	1.11	1.11	1.62	1.72	2.19
8.0	0.83	1.66	2.76	0.00	0.00	0.00	0.30	0.29	0.20	0.52
7.0	1.67	2.43	5.24	0.00	0.30	0.40	0.10	0.38	0.91	0.63
6.0	2.09	3.20	10.48	0.00	0.00	0.10	0.40	0.38	0.91	1.46
5.5	1.53	1.88	8.59	0.10	0.40	0.10	0.00	0.10	0.81	0.83
5.0	4.59	6.19	12.66	0.10	0.81	0.81	0.30	1.05	2.12	2.81
4.5	15.72	26.08	17.32	2.91	4.76	2.12	0.50	2.10	5.06	6.77
4.0	68.17	54.58	34.92	23.17	19.83	14.30	1.11	5.43	9.81	13.86
3.5	0.01	0.03	0.07	36.85	36.98	36.36	4.94	20.52	24.21	28.92
3.0	0.03	0.02	0.06	29.74	25.76	29.42	27.82	44.48	16.83	14.77
2.5	0.02	0.03	0.08	5.76	8.03	11.85	32.16	20.31	7.70	8.06
2.0	0.02	0.04	0.11	0.17	0.97	2.21	11.14	2.24	3.78	4.43
1.5	0.03	0.05	0.20	0.01	0.46	0.66	7.33	0.41	3.52	4.09
1.0	0.04	0.08	0.27	0.00	0.14	0.17	1.82	0.12	2.07	2.32
0.5	0.09	0.05	0.44	0.01	0.09	0.11	1.07	0.11	2.30	2.25
0.0	0.14	0.08	0.49	0.02	0.07	0.04	0.99	0.11	2.24	1.72
-0.5	2.23	1.07	2.24	0.00	0.39	0.24	8.89	0.35	6.07	1.75
-1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.72	2.62

Description of each phi

phi range	description
-1	granule
0 to -1	very coarse sand
1 to 0	coarse sand
2 to 1	medium sand
3 to 2	fine sand
4 to 3	very fine sand
5 to 4	coarse silt
6 to 5	medium silt
7 to 6	fine silt
8 to 7	very fine silt
9	Clay

Appendix III

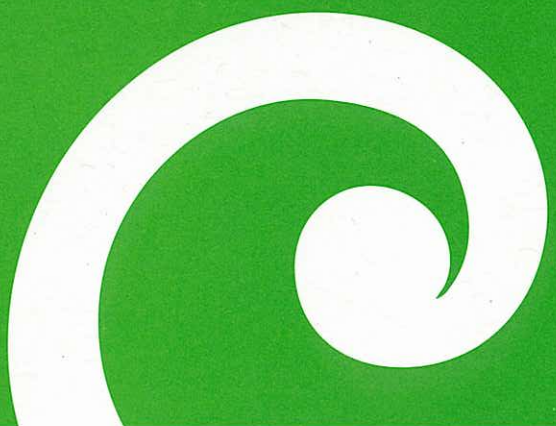
			B1	B2	B3	D1	D2	D3	T1	T2	R1	R2
MOLLUSCA	Bivalvia	*Arthritica bifurca*	1.25	11	27.25	0	0.5	0	4.25	6.25	1.25	1
		Austrovenus stutchburyi	31.25	103.5	56	5.75	52.5	11.00	89	165.5	396.75	95
		Macomona liliana	49.75	20.75	6.25	4	8.25	26.67	17.25	35.5	21.5	16.25
		Ruditapes largillierti	0	0	0	0	0	0	0	0	0	0.25
	Gastropoda	*Acanthochitona* sp.	0	0	0	0	0	0	0	1.25	0.25	0.25
		Amaurochiton glaucus	0	0	0	0	0	0	0	0.5	0.5	0
		Amphibola crenata	0	0	0	0	0	0	0	0.25	0	0
		Cominella glandiformis	0.25	0.25	0.5	0	0	1	3	1.25	0.25	1
		Cominella maculosa	0	0	0	0	0	0	0	0	0.25	0.25
		Diloma subrostrata	0.5	0	0	2.5	0.25	0	0	0.75	0	0.25
		Gastropod sp.A	0	0	0	0	0	0	0.25	0	0	0
		Micrelenchus tenebrosus	0	0	0	0.25	0	0	0	0	0	0.25
		Neoguraleus sp.	0	0	0.25	0	0	1	0.25	0.75	0.25	1
		Notoacmea helmsi	1.5	0.25	0	9.25	6.25	47	5.5	9.25	21.75	11.5
		Notoacmea pileopsis	0	0	0	0	0	0.33	0	0	0	0
		Pyramidellidae	9	0	0	0	0	0	3	5.25	0.25	0
		Turbonilla sp.	4	0.5	0	0	0	0	7	15.75	0.25	0.25
		Xymene plebeius	0.5	0	0	0.25	0	0.33	0	0	0.25	0
ANNELIDA	Polychaeta	*Aonides* sp.	0	0	0	0	0	2.67	0	0	0	0.5
		Arenicolidae sp.	0	0	0	0	0	0.33	0	0	0	0
		Aricidea sp.	0	0	0	0	0	1	0	0	0.25	0.25
		Armandia maculata	0	0	0	0	0	0.67	0.75	0.5	4.25	0.75
		Barantolla sp.	8.5	0.25	0.25	0.75	6.25	4.33	1.5	0.25	0.75	0.5
		Boccardia spp.	2	33	54.75	0.75	10.25	3.67	73.75	73.75	79.5	200.75
		Capitella sp.	0.25	0.5	21.5	0	1.25	1	20.75	19	12.5	6.25
		Cirratulidae	0	0	0	0	0	0	0	6.25	0	0
		Harmothoe sp.	0	0	3.75	0	1	1.67	0	0	18.5	2.75
		Hemipodus simplex	0	0	0	0	0	0	0	0	0.25	0.75
		Hesionid sp.B	0	0	0.25	0	0.25	0.33	0	0	0.25	0
		Hesionid sp.E	0	0	0	0	0	0	0.75	0.5	0	0
		Heteromastus filiformis	59.25	40.75	604	54.25	70.25	35.00	466.75	552	172.75	72.5
		Glycera lamelliformis	0	0.5	0.5	0	0	0.33	0.5	1	0.25	0.25
		Glycera ovigera	0	0	0.25	0	0	0	1	0	0	0
		Glycera sp.	0.25	0	0	0	0	0	0	0	0	0
		Glycinde dorsalis	4.75	3.5	0	0.25	0	0	0.25	0.25	0	0
		Magelona sp.	6	2.25	0.5	24.5	39.25	41.33	0	0.25	0	12.25
		Maldanid sp.	0	0	0	0	0.25	0	0	0	0	0.25

			B1	B2	B3	D1	D2	D3	T1	T2	R1	R2
ANNELIDA	Polychaeta	*Monticellina* sp.	8.75	0	0	0	0	0	152.75	59.75	0	0
		Naineris sp.A	0	0	0	0	0	0	0.25	0.25	5	0.75
		Naineris sp.B	0	0	0	0	0	0	0.5	0	0.5	0
		Nicolea sp.	0	0	0	0	0	0	0	0	2.5	0
		Nicon aestuariensis	2.75	6.75	10.25	0.25	5	0.67	9.75	17.75	14.25	23
		Orbinia papillosa	0	0	0	13.75	16.5	9	0.25	0	1.5	14
		Owenia fusiformis	0.25	0	0	0	0	1.33	3.5	9	1.25	3.25
		Paraonis sp.	0	0	0	0.25	5.75	17.33	0	3	0	0
		Paradoneis sp.	0	0	0	0	0	0	51.5	42.5	0	5
		Pectinaria australis	2.5	0.25	0	0	0	0	0.5	0	0	0.25
		Perinereis nuntia	0	0	0	0	0	0	0.25	1.25	0.25	0
		Nereidae sp.A	0	0	2.5	0.25	1	2.33	1.25	1.25	17.5	17
		Platynereis sp.	0.25	0.5	9	0	0	0	0.25	0	0.25	0
		Phyllodocid sp.A	0	0	0	0	0	0.33	0	0.25	1.25	1
		Pomatoceros sp.	0	0	0	0	0	0	0	0.25	0	0
		Prionospio aucklandica	0.25	0.5	38	0	1.5	4.67	1.75	2.5	0.5	1.25
		Prionospio yuriel	0	0	0	0	0	0	0.25	0	0	0.25
		Prionospio sp.A	0	0	0	0.25	0	0	0	0	0	0
		Sabellidae (Fabricinae)	0	0	0	0	1.5	0	0	0	0	0
		Schistomeringos sp.	0	0	0	0	0	0	0	0	0.25	0
		Scolecolepides sp.	0.25	1	2.5	1.5	0.25	1	0.75	2	1	1.75
		Scolelepis sp.A	0	0.25	0	0.25	3.75	0	0	0	0	0
		Scolelepis sp. B	0	0	0	0	0	0	0	0	0.25	1.75
		Scoloplos cylindrifer	0.25	0.25	1.25	0	0	0	29	76	11.5	8.25
		Scoloplos (Leodamas) sp.	0	0	0	0.5	0	0.67	0.25	0	0	0
		Streblosoma sp.	0	0	0	0	0	0.33	0	0.25	0	0
		Syllid sp.A	0	0	0	0	2.25	0.67	0	1.25	12.5	0.5
		Syllid sp.B	0	0	0	0	0	0	7.75	16.25	32.5	0.5
		Syllid sp.C	0	0	0	0	0.25	0	0	0	0	0
		Syllid sp.D	0	0	0	0	0	0	0	0	0.5	0.75
		Terebella sp.	0	0	0	0	0	0	0	0	37	8
		Terebellid sp.	0	0	0	0	0	0	0	0.25	0.25	0
	Oligochaeta	Oligochaete spp.	0	0	0.25	0	0	0	2.25	14.75	1.25	0.75
ARTHROPODA	Decapoda	*Halicarcinus whitei*	0	0	0	0	0	0	1.25	2.75	0.5	0.75
		Halicarcinus cookii	0.25	0.25	0	0	1.25	2	0	0.25	1	0.5
		Halicarcinus varius	0	0	0	0	0	0.33	0	0	0.25	0
		Hemigrapsus crenulatus	0	0.25	0.25	0	0	0.67	0	1.25	1.25	0

			B1	B2	B3	D1	D2	D3	T1	T2	R1	R2
ARTHROPODA	Decapoda	*Macrophthalmus hirtipes*	2.25	1.75	13	0	0	7.33	7.5	7.75	1.25	3
		Pontophilus sp.	0.75	0	0	0.5	0	0.67	0	0.5	0	0.25
	Ostracoda	*Diasterope?* sp.	0	0	0	0	0	0	0	0	0.75	0.25
		Leuroleberis zelandica	0	0	0	0	0	0	0	0	0	0.25
		Ostracod sp.	0	0	0	0	0	0	0	0	0.75	0
	Amphipoda	*Aora maculata?*	2	5	7	1.25	2.25	2.33	0.5	0.25	141.75	10.5
		Aora sp.	0.25	0	0	0	0.25	0	0	0	0	0.5
		Parawaldeckia sp.	0	0	0	0	0.5	0	0	0	0	0
		Paracorophium excavatum	0	0	0	0	0.25	0	0	4.75	1	0.25
		Proharpinia arenata?	0.25	3.25	0	0.75	0.25	0	0	0	0	0.75
		Proharpinia minuta?	0.25	0	0	0	0	0	0	0	0	0
		Proharpinia sp.	0	0	0	0	0	0	0.25	0	0.25	0
		Amphipod sp.A	1.5	1.25	18.5	0	21.5	17.67	8	10.5	13.25	13
		Amphipod sp.C	1.25	0	0	1.5	0.75	1.33	0	0	28.5	6.75
		Amphipod sp.E	0	0	0	0	0	0.33	0	0.75	0	0
		Amphipod sp.F	0	0	0	0	0	0	0	1.5	0	0
		Amphipod sp.H	0	0	0	0	0	0	0	0.75	0	0
	Isopoda	Isopod sp.A	0	0.25	1.75	4.5	1	1.33	9.5	14	3.5	4.25
		Isopod sp.B	0	0	0	0	0.25	1.00	0	0.75	1.25	0.5
		Isopod sp.C	0	0	0	0	0.25	0.33	0.25	0	0	0
		Munna sp.	0	0	0	0	0.5	0	0	0	0.75	0
		Caprellidae	0	0	0	0.5	0	0	0	0	0	0.25
	Tanaidacea	Tanaid sp.	0	0	0	0	0	0	0	0	5.5	0.5
	Cumacea	Cumacean sp.	0	0	0	0	0.25	0.33	0	0	0	0
		Mysid sp.	0	0.25	0	0	0	0	0	0	0.25	0
NEMERTEA		Nemertine	2.75	0	14	3.25	14.5	13.33	21.25	24.25	22.5	18
COELENTERATA		*Edwardsia* sp.	2	1	0	0.25	0.25	7.33	0.75	0.25	0.5	3
PHORONIDA		Phoronid sp.	0	0	0	0	0	0.33	0.5	0	0	0
ECHINODERMATA	Ophiuroidea	*Amphiura* sp.	0	0	0	0	0	0	0	0	1.75	0
VERTEBRATA	Pisces	*Forsterygion* sp.	0	0	0	0	0	0	0	0	0.25	0

Appendix IV: Number of taxa and individuals in each sample

Station	Number of taxa	Number of individuals
B1a	25	319
B1b	24	190
B1c	16	163
B1d	20	159
B2a	25	409
B2b	15	218
B2c	15	174
B2d	13	158
B3a	24	904
B3b	20	1046
B3c	17	626
B3d	19	1002
D1a	8	77
D1b	11	131
D1c	12	101
D1d	23	219
D2a	25	427
D2b	19	214
D2c	19	221
D2d	26	251
D3a	29	241
D3c	29	302
D3d	29	281
T1a	33	1310
T1b	34	1358
T1c	25	569
T1d	31	795
T2a	33	1266
T2b	32	1102
T2c	39	1339
T2d	41	1152
R1a	41	1477
R1b	46	1099
R1c	38	825
R1d	35	1004
R2a	38	698
R2b	29	319
R2c	45	878
R2d	30	410



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