Table 2. List and description of environmental variables used in analyses.

Group	Variable Name (abbreviation)	Description
Ambient Grain Size (AmbGS)	GS1 – GS5	Five variables expressing the absolute (at replicate level) or average (at site level) percentage of grain sizes of ambient sediments falling into particular size classes at each sampling:
	GS1	< 63 microns
	GS2	63- 124.9 microns
	GS3	125- 249.9 microns
	GS4	250 - 499.9 microns
	GS5	> 499.9 microns
Trapped Total (TrapTot)	Avtrap	Average total sediment trapped ($g.cm^{-2}.day^{-1}$) over the sampling year
	sdtrap	Standard deviation in total sediment trapped ($g.cm^{-2}.day^{-1}$) over the sampling year
	Avfin	The average weight of trapped sediments < 63 microns (g) over the sampling year
Trapped Grain Size (TGS)	TGS1 – TGS5	Five variables expressing the average percentage of grain sizes of trapped sediments falling into particular size classes over the period of the sampling year:
	TGS1	< 63 microns
	TGS2	63- 124.9 microns
	TGS3	125- 249.9 microns
	TGS4	250 - 499.9 microns
	TGS5	> 499.9 microns
Standard deviation in Trapped Grain Size (sdTGS)	sdTGS1 – sdTGS5	Five variables expressing the standard deviation in percentage of grain sizes of trapped sediments falling into particular size classes over the period of the sampling year:
	sdTGS1	< 63 microns
	sdTGS2	63- 124.9 microns
	sdTGS3	125- 249.9 microns
	sdTGS4	250 - 499.9 microns
	sdTGS5	> 499.9 microns
Recently trapped sediments (Trap*)	trap*	Average total sediment trapped over a period of approximately one month prior to biological sampling ($g.cm^{-2}.day^{-1}$)
	trap%fin*	The percentage of trapped sediments < 63 microns obtained over a period of approximately one month prior to biological sampling
	trapfin*	The weight of trapped sediments < 63 microns obtained over a period of approximately one month prior to biological sampling (g)
Distance (D)	D	Rank distance of site from the mouth of the estuary (1-10)
	D2	Rank distance squared (D^2), to examine non-linear patterns in biota with distance
Erosion	BH	Average change in bed height (erosion/accretion) ($cm.day^{-1}$) over the sampling year
	sdBH	Standard deviation of change in bed height ($cm.day^{-1}$) over the sampling year
	BH*	The change in bed height over a period of approximately one month prior to biological sampling

4.3 Statistical Analyses

4.3.1 Analyses of environmental data

Univariate plots (boxplots and plots of means and standard errors) of several individual environmental variables were made for all sites in all estuaries. This was particularly useful to determine the nature of the variation in these variables at other estuaries compared to the values observed for sites at Okura and at the new estuaries, Turanga and Waikopua.

For multivariate analyses, environmental data were averaged at the site level through time because not all variables were measured at each time. Data were then standardized to z-scores (i.e. each variable was transformed by subtracting its mean and dividing by its standard deviation, also called normalisation). All multivariate analyses of environmental data (alone) were done on the basis of Euclidean distances on normalized data. First, to visualize patterns in environmental data non-metric multi-dimensional scaling (MDS, Kruskal and Wish 1978) was used as a robust ordination method (e.g. Clarke 1993). Labels were superimposed on the MDS plots to identify the specific estuary and site. This was helpful to assess whether any consistent patterns occurred due to either a) estuary, or b) distance within each estuary. Separate MDS plots were done for each time of sampling.

When sampling began in Okura estuary, there were existing hydrodynamic models of the estuary and surrounding catchment. No such models were available for the other estuaries included in this investigation. Thus, it was necessary to attempt to characterise the sites we sampled in terms of the environmental data. To characterise the sites, we used a divisive method of finding groups in multivariate data, called k-means partitioning (MacQueen 1967, Legendre and Legendre 1998). This method requires the user to specify the number of groups to be identified *a priori*. The method then partitions the individual observations into the specified number of groups in such a way as to minimize the sum of squared Euclidean distances from observations to their group centroid. In our case, for the environmental data sets we chose to find the best partition into three groups, based on patterns obtained last year (Ford *et al.* 2003).

A principal component analysis (PCA) was used to simplify the 26 environmental variables (many of which were highly correlated) down to a few dimensions, which could be interpreted in terms of the overall environmental gradient in physical characteristics among sites. The PCA biplot provides information regarding the correlation of each variable with principal component axes. Variables with the highest correlations to axes (longest arrows) are most important in describing variation along the gradient identified by the PC axes.

4.3.2 Analyses of biological communities

Non-metric multi-dimensional scaling (MDS) ordinations (unconstrained ordinations) were also used to display the biological data. Symbols were superimposed to investigate potential effects of: a) estuary and distance and b) high, medium and low-energy sites identified using the environmental data. All multivariate analyses of biological data were done using Bray-Curtis dissimilarities of ln(y+1)-transformed species abundances for data pooled at the site level. Separate MDS plots were done at each of the four sampling times.

4.3.3 Relating biota to environmental, spatial and temporal factors

The relationship between the biological data and the environmental data was examined using a distance-based redundancy analysis (dbRDA) with a forward selection procedure. The analysis was performed using the program DISTLM_forward.exe, on the basis of the Bray-Curtis dissimilarity measure of ln(y+1)-transformed abundances. Environmental variables were kept together in sets, as defined in Table 2. Results of this analysis describe and test: (a) the percentage of the variation in the biota explained separately by each set of environmental variables alone (marginal tests) and (b) the percentage of the variation in the biota explained by each set of environmental variables sequentially, fitting the best predictors one set at a time in a single forward selection model (conditional tests). This technique is a kind of multivariate multiple regression, but where the linear model is applied to principal coordinates from the distance matrix, rather than to the raw data directly (see Legendre and Anderson 1999 and McArdle and Anderson 2001 for further details).

We would hope that the most important environmental gradients that describe physical changes in a landscape will also be well represented by gradients in the biological assemblages. This will occur if we have chosen to measure environmental variables that are important to the organisms under investigation. To investigate this relationship we overlayed the energy groupings on the MDS plots showing patterns among biological communities at each time. If there was a strong correlation between these energy groupings and biological assemblages at the sites, we would expect the different energy groupings to appear as separate clusters of points on these plots. In addition, canonical analysis of principal coordinates (CAP) was used to examine and characterise the nature of differences among assemblages at sites having different energy groupings (derived from the environmental data) on the biological assemblages (Anderson and Willis 2003, Anderson and Robinson 2003). Species showing high correlations with the canonical axes from the CAP plots are shown by long arrows on the biplot.

It was also of interest to determine what percentage of the variation in biotic assemblages could be explained by each of the following main temporal and spatial factors in the experimental design: Season (W/S vs. LS), Rainfall (R vs. D), Estuary (7 groups), Sites (10 groups from A-J), and Energy groupings (H, M and L). The biotic data

were analysed on the basis of Bray-Curtis dissimilarities of ln(y+1)-transformed abundances using distance-based redundancy analysis (dbRDA), with a forward selection procedure on each of these factors (coded as a set of indicator variables). This procedure (using the program DISTLM_forward.exe) allowed marginal tests of the amount of variation explained separately by each of these factors and also provided conditional tests of the amount of variance explained by the sequential addition of terms in a forward selection model.

4.3.4 Long-term temporal changes in biological communities

There have now been 12 separate times of sampling of all estuarine sites (apart from Turanga and Waikopua) over a period of 33 months (from August 2002 to April 2005) by researchers from the University of Auckland. A further goal of this study is therefore to examine whether recognisable temporal trends are becoming evident in different energy environments. More particularly, we require the monitoring program to be able to detect, as soon as possible, when a particular site may be going "awry" by reference to the natural variability we have observed (i) at other similar sites and (ii) at that site for all previous times. Recently, Anderson and Thompson (2004) have extended the idea of control charts from the engineering literature (where it is used for univariate response variables) to allow for monitoring of multivariate species abundance data. More particularly, the criterion used is the dissimilarity (deviation) of a new observation at a site at time t, from the centroid (average) of a baseline set of observations at that site. If the system is "in control", each new observation for the assemblage should "bounce around" some "target" centroid for that site through time. However, if there is an impact that dramatically alters the assemblage, then we can expect this dissimilarity to be large relative to the values we have seen for it (and for other similar sites) in the past.

Thus, the basic idea is to plot the Bray-Curtis dissimilarity of a site at time t from the baseline centroid and examine if it is large relative to other such values across the spatial array of sites. We can use bootstrapping of the observations through time within a site (under the null hypothesis that the system is "in control") to put a 95% upper confidence bound on this value (Efron and Tibshirani 1993, Davison and Hinkley 1997). For further details, see Anderson and Thompson (2004). We have found that a baseline of 2 observations actually works quite well for picking up gradual trends as well as sudden pulse effects (Anderson and Thompson 2004).

In the present case, it was possible to generate multivariate control charts for each of 50 different sites. (Note that not enough temporal data is yet available to draw long-term control charts from sites at either Turanga or Waikopua). Analyses were done to obtain appropriate confidence bounds for sites from each of the 3 different energy groupings and results are given in separate plots for each estuary for clarity. If individual sites were identified as going outside the control-chart bounds, then SIMPER (similarity percentage) was used to identify the taxa responsible for differences in those assemblages at that point in time, compared to other times of sampling. An important

additional point here is that the energy group may change through time for certain sites. We have chosen to show the control charts using the initial energy grouping obtained for each site (from August 2002). For each site, times where the site changed its environmental energy classification (e.g., from a low to a medium-energy group, etc.) are identified on each plot.

4.3.5 Effects of rainfall events on faunal assemblages

The sampling design of this monitoring programme has been carefully crafted to specifically examine potential effects of relatively heavy rainfall on estuarine fauna. However, the sizes of rainfall events that have triggered sampling through the years have themselves been quite variable. Now that several rainfall events over several years have been monitored, we wished to examine the extent to which rainfall could explain any consistent identifiable temporal changes (whether short or long-lasting) in assemblage structure.

The overall potential influence of rainfall was therefore examined by looking for a correlation between rainfall and community structure, within each energy environment, including eleven times of sampling (from August 2002; rainfall data was unavailable for the October 2002 sampling time). Rainfall data consisted of the sum (in mm) for the 10 days prior to each biological sampling, as measured from one location relatively central to all estuaries (Oteha at Rosedale (N6493463, E2663620), which was obtained using the ARC's Hydrotel database. In ongoing monitoring, rainfall will be gauged from sites closer to each estuary, but for comparability across years in this analysis, we chose one gauge that had a record extending back to the earliest sampling event. Rainfall values ranged from 1 to 140 mm. Canonical analysis of principal coordinates (CAP) was used to find an axis through the multivariate cloud of species data that had the highest correlation with the rainfall data. Separate CAP analyses were done for sites in each energy grouping.

4.3.6 Computer programs

Non-metric MDS plots and SIMPER analyses were done using the computer program PRIMER v. 5 (Clarke and Gorley 2001). K-means partitioning was achieved using the program Kmeans.exe written by P. Legendre, available from the following website:

http://www.fas.umontreal.ca/BIOL/Casgrain/en/labo/index.html.

CAP analyses and DISTLM were performed using the programs CAP.exe and DISTLM_forward.exe, both available from the following website:

http://www.stat.auckland.ac.nz/people/~mja.

The program ControlChart.exe (written by M. Anderson) was used to calculate the dissimilarities required for control charts and to do the bootstrapping to calculate the upper 95% confidence bounds. Univariate plots were generated using SigmaPlot™ 2000, version 6.10.

5 RESULTS

5.1 Assimilating new sites into the regional model

5.1.1 Environmental data

The environmental parameters measured for all estuaries, including the new additions to the monitoring programme (Turanga and Waikopua), characterised the ambient sediments, trapped sediments, bed height changes and distance from the estuarine mouth. Generally the recordings for the environmental variables in the new estuaries were intermediate to those recorded elsewhere with a few notable exceptions. Along with Puhoi site E and Orewa site F, sites in Turanga (E, H, I, J) and Waikopua (H, I, J) showed some of the finest ambient sediments across all of our sampling sites (Fig. 6; large percentage composition of GS1). This strong influence of fine grain sizes was again visible when the composition of trapped sediments was examined. Generally sites in Mangemangeroa, Turanga and Waikopua showed the largest contribution of fine sediments (GS1) within traps (Fig. 7). The other point to note concerns bed height recordings. Sites in Turanga estuary seemed very stable, however many sites in Waikopua showed, on average, negative change in bed height. In addition, Waikopua site C showed some highly variable bed height recordings, including some measures of erosion larger than any previously recorded in this monitoring programme (Fig. 8).

The overall rate of sediment accumulation in traps through the year was quite high at certain sites in Puhoi (J), Waiwera (C) and Orewa (A, C) (Fig. 9). In contrast, the amount of sediment collected in sediment traps (by weight) was somewhat less in the estuaries of the Whitford embayment and also in Okura (note the difference in the scales of the y-axes in Fig. 9). The sediments obtained in traps in these estuaries were nevertheless generally of finer grain sizes (Fig. 7).

Multi-dimensional scaling (MDS) plots that combine all the environmental information at the four different sampling times showed three relevant points (Fig. 10). First, as has been seen before, there were no consistent estuary or distance-within-estuary groupings (i.e., sites labelled A, B, C, etc. did not group together, nor did all sites within any single estuary (colours)). Second, most sites seem fairly similar in terms of the environmental conditions as the majority of sites were clumped together in these plots. Third, the outlying sites on these plots were not from our new estuaries (Turanga or Waikopua) but were usually the high-energy sites from Puhoi, Waiwera or Orewa estuaries (Fig. 10).
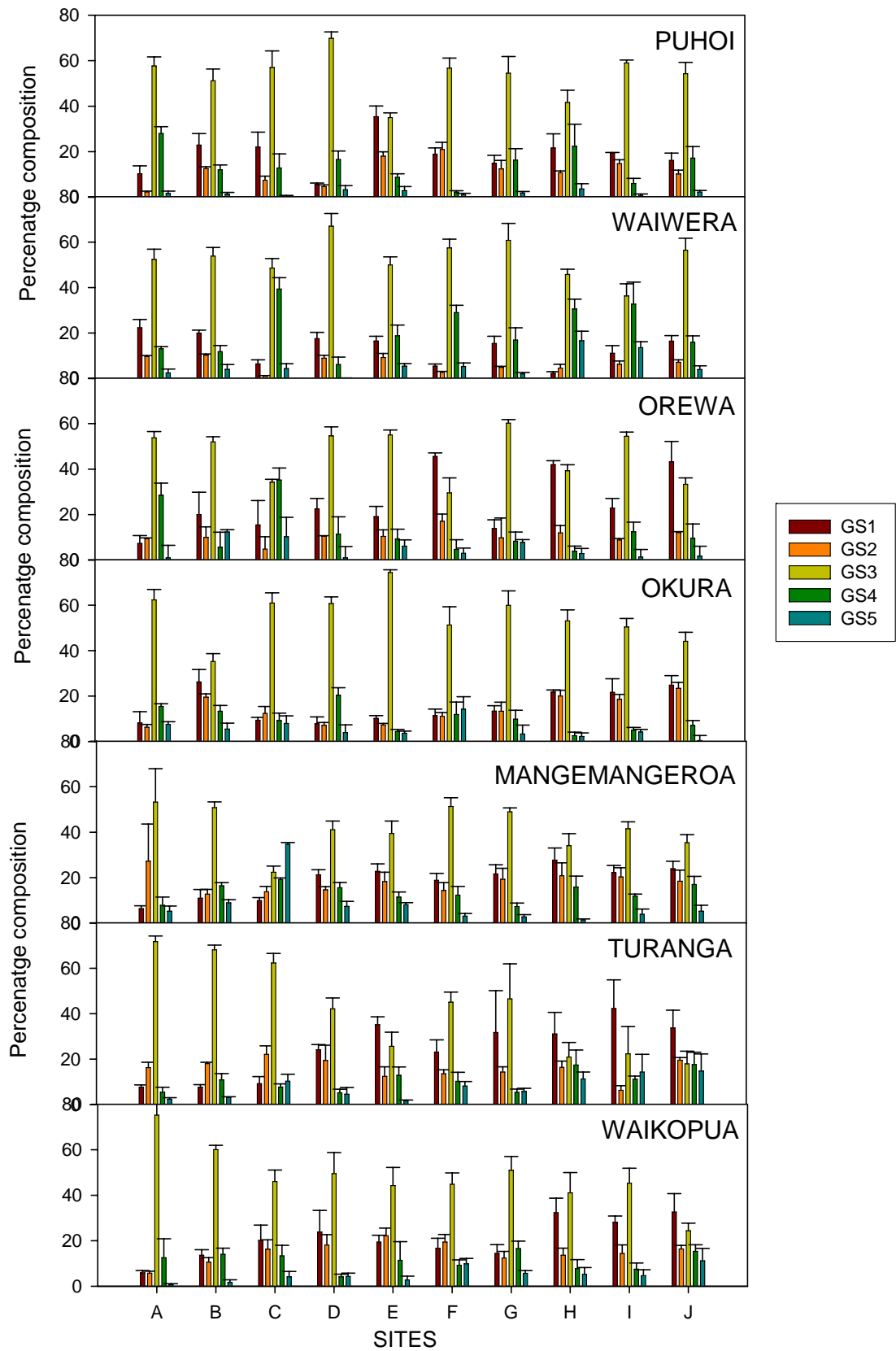
Figure 6. Mean (+1se, *n* = 24) percentage of ambient sediments of different grain sizes averaged across all four sampling times from August 2004 to April 2005.
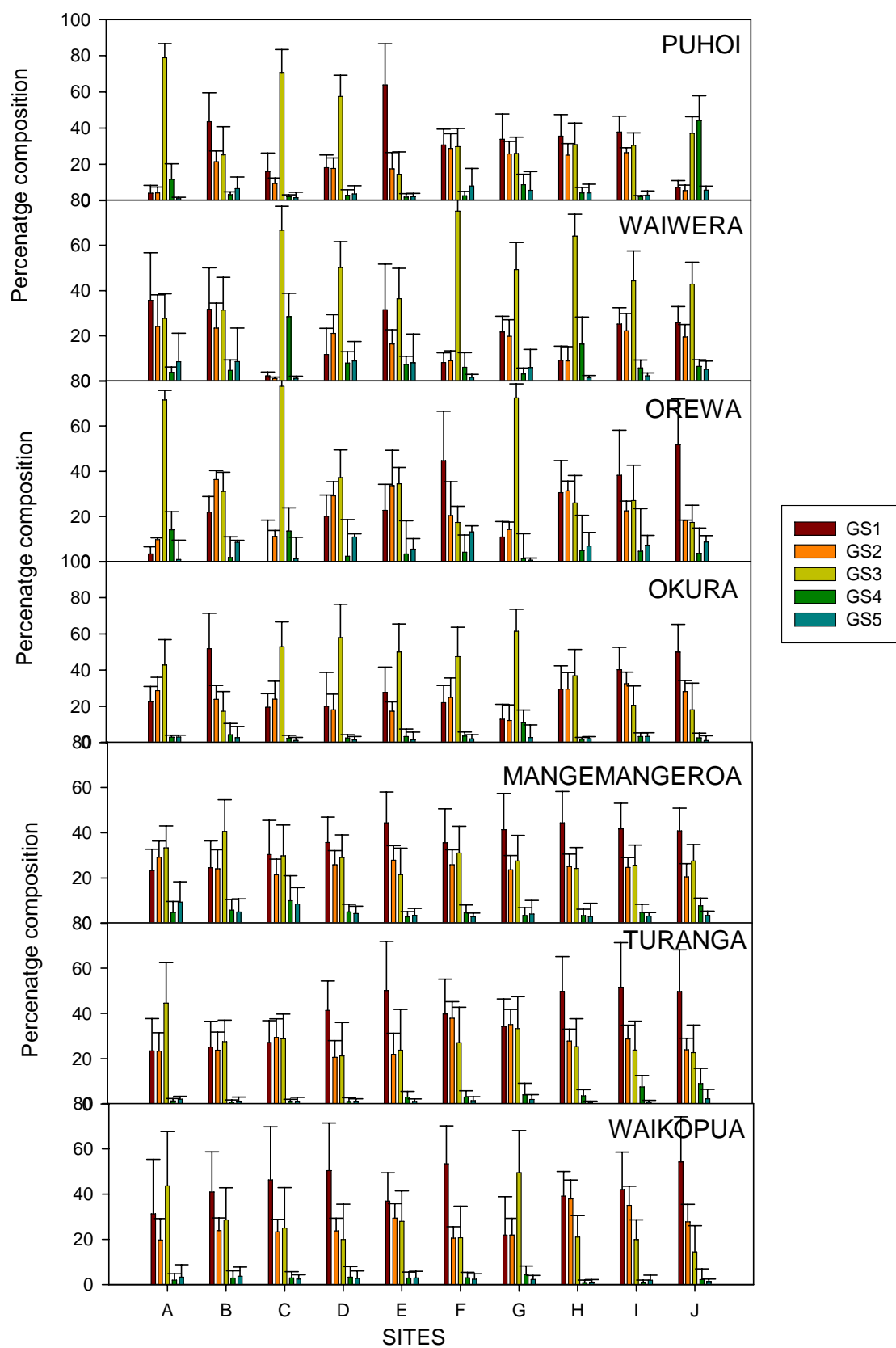
Figure 7. Mean (+1se, *n* = 10-12) percentage composition of sediment of different grain sizes collected in traps for all sites in all estuaries pooled over the sampling period.
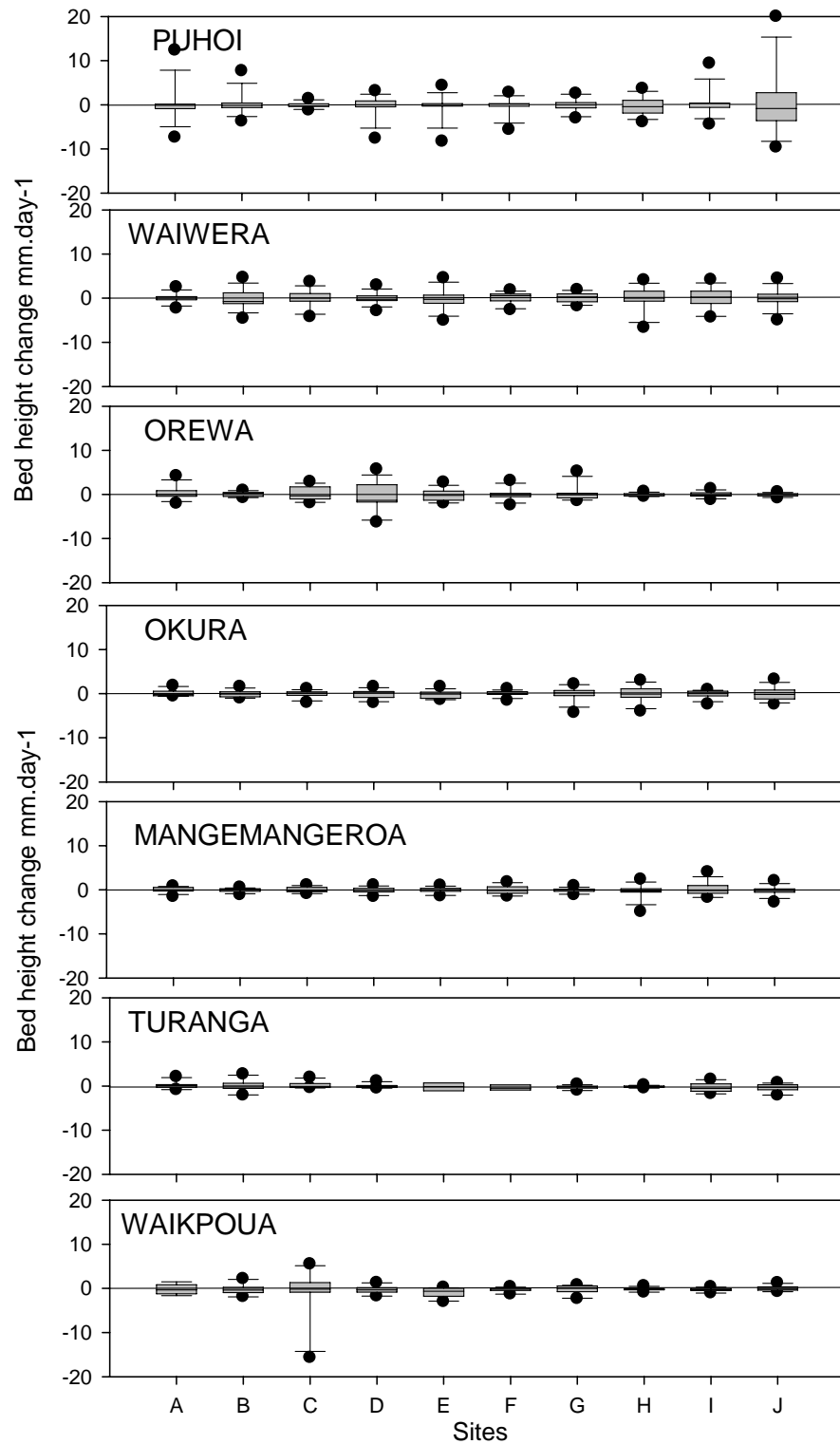
Figure 8. Bed height change at all sites in all estuaries over the entire sampling period. Sample sizes ranged from $n = 8$ to $n = 13$ times per box.
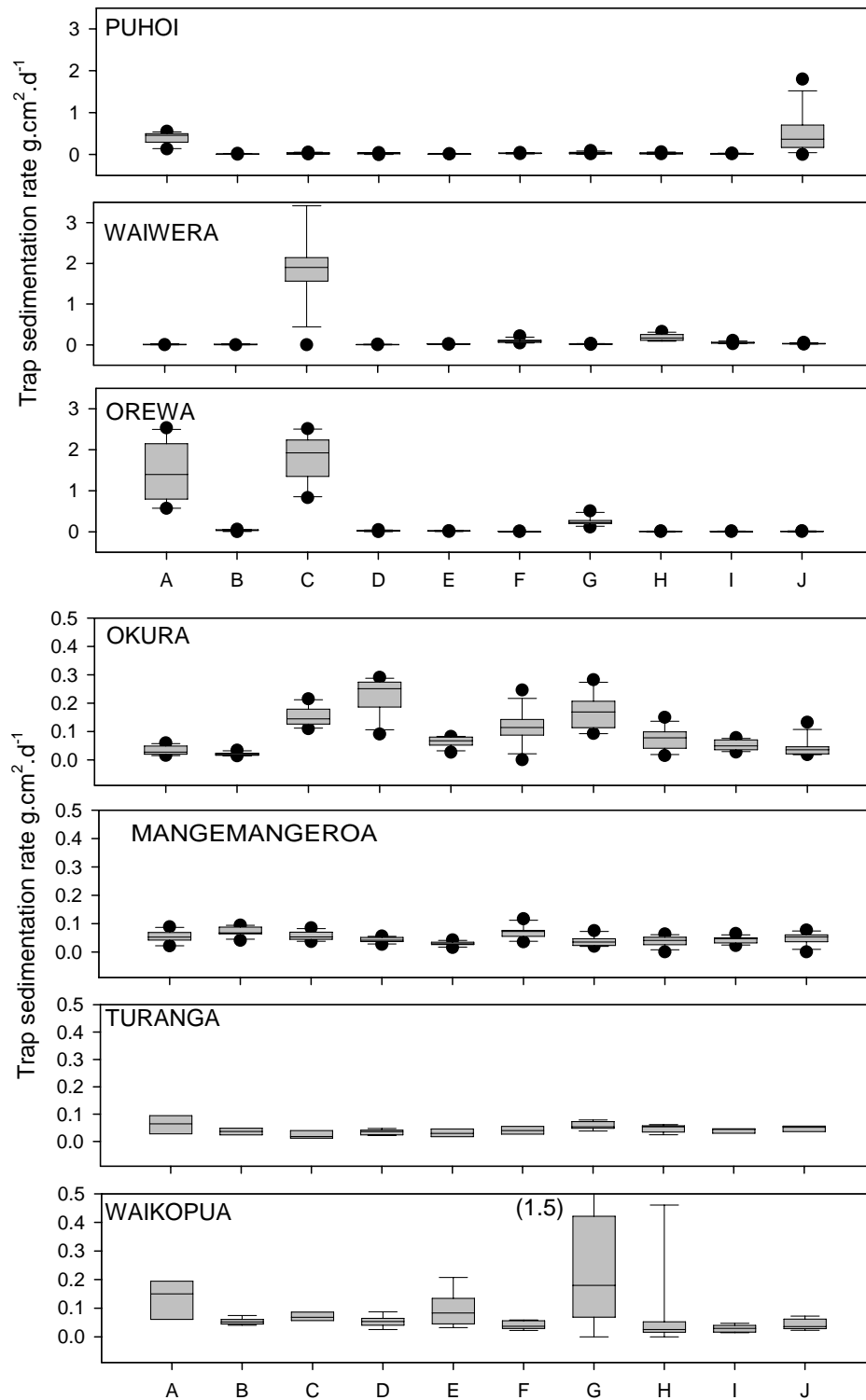
Figure 9. Rate of sediment accumulation in traps at all sites. Note the change of scale on the y-axes. Boxplots for Turanga and Waikopua show no outliers due to fewer measurements being taken at these two estuaries (n = 6 to 12).
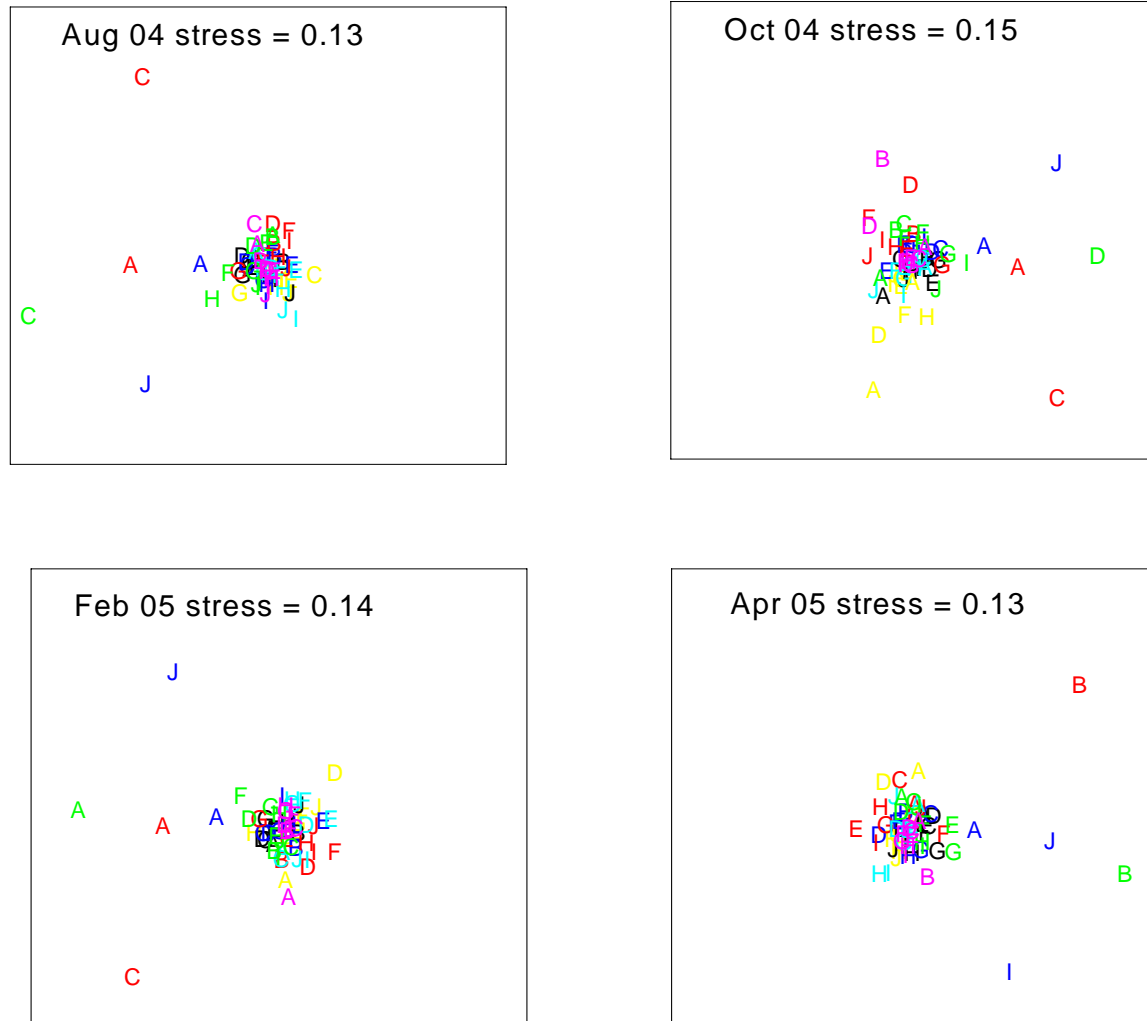
Figure 10. MDS plot of assemblage data from each time of sampling showing estuary and distance information. The analyses were based on normalised Euclidean distances. Observations were pooled at the site level *(n*= 6)*.* Sites are indicated by a coloured letter: the letter indicates the site within an estuary (A-J), while the colour represents the estuary, with Blue = Puhoi, Green = Waiwera, Red = Orewa, Black = Okura, Pink = Mangemangeroa, Yellow = Waikopua and Cyan = Turanaga.

K-means partitioning was used to classify all sites into high, medium or low-energy groups on the basis of environmental data (Table 3) as has been done in previous reports (Ford *et. al.* 2003, 2004). Ninety-two percent of the sites that were classified in the previous reports ended up in the same energy grouping as documented in last year's report (Ford *et al.* 2004). Sites in Turanga and Waikopua estuaries were all classified as either medium or low-energy sites, with the majority of these sites (14/20) being classified as low-energy (Table 3).

In order to determine which measured environmental variables were most important in terms of defining the high, medium and low-energy groupings a principal components analysis (PCA) was done using all environmental measures over the past year (Fig. 11). The first two axes shown in this analysis explained 40% of the variation in the environmental data. A gradient from high to medium/low-energy is seen along PC Axis 1. High-energy sites are on the left side of the plot and medium and low energy sites are on the right side. Generally, medium and low-energy sites are separated on PC Axis 2, although this distinction is was less clear. Medium-energy sites were lower scoring on Axis 2 and low-energy sites were higher scoring.

The environmental variables that were most correlated with PC Axis 1 were TGS3, sdtrap, trap, Avtrap and TGS1. The environmental variables that were most correlated with PC Axis 2 were both distance variables (D and D^2) and GS3. Therefore, high-energy sites are characterised by high rates of sediment accumulation in traps and a high percentage of coarse particles in sediment traps. Medium and low-energy sites are characterised by low rates of sediment accumulation in traps and a high percentage of fine particles in sediment traps. The difference between medium and low-energy sites is generally that medium-energy sites are closer to the mouth and have coarser ambient sediments when compared to low-energy sites. This plot and the patterns seen within it closely resemble similar plots and patterns shown in previous years, (see Figure 8 in Ford *et al.* 2004 and Figure 13 in Ford *et al.* 2003).

Table 3. Results of k-means partitioning of sites into one of three groups based on environmental data. The analyses were based on Euclidean distances of normalised data, pooled at the site level. Sites that were evenly split between two groups were assigned to the group with the least replicates to create a greater balance among groups. Numbers in brackets refer to the proportion of times that a site was classified into that group.

| ESTUARIES	HIGH 6	MEDIUM 31	LOW 33
PUHOI	PA (4/4)	PB (2/4)	PE (4/4)
	PJ (4/4)	PC (4/4)	PG (2/4)
		PD (3/3)	PH (2/3)
		PF (2/4)	PI (3/4)
WAIWERA	WC (3/4)	WA (3/4)	
	WH (3/4)	WB (4/4)	
		WD (4/4)	
		WE (4/4)	
		WF (4/4)	
		WG (4/4)	
		WI (2/4)	
		WJ (2/4)	
OREWA	RA (4/4)	RB (4/4)	RF (4/4)
	RC (4/4)	RD (4/4)	RH (4/4)
		RE (4/4)	RI (3/4)
		RG (4/4)	RJ (4/4)
OKURA		OA (4/4)	OB (4/4)
		OC (4/4)	OH (4/4)
		OD (4/4)	OI (4/4)
		OE (4/4)	OJ (4/4)
		OF (3/3)	
		OG (4/4)	
MANGEMANGEROA		ZA (4/4)	ZD (2/4)
		ZB (4/4)	ZE (3/4)
		ZC (4/4)	ZF (4/4)
			ZG (4/4)
			ZH (4/4)
			ZI (4/4)
			ZJ (4/4)
TURANGA		TA (3/3)	TD (4/4)
		TB (3/3)	TE (2/2)
		TC (4/4)	TF (3/3)
			TG (4/4)
			TH (4/4)
			TI (4/4)
			TJ (4/4)
WAIKOPUA		KA (2/3)	KC (4/4)
		KB (3/4)	KD (4/4)
		KG (2/3)	KE (4/4)
			KF (4/4)
			KH (3/3)
			KI (4/4)
			KJ (4/4)
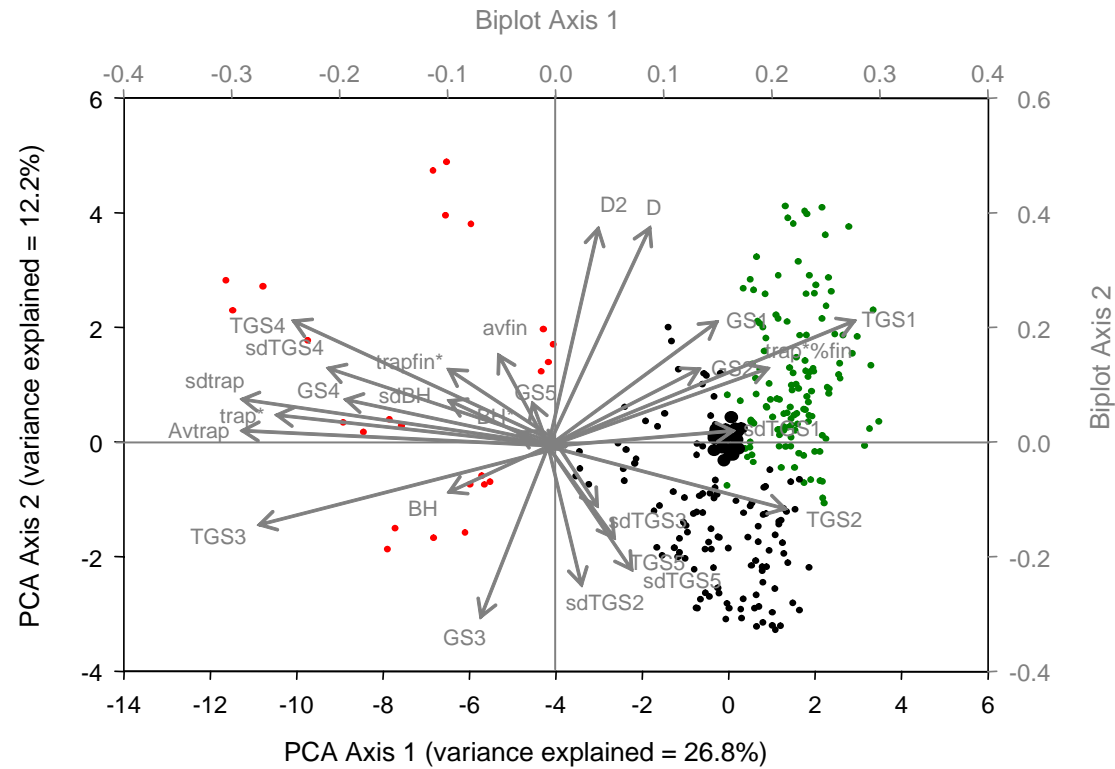
Figure 11. Principal component analysis (PCA) based on the environmental variables with specification of sites as High (dots in red), Medium (dots in black) and Low (dots in green) energy sites. Observations were pooled at the site level. Membership of sites in groups is shown in Table 3. Abbreviations and descriptions of environmental variables are given in Table 2. The axes values in grey relate to the biplot arrows.

5.1.2 Biological data

Ninety-two taxa were identified from the biological monitoring and their identities and total counts per site are given in Appendix B. The mean percentage composition of four taxonomic groups; polychaetes and oligochaetes, molluscs, crustaceans and minor taxa are shown organized by estuary, site and time in Appendix C. Plots of mean abundances (+1se) for ten numerically prominent taxa (which constitute 68% of all individuals sampled) are shown organized by estuary, site and time in Appendix D.

When the community data were viewed in an MDS plot, three patterns emerged (Fig. 12). First, as has been seen before, there were no consistent estuary or distance-within-estuary groupings. Second, there is more separation of individual site labels in the faunal MDS plots compared to the relative clumping of site labels in the environmental MDS plots (compare Fig. 12 with Fig. 10). This indicates that biotic differences among sites were more pronounced than the environmental differences among sites. Third, several sites from the new estuaries (Turanga and Waikopua) do occupy outlying positions on these plots. In particular, Waikopua and Turanga sites I and J are outlying on the MDS plots at all times, and in a different direction to other outlying points, such as Orewa site D. Sites I and J in Turanga and Waikopua are characterised by relatively low numbers of individuals and taxa (Fig. 13, 14). In addition, the fauna at these sites are characterised by large numbers of crustaceans (Appendix C), particularly *Paracorophium sp.* amphipods (Appendix D8). They also have a high contribution from minor taxa (Appendix C), predominantly nematodes.

In summary, sites I and J of Turanga and Waikopua appear unusual compared to other sites on the MDS plots, because they had fewer individuals, fewer taxa, greater proportional abundances of crustaceans and greater numbers of nematodes, on average, compared to other sites.
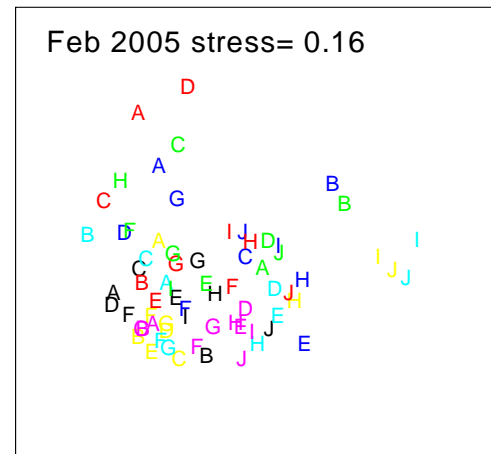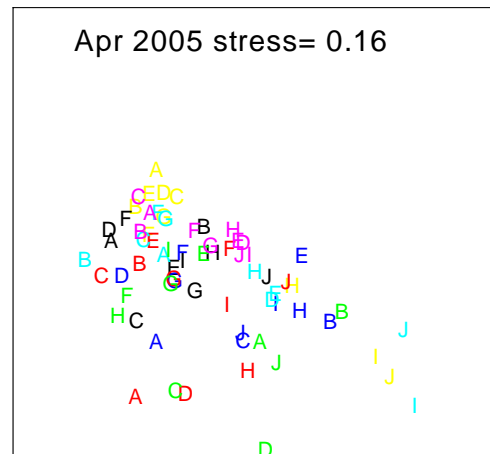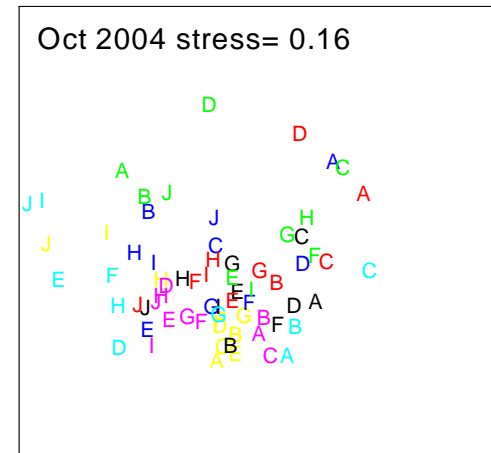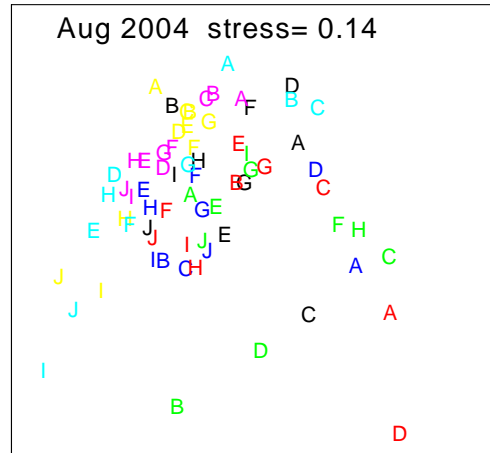
Figure 12. MDS plot of assemblage data from each time of sampling showing estuary and distance information. The analyses were based on the Bray-Curtis dissimilarity measure calculated from *In* (*y* + 1)-transformed species data. Observations were pooled at the site level *(n=* 6). Sites are indicated by a coloured letter: the letter indicates the site within an estuary (A-J), while the colour represents the estuary, with Blue = Puhoi, Green = Waiwera, Red = Orewa, Black = Okura, Pink = Mangemangeroa, Yellow = Waikopua and Cyan = Turanaga.

Figure 13. Mean (+1se, *n* = 6) number of individuals at each site and time for all estuaries. The colour of site letters on the x-axis indicates the hydrodynamic energy of the site (high = red, medium = black, low = green).

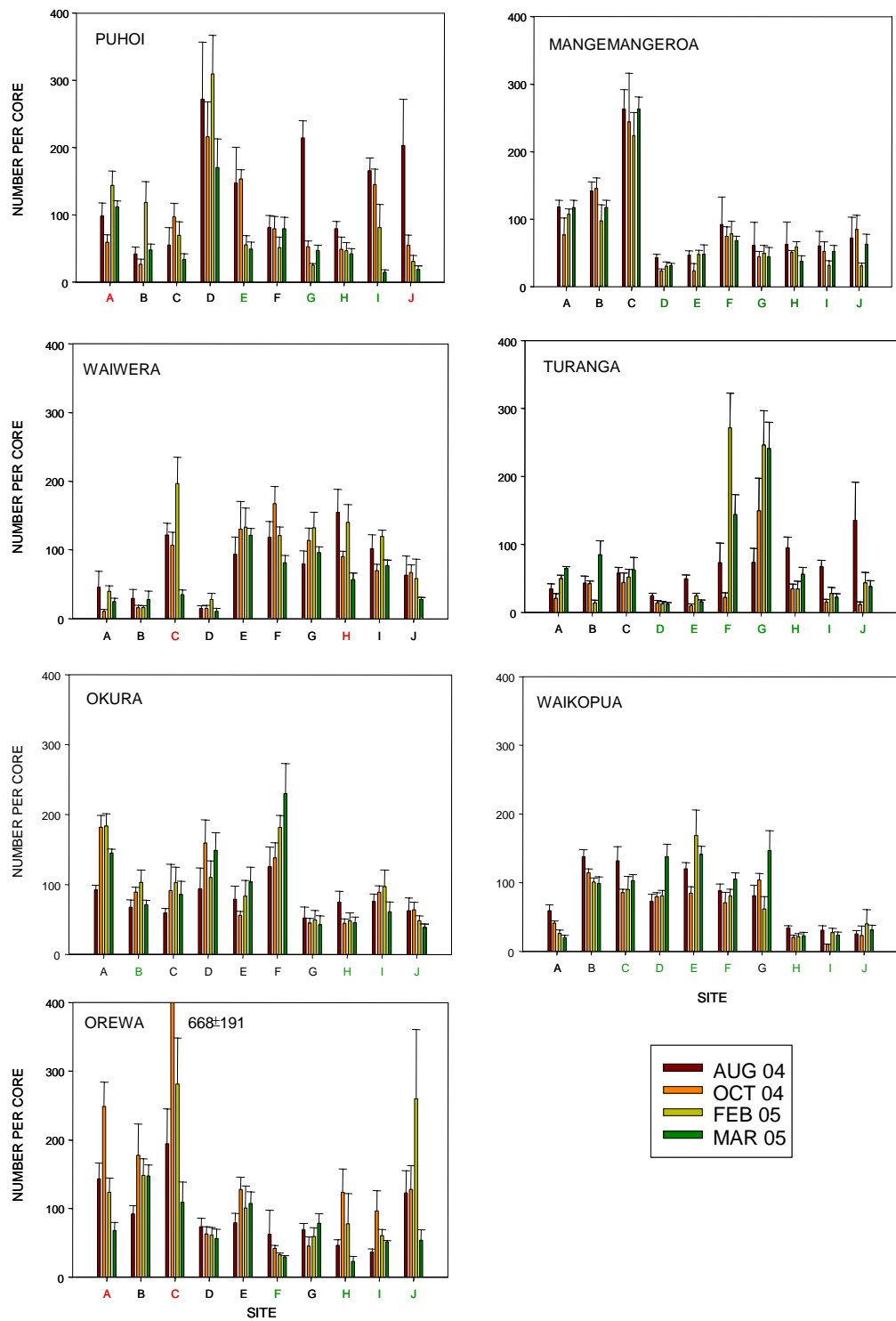**Figure 14.** Mean (+1se, *n* = 6) number of taxa at each site and time for all estuaries. The colour of site letters on the x-axis indicates the hydrodynamic energy of the site (high = red, medium = black, low = green).
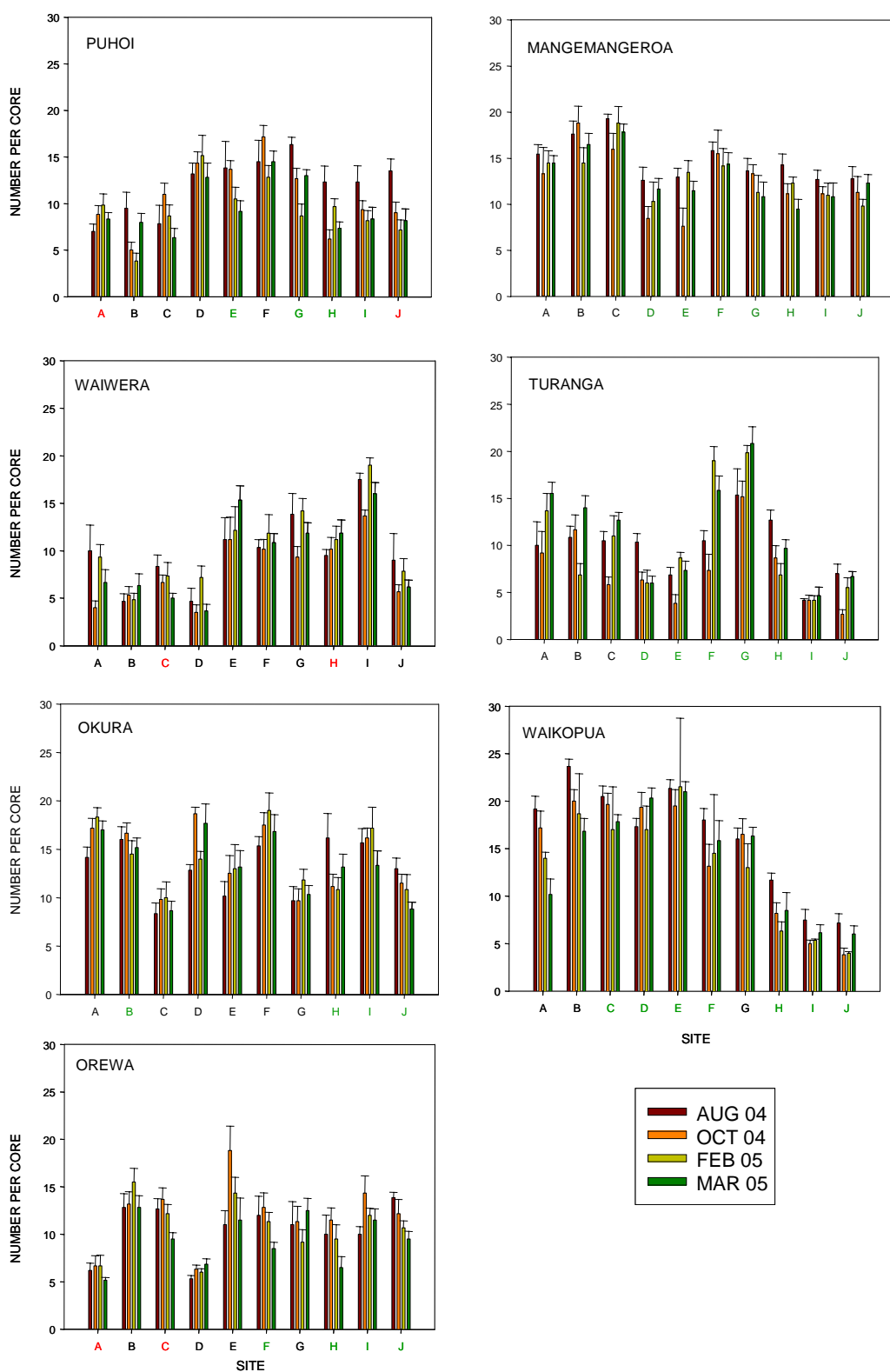
Other patterns of differences in the biota between these new estuaries and other estuaries in the sampling programme were evident:

- Overall, on average, Turanga and Waikopua had fewer cockles, *Austrovenus stutchburyi*, than other estuaries (Appendix D1).

- Turanga showed a pulse in the average abundance of copepods at sites E, F, H and J at the time of the August 2004 sampling, which was seen nowhere else (Appendix D4).

- Average abundances of *Heteromastus filiformis* were greater at Waikopua, Turanga, Mangemangeroa and (interestingly) at Okura compared to anywhere else (Appendix D5). There was also a clear pattern of increasing numbers of *H. filiformis* with distance from the mouth of the estuary for the Whitford embayment estuaries (apart from the relatively depauperate sites I and J in Turanga and Waikopua, Appendix D5).

- Greater average abundances of Nuculidae were observed at Waikopua and at the outer sites of Mangemangeroa (A, B, C) than elsewhere (Appendix D6).

- Apart from small numbers at sites B and C in Turanga, fewer pipis, *Paphies australis*, were recorded in estuaries of the Whitford embayment compared to other estuaries (Appendix D7).

- Overall, the average abundance of *Prionospio sp.* was greater at Waikopua and Mangemangeroa than elsewhere; it was also quite abundant at certain sites and times in Turanga (Appendix D9).

- Greater average abundances of crabs were sampled from certain sites in Waikopua (B-G), Turanga (F, G) and Mangemangeroa (A-C) compared to elsewhere (Appendix D10).

5.2 Relating biota to environmental, spatial and temporal factors

The 26 measured environmental variables together explained approximately 40% of the variation in the biotic assemblages (Table 4). The forward selection procedure identified that the most important set of variables was the texture of trapped sediments at a site (TGS), which alone accounted for 22% of the variability in community structure (Table 4).

Table 4. Results of distance-based redundancy analysis (dbRDA) examining the proportion of variation in the biota (based on Bray-Curtis dissimilarities of ln(y+1) abundances) explained by sets of environmental variables in individual (marginal) and in conditional (sequential) tests.

Marginal tests:

Variable	SS(Trace)	F	P	Variance explained
Erosion	31867	6.76	0.001	7.08%
Distance	43849	14.41	0.001	9.74%
AmbGS	74473	10.47	0.001	16.54%
TGS	98429	14.78	0.001	21.87%
sdTGS	77112	10.91	0.001	17.13%
TrapTot	49228	10.89	0.001	10.94%
Trap*	62222	14.22	0.001	13.82%

Conditional tests:

Variable	SS(Trace)	F	P	Variance explained	Cumulative
TGS	98429	14.78	0.001	21.87%	21.87%
sdTGS	25937	4.12	0.001	5.76%	27.63%
AmbGS	17778	2.96	0.001	3.95%	31.58%
Distance	15502	6.78	0.001	3.44%	35.02%
TrapTot	10581	3.16	0.001	2.35%	37.37%
Erosion	9762	2.98	0.001	2.17%	39.54%
Trap*	3505	1.07	0.165	0.78%	40.32%

Interestingly, the next-most important set of variables was the variation in grain sizes of trapped sediments (sdTGS), followed by the texture of ambient sediments (AmbGS). These results are similar to those obtained last year (see Table 7 in Ford *et al.* 2004) and they imply that it is not so much the amount of sediment arriving at a site which alters biota, but rather the texture of those sediments that may alter biological assemblages more gravely. Indeed, although the sites in the upper reaches of Turanga and Waikopua may not have larger amounts of sediments deposited (by weight) than other sites in the monitoring program (e.g., see Fig. 9), the larger proportion of fine sediments in traps (see Fig. 7) suggests one reason these assemblages may be distinct from those seen elsewhere to date.

The relative importance of the energy groupings derived from the environmental data in explaining variation in the biota was also evidenced by dbRDA. Indeed, the energy groupings explained 19% of the variation in the biota, which was larger than any of the other spatial or temporal factors in the design (Table 5). Individual estuaries (as a factor) and the positioning of sites (A-J) also explained relatively high proportions of the biotic variation, at 17% and 15%, respectively. Interestingly, the variation in the biota explained by individual estuaries did not overlap much with the variation explained by

the energy groupings; that is, the factor "Estuary" explained nearly as much of the biota (~13%) after fitting the energy groupings as it did alone (Table 5). Thus, estuary-specific effects were more evident this year than in previous years, due to the addition of the two new arms of the Whitford embayment, which were reasonably distinguishable biologically from other estuaries (as seen in section 3.1.2 above).

In contrast, the variation explained by temporal factors (season and rainfall) was negligible compared to the spatial factors in the design (Table 5). Rainfall effects, explaining less than 0.5% of the biotic variation, were not even identifiable as statistically significant when considered independently ($P = 0.142$).

Table 5. Results of distance-based redundancy analysis (dbRDA) examining the proportion of variation in the biota (based on Bray-Curtis dissimilarities of ln(y+1) abundances) explained by spatial and temporal factors in individual (marginal) and in conditional (sequential) tests.

Marginal tests:

Variable	SS(Trace)	F	P	Variance explained
Season	6569	3.98	0.001	1.41%
Rainfall	2447	1.47	0.142	0.53%
Estuary	79306	9.33	0.001	17.02%
Site	72333	5.51	0.001	15.53%
Energy	88745	32.59	0.001	19.05%

Conditional tests:

Variable	SS(Trace)	F	P	Variance explained	Cumulative
Energy	88745	32.59	0.001	19.05%	19.05%
Estuary	59380	8.44	0.001	12.75%	31.79%
Site	43194	4.58	0.001	9.27%	41.06%
Season	6569	6.40	0.001	1.41%	42.47%
Rainfall	2447	2.40	0.005	0.53%	43.00%

When environmental energy groupings were overlaid onto the MDS plots of faunal data (Fig. 15), a relatively clear separation was seen at each time between the different coloured dots, further indicating that overall variation in biological data was strongly correlated with the three environmental energy groupings. Next, we used CAP (separately at each time) to find axes in the multivariate cloud of biological data (at the site level) that were best at separating the energy groupings. These analyses revealed that the energy groupings could clearly be identified in the space of the biological variables (Table 6). The total allocation success ranged from 79% to 90% at all times, and all times showed statistically significant differences among the energy groups.

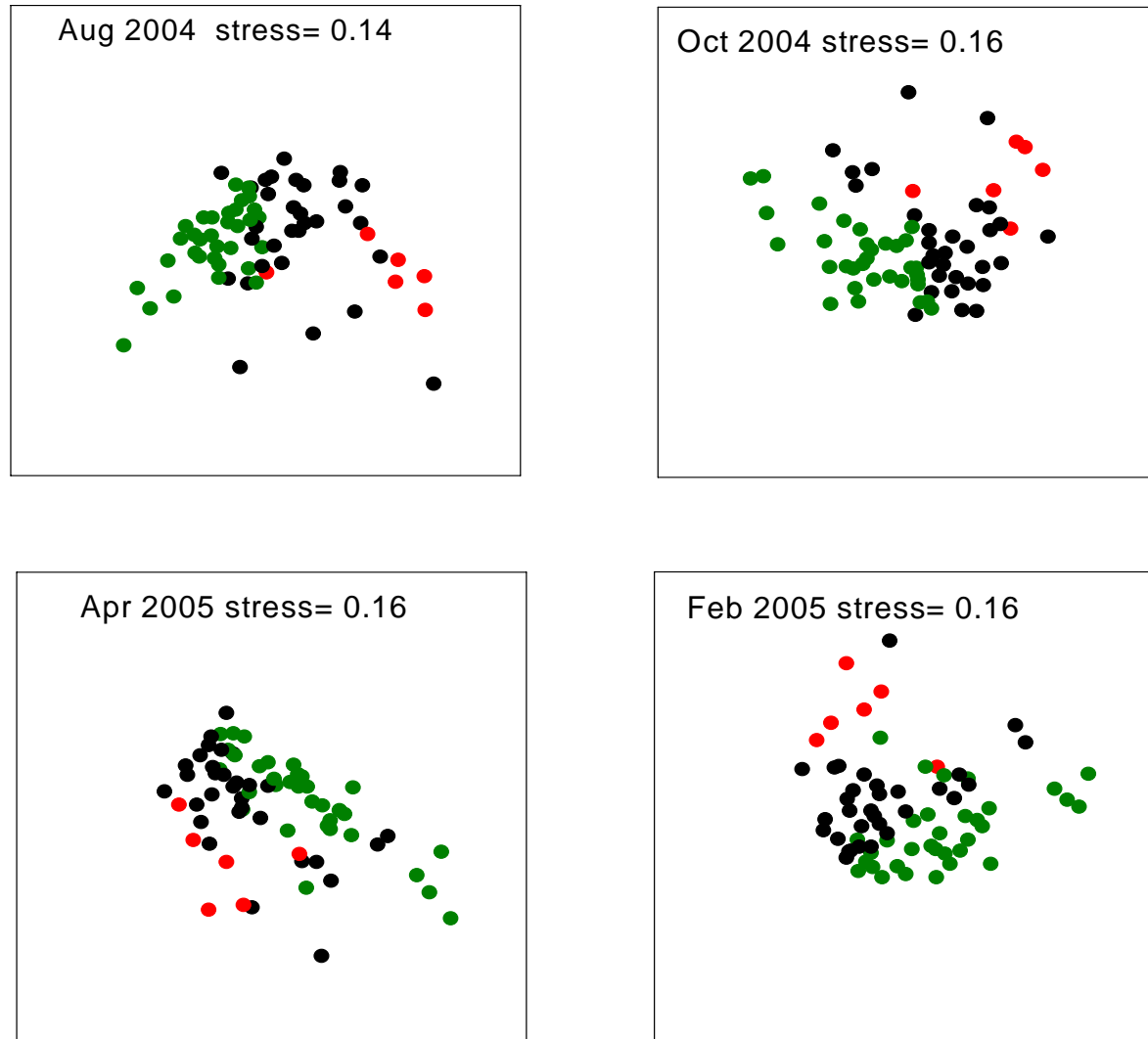**Figure 15.** MDS plots of assemblage data at each sampling time showing different hydrodynamic energy groupings (obtained from environmental data). The analyses were based on the Bray-Curtis dissimilarity measure calculated from *ln* (*y* + 1)-transformed species data. Observations were pooled at the site level *(n*=6). High-energy sites are shown by red dots, medium-energy sites by black dots and low-energy sites by green dots.

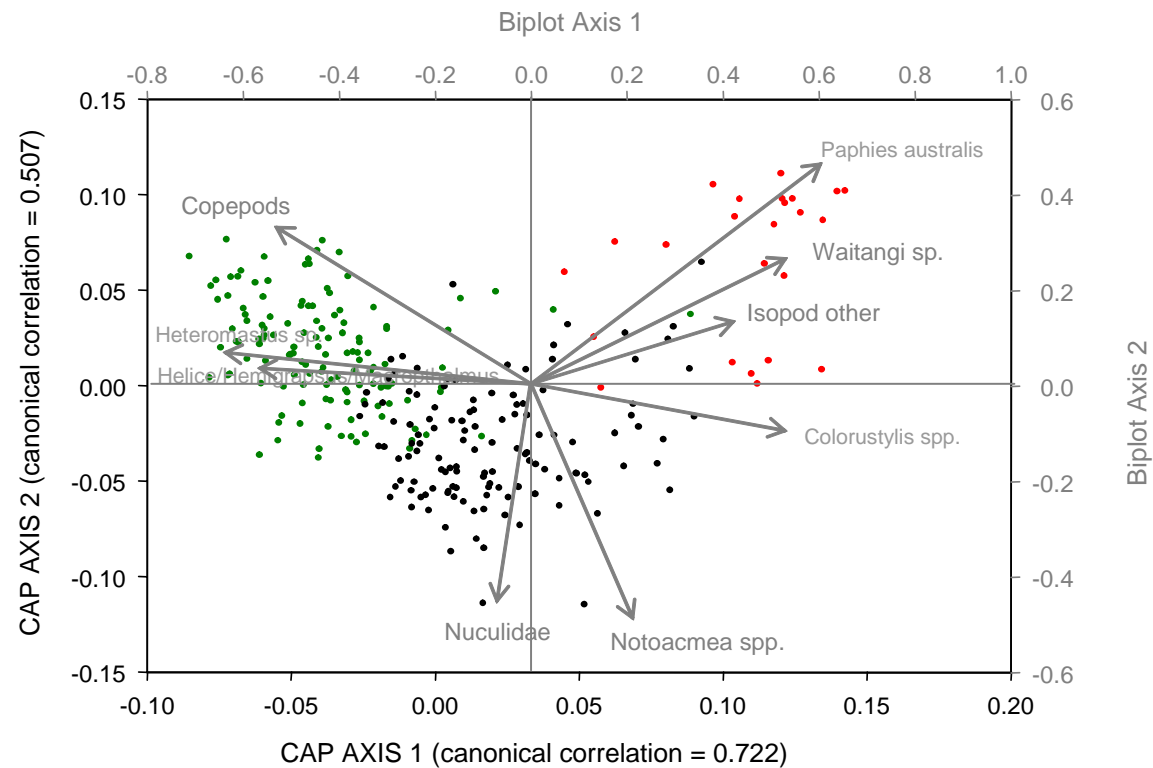**Figure 16.** CAP plot relating the taxa to the hydrodynamic groupings. Sites are displayed as High (dots in red), Medium (dots in black) and Low (dots in green) energy sites. The analysis was obtained from Bray-Curtis dissimilarities of ln(y + 1) transformed species counts. Observations were pooled at the site level. Correlation biplot arrows are shown for taxa with a correlation > 0.5 on either axis.

An overall CAP analysis was done and fauna having strong correlations with the axes (arrows on the biplot) indicated which taxa were responsible for the group differences (Fig. 16). High-energy sites were characterised by large numbers of the bivalve *Paphies australis,* the amphipod *Waitangi* sp., the cumacean *Colorustylis* sp. and the isopod "other isopod". Medium-energy sites were characterised by high numbers of bivalves of the family Nuculidae and the limpet *Notoacmea* spp. Low-energy sites were characterised by large numbers of copepods, crabs (*Helice, Hemigrapsus* and *Macropthalmus* spp.) and the capitellid polychaete *Heteromastus sp*. These taxa are largely those found to be indicative of the energy groupings in previous years (Ford *et al.* 2003, 2004). Univariate plots of the abundances of these taxa over time are shown in Appendix E.

Table 6. Results of CAP analysis examining the effect of energy grouping (from environmental data) on faunal data. *m* = the number of principal coordinate (PCO) axes used in the CAP procedure, %Var = the percentage of the total variation explained by the first *m* PCO axes, Allocation success = the percentage of sites correctly allocated into each energy group, using the faunal data. *P*-values were obtained using 999 random permutations

			Allocaton Success %				
	m	% Var	High	Low	Medium	Total	P
August 2004	6	74	67	91	81	84	0.001
October 2004	7	74	67	97	87	90	0.001
February 2005	4	60	83	88	68	79	0.001
April 2005	7	76	67	76	87	80	0.001

5.3 Changes in community structure over time

Control charts were used to assess how community structure was changing over time for each site. These were done separately for sites in different energy groupings (Figs. 17-19). High-energy sites were found to be more variable than low or medium-energy sites. This can be seen because the upper confidence bound on dissimilarities through time for high-energy sites is higher (~50%) than for either medium or low-energy sites (~45%). In addition, most changes seen were transient and were not coincident with rainfall samplings. In particular, the "pulse" effects of rainfall observed for Puhoi last year (sites C and I) did not occur this year (Figs. 18, 19).

This year, only one persistent change in community structure through time was identifiable from the control charts: at site RC (Fig. 17). At Orewa site C from March 2004, the community composition changed abruptly and remained altered through to

April 2005. This particular change is, however, easy to explain. In March 2004, it was necessary to change the location of this site by approximately 70m because a channel had formed through the edge of the site. This channel caused problems for taking sediment trap and bed height measurements and altered the area available for biological sampling. SIMPER analysis revealed that the new site (which was chosen to be as environmentally similar to the former Orewa site C as possible), actually has greater abundances of barnacles, polychaetes (*Aonides sp.*), cockles (*Austrovenus*) and limpets (*Notoacmea* spp) than the older site labeled RC. Thus, we propose that in the next report, the baseline for site RC should start at March 2004, the time of its necessary shift in location.

Changes in the positioning of sites are not desirable, but they are an inevitable consequence of the dynamic nature of soft substrata and channels in estuaries. Thus, such changes are bound to occur over time in a monitoring programme such as this one, as the geomorphology of the estuary changes subtly over time. It is reassuring that the control chart technique was sensitive enough to pick up on this change in the positioning of the one site, even though it was chosen to be (on the face of it) highly similar environmentally to what had been measured and sampled before. This gives us confidence that any important persistent changes in assemblage structure through time will be detected using our approach.

Several sites in Waiwera (A, B, D, E, F, G) and site B in Puhoi changed from being classified as low-energy sites to medium-energy sites in August 2003 (Fig. 19). A change from low to medium-energy is not the kind of change we would expect through time if estuaries are experiencing infilling. Perhaps of greater potential concern were the sites that changed from high to medium-energy sites (WH, WI, RG) and those that changed from medium to low-energy (PG). Despite such changes in their environmental classification, these sites did not demonstrate any strong or persistent changes in the biota from their own baseline community structure measured back in 2002 (i.e., the control charts show that they still remain within the confidence bounds expected Figs. 17-19). As medium and low-energy sites can be difficult to distinguish from one another, such changes in environmental classification are not a cause for great alarm, but will continue to be carefully monitored.

Appendix E shows patterns through time for several prominant taxa, particularly those characterising high, medium and low-energy environments. *Austrovenus stutchburyi* are fairly consistent through time, while crabs, copepods and *Notoacmea sp.* are all somewhat variable. Importantly none of these show any clearly consistent increases or decreases. The capitellid polychaete *Heteromastus sp.* appears to be decreasing through time at low-energy sites at Okura estuary. The cumacean *Colorustylis* spp. characterises high-energy sites across the region, but is also consistently abundant in medium-energy sites at Mangemangeroa. The pipi *Pahies australis* occurs consistently at high-energy sites and can reach extremely high densities (> 1000 per set of 6 cores), but these peaks are transient. The amphipod *Waitangi sp.* is also found in greatest abundance at high-energy sites, but shows no clear temporal trends. Nuculid bivalves

were most abundant (and variable) at Mangemangeroa, but are present fairly consistently at lower numbers over time at most sites. Importantly, the total number of taxa and the total number of individuals is shown to be quite stable through time (Appendices E11, E12).

Figure 17. Control charts for the all high-energy sites by estuary. The analysis was done on Bray-Curtis dissimilarities of ln(y + 1) transformed species counts. 95%CI = upper 95% confidence bound obtained by bootstrapping. Circles around points indicate that the site at that time has been reclassified into a different energy grouping from that of the initial time of sampling.
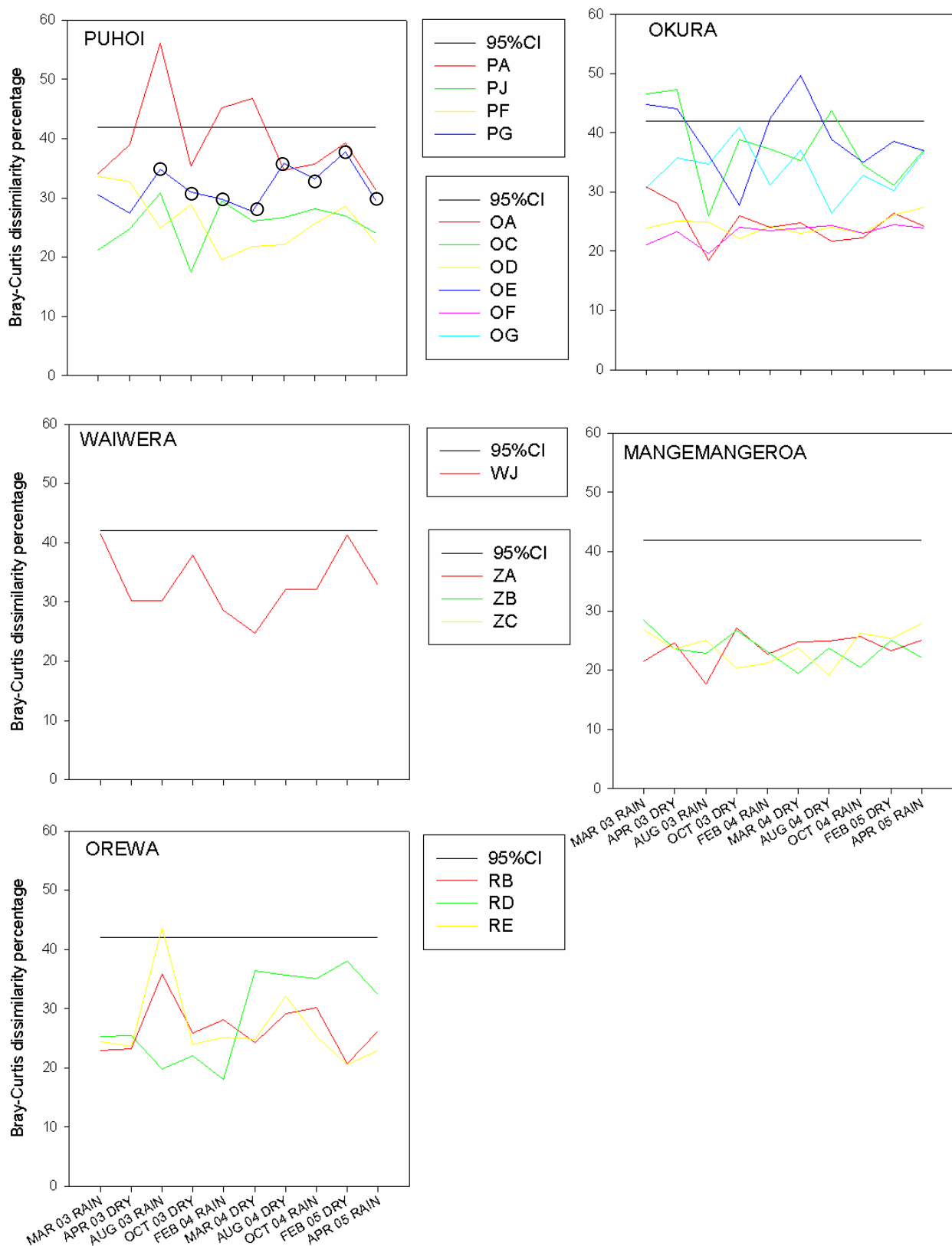
Figure 18. Control charts for the all medium-energy sites by estuary. The analysis was done on Bray-Curtis dissimilarities of ln(*y* + 1) transformed species counts. 95%CI = upper 95% confidence bound obtained by bootstrapping. Circles around points indicate that the site at that time has been reclassified into a different energy grouping from that of the initial time of sampling.
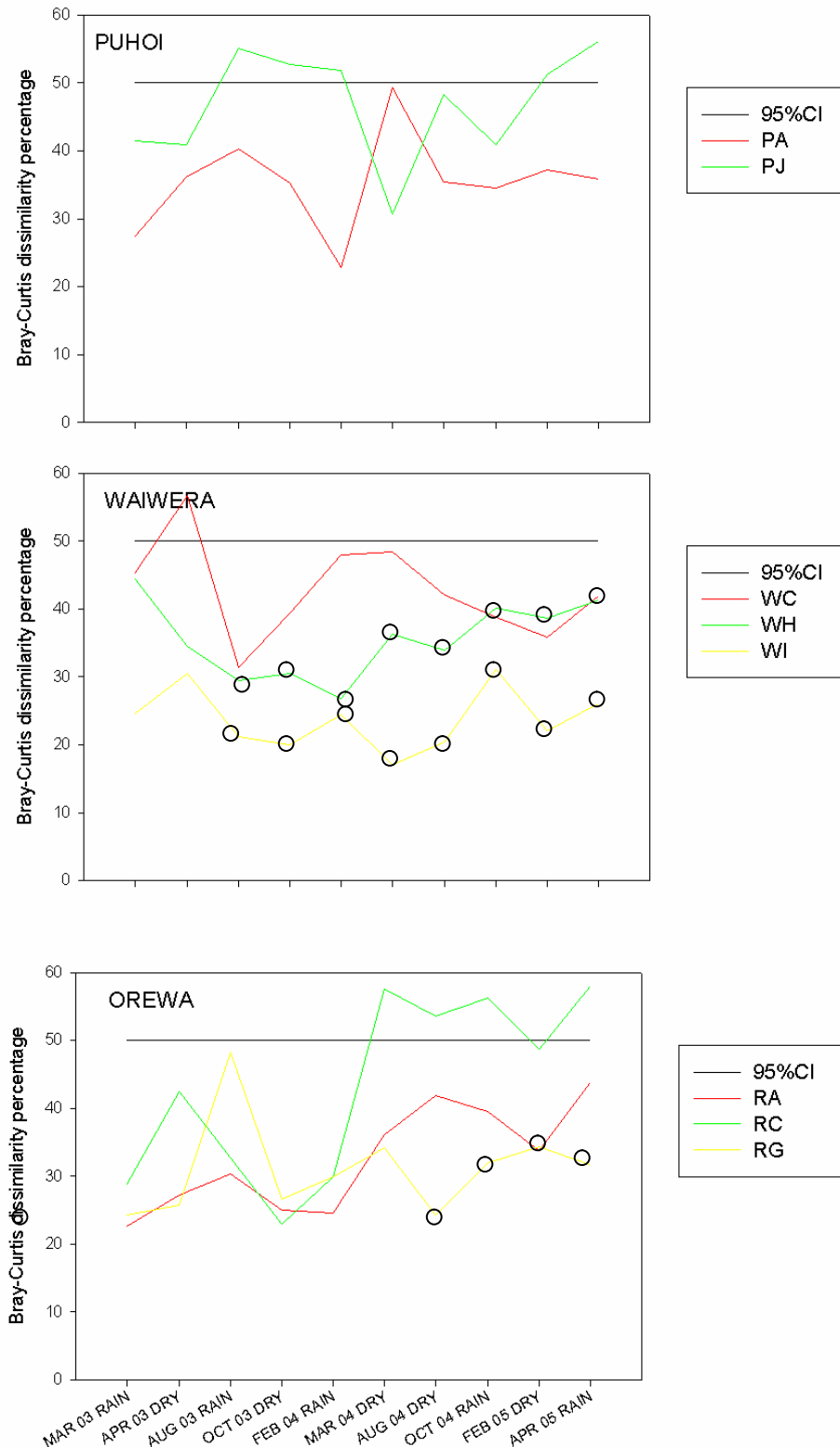
Figure 19. Control charts for the all low-energy sites by estuary. The analysis was done on Bray-Curtis dissimilarities of ln(*y* + 1) transformed species counts. 95%CI = upper 95% confidence bound obtained by bootstrapping. Circles around points indicate that the site at that time has been reclassified into a different energy grouping from that of the initial time of sampling.
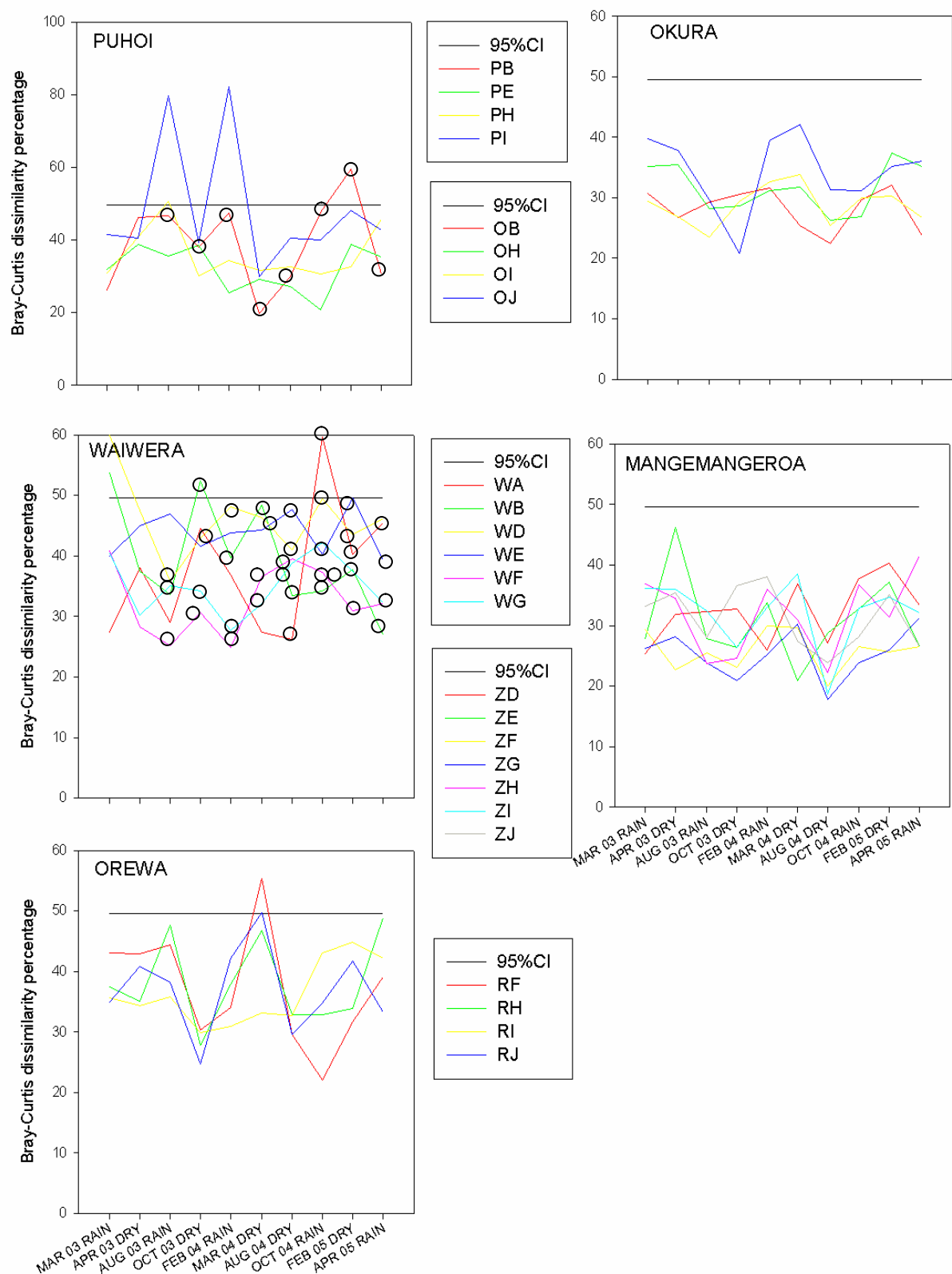
5.4 The influence of rainfall on community structure

The influence of rainfall was gauged by looking for a combination of principal coordinates (based Bray-Curtis dissimilarities in community structure) that would result in the highest correlation with measured rainfall. All available information to date was used for this analysis, in order to obtain the greatest power to detect any possible effects, because individual rainfall events have never previously been observed to have clear or consistent effects in these systems (Ford *et al.* 2003, 2004).

The canonical correlation of the community structure with measured rainfall was 0.21, 0.28 and 0.34 for the low, medium and high-energy sites, respectively (Fig. 20). This was statistically significant ($P < 0.01$ in all cases), but is obviously still a fairly weak signal. The taxa having the highest correlations with these canonical axes were examined alone for their relationship with rainfall. These were *Scololepis sp.*, Isopod spp. and Capitellids and Oligochaetes. In all three cases, rainfall explained less than 1% of the variation, suggesting that, at least across the range of rainfall events sampled by this monitoring programme, there is little or no evidence that rainfall events are important in structuring communities through time. It should be noted, however, that at this time extensive development is not occurring in any catchment; therefore, impacts of heavy rainfall on estuaries are not expected.
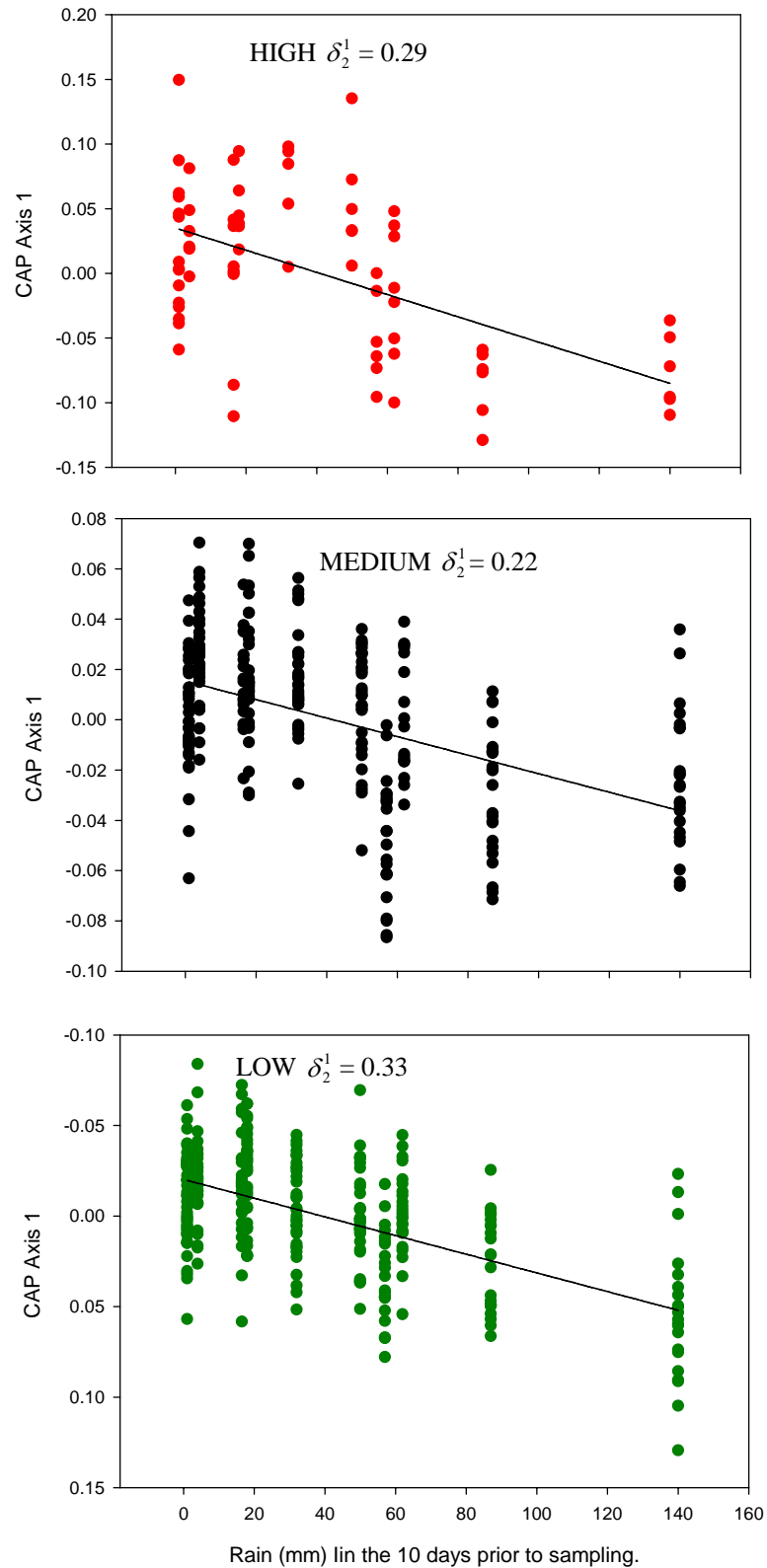
Figure 20. Canonical analysis (CAP) of the relationship between community structure (on the basis of Bray-Curtis dissimilarities of ln(y+1) transformed abundances) versus rainfall, done separately for the three different energy groupings. There were 11 different sampling occasions from August 2002 until April 2005.

6 DISCUSSION

By reference to the points raised in section 1.3 outlining the primary goals of this study, we consider the following take-home messages for the monitoring programme this year:

6.1 Are existing estuaries providing a good set of reference locations for monitoring Okura on a regional basis?

The physical characteristics of the sites at Okura continue to fall within the range of characteristics seen across monitored estuaries in the region. The estuaries chosen are indeed providing a good set of reference locations. The two additional estuaries from the Whitford embayment, Turanga and Waikopua, along with Mangemangeroa, have sites which are similar to Okura in a number of respects. None of these estuaries have sites categorised as "high-energy" sites. In addition, all of these estuaries will potentially suffer from changes in land-use over time, as Auckland's urban development continues to sprawl to the north and south. Perhaps the most serious concern is the potential loss of biodiversity from sediment inputs. Currently the biodiversity of taxa is relatively high in these estuaries (e.g., Fig. 13) and ongoing monitoring is essential.

6.2 Is the environmental model of high, medium and low-energy sites across all estuaries still valid?

Evidence for the past three years of monitoring suggests that these energy groupings are useful and identify significantly different types of ecological assemblages. In addition, the component biota that make up the different energy groupings appear to be temporally fairly consistent. Nevertheless, it is somewhat difficult to find a convenient "line in the sand" to draw a clear distinction between low and medium-energy sites and several sites have changed identity over the last two years.

We consider that, although this method of classification is useful and warranted, it may also be helpful in the future to consider the variation in physical dynamics across sites in terms of a more gradual "gradient" type of approach, rather than in terms of discrete "groups". A gradient approach to modeling the physical dynamics of sites may be more sensitive to smaller changes and can provide more power than a grouping model (e.g. Somerfield *et al*. 2002, Hewitt *et al*. 2005). It can also be quite useful for tracking subtler changes in sites through time (for example, by reference to the characteristics of trapped sediments and distance from the mouth of the estuary, Fig. 11).

6.3 Can differences in biological communities from the high, medium and low-energy sites be detected and characterised in terms of component fauna?

There were significant differences among the biological communities in the three energy groupings. Biotic information alone successfully classified sites into the correct environmental grouping with a success rate of 83% on average (Table 6). In addition, similar fauna were indicative of sites in a given energy classification as were identified in previous years: low-energy sites were characterised by crabs (*Helice*, *Hemigrapsus*, *Macropthalmus* spp.), copepods and *Heteromastus filiformis*, medium-energy sites were characterised by *Austrovenus stutchburyi*, Nuculidae, *Notoacmea sp.*, and high-energy sites were characterised by *Paphies australis*, isopods and amphipods such as *Waitangi sp.* and the cumacean *Colorustylis* spp. (Fig. 16).

Our results are broadly consistent with the occurrence and relative densities of organisms expected in response to changes in sediment mud content, as provided in the models given by Thrush *et al.* (2003b). For example, numbers of taxa and individuals are relatively low and the abundances of crabs and *Heteromastus sp.* are relatively high at our muddiest sites (in the upper reaches of Waikopua and Turanga), in agreement with their predictions. Thrush *et al.* (2003b) also predicted that the sandiest sites, having 0% mud content, should show the greatest frequency of occurrence and the highest densities of bivalve species, such as Nuculids and *Austrovenus stutchburyi*. Our data show, however, that these bivalves were more abundant at medium-energy than at high-energy sites, even though the latter have smaller mud content. This suggests that the models in Thrush *et al.* (2003b) are limited and are better for some taxa than for others; they did not attempt to include the full range of environments over which some of these organisms can and do occur.

6.4 What are the long-term temporal patterns of changes in assemblages? Are there any current signs of impact?

No decreases in diversity were detected at any sites, such as would be predicted for the Whitford embayment estuaries under scenarios of catchment development (Senior *et al.* 2003). This relative stability in communities is not unexpected at this pre-development stage. Control charts revealed that assemblages at all monitored sites are currently all within the bounds of what would be expected, given natural variability through time measured to date. Assemblages that have appeared "outside the bounds" of control-chart limits (i.e., which have exceeded a given percent dissimilarity from the baseline assemblage at that site as measured in August-October 2002) have rapidly come back within the bounds at the next sampling date.

The only exception to this was site C at Orewa. This site demonstrated a persistent change in assemblage structure as and from March 2004 (Fig. 17). This was caused by the need to change the physical location of this site, due to a natural alteration in the

position of the channel in the estuary. It is revealing (and reassuring) to note that the control chart technique was sensitive to this change in the positioning of the site. Even though the new position was only ~ 70 m away and was purposefully chosen to be as similar in physical characteristics as possible, a small spatial shift such as this can make a big difference to the biota. The messages here are clear – (1) that the biota in these estuarine inter-tidal habitats can change dramatically on relatively small spatial scales (10's of metres) and (2) that the control charts provide a useful and sensitive tool for detecting any clear and relevant changes in assemblage structure at individual sites when they do occur.

6.5 Are there identifiable effects due to rainfall events and can these be characterised in terms of specific fauna?

In the current year of sampling, no significant effects of rainfall on assemblages were detected (Table 5). When the full time-series of biological data was examined and a correlation was sought between assemblage structure and specific measures of rainfall, some statistically significant but weak correlations were detected (Fig. 20). However, these effects were not characterisable and none of the individual taxa examined appeared to demonstrate any clear effects of rainfall (r^2 < 0.01 in all cases). Therefore, effects of heavy rainfall, at least across the range of rainfall events examined in this programme since August 2002, have not shown any important ecological impacts.

It is likely that the reason for the lack of detectable effects is due to there not having been any catastrophic rainfall events during the life of this monitoring programme to date. It is also the case that any effects that have been detected (such as the "spikes" in the control charts for certain sites at Puhoi last year) were short-lived because estuarine environments are naturally fairly changeable environments which experience short periods of floods and concomitant drops in salinity and other changes, to which most of these organisms are reasonably well-adapted. None of the rainfall events monitored have yet resulted in large depositions of terrigenous sediments which would cause irreversible changes in resident fauna, as evidenced by control charts as well as sediments collected in traps to date. Development of catchments has not, however, begun on a large scale, so this result is not unexpected.

It is also worth noting here that temporal variation in assemblages throughout the past three years has, in general, been extremely slight compared to spatial variation. Seasonal effects this year accounted for only 1.41% of the variation in assemblage structure (Table 5) and no clear seasonal patterns have appeared in any of the control charts. This result is consistent with other monitoring programmes which have not detected any strong or consistent seasonal signal for either the Mahurangi or Manukau estuaries over longer time scales (Turner *et al.* 1995; Cummings *et al.* 2003).

6.6 Do the new sites at Turanga and Waikopua fall within the range of what has been observed elsewhere in terms of physical dynamics and in terms of fauna?

Many of the twenty new sites included in the monitoring programme at Turanga and Waikopua did fall within the range of existing monitored sites across the region in terms of their physical characteristics. However, several sites in the upper reaches of Turanga (E, H, I, J) and Waikopua (H, I, J) had some of the finest ambient sediments across all of the sampling sites. All of the estuaries in the Whitford embayment also tended to have larger percentages of fine sediments in traps than did sites in other estuaries. Furthermore, it is interesting to note that, as occurred last year, the greatest percentage of variation in assemblage structure was driven by grain-size characteristics in trapped sediments (as opposed to ambient sediments, although these are correlated, Table 4). Indeed, it is perhaps the rate of sedimentation of sediments in the fine fraction (< 63 microns) that is the most relevant issue for the biota, which should be the main focus for monitoring, rather than simply the overall amount of sediment in the traps.

The sites with the finest ambient sediments (Turanga (E, H, I, J) and Waikopua (H, I, J)) also had very low biodiversity, with small total abundances and small numbers of taxa (Figs. 13, 14). This agrees with the categorisation of Senior *et al.* (2003) who described this area (BCV 1) as having low diversity. These sites were also unusual because they had greater average proportional abundances of crustaceans and nematodes compared to other sites. High diversity areas as characterised by Senior *et al.* (2003), particularly Mangemangeroa sites B and C, also showed large numbers of individuals and taxa in this monitoring programme (Figs. 13, 14).

6.7 How can these sites be classified by reference to the high, medium and low-energy groupings identified across the region?

Sites in Turanga and Waikopua were all classified as either medium or low-energy sites. We consider that several of these sites (H, I, J) actually extend the current spectrum of physical dynamics for monitoring, being extremely low-energy sites, with dense and very fine sediments. Some of the differences in the biota at this end of the spectrum could also be caused to some extent by a difference in tidal height. Although all sites are generally known to be in the mid to low inter-tidal zone, tidal height does vary slightly across monitored sites, and we consider that it should be more carefully measured and modelled explicitly as an additional environmental variable.

6.8 What characterises differences in physical dynamics or biota at Turanga and Waikopua compared to the other estuaries?

We consider that it is the addition of these two new estuaries that resulted in "Estuaries", as a factor, being more important in explaining biotic assemblage structure than in previous years (Table 5). In addition to extending the low-energy end of the physical spectrum, other general patterns of differences at these estuaries in terms of biota were clear from plots of some of the primary taxa (Appendix D). Turanga, Waikopua (and to some extent Mangemangeroa) tended to have, on average, fewer cockles (*Austrovenus stutchburyi*) and pipis (Paphies australis) but greater average abundances of copepods, Nuculidae, *Heteromastus filiformis*, *Prionospio sp.* and crabs (*Helice/Hemigrapsus/Macropthalmus* spp.). Despite the upper reaches of Turanga and Waikopua being somewhat depauperate, the number of taxa in the middle and outer reaches of these estuaries was quite substantial, with site B at Waikopua actually recording the highest average diversity of any site this year (Figs. 13).

7 RECOMMENDATIONS

On the basis of the above results, we offer the following recommendations for future monitoring:

❑ Gradient modelling of environmental variables and biotic responses
In addition to the model of estuarine sites across the region defined by the three "energy" groupings, we suggest that a gradient approach be used for modeling sites in terms of physical dynamics and that the biotic assemblages be related to the (one or more) physical gradient(s). A similar approach is currently being used, for example, in the ARC's development of a regional model for benthic health in response to heavy metal contaminants (Hewitt *et al.* 2005). Such an approach may have greater power and be more sensitive to smaller directional changes in either the environmental conditions or the biological assemblages at a given site.

❑ Continued monitoring, to aid prediction and to detect changes in biodiversity
The extent of baseline data we now have puts the ARC in the driver's seat with respect to making good predictive models of the nature of the assemblages we should expect to find at any given time at any of these monitored sites. The importance of developing good predictive models for ecology and environmental analysis cannot be overstated. Peters' (1991) original critique for ecology (i.e., that it lacks good predictive quantitative models) unfortunately still holds to this day. Thrush *et al.* (2003b) provided some insightful steps in this direction with large-scale models of the responses of several key species to sediment mud content across many estuaries of the North Island. Clearly more work can be done in this area and the baseline data we have collected across the region to date as part of ongoing monitoring can provide a terrific launching pad for developing spatially-explicit regional models of fauna in different sedimentary regimes.
Senior *et al.* (2003) discussed the fact that perhaps the greatest risk from sedimentation impacts lies in the threats to biodiversity. Indeed, the upper reaches of the Waikopua and Turanga estuaries might already be considered to be impacted from extensive fine sediment depositions, showing associated limits in diversity. Thus, we consider the monitoring programme should be finely tuned to detect the changes to diversity we would expect from catchment development, such as decreases in richness and the loss of either patchily distributed or sensitive species, such as bivalves.

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9 **Appendix A.** Global Positioning System (GPS) coordinates of sites. Note that the coordinates for Orewa site C have changed as the site was moved due to channel movement in March 2004.

	Puhoi (P)		Waiwera (W)		Orewa (R)		Okura (O)	
Site	Lat. (S)	Long. (E)	Lat. (S)	Long. (E)	Lat. (S)	Long. (E)	Lat. (S)	Long. (E)
A	36° 31.61	174° 42.60	36° 32.56	174° 42.34	36° 35.95	174° 41.82	36° 39.55	174° 44.42
B	36° 31.88	174° 42.58	36° 32.52	174° 42.36	36° 35.88	174° 41.71	36° 40.63	174° 43.54
C	36° 31.61	174° 42.52	36° 32.45	174° 42.31	36° 35.92	174° 41.65	36° 40.37	174° 43.47
D	36° 31.82	174° 42.44	36° 32.47	174° 42.17	36° 35.92	174° 41.65	36° 40.61	174° 43.38
E	36° 31.73	174° 42.27	36° 32.39	174° 42.23	36° 35.87	174° 41.15	36° 40.51	174° 43.36
F	36° 31.80	174° 42.15	36° 32.45	174° 42.15	36° 36 02	174° 41.16	36° 40.13	174° 43.29
G	36° 31.66	174° 42.01	36° 32.43	174° 42.07	36° 35.84	174° 41.11	36° 40.15	174° 43.19
H	36° 31.66	174° 41 94	36° 32.48	174° 41.90	36° 35.85	174° 40.95	36° 40.17	174° 43.12
I	36° 31.54	174° 41 67	36° 32.44	174° 41.79	36° 35.73	174° 40.76	36° 40.25	174° 43.36
J	36° 31.57	174° 41 64	36° 32.42	174° 41.73	36° 35.68	174° 40.77	36° 40.28	174° 42.56

	Mangemangeroa (Z)		Turanga		Waikopua	
Site	Lat. (S)	Long (E)	Lat. (S)	Long (E)	Lat. (S)	Long (E)
A	36° 54.44	174° 57.47	36°54.40'	174°58.49'	36°54.08'	174°58.58'
B	36° 54.60	174° 57.39	36°54.49'	174°58.56'	36°54.17'	174°58.45'
C	36° 54.67	174° 57.33	36°54.70'	174°57.80'	36°54.19'	174°58.50'

D	36° 54.67	174° 57.27	36°54.92'	174°57.84'	36°54.20'	174°58.58'
E	36° 54.66	174° 57.23	36°55.18'	174°57.86'	36°54.18'	174°59.11'
F	36° 54.68	174° 57.20	36°55.32'	174°57.95'	36°54.24'	174°59.16'
G	36° 54.80	174° 56.98	36°55.38'	174°58.95'	36°54.26'	174°59.27'
H	36° 54.86	174° 56.91	36°55.74'	174°58.24'	36°54.29'	174°59.34'
I	36° 54.88	174° 56.93	36°55.90'	174°58.24'	36°54.30'	174°59.39'
J	36° 54.94	174° 56.79	36°55.93'	174°58.21'	36°54.46'	174°59.39'

Appendix B. List of taxa with their corresponding taxonomic group and the total number identified and recorded in the study.

MOLLUSCS	Group	Total
Austrovenus stutchburyi	Bivalvia	18302
Paphies australis	Bivalvia	10473
Nuculidae	Bivalvia	11748
Macomona lilliana	Bivalvia	2906
Notoacmea spp.	Gastropoda	2023
Arthritica bifurcata	Bivalvia	1753
Cominella glandiformis	Gastropoda	338
Theora sp.	Bivalvia	279
Diloma subrostratum	Gastropoda	244
Musculista senhousia	Bivalvia	188
Bivalve unknown	Bivalvia	169
Sypharochiton pelliserpentis	Polyplacophora	59
Soletellina siliqua	Bivalvia	46
Haminoea zelandiae	Opistobranchia	45
Gastropod unknown	Gastropoda	44
Zeacumantus sp.	Gastropoda	44
Chemnitzia sp	Gastropoda	40
Mactridae	Bivalvia	35
Xenostrobus spp.	Bivalvia	33
Paphies subtriangulata	Bivalvia	17
Amphibola crenulata	Gastropoda	16
Bulla spp.	Opistobranchia	15
Venericardia	Bivalvia	14
Opisthobranch other	Opistobranchia	13
Cominella adspersa	Gastropoda	8
Corbula zelandica	Bivalvia	5
Cominella maculosa	Gastropoda	2
Microlenchus sp.	Gastropoda	2

CRUSTACEANS	Group	Total
Barnacles	Cirripedia	18730
Paracorophium sp.	Amphipoda	11605
Waitangi sp.	Amphipoda	4579
Copepods	Copepoda	4304
Colorustylis spp.	Cumacea	4015
Helice/Hemigrapsus/Macropthalmus spp.	Decapoda	2285
Isopod other	Isopoda	2119

Parakalliope sp.	Amphipoda	1897
Phoxocephalid	Amphipoda	821
Crab megalopa	Decapoda	306
Shrimp	Decapoda	222
Halicarcinus spp.	Decapoda	220
Cirolana sp.	Isopoda	217
Amphipod other	Amphipoda	158
Leptostracean	Crustacea	90
Mysid shrimp	Mysidacea	90
Crab other	Decapoda	19
Mantis shrimp	Malacostraca	8

POLYCHAETES AND OLIGOCHAETES	Group	Total
Prionospio spp. complex	Spionidae	10083
Heteromastus sp.[1]	Capitellidae	6402
Capitella sp. & Oligochaetes	Capitellidae and Oligochaete	5595
Nereid/Nicon spp. complex	Nereidae	3210
Pseudopolydorid complex	Spionidae	2512
Aonides spp.	Spionidae	2387
Exogonid	Syllidae	2249
Scoloplos cylindifer	Orbiniidae	2131
Cossura coasta	Cossuridae	1599
Glyceridae	Glyceridae	876
Macroclymenella stewartensis	Malanidae	454
Pectinaria sp.	Pectinariidae	323
Scolelepis sp.	Spionidae	310
Orbinia papillosa	Orbiniidae	285
Orbinid other	Orbiniidae	249
Scolecolepides sp.	Spionidae	239
Armandia sp.	Opheliidae	198
Magelona dakini	Magelonidae	185
Aricidea sp.	Paraonidae	120
Polychaete other	Polychaete	110
Timarete anchylochaeta	Cirratulidae	98
Syllid other	Syllidae	89
Paraonis sp.	Paraonidae	40
Spionid other	Spionidae	23
Aphroditidae	Aphroditidae	39
Goniada	Goniadidae	38
Aglaophamus macroura	Nephtyidae	31
Hesionidae	Hesionidae	28
Minuspio sp.	Spionidae	11
Aphroditidae	Aphroditidae	4

Polynoidae	Polynoidae	9
Paraonid	Paraonidae	8
Owenia fusiformis	Oweniidae	5
Diopatra sp.	Onuphidae	1

MISCELLANEOUS	Group	Total
Anthopleura spp.	Anthozoa	2982
Nematode	Nematoda	1346
Nemertean	Nemertea	1172
Edwarsia sp.	Anthozoa	109
Sipunculid	Nonsegmented coelomate worm	99
Insect	Insecta	62
Miscellaneous	Miscellaneous	28
Anemone other	Anthozoa	27
Phoronid	Phoronida	21
Platyhelminth	Platyhelminth	10
Fish	Pisces	9
Mite	Acari	2

[1] *Heteromastus* sp. was *Notomastus sp.* last year