Auckland
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TE RAUHITANGA TAIAO

ECOLOGICAL MONITORING OF THE OKURA AND WHITFORD ESTUARIES 2004-2005: TEMPORAL AND SPATIAL EXTENSION OF REGIONAL MODELS

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2 EXECUTIVE SUMMARY

This report summarizes the results of the Okura monitoring programme for the year 2004-2005. The original aim of this programme was to determine whether land disturbance associated with varying degrees of urbanisation in the surrounding catchment causes ecologically damaging sedimentation to the intertidal soft-sediment infauna in Okura Estuary. In recent years, Mangemangeroa, Turanga and Waikopua estuaries of the Whitford embayment have been added to the monitoring programme, as they too are expected to be potentially impacted by sediment inputs from urbanisation through time.

This monitoring programme is intended to verify the validity of modelling and environmental risk predictions used to underpin development planning decisions. The programme involves sampling of selected biological and physical parameters at each of ten sites in each of seven estuaries. Development is expected in the catchments surrounding Okura, Mangemangeroa, Turanga and Waikopua estuaries, and it is envisaged that the estuaries at Puhoi, Waiwera and Orewa may act as control or reference estuaries, although any of the estuaries may show signs of impact over time. The design of the monitoring programme allows for rigorous detection of short and long-term potential impacts at individual sites and at the scale of the whole estuary, for each estuary through time. The timing of the surveys also allows rigorous inferences to be made about the effects of sedimentation due to heavy rainfall, including 4 distinct sampling times per year: 1 sampling after rainfall and 1 sampling after a dry period in each of two seasons. Monitoring to date has provided a baseline for future comparison, as development has yet to proceed in Okura, Turanga and Waikopua catchments. New to the monitoring programme this year were the Waikopua and Turanga estuaries. It was therefore of interest to place these sites into the context of models developed for the region to date.

The physical hydrodynamics of the estuaries allowed sites across the region to once again be classified into relatively high, medium or low-energy sites. The fauna characterising assemblages in these energy groupings were consistent with what was found last year, with low-energy sites being characterised by crabs (*Helice*, *Hemigrapsus*, *Macropthalmus* spp.), copepods and *Heteromastus filiformis*, medium-energy sites being characterised by *Austrovenus stutchburyi*, Nuculidae, *Notoacmea sp.*, and high-energy sites being characterised by *Paphies australis*, isopods and amphipods such as *Waitangi sp.* and the cumacean *Colorustylis* spp.

It was found that the upper reaches of the Waikopua and Turanga estuaries differed from other sites sampled to date in that the ambient sediments were finer, effectively extending the spectrum of low-energy sites. The number of taxa and the number of individuals were more depauperate and greater proportional abundances of nematodes and crustaceans were found there. Other general patterns of differences at these estuaries in terms of biota were that 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.). Biodiversity showed a similar pattern to that seen at Okura, being relatively high in the middle and outer reaches of these estuaries.

Spatial variation was generally very high from site to site and some distinctive biological assemblages could be identified as characteristic of certain estuaries. The most important environmental variables in explaining community structure were the grain size characteristics of trapped sediments and ambient sediments. Together the environmental variables explained just over 40% of the variation in community structure (at the site level).

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. These analyses were shown to be very sensitive to detecting relevant ecological changes in community structure, as was evidenced by a clear effect detected when one of the monitored sites needed to be moved a short distance (due to a change in the position of a channel in Orewa). Temporal variation was, overall, very slight and no significant persistent ecological effects of rainfall were detected, either within the current year of sampling or over the entire time series for the monitoring programme to date (11 times over three years). Seasonal effects were also extremely minor, explaining < 2% of the variation in community structure.

We recommend a continuation of the present sampling design in these monitoring programmes. Rainfall measures and effects can continue to be examined as a structured feature of the experimental design and on a correlative basis within this protocol. We also recommend an overall gradient approach to modeling responses of assemblages to sedimentary regimes across the estuaries, such as that being explored in terms of regional contaminant effects. The continuation of a temporal series provides a strong baseline against which future possible land development impacts can be measured. Continued monitoring should emphasise important trends in biodiversity, with a focus on spatially explicit predictive modeling to detect changes in biotic assemblages associated with land-use changes.

3 INTRODUCTION

3.1 Background

Changes in land-use can degrade estuarine ecosystems through increased sedimentation. Terrigenous sediments flushing into estuarine ecosystems increase turbidity and sediment deposition. Although estuarine in-filling is a natural process, there is now clear evidence that human activities have increased the speed of sediment accumulation in many estuaries across New Zealand, particularly those in urban environments (Hume and Swales 2003, Hayward *et al.* 2004). Potential ecological effects of increased freshwater inputs and sediment in-filling include smothering of fauna, decreased feeding efficiency for many filter-feeders, decreased ability of bivalves to burrow, large-scale habitat changes and overall decreases in estuarine biodiversity (e.g. Edgar and Barrett 2000, Benedetti-Cecchi *et al.* 2001, Hewitt 2002, Hancock and Hewitt 2004, Cummings and Thrush 2004, Lohrer *et al.* 2004). In addition, many estuarine organisms have limited dispersal capabilities, meaning that catastrophic changes due to sediment deposition can result in irreversible ecological changes (Thrush *et al.* 2003a, Lundquist *et al.* 2004).

Ongoing development and urbanisation through time in the areas surrounding the Okura Estuary has raised concerns that resulting increases in sediment deposition would cause significant impacts on soft-sediment benthic intertidal fauna. Considerable previous scientific work has been done in the Okura estuary by NIWA and the University of Auckland, as outlined and reviewed by Anderson *et al.* (2001, 2002) and Ford *et al.* (2003, 2004). Also, a recent review by Thrush *et al*. (2004) highlighted the need for better information on processes, rates and connectivity in seafloor ecosystems to underpin effective management decisions.

In the past year some substantial changes to land-use have occurred in estuaries that we monitor, which may lead to future impacts. Resource consent has been granted by Rodney District Council and Auckland Regional Council for a cleanfill site at the head of the Okura River. Bral Holdings has been granted resource consent for 20,000 cubic metres of earthworks and unloading of 280,000 cubic metres of cleanfill rubbish (NZ Herald 9-Sep-2004). Large-scale earthworks have also been ongoing, primarily in the Waiwera catchment but also in the Puhoi catchment, in order to extend the northern motorway via the Alpurt extension (Fig. 1).

In addition to the previous research focused on the Okura estuary (see the Introduction of Ford *et al.* 2003), 5 other estuaries have been included in a regional monitoring programme from 2002 to the present (see Ford *et al.* 2004). The findings from Ford *et al.* (2004) of the last 2 years of monitoring the Puhoi, Waiwera, Okura, Orewa and Mangemangeroa estuaries have shown:

Figure 1. Road works in the Waiwera catchment for the Alpurt motorway extension as photographed in Februrary 2005.

1) The physical characteristics of sites within Okura fell within the range of physical characteristics measured for the other four estuaries. These estuaries continue to be 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 has been developed and validated using 2 years of data. This model provides a clear and sensitive way of detecting temporal change in each of the estuaries currently monitored.

3) The differences between biological communities from high, medium and low energy sites are quite consistent. All species highlighted in Ford *et al.* (2003) as being important for this distinction exhibited the same patterns of relative abundance in Ford *et al*. (2004).

4) Just under half of the variance in the biological communities (47%) across all estuaries was successfully modeled by the measured environmental variables.

5) There was a significant relationship between the fauna and the environmental variables, and the relationship between the two was relatively constant over time and between different estuaries. Sites with similar environmental variables through time were consistently placed in similar energy groups, which held distinct faunal assemblages.

6) Seasonal effects were only observed at low-energy sites, with no consistent effects of precipitation.

7) Pulse changes in assemblage structure have been observed for many of the estuaries, visible at high, medium and low-energy sites. Puhoi estuary appeared to be most susceptible to sudden, but reversible, changes in assemblage structure, apparently in response to rainfall events. Okura and Mangemangeroa showed the least variability in environmental conditions and the most stability in community structure over time.

3.2 Whitford embayment and associated tributaries

Since the last report, scientists at the University of Auckland, through its commercial arm UniServices, have been contracted to undertake monitoring of two additional Whitford embayment tributary estuaries, Turanga and Waikopua. This is to determine whether, and to what extent, development of the Whitford catchment over time degrades the quality of the estuarine habitat by increasing sediment input, resulting in a modification of the estuarine biota. Turanga and Waikopua estuaries have been integrated into the Okura monitoring programme to give a regional viewpoint regarding potential impacts of sedimentation, from the scale of individual sites to the entire Whitford embayment.

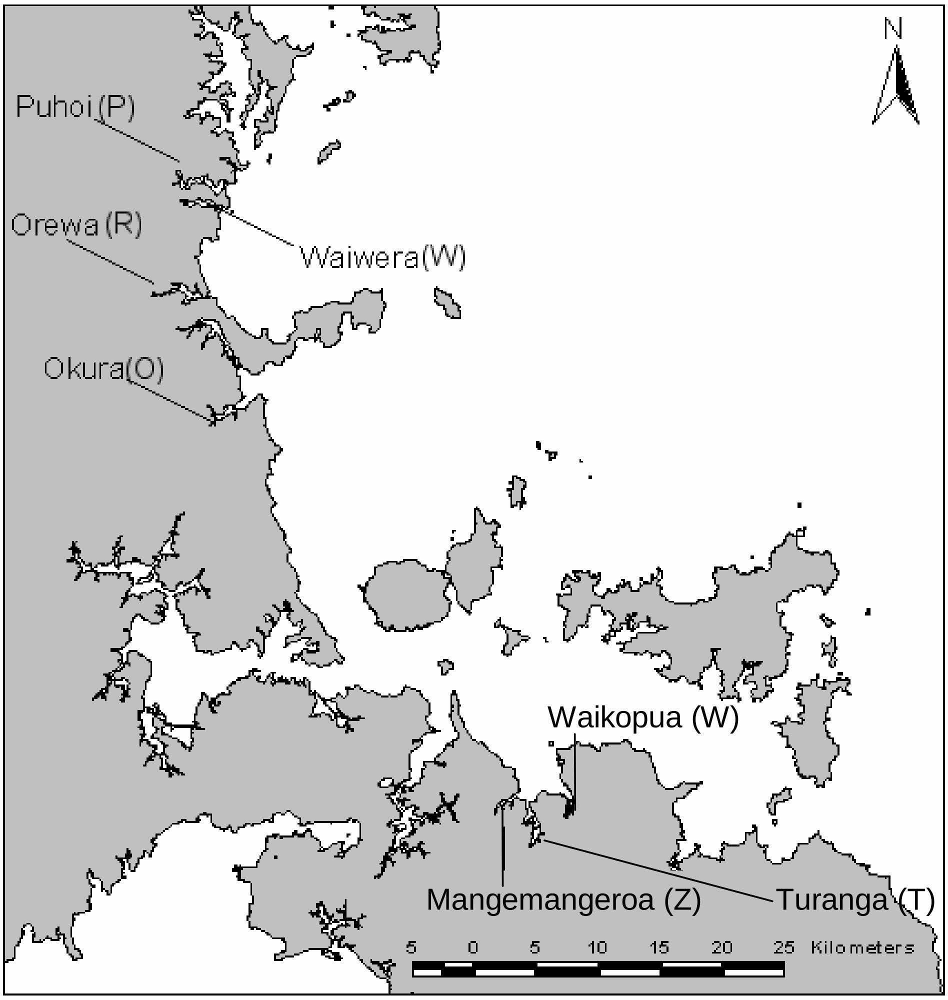

Figure 2. Map of the East Coast of the Auckland Region showing all five estuaries sampled. Abbreviations used for estuaries in reporting results are shown in brackets after each name.

It is expected that the level of rural-residential development will increase over the next 5-15 years, resulting in an increase in sediment loading to the Whitford embayment. It is clear that the Whitford embayment already has undergone significant broad-scale degradation of habitat due to historic activities in the catchment (Oldman and Swales 1999). Analyses indicated that ecologically damaging sediment deposition events are already occurring frequently in the Whitford tributary estuaries and inner embayment (Fig. 3, see Senior *et al.* 2003), and sedimentation in the upper reaches of the estuaries has been rapid.

Mangemangeroa was also found to have a greater sediment loading and rate of sediment accumulation than either Waikopua or Turanga, with 1m of sediment accumulated at the inland end of the estuary since 1953 and a current SAR (Sediment Accumulation Rate) of nearly 30mm per year. This high rate of sediment accumulation has been aided by a steep, easily eroded pasture catchment (Swales *et al.* 2002, Nicholls and Ellis 2002). The sediment loads in this embayment are expected to increase dramatically in the future under various development scenarios, as outlined by Senior *et al*. (2003).

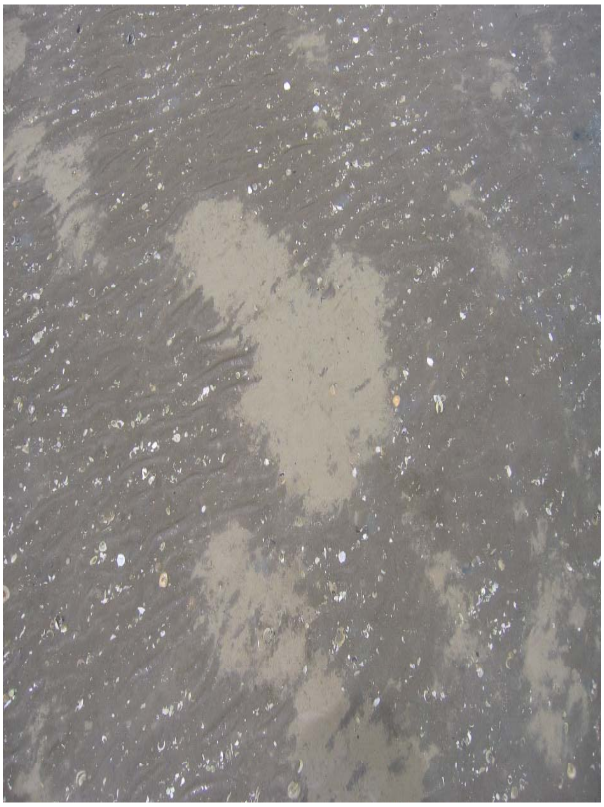

Figure 3. Photograph of sedimentation patches as viewed on the intertidal sediments near Turanga site B (29/10/04). The central patch of sedimentation is approximately 70 cm in length.

3.3 Purpose of the present report

The two essential goals of the present document are to provide an update on the monitoring programme across the five estuaries included in previous studies and to provide new information on the two new estuaries included this year. More particularly:

1. For ongoing monitoring of the five estuaries included in previous studies:

    a. Do the physical characteristics of the sites within Okura continue to fall within the range of physical characteristics measured for the other estuaries?

    b. Is the environmental model of high, medium and low-energy sites across all estuaries still valid given information obtained from the current year of sampling?

    c. Can the differences in the biological communities from the high, medium and low-energy sites still be detected, and if so, are these differences driven by the same relative differences in abundances of taxa previously described?

d. What are the long-term temporal patterns of change in assemblage structure for sites in different estuaries and in different energy environments? Are there any current signs of important sudden or gradual changes in the fauna since monitoring of these estuaries began in August 2002?

e. Are there identifiable temporal effects associated with rainfall events and, if so, can these be characterised in terms of specific fauna?

2. For the addition of Turanga and Waikopua estuaries:

   a. Do all of the new sites sampled from these tributaries of the Whitford embayment fall within the range of what we have observed elsewhere in the region, in terms of the physical data and in terms of the fauna?

   b. Given the physical data collected from these estuaries, how can these sites be classified by reference to the high, medium and low-energy groupings identified across the region?

   c. If these new estuaries show differences from other estuaries, what characterises these differences, in terms of physical dynamics and also in terms of the biota?

4 METHODS

In general, the field and laboratory methods used were identical to those used for this monitoring programme last year (Ford *et al*. 2004), except with regard to the sampling of ambient sediments. Following discussions with the ARC, it was decided to modify the method of collection of ambient sediments to comply with NIWA methods, as described in Cummings *et al*. (2001). The "Surface (0-2 cm) sediment is collected from random areas within each site and bulked for subsequent analysis". This method requires less processing for a reliable result and is more sensitive to changes in sediment surface depositions.

4.1 Field methods

4.1.1 Site selection

Twenty new sites were chosen in the Whitford embayment to add to the fifty sites in the broader Auckland region already monitored. The new sites were positioned by reference to existing information concerning several areas that were either of high biological diversity and/or of high risk to sediment impacts (Senior *et al*. 2003). More specifically, Senior *et al*. (2003) described six areas at risk of ecologically damaging sedimentation within the Whitford embayment. These were termed "Bands of Common Vulnerability" (BCV), and "Regions of Special Vulnerability" (RSV) (see details in Fig. 4).

RSV 1 has a slightly lower risk of ecological damage than BCV 2, however high densities of suspension feeders were observed in this area, which are likely to be adversely affected by increased turbidity. Thus, the risk of ecological damage is likely to be higher than that predicted solely on the basis of sediment deposition (Senior *et al*. 2003). RSV 2, as a sub-area of BCV 3, is likely to have a strong negative ecological response to sediment deposition, although the frequency of events is likely to be less than in other parts of BCV 3. RSV 2 is a highly diverse area within the embayment, with high densities of juveniles and a variety of suspension feeders.

BCV 1 is an area of low biodiversity, and dispersion modeling predicts frequent depositional events would occur in this area. However, many common estuarine mud species found in these upper reaches are adversely affected by sediment deposition. Under all land-use scenarios modeled by Senior *et al.* (2003), BCV 2 is the region most likely to experience significant loss of taxa due to high sediment thresholds being exceeded more frequently than in other areas. BCV 3 represents a shallow part of the embayment that should experience ecological damage less frequently than areas closer to sediment sources. BCV 3 contains high densities of suspension feeders and juveniles, particularly along channel margins, which are likely to be adversely affected by increased turbidity. BCV 4 (not shown in Fig. 4) comprises the outer embayment where ecological response to sediment deposition is likely to be weakest, therefore the risk of ecological damage is the lowest in this area of the embayment.

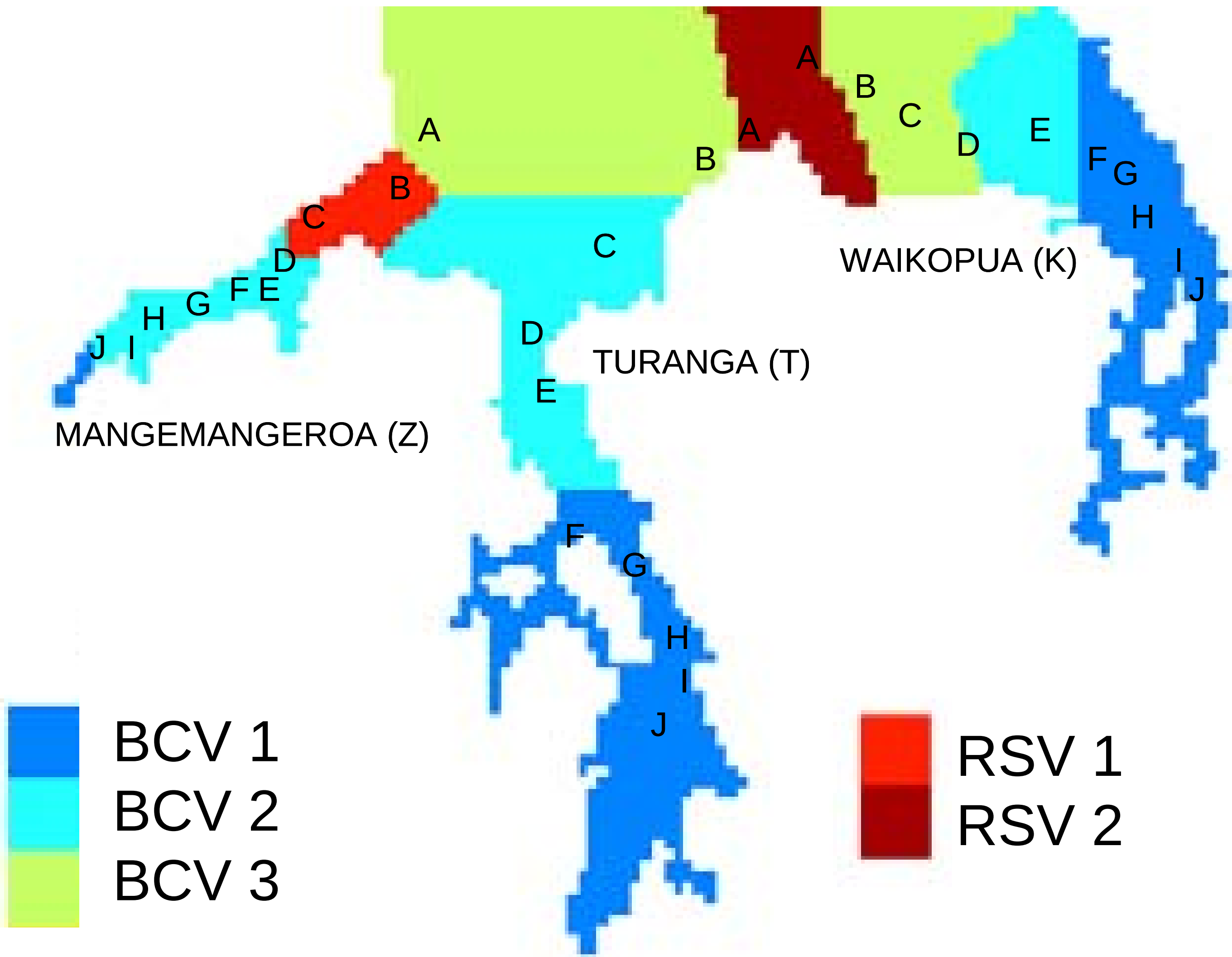

Figure 4. Sites A-J in each of the three Whitford embayment estuaries shown in relation to the zones of risk from sediment run-off: RSV = Regions of Special Vulnerability, BCV = Bands of Common Vulnerability. Adapted from figure 5.2 of Senior *et al.* (2003).

Sites were chosen within each estuary on the basis of four criteria:

1. to cover the gradient from the mouth to the upper reaches of the estuary:
2. to span the range of sediment grain size textures available within each estuary;
3. to avoid spatial confounding of environmental gradients (i.e., it was important that not all sites with fine sediments be located in the upper reaches of the estuary); and
4. to cover the most susceptible zones within the estuary to sedimentation as described by Senior *et al*. (2003).

Mangemangeroa has sites situated in BCV 2, 3 and RSV 1. Turanga and Waikopua have sites situated in BCV 1, 2, 3, and RSV 2. Sites for Turanga and Waikopua were selected from the ecological and environmental data contained in Senior *et al*. (2003), inspections of aerial photographs and observations of sites in the field.

Ten sites were sampled in each estuary. GPS locations of these sites are listed in Appendix A. Sites were labelled alphabetically and sequentially (A - J) from the mouth of the estuary (A) to its upper reaches (J) (Fig. 5). In the presentation of results, sites within estuaries are generally referred to by a two-letter abbreviation. The first letter indicates the estuary (Fig. 2), while the second letter indicates the position of the site in the estuary relative to the mouth (from A-J).

4.2 Timing of Sampling

Sampling occurred within 2 discrete 3-month blocks (hereafter referred to as seasons): August - October 2003 (Winter/Spring (W/S) and February - April 2004 (Late Summer (LS)). Within each season, sampling was event-driven and occurred twice: (i) once 7-10 days after a rainfall event, defined as ≥ 15mm of rainfall in a 24-hour period ('Rain') and (ii) once when such a rainfall event had not occurred in ≥ 10 days ('Dry'). Examination of seventeen years of data from the Leigh Marine Laboratory meteorological records showed that a rainfall event of 15 mm was an event that could be reliably expected to occur at least twice in every season. Rainfall was gauged from the St. Heliers weather station, which is a site central to all estuaries. Data were obtained from: http://homepages.paradise.net.nz/tmcgavin/current_nzweather.html.

All estuaries were sampled within a period of 5 days at each of the four times of sampling (Table 1).

Table 1. Sampling dates for 2004-2005.

Sampling Period	'Rain' Sampling	'Dry' Sampling
Winter/Spring 2004	14-18 October 2004	16-18 August 2004
Late Summer 2005	4-6 April 2005	7-9 February 2005

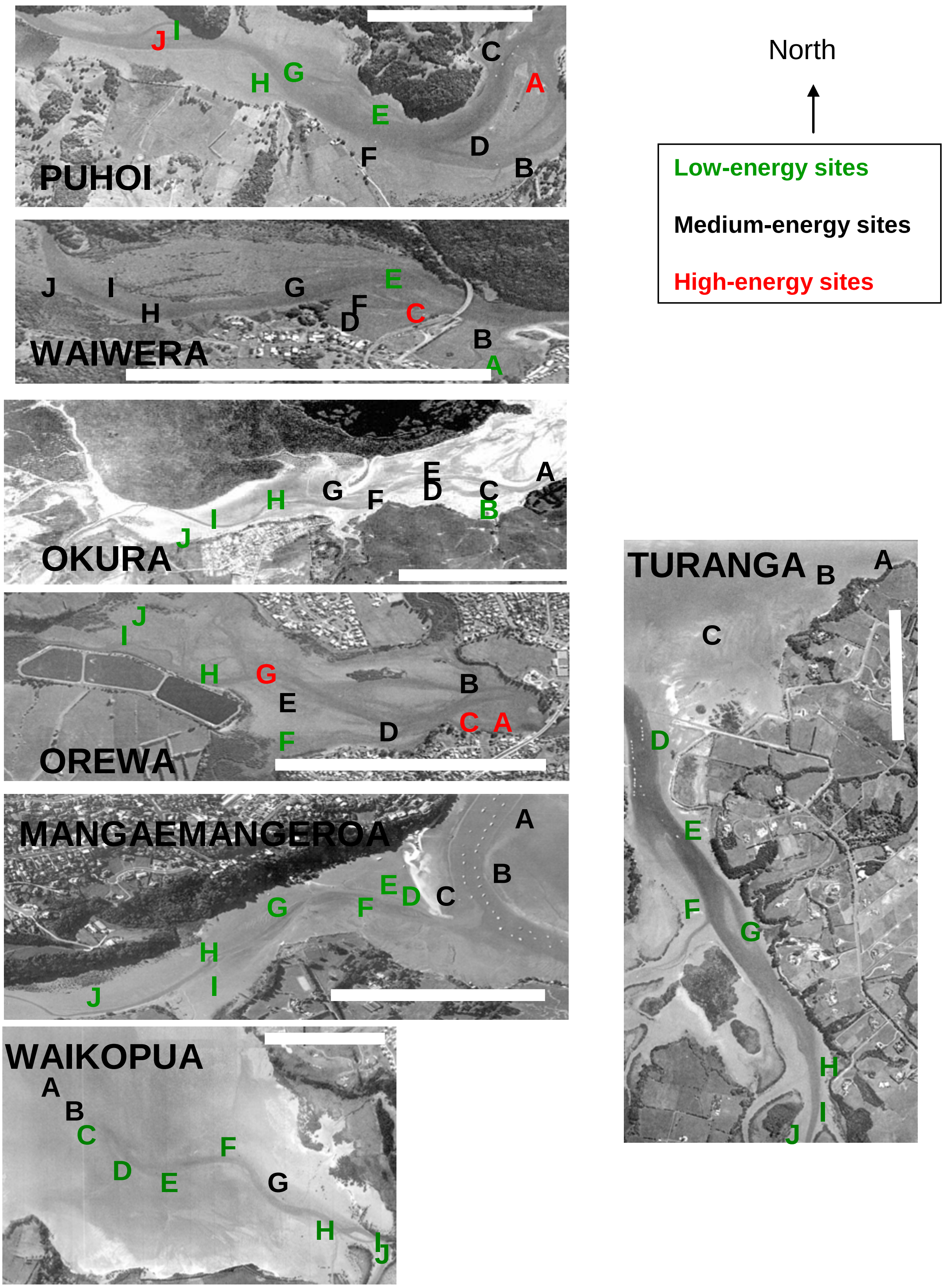

Figure 5. Maps of all estuaries showing sites in each of three environmental groupings. Bars equal 1km in the along-estuary direction only. Note scales are unequal in the horizontal and vertical planes. Estuary flats vary in width up to 200m.

4.2.1 Sampling of fauna

At each site the corner closest to the channel of an area measuring 50 m parallel to the shore (the x-axis) and 25 m perpendicular to the shore (the y-axis) was marked with a permanent flag. There were $n = 6$ cores obtained from random positions within each area by choosing a random number between 0 and 49 and between 0 and 24 for the x and y-axes, respectively. Cores were circular in shape, measuring 130 mm in diameter and 150 mm deep. Each core was sieved in the field using 0.5 mm mesh. Material retained on the sieve was brought back to the laboratory for sorting and taxonomic identification. All organisms retained were preserved in 70% isopropyl alcohol with 0.01% rose bengal.

Where possible, organisms were identified to the species level. Some specimens were unable to be unambiguously identified, and are grouped together. All organisms were identified to the lowest level of taxonomic resolution possible. This varied, depending on the particular group. For example, nemerteans were grouped at phylum level, while bivalves were identified to species. Some polychaetes could be identified to species level, while others could only be identified to the genus or family level (see Appendix B).

4.2.2 Measures of ambient sediment texture

One core (20mm x 20mm) was obtained to sample ambient grain sizes of sediments adjacent to each faunal core, and the six cores per site were combined to give approximately 60gm wet weight. Samples were dried and treated with 10% hydrogen peroxide until fizzing ceased, to dissolve organic matter. Samples were then dried again and weighed to obtain a total dry weight. They were then deflocculated for at least 12 hours (using Calgon 2g per litre) and wet sieved on a stack of sieves (500, 250, 125 and 63μm). Each fraction (>500, 250-499, 125-249, 63-124 and <63μm) was dried, weighed and calculated as a percentage of the total weight. The fraction less than 63 μm was calculated by subtraction of all other dry weights from the initial dry weight due to the inherent difficulties in settling and drying these fine sediments.

4.2.3 Measures of sediments in traps and changes in bed height

Sediment inputs were characterised at each site by a combination of a sediment trap and a depth-of-disturbance rod. A sediment trap (36 mm diameter by 500 mm deep) was placed at the lowest point of each site so that the opening was 200-250 mm above the sediment surface. These traps collected sediment settling from the water column. Depth-of-disturbance rods (Clifton 1969, Greenwood and Hale 1980) were adapted from previous designs (Anderson *et al.* 2002) due to safety concerns and problems of sample reclamation. Marker poles with sediment traps attached were used to gauge relative change in the height of the bed. Measurements were taken between the top of the sediment trap holder and the ambient sediment surface at least once a month. The height of the top of the sediment trap holder above the sediment surface measured the net erosion or accretion at a site. When scour was present at the base of the marker poles the height of the top of the holder was estimated in relation to the ambient bed height at the pole independent of any scouring using a ruler.

Sediment traps were deployed at each site in the field for a period of approximately one month at a time, such that a continuous record was gained for the past year (except for sediment traps lost). At deployment and collection, measurements were also taken of the depth-of-disturbance rods. Sediment collected from traps was filtered (mesh size ~ 2 μm), dried and weighed. These sediments were then sub-sampled, pre-treated for organics, deflocculated and wet-sieved as for ambient sediments to characterise their grain-size fractions (see section 2.1.4).

Trapped sediment measures integrate both deposition from the water column and resuspension of material from the bed. Trapped sediments do not precisely quantify sediment deposition *per se*. However, they have provided a useful measure that, although often partially correlated with ambient sediments, has proven more useful in explaining biotic assemblages than ambient sediment composition alone (Ford et al. 2004). Trapped sediment measures are also likely to provide a better indication of an increase in sediment deposition than ambient sediments are, and it was therefore considered wise to retain these environmental measurements. Traps collected from sites RA, RC and PJ often showed an aspect ratio of less than 7:1, so measures of trapped sediment are conservative for these sites. However, we note that trapped sediments at these sites are generally dominated by coarse sediments; we would be unlikely to underestimate significant deposition of fine sediments, which are those more likely to have a recent terrestrial origin. Table 2 contains a summary of all the environmental variables measured and used in subsequent analyses.