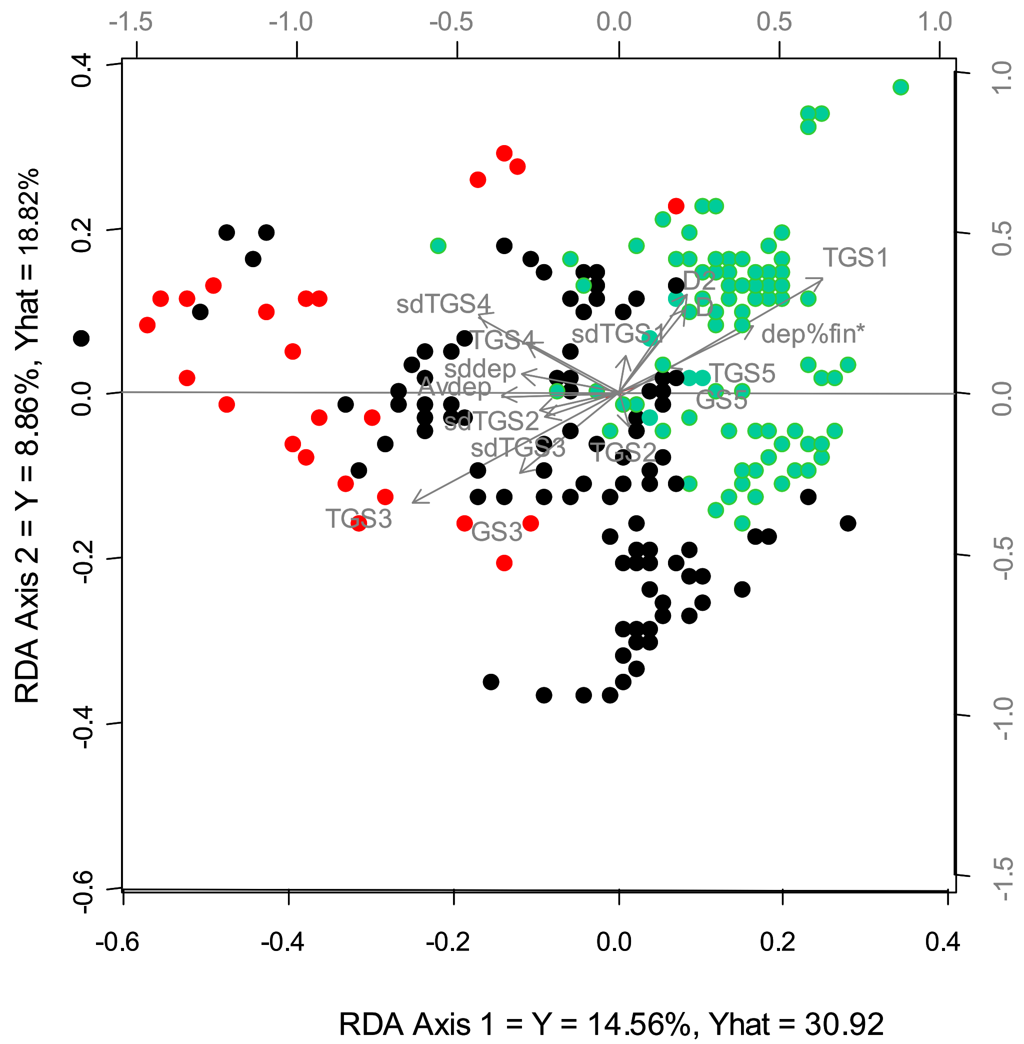

Figure 11. Distance-based RDA ordination relating the environmental variables to the 86 taxonomic variables for all sampling times. The analysis was done on principal coordinate axes obtained from Bray-Curtis dissimilarities of ln(y + 1) transformed species counts, with correction method 1 for negative eigenvalues (see Legendre and Anderson 1999). Observations were pooled at the site level. Sites of different hydrodynamic energy levels are indicated by different coloured dots as in previous plots (High-energy = red, Medium-energy = black, low-energy = green). Names of variables are given in Table 2. Variables with low correlation values (short arrows) were not shown as they obscured the plot and are of lesser importance. The axes values in grey relate to the biplot arrows (also in grey).

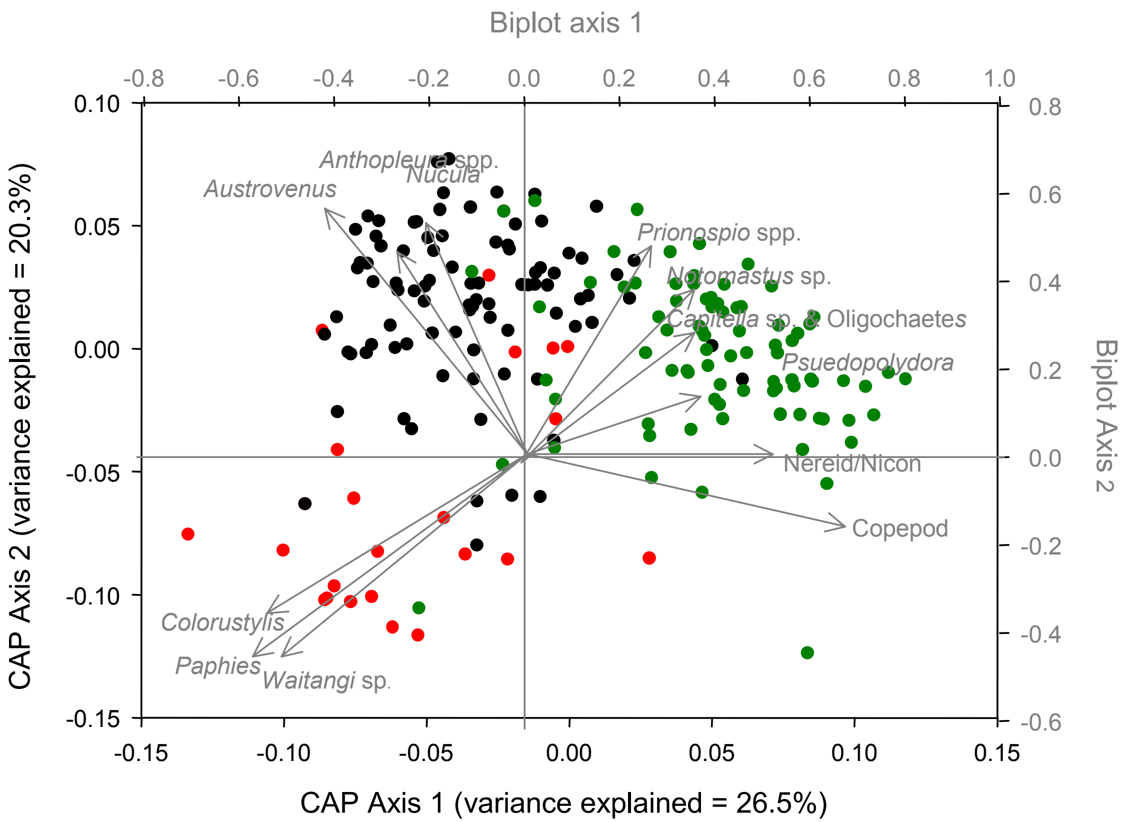

Figure 12. CAP plot relating the taxa to the hydrodynamic groupings. Sites are displayed as High (dots in red), Medium (dots in black) and Low (dots in green) energy sites. The analysis was obtained from Bray-Curtis dissimilarities of ln(y + 1) transformed species counts. Observations were pooled at the site level. Correlation biplot arrows are shown for taxa with a correlation > 0.5 on either axis or if identified as important from the analysis of Ford *et al.* (2003). Full names for all taxa are given in Figure 12.

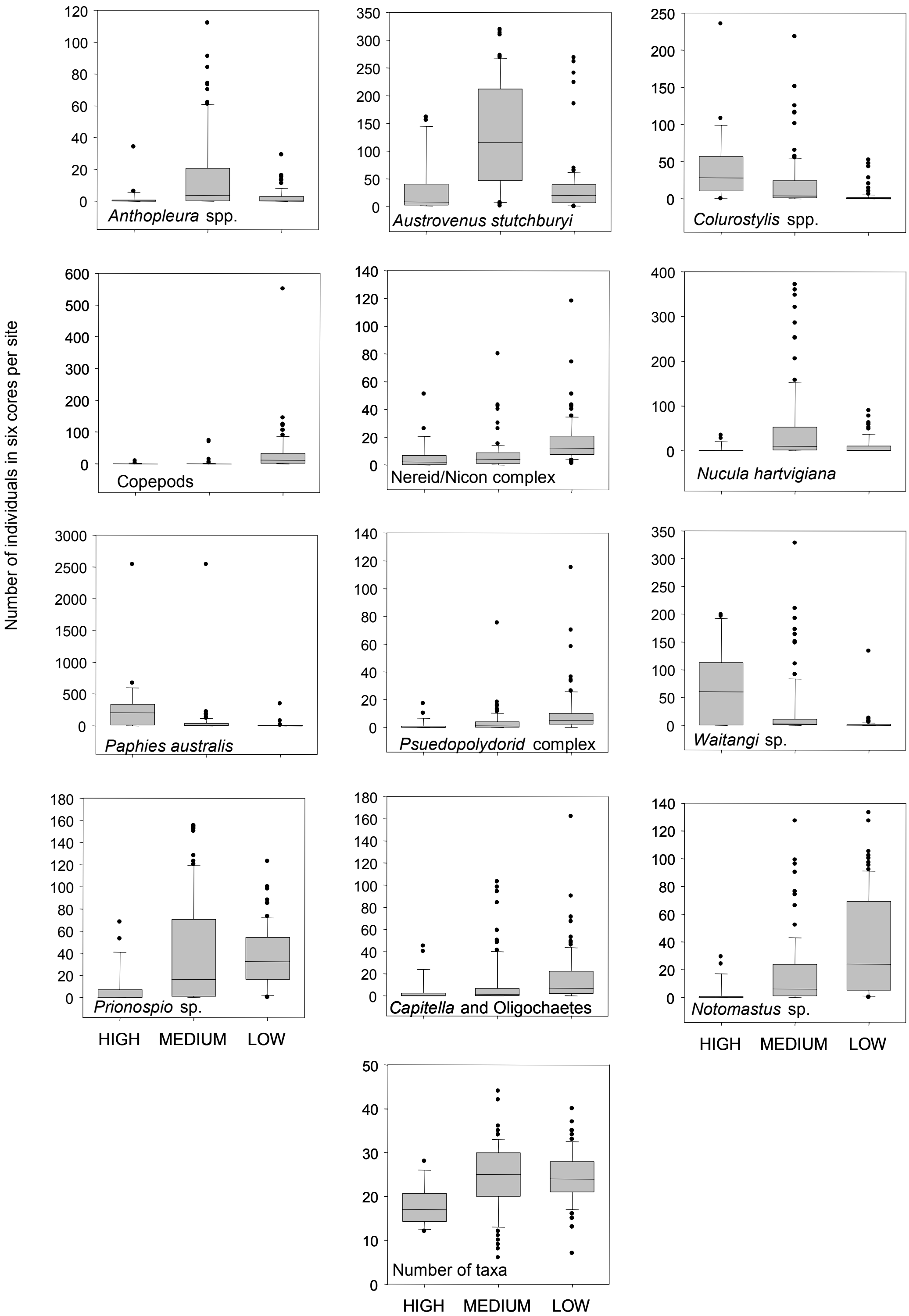

Figure 13. Boxplots of densities of individual taxa for all sampling times from 2003-2004 in High, Medium or Low energy sites. For high-energy sites, n = 24 (6 sites x 4 times), for medium-energy sites, n = 92 (23 sites x 4 times) and for low-energy sites n = 84 (21 sites x 4 times).

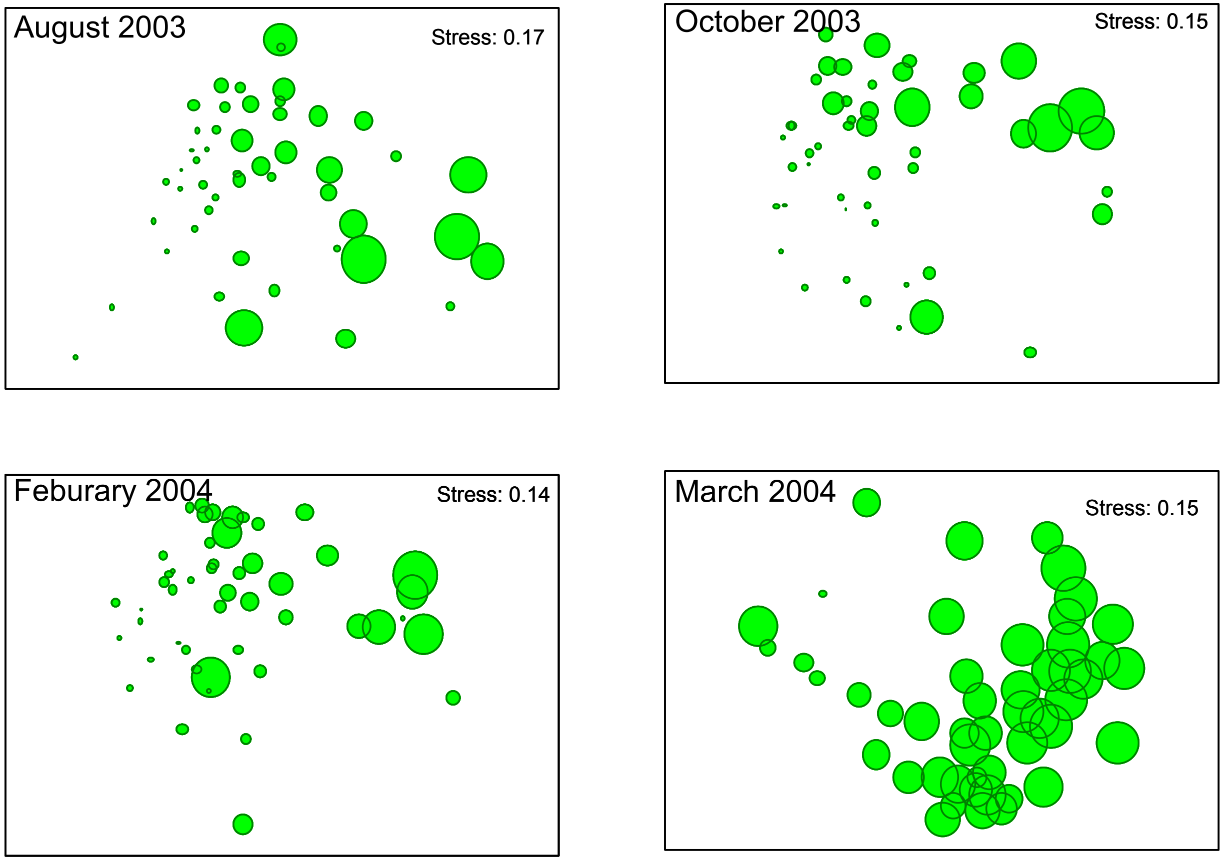

Figure 14. Bubble plots showing PCA axis 1 from Figure 8 (environmental data) superimposed as bubbles onto the MDS plots obtained from biological data at each of the four sampling times.

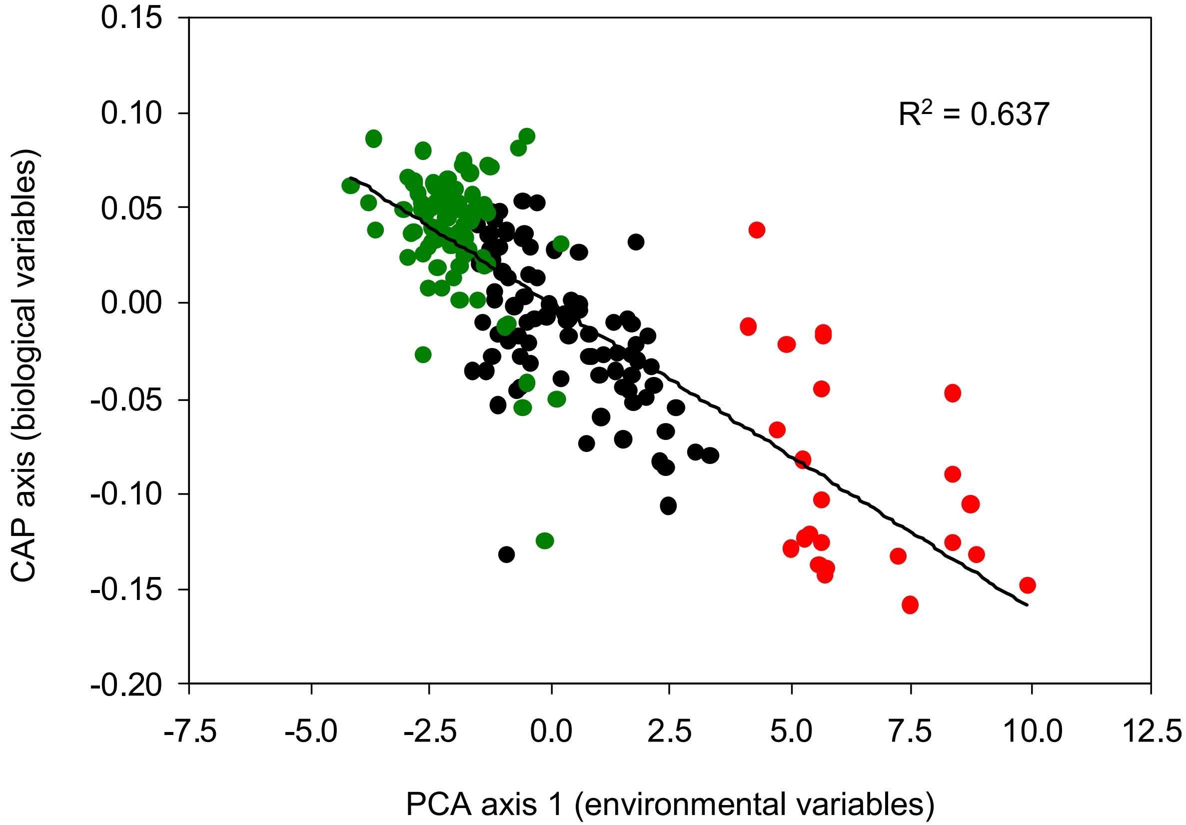

Figure 15. CAP analysis correlating biological data at the site level with the scores from the first PCA on environmental data (Figure 11) for all sampling times. High-energy sites = red dots, Medium-energy sites = black dots and Low-energy sites = green dots.

3.2.f. Effects of season and precipitation

The different energy assemblage groupings provide us with biologically similar communities across all estuaries that could be examined to determine whether any seasonal or rain-related patterns were present. By analysing these groups separately, much of the spatial variation is eliminated, allowing detection of even relatively weak temporal effects. Biological data for each set of sites (high, medium and low-energy) were analysed in response to the factors of Season and Precipitation (Table 9). Only in the low-energy sites was any significant effect detected, and this was a seasonal effect (Table 9). The comparison of MDS and CAP plots showed that this seasonal effect, although statistically significant, did not occur in a direction along axes of the greatest variability in the data (Fig. 16). The taxa most strongly correlated with the seasonal difference (*Notoacmea* sp., *Owenia fusiformis,* mites, *Amphibola crenulata,* other amphipods and *Diopatra* sp.) were all present at low densities (<1.5 per 6 cores from a site) and correspondingly showed fairly trivial, although statistically detectable differences between seasons (<0.6 of an individual per 6 cores from a site) and in no consistent direction. These results agree with those obtained last year, indicating that temporal differences were trivial by comparison to spatial differences. The only difference found this year was in the low-energy habitats, which were suggested as being the most sensitive habitats to temporal changes last year (Ford et al. 2003c).

Table 6. Results of permutational multiple regression of individual environmental variables on the species data for (a) each variable taken individually (ignoring other variables) and (b) forward selection of variables, where the amounts explained by each variable added to the model takes into account the variability explained by variables already in the model (i.e. those variables listed above it). %Var = the percentage of the variance in the species data explained by that variable.

(a) variables taken individually

Variable	% Var	pseudo-*F*	*P*
TGS1	14.56	33.75	**0.001**
TGS3	14.56	33.75	**0.001**
sdTGS4	10.31	22.77	**0.001**
dep*%fin	9.69	21.25	**0.001**
GS3	8.39	18.12	**0.001**
Avdep	8.35	18.03	**0.001**
dep*	7.45	15.94	**0.001**
TGS4	7.11	15.16	**0.001**
sddep	7.00	14.91	**0.001**
D2	6.57	13.91	**0.001**
D	6.21	13.10	**0.001**
sdTGS2	6.11	12.89	**0.001**
sdTGS3	5.93	12.48	**0.001**
TGS5	4.97	10.35	**0.001**
GS2	4.74	9.86	**0.001**
GS4	4.03	8.31	**0.001**
GS1	3.86	7.95	**0.001**
sdTGS5	3.86	7.95	**0.001**
sdBH	3.42	7.01	**0.001**
TGS2	3.12	6.37	**0.001**
GS5	2.81	5.73	**0.001**
sdTGS1	2.31	4.68	**0.001**
avfin	2.25	4.55	**0.001**
BH	1.93	3.91	**0.001**
depfin*	0.72	1.43	0.18
BH*	0.51	1.02	0.379

(b) variables fitted sequentially

Variable	pseudo-*F*	*P*	% Var	% Var cumulative
TGS1	33.75	**0.001**	14.56	14.56
sdTGS4	15.78	**0.001**	6.34	20.90
sdTGS1	12.42	**0.001**	4.71	25.61
sdTGS5	6.43	**0.001**	2.37	27.99
D	6.27	**0.001**	2.26	30.24
TGS3	5.99	**0.001**	2.1	32.34
sddep	5.25	**0.001**	1.55	33.89
GS3	4.51	**0.001**	1.29	35.18
GS4	3.79	**0.001**	1.26	36.44
avfin	3.76	**0.001**	1.72	38.16
sdTGS3	3.28	**0.001**	1.06	39.22
TGS5	3.08	**0.001**	0.99	40.20
Avdep	3.01	**0.003**	0.95	41.15
GS2	2.68	**0.002**	0.84	41.99
dep*%fin	2.69	**0.001**	0.84	42.83
TGS2	2.66	**0.004**	0.67	43.50
TGS4	2.62	**0.003**	0.81	44.32
BH	2.46	**0.006**	0.8	45.11
sdTGS2	2.17	**0.01**	0.76	45.87
GS5	2.00	**0.018**	0.6	46.47
dep*	1.78	**0.043**	0.54	47.01
sdBH	1.79	**0.033**	0.54	47.55
depfin*	0.97	0.465	0.29	47.84
BH*	0.86	0.605	0.26	48.10
D2	0.53	0.594	0.16	48.26
GS1	0.01	0.978	0	48.26

Table 7. Results of permutational multiple regression of sets of environmental variables on the species data for (a) each set of variables taken individually (ignoring other sets) and (b) forward selection of sets of variables, where the amounts explained by each set added to the model takes into account the variability explained by sets of variables already in the model (i.e. those sets of variables listed above it). %Var = the percentage of the variance in the species data explained by that set of variables.

(a) sets taken individually

Variable	% Var	pseudo-*F*	*P*
TrapsdGS	26.04	13.66	**0.001**
TrapGS	21.97	10.93	**0.001**
AmbGS	16.31	7.56	**0.001**
Traptot	14.75	11.31	**0.001**
Trap*	13.89	10.54	**0.001**
Dist	7.55	8.04	**0.001**
Erosion	5.63	3.89	**0.001**

(b) sets fitted sequentially

Variable	pseudo-*F*	*P*	% Var	% Var cumulative
TrapsdGS	13.66	**0.001**	26.04	26.04
TrapGS	5.27	**0.001**	9.05	35.09
AmbGS	2.34	**0.001**	3.87	38.96
Traptot	3.77	**0.001**	3.58	42.54
Trap*	1.73	**0.006**	1.60	45.68
Erosion	1.62	**0.004**	1.54	44.08
Dist	2.31	**0.002**	1.40	47.07

Table 8. Results of permuational multivariate analysis of covariance on effects of different estuaries on the species data over and above what was explained by environmental variables. %Var = the percentage of the variance in the species data explained.

Source	df	%Var	MS	F	P
Environmental variables (covariables)	26	47.5	0.63		
Estuaries *given* environmental variables	4	3.9	0.34	3.40	**0.001**
Residual	169	48.6			
Total	199				

Table 9. Results of permutational distance-based MANOVA investigating the effects Season and Precipitation on macrofaunal species abundance and composition within the different energy groups. The analysis was based on Bray-Curtis dissimilarities on data for 86 variables (taxa) transformed to ln(y + 1). P-values were obtained using 999 permutations.

a) Low-energy sites

Source	df	SS	MS	F	P
Season (Se)	1	2817.815	2817.815	2.3203	**0.014**
Precipitation (P)	1	1779.535	1779.535	1.4653	0.117
SexP	1	1446.328	1446.328	1.1909	0.256
Residual	80	97155.41	1214.443		
Total	83	103199.1			

b) Medium-energy sites

Source	df	SS	MS	F	P
Season (Se)	1	2618.176	2618.176	1.6925	0.086
Precipitation (P)	1	1666.732	1666.732	1.0774	0.334
SexP	1	2058.693	2058.693	1.3308	0.204
Residual	88	136131.5	1546.949		
Total	91	142475.1			

c) High-energy sites

Source	df	SS	MS	F	P
Season (Se)	1	1955.581	1955.581	1.1078	0.302
Precipitation (P)	1	1354.355	1354.355	0.7672	0.584
SexP	1	1173.313	1173.313	0.6647	0.634
Residual	20	35305.43	1765.272		
Total	23	39788.68			

3.2.g. Control charts of assemblages through time

Multivariate control charts monitoring assemblages in all estuaries from August 2002 until the present (8 times of sampling) are shown in Fig. 17-19. Certain sites at Puhoi estuary in all energy environments (PB, PC, PE, PG, PH, PJ, Figs. 17-19) showed changes in community structure that exceeded control chart upper bounds in a manner that appeared to be cyclical. These changes in community structure occurred specifically at times of sampling following heavy rainfall events. Two medium-energy sites at Waiwera (WB and WD) also showed important changes that were over a similar time scale as those observed at Puhoi estuary, but these were associated with sampling after relatively dry periods. Other sites showed significant changes in community structure that may be cyclical i.e. sites RF and RH, however they occurred over longer time scales and were not correlated with rainfall events. Other sites showed once-only significant changes in community composition (ZE, WC, RC). Sudden dramatic changes in biological communities in response to rainfall events, followed by a return to an assemblage similar to what was seen before therefore occur at small time scales mostly at Puhoi estuary. These may be described as "pulse" environmental perturbations, because they do not appear to have any longer term persistent effects. Okura was the most stable estuary, showing no dramatic changes in community composition at any site, followed closely by Mangemangeroa. Monitoring needs to persist to assess whether changes in community composition are cyclical, simply brief pulses or symptomatic of gradual community change over time. Control charts emphasizing sudden changes in assemblages (i.e. the charts on the left-hand side of Fig. 17-19) were very similar to those emphasizing gradual changes (the charts on the right-hand side of Fig. 17-19).

SIMPER was used to determine the taxa driving dramatic changes in assemblage structure that were identified at particular times and places in control charts (Fig. 17-19). These analyses revealed a remarkably consistent suite of species were involved in generating temporal differences (Appendix E). Large fluctuations in densities of the Pipi *Paphies australis,* barnacles and the amphipods *Waitangi* sp. and *Paracoropium* sp., the polychaetes *Psuedopolydora* complex and *Prionospio* spp. complex, capitellids and oligochaetes seemed mainly responsible for these differences. Fluctuations were not in a consistent direction by reference to rainfall events, i.e., a different assemblage could be due to a gain or loss of any of these species at a particular time and place. For example, the significant differences correlated with rainfall events at sites PI and PH were apparently due to decreases in *Paracoropium*, *Pseudopolydora* complex and capitellids and oligochaetes, at both times. At site PI, this change was accompanied by an increase in the pipi, *Paphies australis*, and in copepods and *Colorustylis* spp. and *Waitangi* sp. At site PH the change was accompanied by an increase in the number of copepods and a decrease in the densities of the bivalves *Austrovenus* and *Macomona,* mysid shrimps and the orbinid polychaete *Scoloplos cylindifer.* However, when changes at sites within a specific energy level were examined, differences among sampling times were generally characterised by a shift towards taxa more typical of other energy levels. In the high-energy site (PJ), assemblages occurring at times that differed from what was usually observed were characterised by taxa more typical of lower-energy sites (high densities of *Prionospio* spp. complex, low densities of *Paphies australis* and *Colorustylis* spp.). At low-energy sites, assemblages occurring at times that differed from what was usually observed were generally characterised by taxa more typical of high-energy sites (high counts of *Paphies australis* and *Waitangi* sp. and low counts of capitellids, oligochaetes, copepods and *Prionospio* spp. complex). In Medium-energy sites, important differences through time were characterised by increases or decreases of many different taxa (*Austrovenus stutchburyi, Paphies australis, Paracorophium sp., Prionospio* sp. complex).

One taxon which characterised each energy type was selected to assess whether any trends were visible in their abundance over the two years while sampling of all estuaries has been ongoing (Fig. 20). *Waitangi* sp. in high-energy sites and *Austrovenus stutchburyi* in medium-energy sites were variable in their abundance over the past two years without showing any consistent trends. *Notomastus* sp. capitellids in low-energy sites showed a consistent pattern of decrease over the past two years of sampling. Examination of data at the individual site level (not pictured) showed this pattern was driven by only a few sites (OB, PE, RF, ZF) with very high densities at the first or second sampling time, which subsequently decreased.

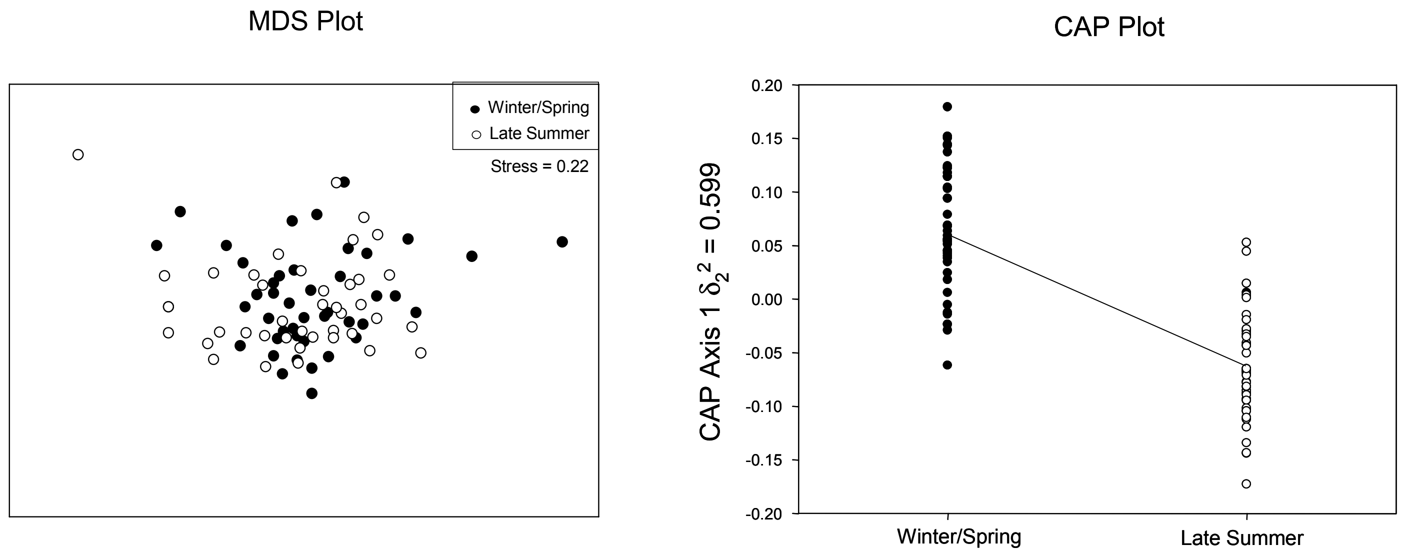

Figure 16. Non-metric MDS plot (left-hand side) and CAP plot (right-hand side) showing the effects of Season in low-energy sites from all samplings. Analyses were based on Bray-Curtis dissimilarities of 86 variables that were transformed to ln(*y* + 1). Each point represents pooled information from *n* = 6 cores

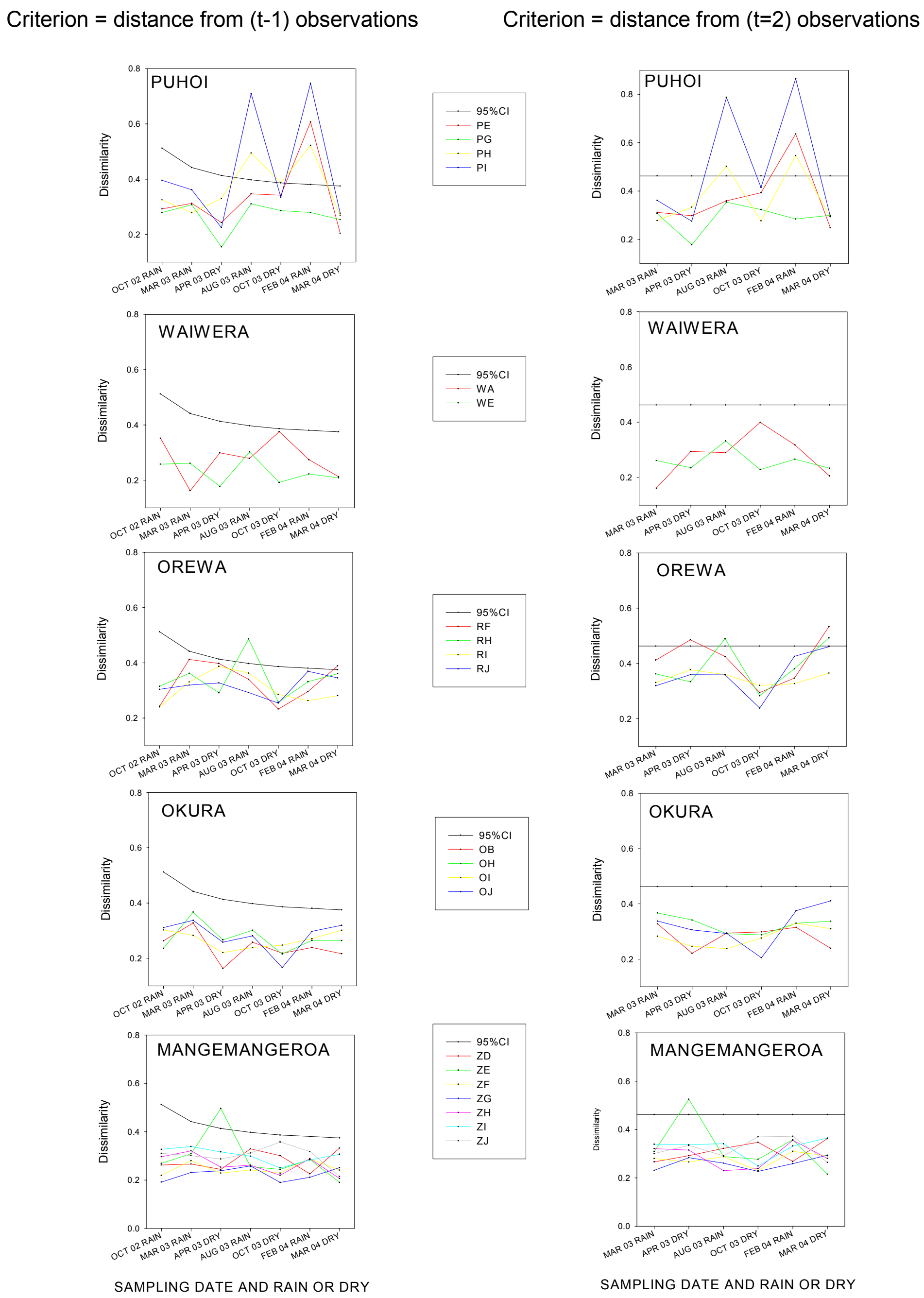

Figure 17. Control charts for the low-energy sites in all estuaries. The analysis was done on Bray-Curtis dissimilarities of ln(y + 1) transformed species counts. Charts on the left will tend to emphasise sudden changes in assemblage structure. Charts on the right will tend to emphasise longer-term trends over time in assemblages (Anderson and Thompson 2004). 95%C.I. = upper 95% confidence bound obtained using bootstrapping.

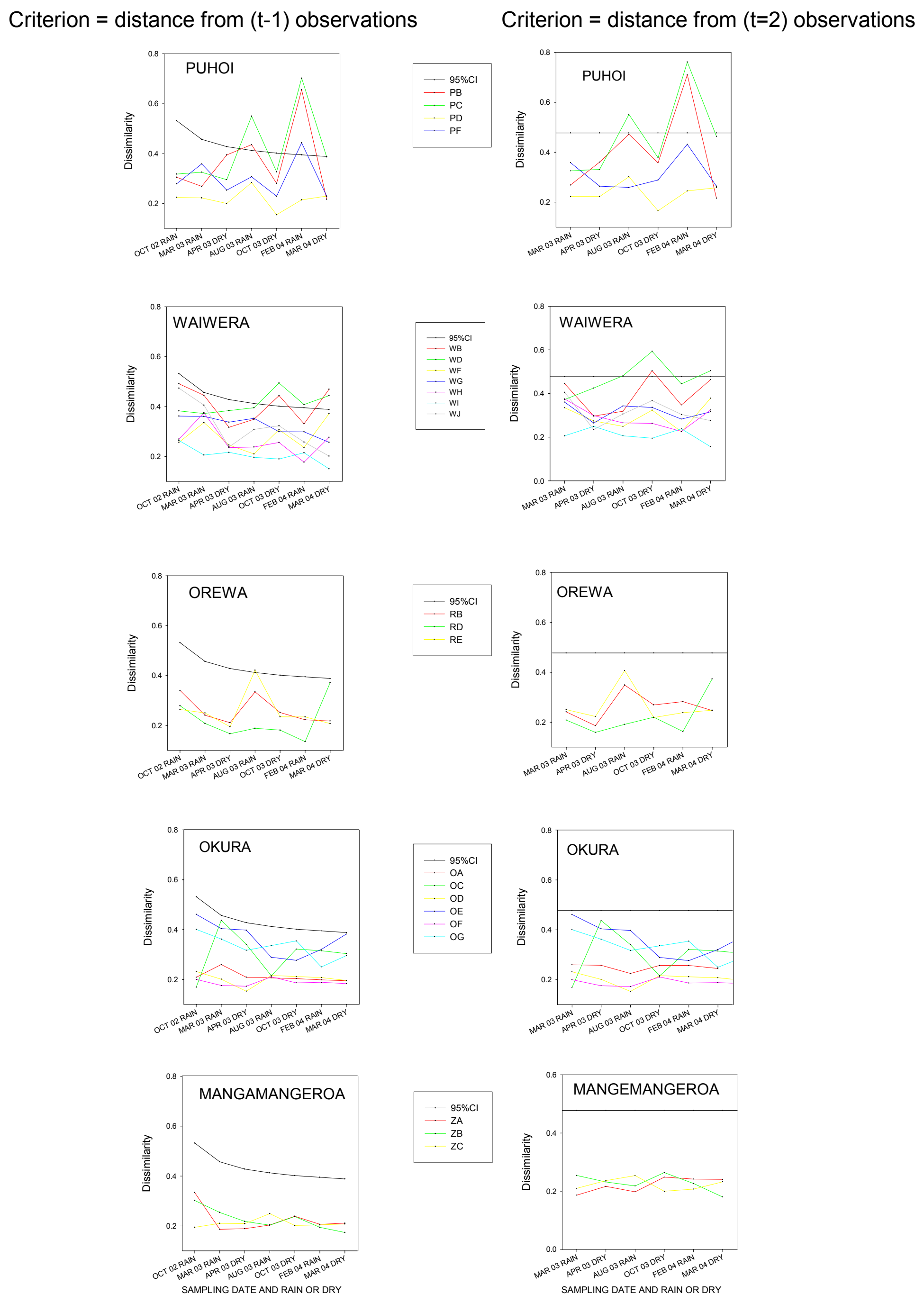

Figure 18. Control charts for the medium-energy sites in all estuaries. The analysis was done on Bray-Curtis dissimilarities of ln(y + 1) transformed species counts. Charts on the left will tend to emphasise sudden changes in assemblage structure. Charts on the right will tend to emphasise longer-term trends over time in assemblages (Anderson and Thompson 2004). 95%C.I. = upper 95% confidence bound obtained using bootstrapping.

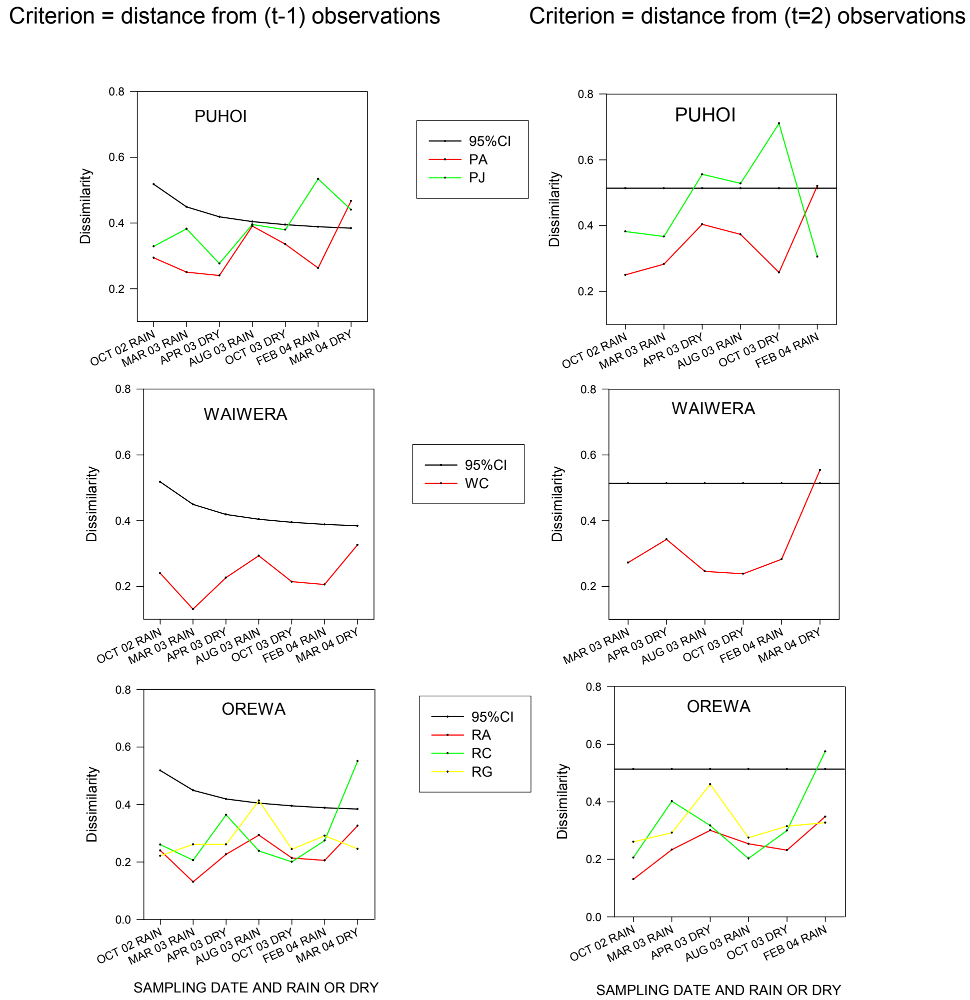

Figure 19. Control charts for the medium-energy sites in all estuaries. The analysis was done on Bray-Curtis dissimilarities of ln(y + 1) transformed species counts. Charts on the left will tend to emphasise sudden changes in assemblage structure. Charts on the right will tend to emphasise longer-term trends over time in assemblages (Anderson and Thompson 2004). 95%C.I. = upper 95% confidence bound obtained using bootstrapping.

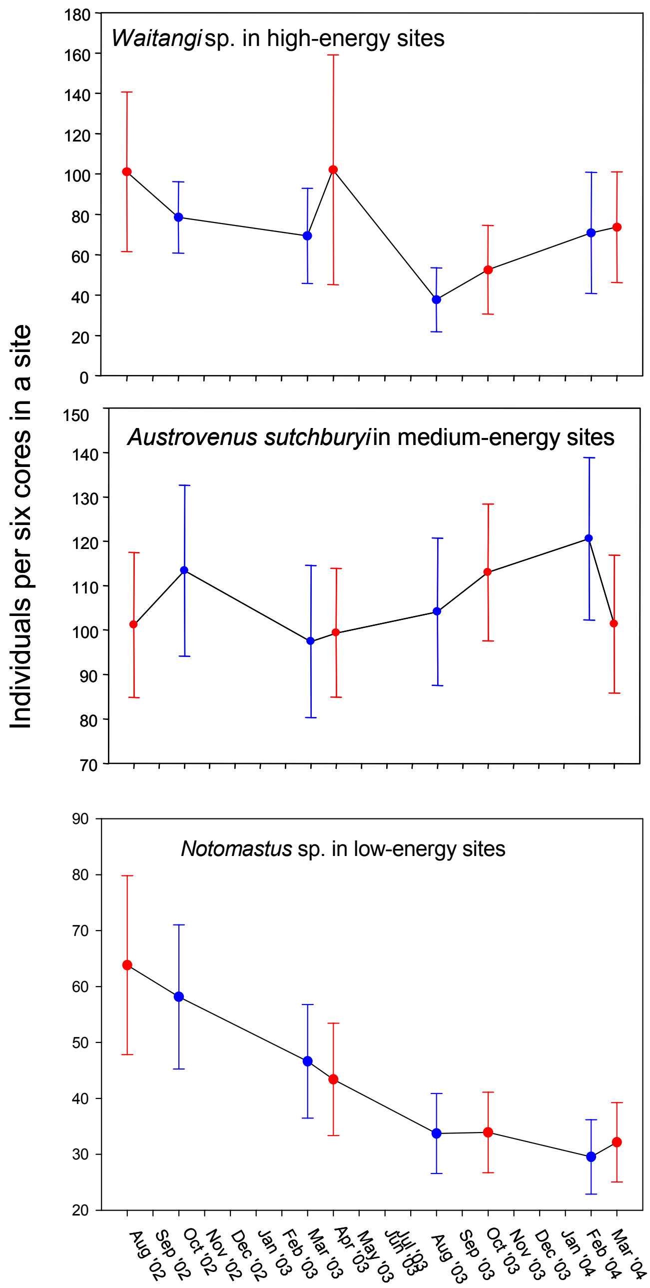

Figure 20. Univariate plots of selected taxa within their distinctive energy habitats. Symbols in blue denote sampling after rainfall events and symbols in red denote sampling after a relatively dry period. For the high, medium and low-energy plots, *n* = 6, 23 and 21 sites respectively.

4. DISCUSSION

The main aim of this report was to check for the continued relevance of high, medium and low-energy classification of sites created last year across all estuaries, in order to better detect impacts at a regional scale. In addition, we can now begin to track biological change over all estuaries over time to gain further insights into the levels of pre-impact variation and therefore the sensitivity of our monitoring.

The environmental monitoring showed similar trends to those seen in the previous year (Ford et al. 2003c). The grain sizes of the ambient sediments were very similar in the patterns seen between sites at each time, however, in March 2004, there was a decrease in fine sediments and an increase in coarse sediments at nearly all sites (excluding ZC where the reverse trend was apparent). This change may have been caused by a large storm between February and March that could have eroded a surface layer of fine sediments. The complex nature of sediment movement during a storm (Swales et al. 2003) may also lead to deposition of fine sediments, as was seen at Mangemangeroa. Precipitation records indicated that greater than 100mm of rain fell over the 27^{th} and 28^{th} of February (as recorded at Brynderwyn, Papatoetoe, Grey Lynn and Epsom). There was, however, no consistent pattern of erosion recorded in March that correlated with this change in grain size, although this sampling time was the fourth most erosive out of the past twelve months recorded. Bed height change showed patterns consistent with the previous year, although this year more variability was evident. Trapped sediments also showed patterns consistent with the previous year's recordings. It was therefore not particularly surprising that with similar sets of environmental measures our groupings of sites based on environmental characteristics were extremely similar (86% identical) to that seen in the previous year. This confirms that the environmental conditions at our sites were relatively stable through time and hence these data will be very useful as a baseline for detecting any future temporal or spatial changes.

Okura estuary was again intermediate among estuaries in terms of both environmental and biological measurements. Okura and Mangemageroa were the most sheltered estuaries, possessing only medium and low-energy sites. These estuaries were also the most clumped (least variable) when MDS ordinations of the biological variables were plotted. This pattern was logical as the high-energy sites, missing from these estuaries, showed the highest levels of multivariate dispersion. Both Mangemangeroa and Okura estuaries are relatively sheltered, (by Whitford embayment and Whangaparoa peninsula, respectively) and do not have constricted channels, which can lead to high flows and a change in the biological communities. Communities in these two estuaries were also the most stable over time, as seen in control charts. Interestingly, our sites B-F (approximately) at Mangemangeroa were characterised as being in an area of special vulnerability due to the presence of large numbers of suspension feeders, including some juveniles (Senior *et al.* 2003). These sites showed no greater variability in community structure over time than any other sites (excluding one time at site ZE) indicating no large pulses of recruitment, mortality or emigration of taxa from these sensitive areas over the sampling period.

There was consistent agreement between environmental and biological gradients throughout the study. The most variable grouping of sites (high-energy) showed the most variable biological communities and the least variable group of sites (low-energy) showed the least variable biological communities. This agreement was also demonstrated by the close correlation between environmentally identified groupings of sites (high, medium and low-energy) and biologically different communities. High-energy sites were characterised by relatively high densities of the bivalve *Paphies australis,* the cumacean *Colorustylis* spp. and the amphipod *Waitangi* sp. Medium-energy sites were identified by relatively high densities of the bivalves *Austrovenus stutchburyi* and *Nucula hartvigiana* and the anemone *Anthopleura* spp. Low-energy sites were distinguished by relatively high densities of the polychaetes of *Psuedopolydorid* complex, Nereid/Nicon complex and copepods. Taxa from the previous year report that were characteristic of different energy habitats were here identified as either a) again characterising the same community or b) showing the same trend as in the previous years report. This three-group model is in contrast to the conceptual model of Lundquist *et al.* (2003), which describes two habitats. One community has low or moderate exposure to catchment runoff and is biologically characterised by the polychaetes *Heteromastus filiformis, Cossura* sp., and Glycerids, the bivalve *Nucula hartvigiana* and the crab *Macropthalmus hirtipes.* The other community has little exposure to tidal currents and is distinguished by dominance of the crab *Helice crassa,* the amphipod *Paracalliope novizealandiae* and oligochaetes. Lundquist *et al.* (2003) sampled a number of estuaries; in the two estuaries that overlap with our monitoring programme their sites were either further up the estuary (Puhoi) or at the top end of our sampling sites (Okura). They also used some of the same taxa to characterise groupings as have been used in this report (*Nucula,* Capitellids and oligochaetes). Both models appear to be soundly based, with the NIWA study describing gradients in biological communities either in different areas of estuaries or nested within our low or medium-energy groupings.

When the environmental variables and biological variables were related, there were some similarities and some differences noted compared to last year (Ford et al. 2003c). The established monitoring program appeared to be effective in measuring the majority of the variance associated with the different estuaries in this study and in the previous year. In either case, less than 10% of the variance associated with the environmental variables was explained by the addition of which estuary the site originated from. Trapped sediment information was far more important, while ambient sediment information was far less important, in explaining variation in biological communities this year compared to last year (compare results in Table 7b this year compared with those given in Table 8b in Ford et al. 2003c). This was an interesting result, given that the ambient sediments were measured with greater precision this year than last year. However, trapped and ambient sediment characteristics are highly correlated with one another. In addition, new information regarding recently trapped sediments was added this year, which further helped to explain biological variation.

Community structure and trapped sediment characteristics were relatively unchanged over the four sampling times (as seen in Figure 9 and Figures 5 and 6, respectively) while ambient sediments became markedly coarser in March 2004. Thus, the two temporally stable sets of measures were highly correlated, but no change in biological communities was seen in response to the change in ambient sediment texture recorded in March 2004. This could also explain why the correlation between ambient grain size information and community structure was weaker this year than previously. A delayed change in community structure may yet be seen in response to changes in ambient grain sizes. On the other hand, this could be just a transient change, with no important biological consequences. Data from six years of monitoring in the Netherlands suggest that long-term average environmental conditions are more important than short-term fluctuations for determining presence or absence of fauna, i.e. that fauna may not change markedly with short-term environmental changes (Ysebaert and Herman, 2002). Further monitoring should clarify this issue.

The relationship between environmental and biological variables appeared to be reasonably strong and could be modelled directly using the canonical correlation analysis (CAP) of the biota on the first PC axis of environmental variables. The analysis suggested that the most obvious change along the gradient occurred between high-energy sites and medium-energy sites. The high-energy sites were also generally more variable in their community response. Thus, relatively small changes in environmental conditions may cause relatively large changes in community structure, particularly at high-energy sites. High-energy sites are also the most resilient in terms of recovering from disturbances (Hewitt et al. 2003). Changes in community structure at high-energy sites may therefore be relatively short-lived, unless a disturbance affected a large spatial scale, or affected the long-term hydrodynamic conditions at a site.

Temporal changes in community structure across all estuaries were again small by comparison to the spatially driven community changes. Low-energy sites again appeared the most sensitive to temporal changes with a seasonal effect being detected in only these sites. This effect was fuelled by small changes in densities of rare taxa which were relatively trivial by comparison to spatial differences. Control charts showed some evidence, particularly at Puhoi estuary, of cyclical 'pulse' effects on communities, which quickly reverted to a more 'normal' community. These pulse effects were seen across sites from all energy classifications (high, medium and low) and some were correlated with samplings following heavy rainfalls, although the timing of these pulse effects was not consistent between estuaries. This suggests that factors affecting community composition to cause unusual biotic assemblages at one time were not acting on a regional scale, but appear specific to each estuary. These unusual observations were mainly caused by pulses of high-energy taxa in low-energy sites, pulses of low-energy taxa in high-energy sites, and pulses of taxa typical of all energy sites in medium-energy sites. Due to the strong linkage between environmental and biological communities this suggests that short-term changes in the hydrodynamic energy of sites, (perhaps due to heavy rainfall events) may cause the movement of taxa into other areas, where they either die, or emigrate from between sampling times. Puhoi estuary is relatively broad with shallow channels, a large catchment, and presumably higher flow rates than many of the other estuaries. These factors may be combining to make the environmental conditions in the estuary more changeable, and hence the community structure more changeable in response. Another possibility is that Puhoi estuary was less stable then Okura estuary due to its relatively high sedimentation rate (4.1 – 5.8mm.yr cf. Okura estuary 0.5 to 3.5mm .yr, Swales *et al.* 2002). This fact may explain why high-energy sites show short-term presence of low-energy fauna, however it is unclear how high-energy fauna may occur fleetingly at low-energy sites.

5. CONCLUSIONS

We assess each of the questions raised and enumerated in the introduction (section 1.2), in turn, below:

1. The physical characteristics of the sites within Okura estuary continue to fall within the range of physical characteristics measured for the other estuaries (Puhoi, Waiwera, Orewa and Mangemangeroa). Therefore, these estuaries are excellent reference estuaries for ongoing monitoring and detection of impacts at Okura.
2. The environmental model of high, medium and low-energy sites across all estuaries is still valid given all the information from 2002 to 2004, and should provide a clear way of detecting temporal change in each of these estuaries in an appropriate regional context.
3. The differences between biological communities from the high, intermediate and low-energy sites are quite consistent. Five out of the nine taxa highlighted in this report as having relative densities that were most important in causing these differences are identical to those highlighted last year. In addition all species highlighted as important for this distinction last year show the same patterns of relative abundance this year.
4. The modelling of the biological communities from the environmental data has improved this year compared to last year. The addition of extra ambient sediment measurements has not caused this change however, as ambient sediments were far less important in explaining variance this year than last. Rather, trapped sediment information was more important in explaining biological variation this year. Modelling of fauna at the replicate level (not shown in this report) was attempted using the large amount of ambient sediment information, but was less successful than modelling of the fauna at the site level. Nevertheless, important variation in ambient sediments did occur across the four sampling times. We therefore recommend that ambient sediment measurements still be taken at each time of biological sampling, but that less replication per site is necessary to maintain adequate precision in the measurement of ambient sediments (i.e., n = 3 cores per site would be sufficient).
5. There are estuary-specific effects on communities that cannot be explained by the measured environmental variables. However the amount of variability explained by these factors in this year, as it was in the previous year, is less then 10% of the variation explained by the measured environmental variables. This indicates the monitoring programme is measuring the most relevant environmental variables in each estuary.
6. There was a strong and significant relationship between the fauna and the environmental variables. Just under half of the variance in the biological communities (47%) across all estuaries was successfully modelled by the measured environmental variables. The environmental variables, the fauna and the relationship between the two were relatively constant over time and between different estuaries. Sites with similar environmental variables through time were consistently placed in similar energy-groups, which consistently held distinct faunal assemblages.

7. Seasonal effects were trivial and were only observed at low-energy sites. Consistent effects of precipitation were not detected.

8. There were 'pulse' changes in assemblage structure (short-term non-persistent effects) observed for many of the estuaries since monitoring of all estuaries began in August 2002, and these were visible at high, medium and low-energy sites. Puhoi estuary appeared to be particularly susceptible to sudden but quickly reversible changes in assemblage structure. Such changes in Puhoi also occurred apparently in response to rainfall events. The two estuaries that showed the least variability in environmental conditions, Okura and Mangemangeroa, also showed the greatest stability in the structure of their assemblages over time.

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7. APPENDICES

Appendix A. Global Positioning System (GPS) coordinates of sites

	Puhoi (P)		Waiwera (W)		Orewa (R)		Okura (O)		Maungamaungaroa (Z)	
Site	Lat. (S)	Long. (E)	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′	36° 54.44′	174° 57.47′
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′	36° 54.60′	174° 57.39′
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′	36° 54.67′	174° 57.33′
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′	36° 54.67′	174° 57.27′
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′	36° 54.66′	174° 57.23′
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′	36° 54.68′	174° 57.20′
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′	36° 54.80′	174° 56.98′
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′	36° 54.86′	174° 56.91′
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′	36° 54.88′	174° 56.93′
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′	36° 54.94′	174° 56.79′

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

MOLUSCS	Group	Total	POLYCHAETES	Group	Total
Austrovenus stutchburyi	Bivalvia	15568	Prionospio spp. complex	Spionidae	6671
Paphies australis	Bivalvia	10740	Notomastus sp.	Capitellidae	4843
Nucula hartvigiana	Bivalvia	5549	Nereid/Nicon spp. complex	Nereidae	2250
Macomona lilliana	Bivalvia	1986	Aonides spp.	Spionidae	1661
Notoacmea spp.	Gastropoda	1256	Psuedopolydora complex	Spionidae	1357
Arthritica bifurcata	Bivalvia	878	Cossura coasta	Cossuridae	1222
Cominella glandiformis	Gastropoda	297	Exogonid sp.	Syllidae	1096
Diloma subrostratum	Gastropoda	190	Glycera lamellipoda	Glyceridae	701
Musculista senhousia	Bivalvia	56	Scoloplos cylindifer	Orbiniidae	644
Sypharochiton pelliserpentis	Polyplacophora	49	Scolelepis sp.	Spionidae	549
Soletellina selaqua	Bivalvia	38	Orbinia papillosa	Orbiniidae	448
Theora sp.	Bivalvia	37	Scolecolepides sp.	Spionidae	271
Zeacumantus sp.	Gastropoda	27	Orbinid other	Orbiniidae	233
Haminoea zelandiae	Opistobranchia	25	Timarete anchylochaeta	Cirratulidae	155
Cominella adspersa	Gastropoda	18	Glycera spp. other	Glyceridae	145
Opisthobranch other	Opistobranchia	16	Pectinaria sp.	Pectinariidae	107
Microlenchus sp.	Gastropoda	13	Magelona dakini	Magelonidae	104
Amphibola crenulata	Gastropoda	11	Syllid other	Syllidae	86
Bivalve unknown	Bivalvia	9	Aricidea sp.	Paraonidae	55
Bulla spp.	Opistobranchia	8	Macroclymenella stewartensis	Malanidae	29
Crassostrea sp.	Bivalvia	8	Spionid other	Spionidae	23
Corbula zelandica	Bivalvia	6	Paraonid sp.	Paraonidae	20
Gastropod unknown	Gastropoda	4	Aglaophamus macroura	Nephtyidae	19
Odostomia spp	Gastropoda	4	Cirratulidae other	Cirratulidae	8
Turbo smaragdus	Gastropoda	4	Armandia sp.	Opheliidae	7
Xenostrobus pulex	Bivalvia	4	Minuspio sp.	Spionidae	6
Cirsotrema zelebori	Gastropoda	3	Aphroditidae	Aphroditidae	4

Appendix B continued. *List of taxa*...

Mytilus	Bivalvia	3
Amalda sp.	Gastropoda	2
Cominella maculosa	Gastropoda	2
Sypharochiton sinclairii	Polyplacophora	2
Venericardia sp.	Bivalvia	2
Cyclomactra ovata	Bivalvia	1
Dosinia spp.	Bivalvia	1
Melagraphia sp.	Gastropoda	1
Modiolarca impacta	Bivalvia	1
Zeacolpus spp	Gastropoda	1

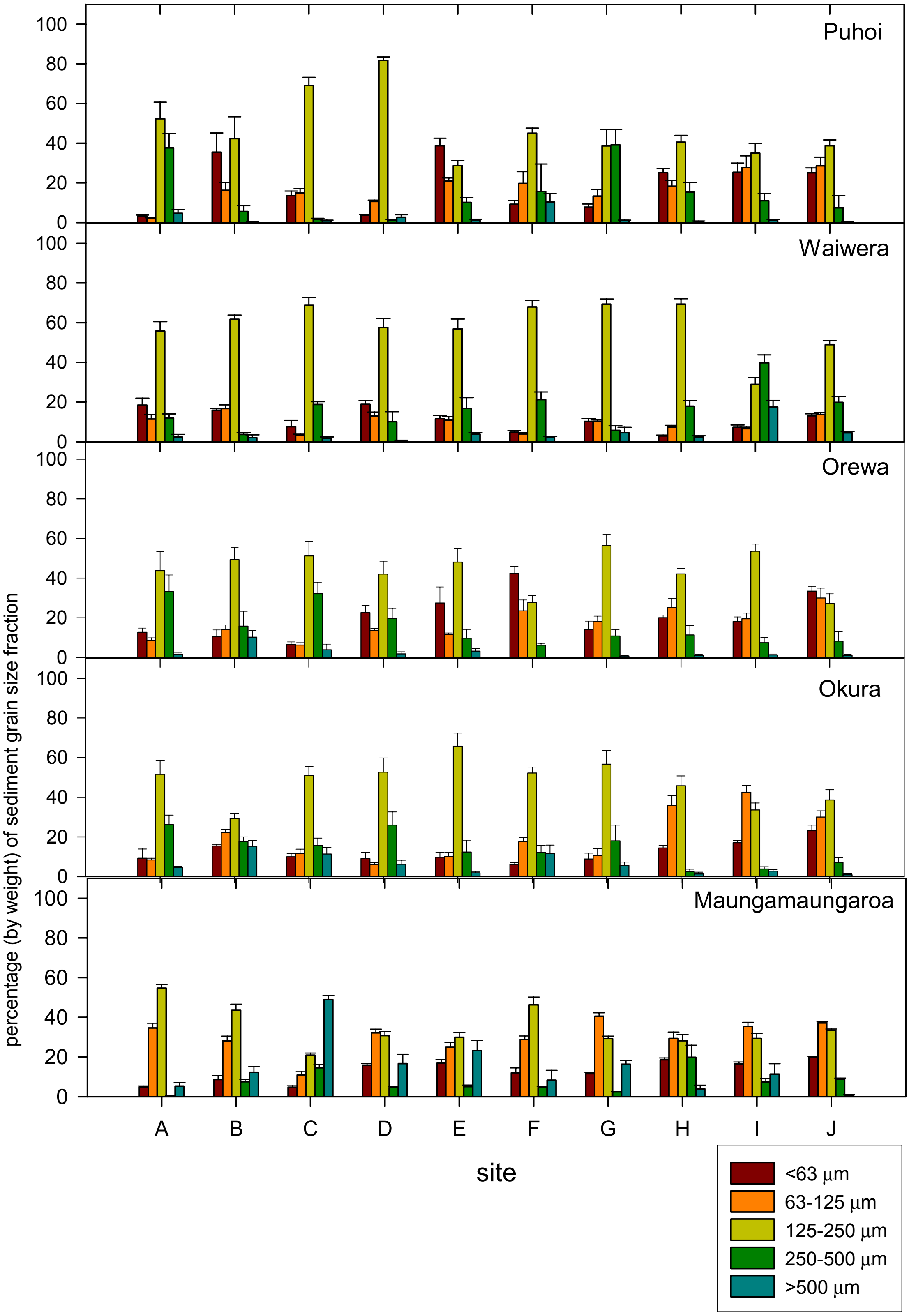
CRUSTACEANS	**Group**	**Total**
Barnacles	Cirripedia	4565
Waitangi sp.	Amphipoda	4087
Paracorophium sp.	Amphipoda	3245
Colorustylis spp.	Cumacea	3081
Copepod sp.	Copepoda	2946
Helice/Hemigrapsus spp.	Decapoda	1063
Isopod sp. (thin head)	Isopoda	900
Parakalliope sp.	Amphipoda	721
Psuedosphaeroma sp.	Isopoda	326
Phoxocephalid	Amphipoda	325
Cirolana sp.	Isopoda	234
Halicarcinus spp.	Decapoda	202
Crab juvenile	Decapoda	170
Ostracod sp.	Ostracoda	146
Mysid shrimp	Cumacea	91
Shrimp	Decapoda	71
Amphipod other	Amphipoda	70
Leptostracean	Leptostracea	24

Glycera americana	Glyceridae	3
Owenia fusiformis	Oweniidae	3
Travisia	Opheliidae	3
Asychis sp.	Malanidae	2
Diopatra sp.	Eunicae	2
Ampharetidae	Ampharetidae	1
Polychaete (funnel-head)		1
Sabellid sp.	Sabellidae	1
Sphaerodoridae	Sphaerodoridae	1

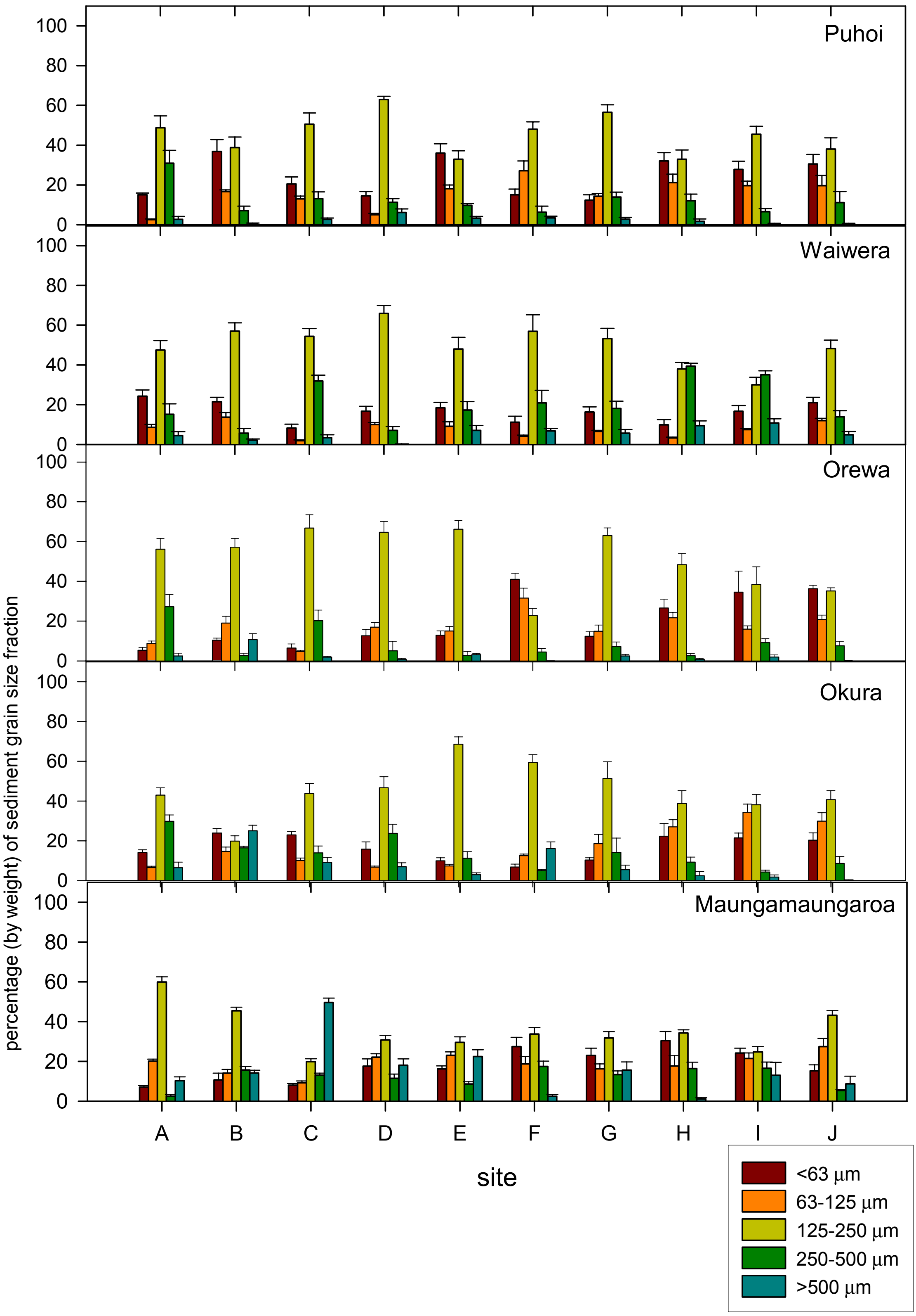
CRUSTACEANS (continued)	**Group**	**Total**
Alpheus sp.	Decapoda	15
Isopod other	Isopoda	9
Sphaeroma guoyanum	Isopoda	6
Pinnotheres sp.	Decapoda	5
Mantis shrimp	Stomatopoda	4
Decapod unknown	Decapoda	2

MISCELLANEOUS	**Group**	**Total**
Capitella sp. & Oligochaetes	Capitellidae and Oligochaete	2570
Anthopleura spp.	Anthozoa	1742
Nemertean	Nemertea	645
Nematode	Nematoda	74
Sipunculid	Nonsemented coelomate worm	69
Insect	Insecta	30
Platyhelminth	Platyhelminth	11
Anemone (free living)	Anthozoa	5
mite	Insecta	5
Fish	Pisces	4
Hydrozoan	Cnidarian	2

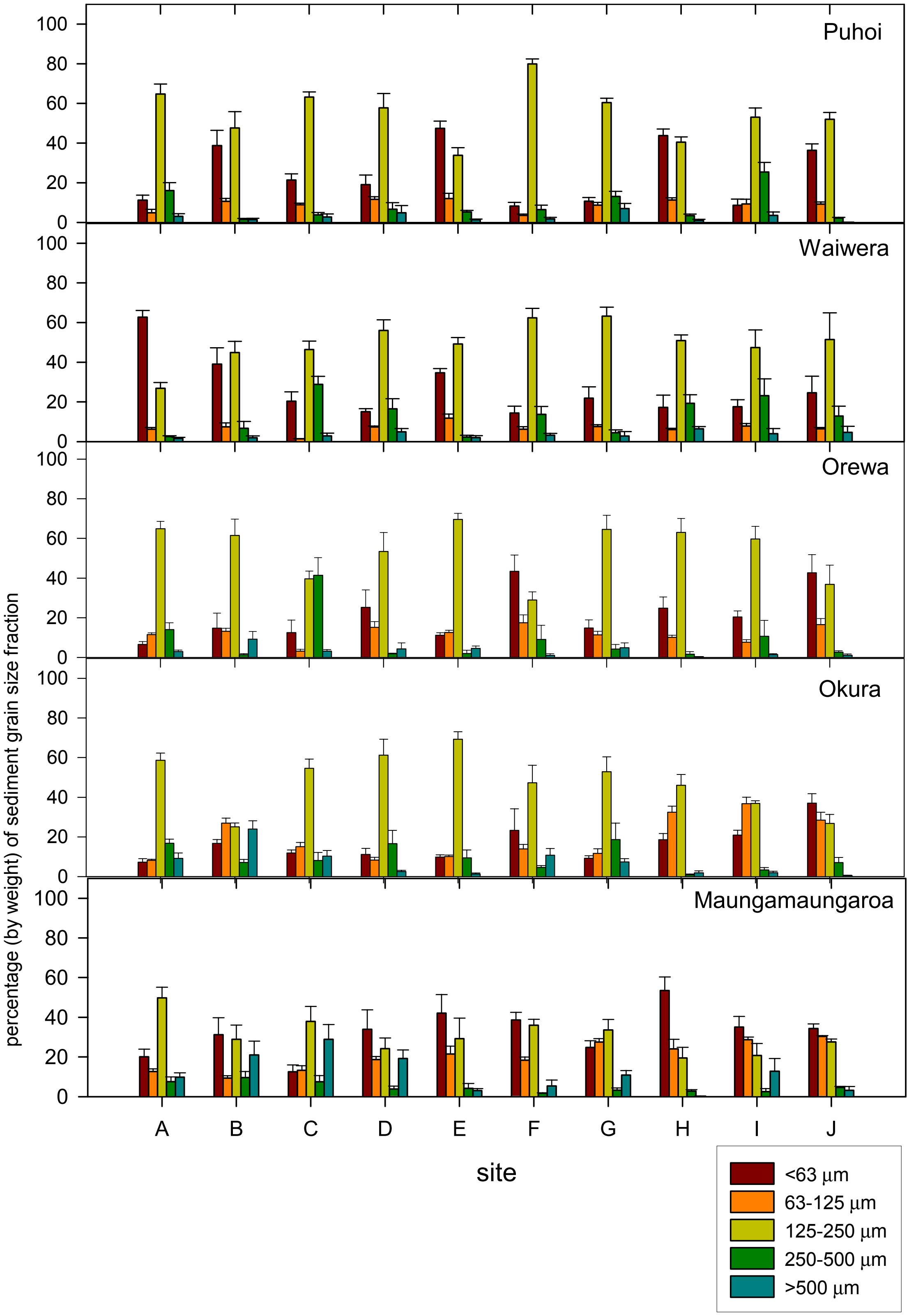
Appendix C. Grain size information for ambient sediments



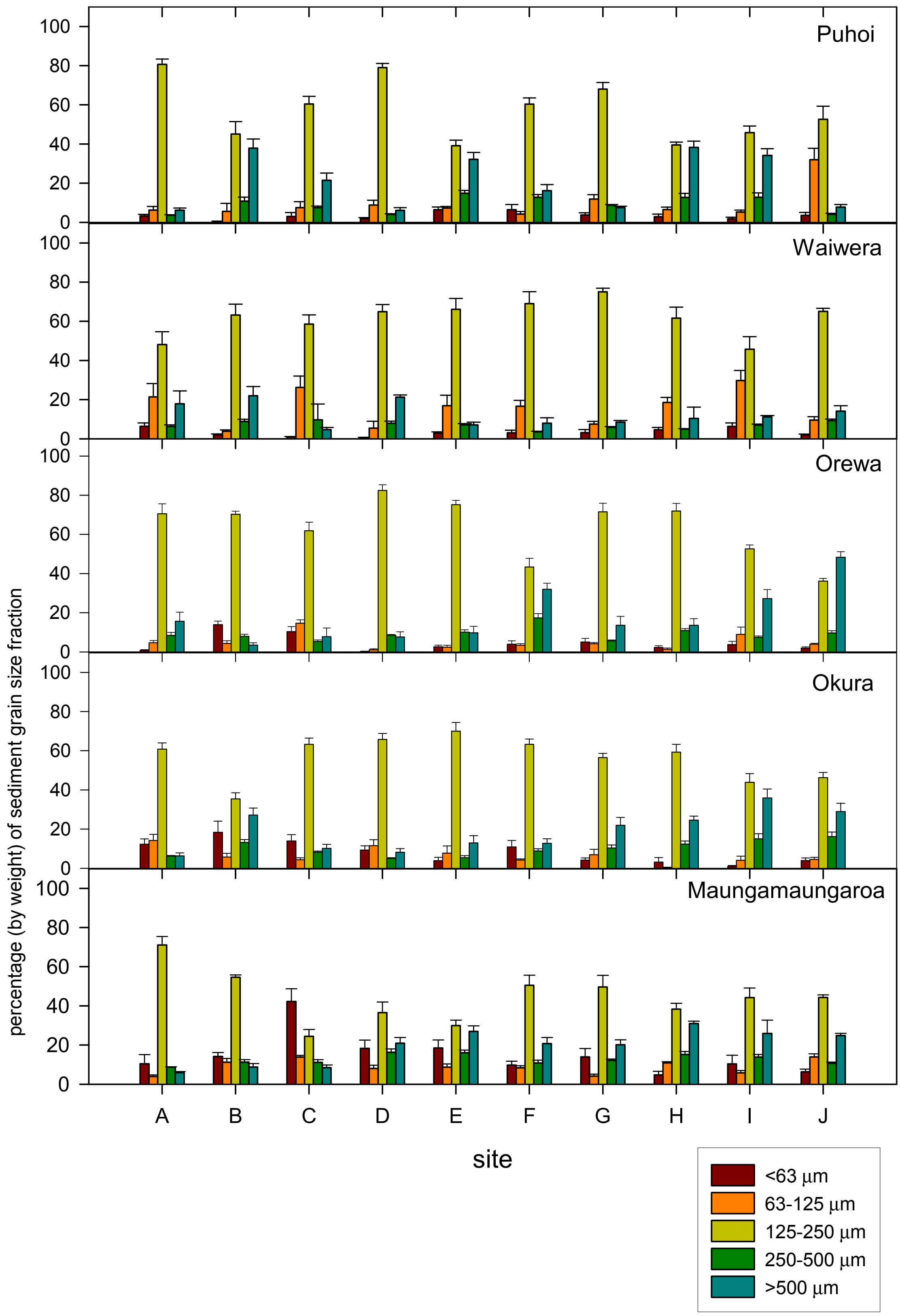
Appendix. C.1 Mean percentage (+S.E., *n* = 6) of ambient sediments of different grain sizes for August 2003 sampling of all sites in all estuaries.



Appendix. C.2 Mean percentage (+S.E., *n* = 6) of ambient sediments of different grain sizes for October 2003 sampling of all sites in all estuaries.

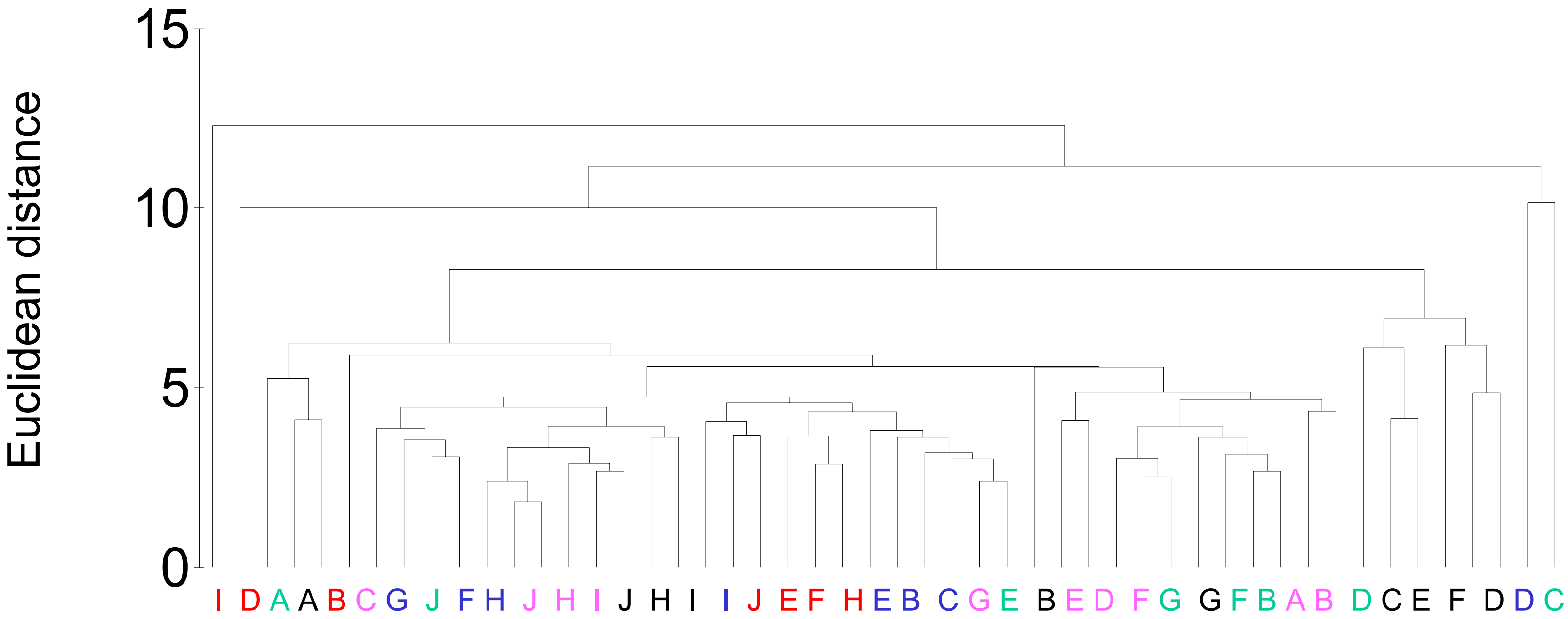


Appendix. C.3 Mean percentage (+S.E., *n* = 6) of ambient sediments of different grain sizes for February 2004 sampling of all sites in all estuaries.

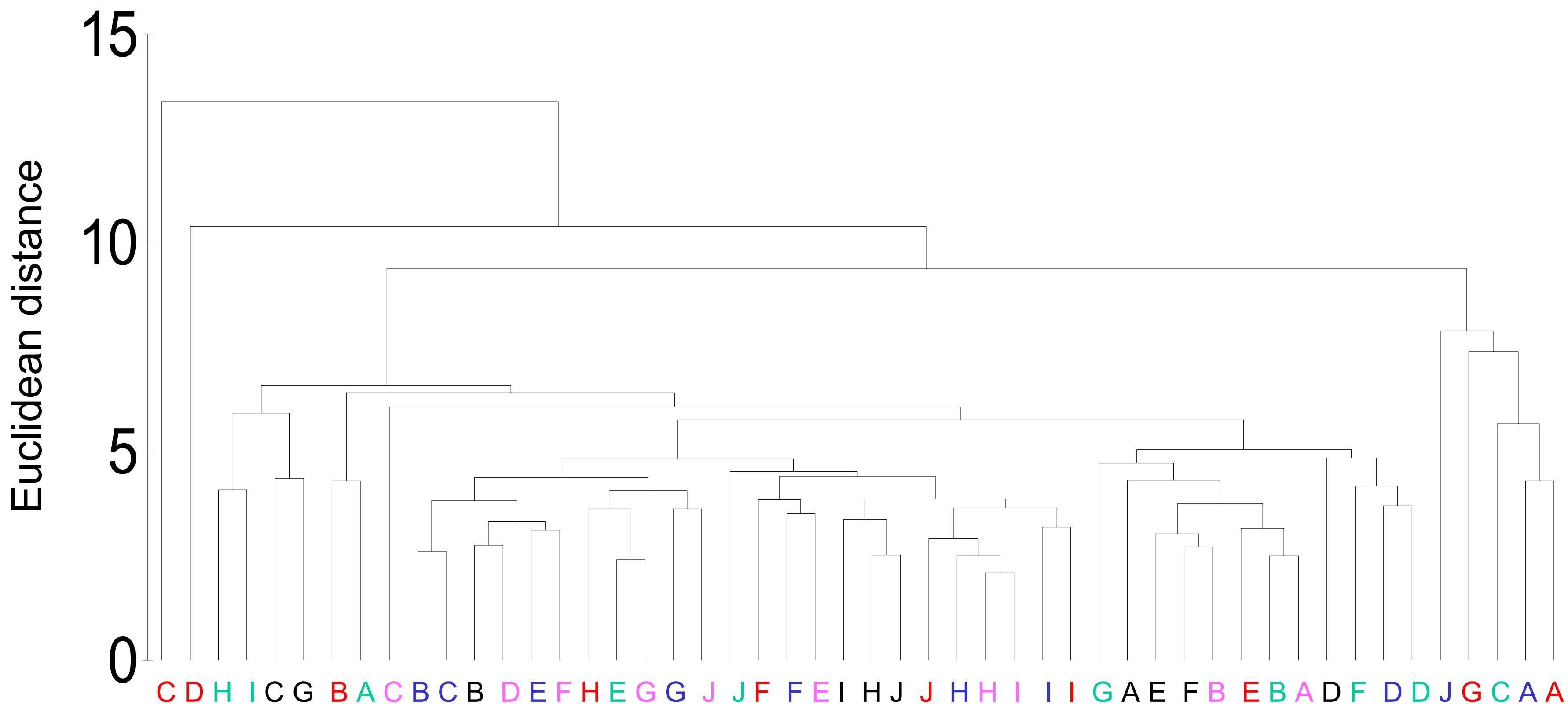


Appendix. C.4 Mean percentage (+S.E., *n* = 6) of ambient sediments of different grain sizes for March 2004 sampling of all sites in all estuaries.

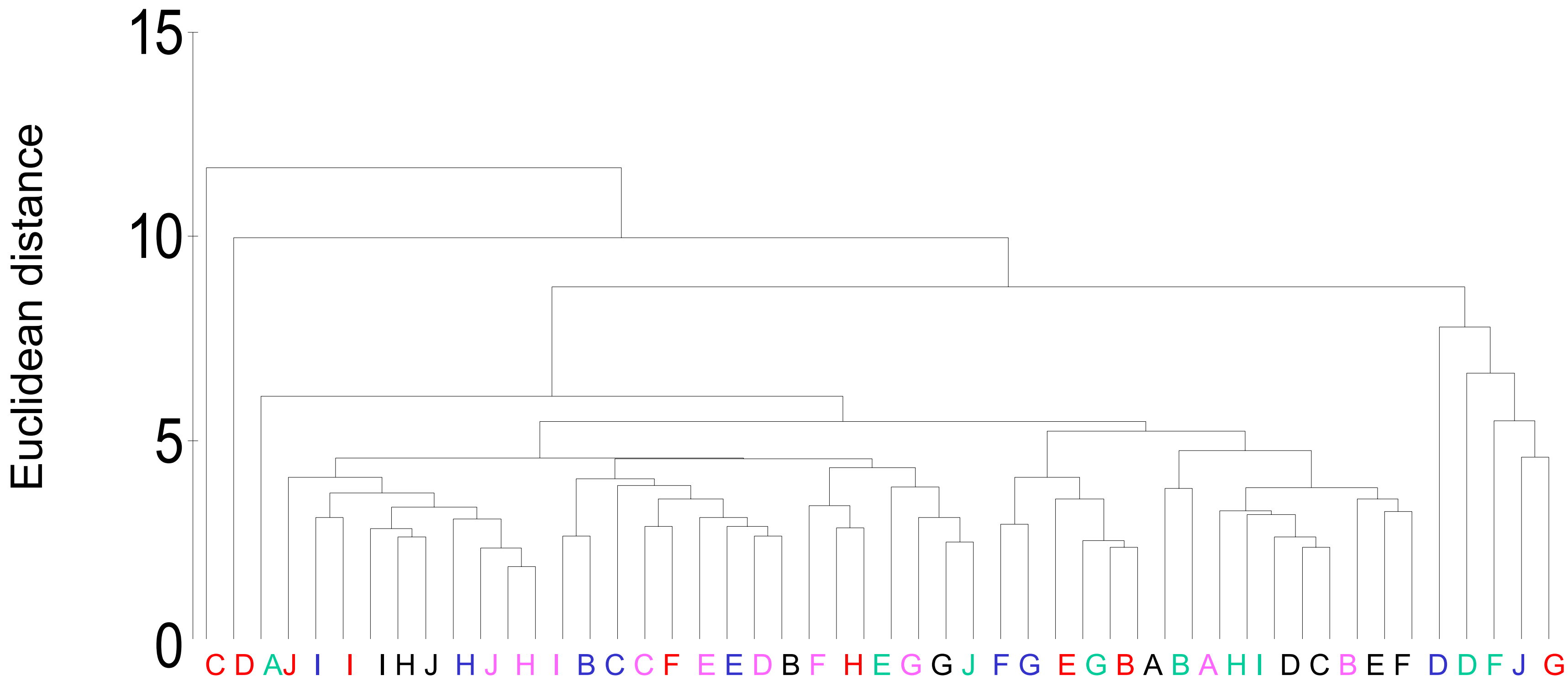
Appendix D. Dendograms for environmental data from August and October 2003 and February and March 2004.



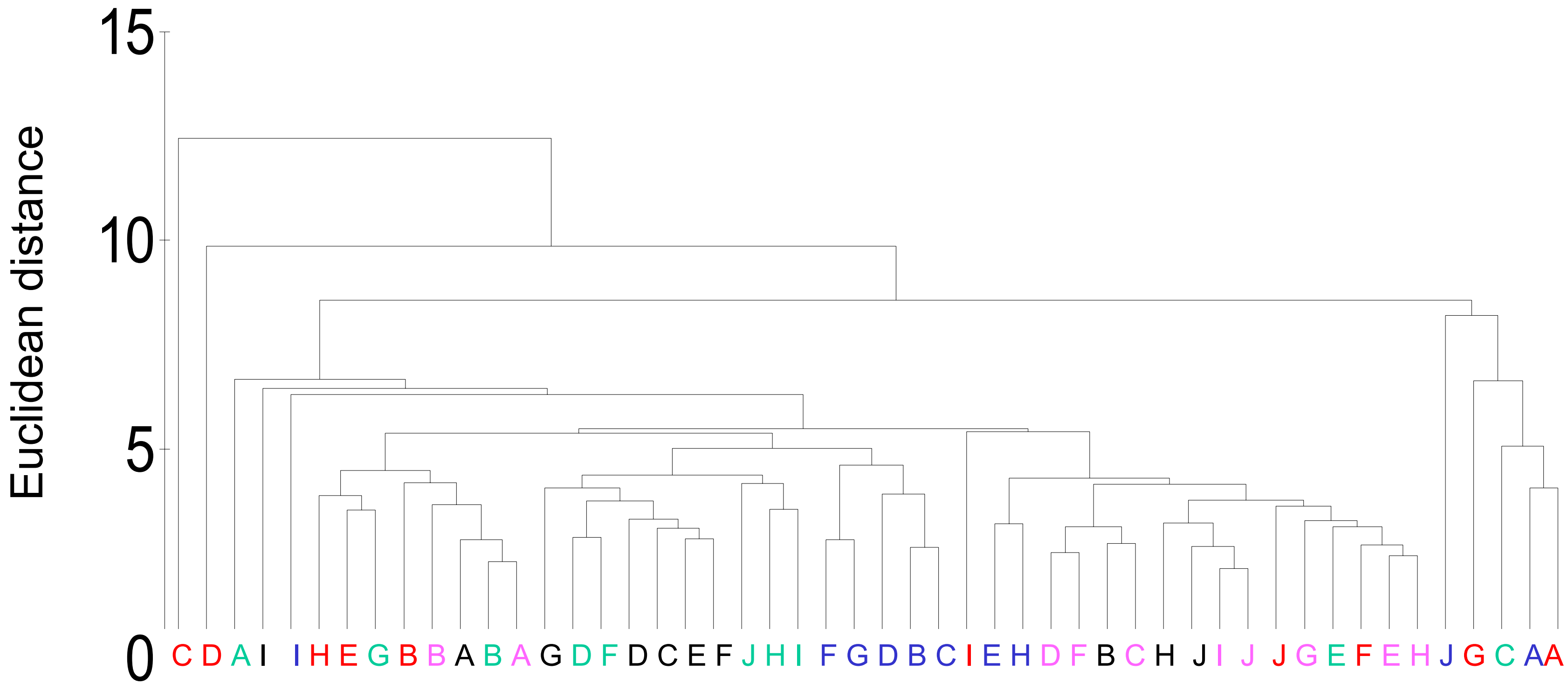
Appendix D1. Dendrogram from hierarchical agglomerative cluster analysis of environmental data from August 2003 for all sites in all estuaries. The analyses were based on the Euclidean distance calculated from z-scores of raw environmental data. Observations were pooled at the site level. Sites are indicated by a coloured letter. The letter indicates the site within an estuary (A-J), while the colour represents the estuary: Blue = Puhoi, Green = Waiwera, Red = Orewa, Black = Okura and Pink = Maungamaungaroa.



Appendix D2. Dendrogram from hierarchical agglomerative cluster analysis of environmental data from October 2003 for all sites in all estuaries. The analyses were based on the Euclidean distance calculated from z-scores of raw environmental data. Observations were pooled at the site level. Sites are indicated by a coloured letter. The letter indicates the site within an estuary (A-J), while the colour represents the estuary: Blue = Puhoi, Green = Waiwera, Red = Orewa, Black = Okura and Pink = Maungamaungaroa.



Appendix D3. Dendrogram from hierarchical agglomerative cluster analysis of environmental data from February 2004 for all sites in all estuaries. The analyses were based on the Euclidean distance calculated from z-scores of raw environmental data. Observations were pooled at the site level. Sites are indicated by a coloured letter. The letter indicates the site within an estuary (A-J), while the colour represents the estuary: Blue = Puhoi, Green = Waiwera, Red = Orewa, Black = Okura and Pink = Maungamaungaroa.



Appendix D4. Dendrogram from hierarchical agglomerative cluster analysis of environmental data from March 2004 for all sites in all estuaries. The analyses were based on the Euclidean distance calculated from z-scores of raw environmental data. Observations were pooled at the site level. Sites are indicated by a coloured letter. The letter indicates the site within an estuary (A-J), while the colour represents the estuary: Blue = Puhoi, Green = Waiwera, Red = Orewa, Black = Okura and Pink = Maungamaungaroa.

Appendix E. SIMPER results showing the most important five species contributing to the difference between times outside and inside control chart confidence intervals in Figures 17 to 19. Cum% = the cumulative percentage of variation explained by the sum of each taxa down to that point in each table.

Site PH low-energy

Species	within C.I. Av.Abund	outside C.I. Av.Abund	Av.Diss	Diss/SD	% Var.	Cum.%
Capitella sp. + Oligochaetes	63.6	5	5.61	1.81	9.95	9.95
Paracorophium sp	36.6	1	4.99	1.66	8.84	18.79
Copepods	35	0	3.93	1.25	6.97	25.76
Psuedopolydora complex	30.2	2	3.39	1.41	6.01	31.78
Mysid shrimp	0	11.5	3.27	0.94	5.79	37.57

Site PI low-energy

Species	within C.I. Av.Abund	outside C.I. Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Paracorophium sp.	44.2	0	7.97	3.42	10.43	10.43
Capitella sp. + Oligochaetes	43.6	0	7.7	2.77	10.08	20.51
Paphies australis	1	172	5.11	1.06	6.69	27.2
Waitangi sp.	1.2	66.5	4.39	1.21	5.75	32.95
Psuedopolydora complex	7.2	0	4.01	1.95	5.25	38.2

Site RH low-energy

Species	within C.I. Av.Abund	outside C.I. Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Prionospio spp. complex	41.8	1.5	11.69	1.3	18.56	18.56
Paphies australis	0.2	36.5	10.83	0.93	17.2	35.76
Capitella sp. + Oligochaetes	31.8	5	8.27	1.32	13.13	48.89
Scoloplos cylindifer	17.8	3.5	4.88	1.15	7.74	56.64
Paracorophium sp.	13.4	10	4.74	1.05	7.52	64.16

Site PB medium-energy

Species	within C.I. Av.Abund	outside C.I. Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Capitella sp. + Oligochaetes	138.8	2.5	5.64	2.8	9.58	9.58
Cossura coasta	67.4	0	4.09	1.13	6.94	16.53
Austrovenus stutchburyi	5	157.5	3.89	1.4	6.6	23.13
Prionospio spp. complex	11.2	78.5	3.87	1.72	6.57	29.7
Barnacle	0	36	3.42	1.48	5.82	35.52

Site PC medium-energy

Species	within C.I. Av.Abund	outside C.I. Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Paphies australis	4.4	1271.5	7.55	1.28	11.37	11.37
Paracorophium sp.	55	0.5	5.31	1.89	8	19.37
Capitella sp. + Oligochaetes	35.4	3.5	4.6	1.91	6.94	26.31
Waitangi sp.	2.8	14	3.8	1.81	5.72	32.03
Barnacle	0	5.5	3.52	6.09	5.3	37.33

Site WB medium-energy

Species	within C.I. Av.Abund	outside C.I. Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Paphies australis	509.6	8.5	4.13	1.17	7.83	7.83
Notomastus sp.	0.6	17	4.12	2.49	7.81	15.64
Paracorophium sp.	30.2	62.5	3.85	1.4	7.29	22.93
Nereid/Nicon spp. complex	0.4	7.5	3.43	5.7	6.49	29.42
Capitella sp. + Oligochaetes	28	22	2.87	1.24	5.44	34.86

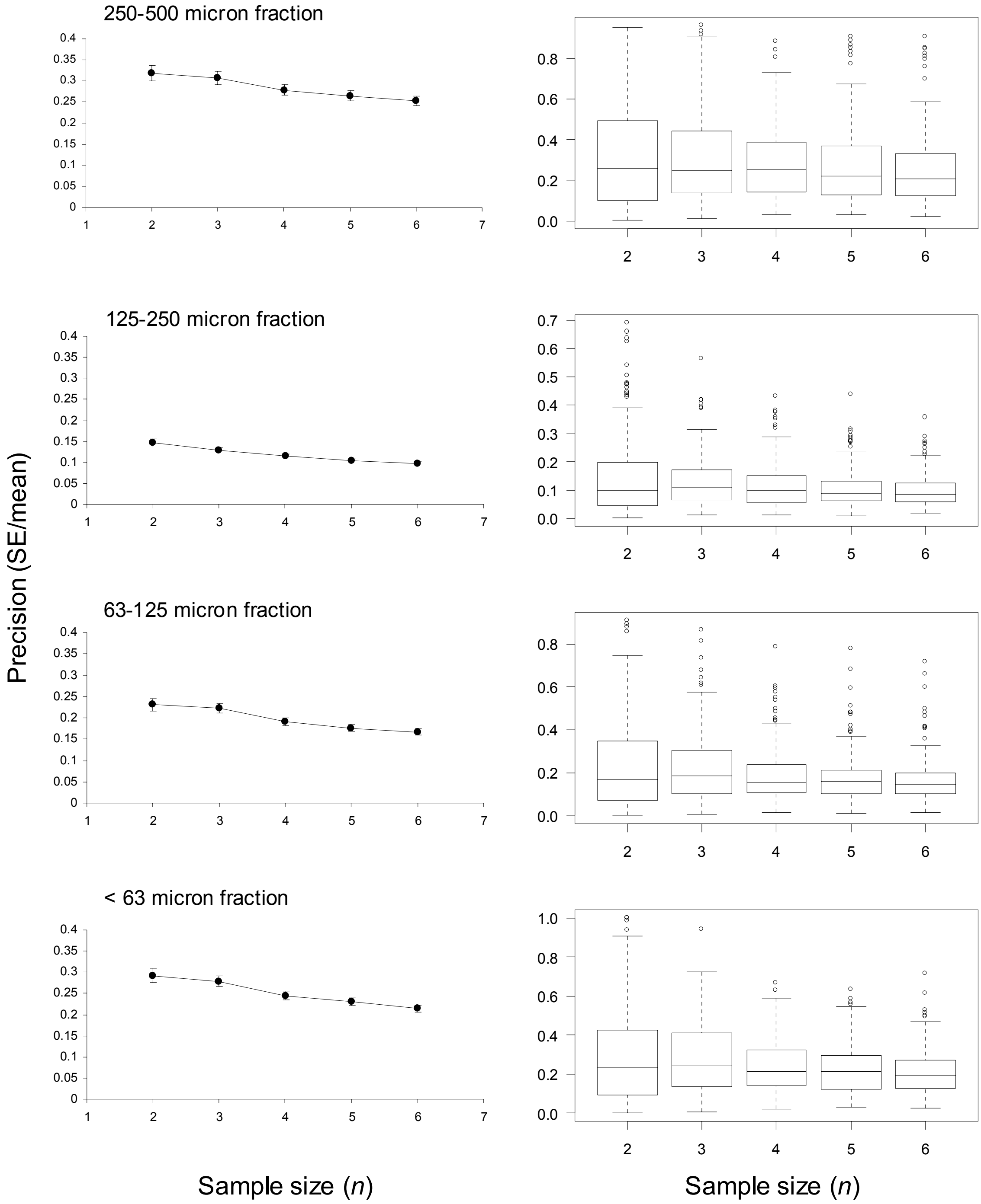
Site WD medium-energy

Species	within C.I. Av.Abund	outside C.I. Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Paphies australis	7.4	16	5.98	2.37	10.84	10.84
Waitangi sp.	0.4	11.5	5.74	3.26	10.41	21.25
Capitella sp. + Oligochaetes	26	16.5	4.94	1.32	8.96	30.21
Paracorophium sp.	14	2	4.63	1.48	8.39	38.6
Scolecolepides sp.	10.2	4.5	4.03	1.34	7.31	45.9

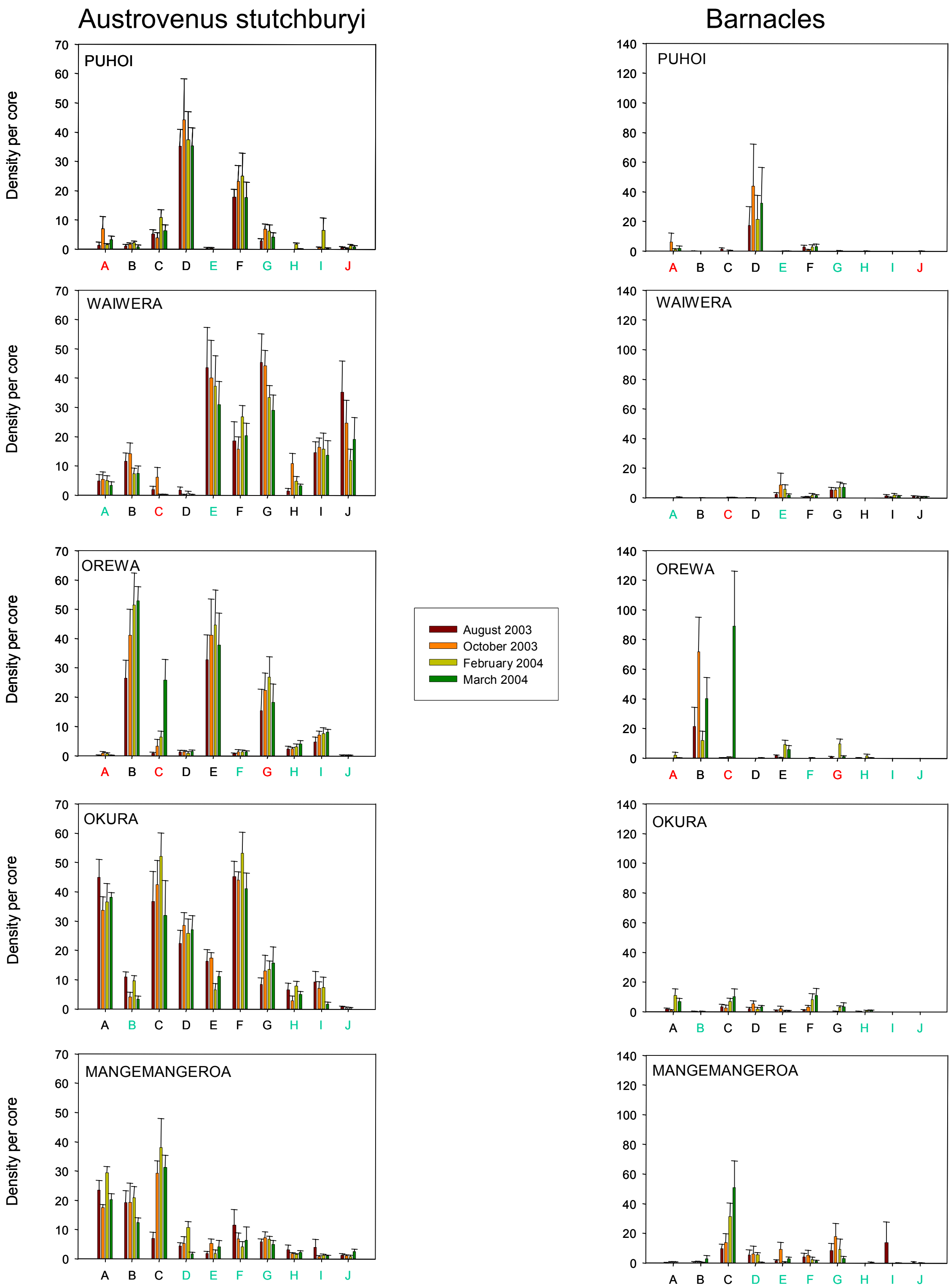
Site PJ high-energy

Species	within C.I. Av.Abund	outside C.I. Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Prionospio spp. complex	0	53	6.17	11.33	10.09	10.09
Paphies australis	179.5	0	5.67	1.67	9.28	19.37
Colorustylis spp.	60.83	0	4.57	1.9	7.47	26.84
Orbinid other	0	10	3.71	11.33	6.07	32.9
Glycera spp.	0.33	7	2.86	4.5	4.68	37.59

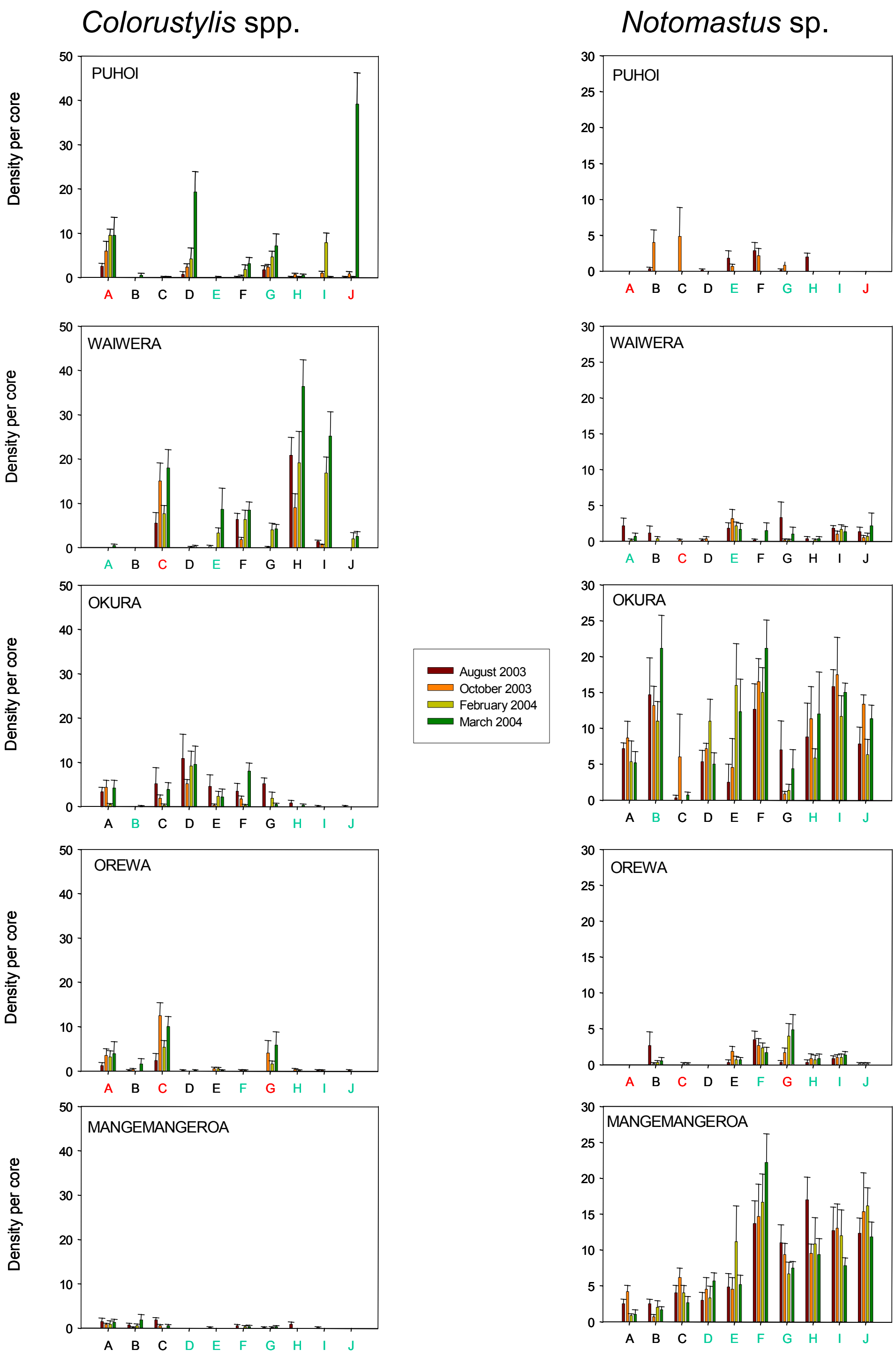
Appendix F. Plots of precision for ambient sediment samples per site at differing levels of replication (*n* = 200 per boxplot or point)



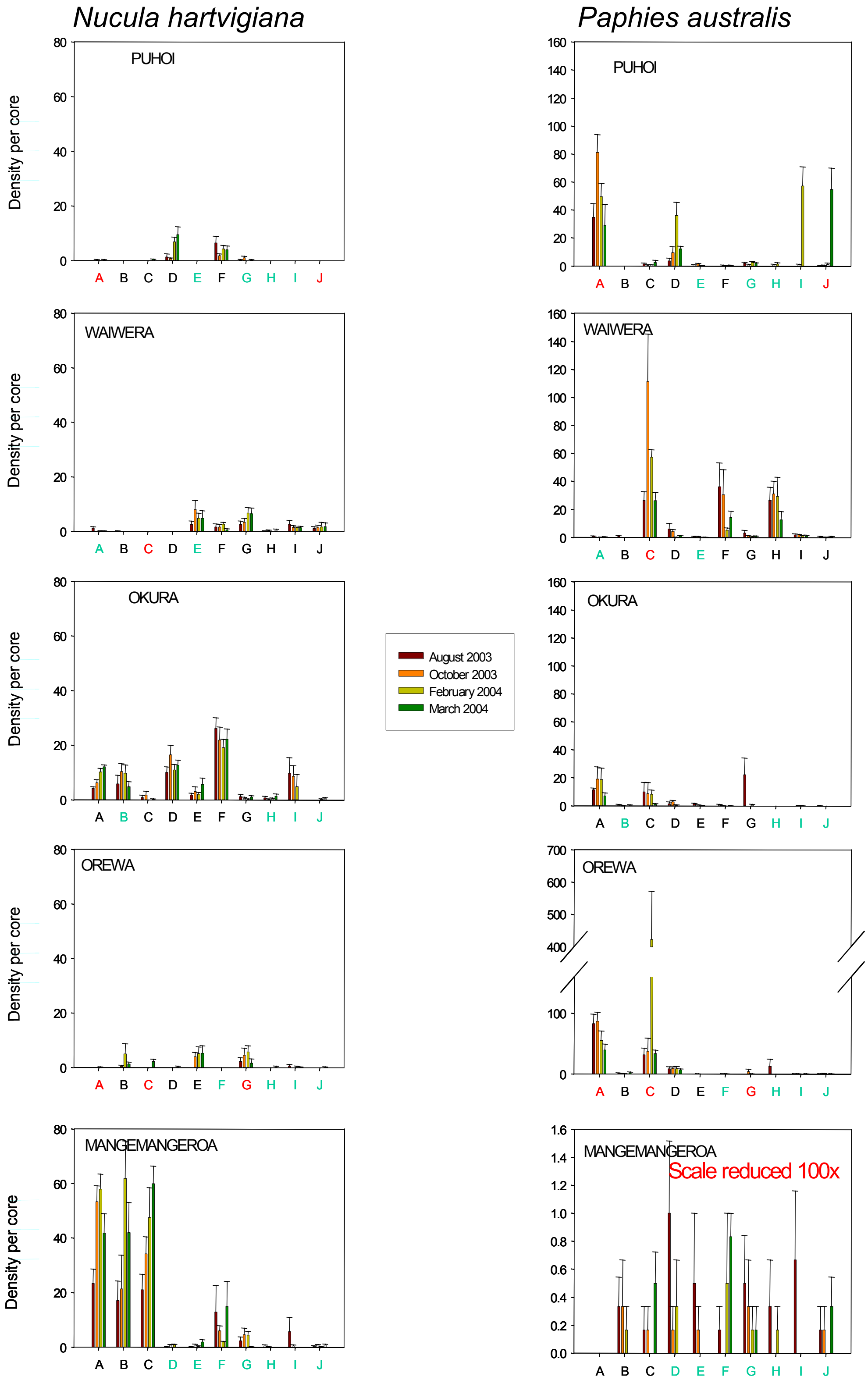
Appendix G. Univariate plots of 9 common taxa across all sites and times (accounts for 67% of all individuals)



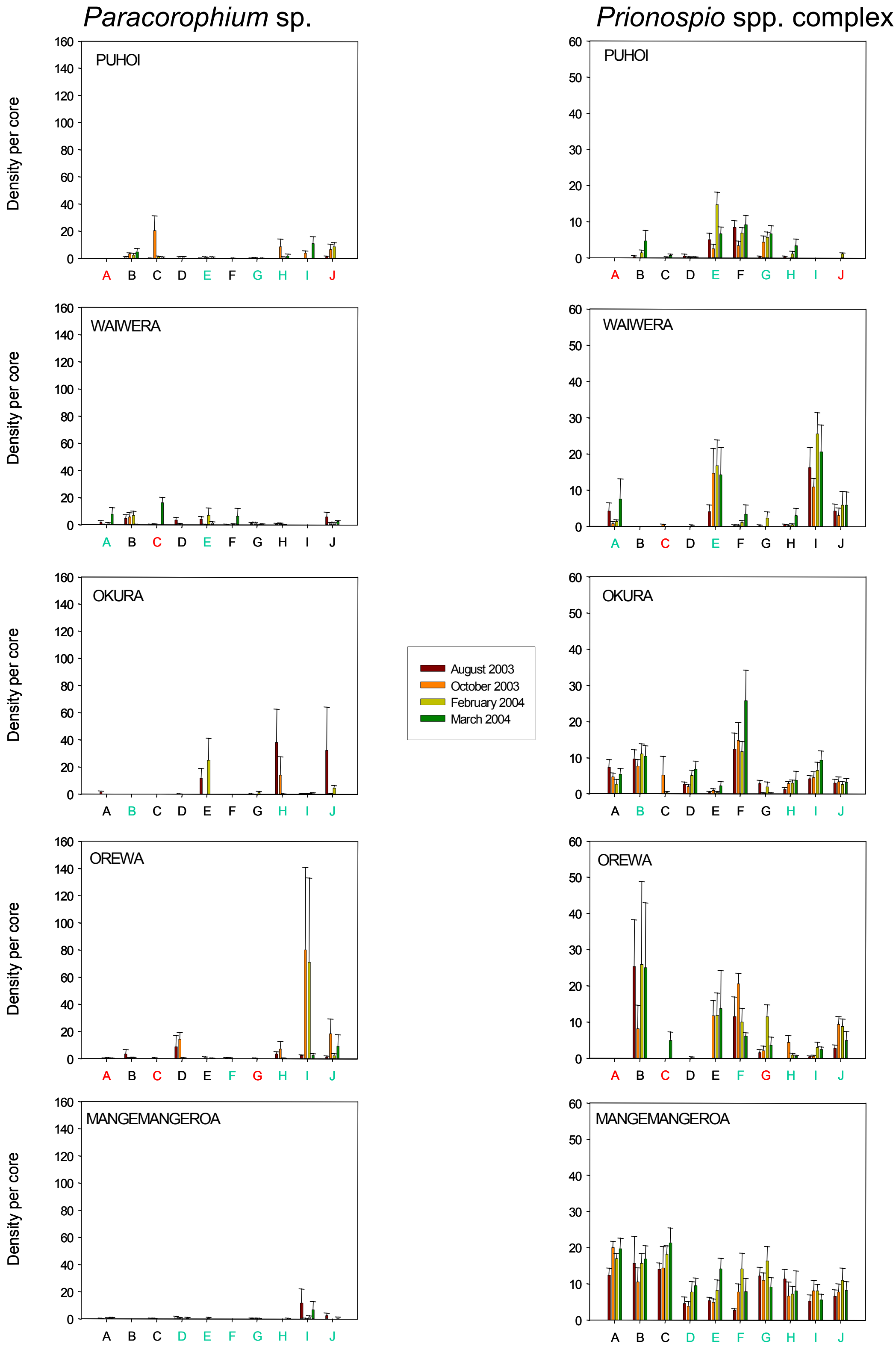
Appendix G.1 *Austrovenus stutchburyi* and Barnacles common taxa from the monitoring programme at each site and time for all estuaries (*n*=6 per bar, errors = std. error).The colour of site letters on the x-axis indicates the hydrodynamic energy of the site (high = red, medium = black, low = green).



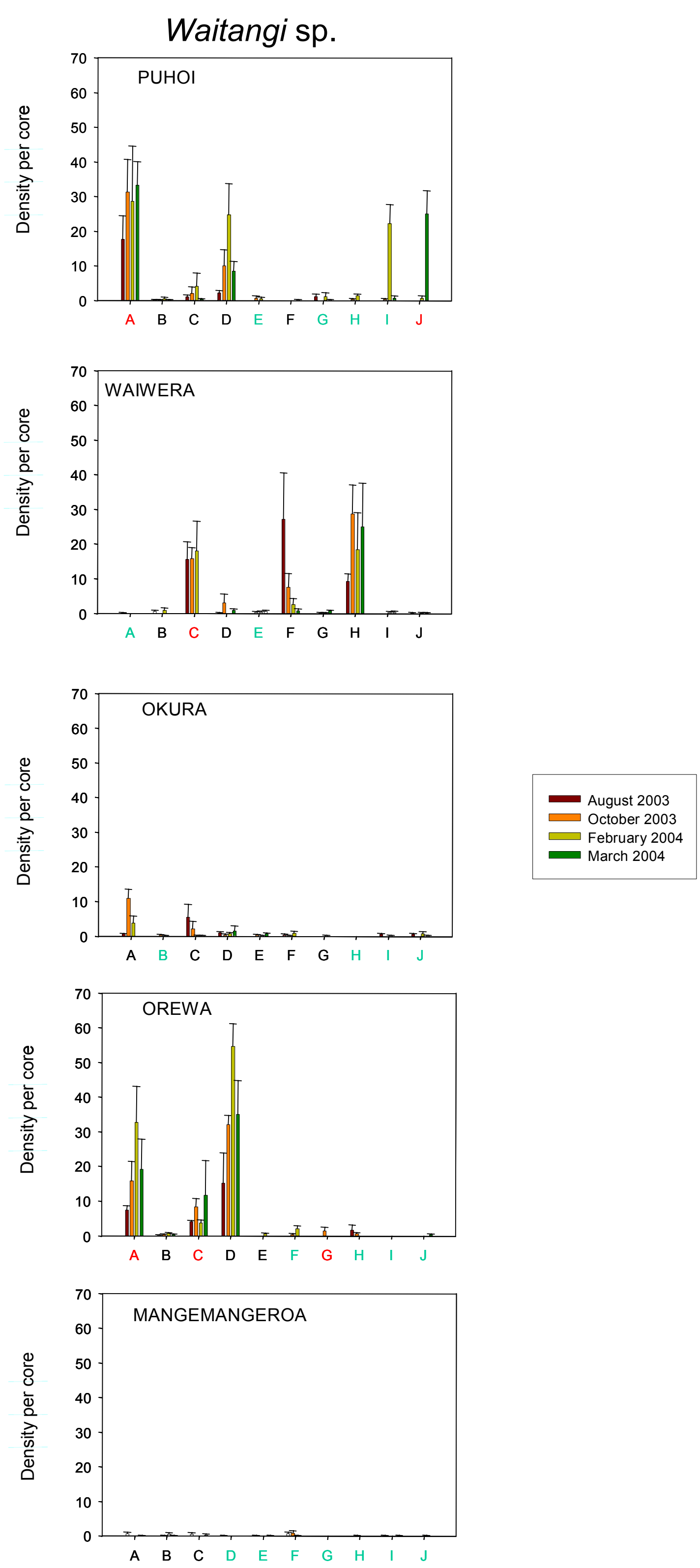
Appendix G.2 *Colorustylis* spp. and *Notomastus spp.* from the monitoring programme at each site and time for all estuaries (*n*=6 per bar, errors = std. error). The colour of site letters on the x-axis indicates the hydrodynamic energy of the site (high = red, medium = black, low = green.



Appendix G.3 *Nucula hartvigiana*. and *Paphies australis.* from the monitoring programme at each site and time for all estuaries (*n*=6 per bar, errors = std. error). The colour of site letters on the x-axis indicates the hydrodynamic energy of the site (high = red, medium = black, low = green.



Appendix G.4 *Paracorophium* sp. and *Prionospio* spp. complex from the monitoring programme at each site and time for all estuaries (*n*=6 per bar, errors = std. error). The colour of site letters on the x-axis indicates the hydrodynamic energy of the site (high = red, medium = black, low = green.



Appendix G.5 *Waitangi* sp. from the monitoring programme at each site and time for all estuaries (*n*=6 per bar, errors = std. error). The colour of site letters on the x-axis indicates the hydrodynamic energy of the site (high = red, medium = black, low = green.