

Waikanae Estuary

Fine Scale Monitoring 2010/11



Prepared
for
**Greater
Wellington
Regional
Council**
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By

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WAIKANAE ESTUARY - EXECUTIVE SUMMARY

Waikanae Estuary

Vulnerability Assessment
Identifies issues and recommends monitoring and management. Completed in 2007 (Robertson and Stevens 2007b)

Waikanae Estuary Issues
Moderate eutrophication
Excessive sedimentation
Habitat Loss (from artificial mouth opening, also terrestrial margin)

Monitoring

Broad Scale Mapping

Sediment type
Saltmarsh
Seagrass
Macroalgae
Land margin

5-10 yearly

First undertaken in 2004. Macroalgae undertaken 2010, 2011.

Fine Scale Monitoring

Grain size, RPD, Organic Content
Nutrients, Metals, Invertebrates, Macroalgae,
3-4yr Baseline then 5 yearly
Baseline yet to be completed. Next survey 2012

Sedimentation rate annually

Condition Ratings

Area soft mud, Area saltmarsh, Area seagrass, Area terrestrial margin, RPD depth, Benthic Community, Organic content, N and P, Toxicity, Sedimentation rate.

Other Information

Previous reports, Observations, Expert opinion

ESTUARY CONDITION

Moderate Eutrophication
Excessive Sedimentation
Low Toxicity
Habitat Degraded (saltmarsh, terrestrial margin)

Recommended Management

- Limit artificial mouth opening
- Reduce floodgate constrictions
- Limit intensive landuse.
- Set nutrient, sediment guidelines.
- Margin vegetation enhancement.
- Manage for sea level rise.
- Enhance saltmarsh/seagrass.
- Manage weeds and pests.

This report summarises the results of the second year of fine scale monitoring of one intertidal site within Waikanae Estuary, a 2km long, tidal river estuary that discharges to the Tasman Sea, just north of Paraparaumu. It is one of the key estuaries in Greater Wellington Regional Council's (GWRC's) long-term coastal monitoring programme. An outline of the process used for estuary monitoring and management in GWRC is presented in the margin flow diagram, and the following table summarises fine scale monitoring results, condition ratings, overall estuary condition, and monitoring and management recommendations.

FINE SCALE MONITORING RESULTS

- Sediment Oxygen: Redox Potential Discontinuity (RPD) was 3-10cm deep indicating good oxygenation.
- The invertebrate organic enrichment tolerance rating indicated a "low to moderate" condition.
- The indicator of organic enrichment (Total Organic Carbon) was at low concentrations.
- Nutrient enrichment indicators (total nitrogen and phosphorus) were at low-moderate concentrations.
- The sediment had moderate to high mud concentrations (approximately 16-20% mud).
- The benthic invertebrate mud tolerance rating was "high" - dominated by mud tolerant species.
- Heavy metals were well below the ANZECC (2000) ISQG-Low trigger values.
- Intertidal macroalgal cover was low.

CONDITION RATINGS	Site A 2010	Site A 2011
Sedimentation Rate	Plates Deployed	Very High
Mud tolerance (inverts)	High	Mod-High
RPD Profile (sediment oxygenation)	Fair-Good	Good
TOC (Total Organic Carbon)	Very Good	Very Good
Total Phosphorus (TP)	Good	Good
Total Nitrogen (TN)	Good	Good
Organic enrichment (inverts)	Low to Moderate	Low
Metals (Cd, Cu, Cr, Pb)	Very Good	Very Good
Metals (Ni, Zn)	Good	Good
DDT	Very Good	Not Tested

ESTUARY CONDITION AND ISSUES

The second year of baseline monitoring shows that the dominant intertidal habitat (i.e. unvegetated mud/sand) in the Waikanae Estuary was generally in a good-fair condition. The presence of elevated mud contents, moderately oxygenated sediments, low-moderate nutrients, and a typical upper estuary benthic invertebrate community (high numbers of mud and low salinity tolerant species) suggests that the estuary is moderately enriched, and has excessive fine sediment inputs. Such findings however, must be considered alongside the knowledge that the estuary has been physically altered from its original state through blocking tidal access to a large estuarine arm and loss of habitat through artificial mouth opening. The result is a much lowered ability of the estuary to function efficiently and provide valuable habitat for fish and birdlife.

RECOMMENDED MONITORING AND MANAGEMENT

In order to establish baseline conditions in this priority estuary, fine scale monitoring (including sedimentation rate and macroalgal mapping) is being undertaken annually for one more year (next monitoring scheduled for January 2012). Broad scale habitat mapping is to be undertaken every 10 years (next scheduled in 2014).

The 2011 fine scale monitoring results reinforce the need for management of nutrient and especially fine sediment sources entering the estuary. It is recommended that sources of elevated loads in the catchment be identified and management undertaken to minimise their adverse effects on estuary uses and values. In order to improve estuary function, it is also recommended that steps be taken to increase the extent of high value estuary habitat (saltmarsh, intertidal flats and natural vegetated margin) wherever possible.

1. INTRODUCTION

OVERVIEW



Figure 1. Waikanae Estuary - mid estuary looking towards Waikanae beach.

Developing an understanding of the condition and risks to coastal and estuarine habitats is critical to the management of biological resources. Recently, Greater Wellington Regional Council (GWRC) undertook vulnerability assessments of its region's coastlines to establish priorities for a long-term monitoring programme for the region (Robertson and Stevens 2007a, 2007b and 2007c). These assessments identified the following estuaries as priorities for monitoring: Porirua Harbour, Whareama Estuary, Lake Onoke, Hutt Estuary and Waikanae Estuary.

GWRC began monitoring Waikanae Estuary in January 2010 (Robertson and Stevens 2010a), with the work being undertaken by Wriggle Coastal Management using the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002) plus recent extensions.

The Waikanae Estuary monitoring programme consists of three components:

1. **Ecological Vulnerability Assessment** of the estuary to major issues (Table 1) and appropriate monitoring design. This component has been completed for Waikanae Estuary and is reported on in Robertson and Stevens (2007b).
2. **Broad scale habitat mapping** (EMP approach). This component, which documents the key habitats within each estuary and changes to these habitats over time, has been completed for the Waikanae Estuary (Stevens and Robertson 2004).
3. **Fine Scale Monitoring** (EMP approach). Monitoring of physical, chemical and biological indicators (Table 2) including sedimentation plate monitoring. This component, which provides detailed information on the condition of the Waikanae Estuary, was first undertaken in January 2010 and again in January 2011 (the subject of the current report).

The Waikanae Estuary is a moderate-sized (2km long, 40-50m wide, 1-2m deep) "tidal river mouth" type estuary which drains onto a broad flat (dissipative) beach just north of Paraparaumu. As is typical in such situations, the majority of the estuary area consists of a long, shallow lagoon type estuary running along the back of the beach parallel to the sea. This results from the continual action of ocean currents from the north that generate a sandspit that pushes the mouth progressively southwards. However, in the case of the Waikanae Estuary, this lower part of the estuary is regularly lost because the channel is periodically artificially opened to the sea at the north end to protect land to the south. In addition, floodgates restrict tidal action and flushing to a large historical estuarine arm. Such actions, mean that the lower estuary and the old estuarine arm have much-reduced ecological values in that there is limited potential for long-term estuarine communities to establish. The middle and upper estuary in the main arm are, however, much more stable (including some saltmarsh and tidal flats) and, consequently, have been targeted for the fine scale monitoring programme. There are also various freshwater lakelets around the margins.

Like other moderate-sized tidal river estuaries, the Waikanae is usually freshwater dominated at low tide and at high tide consists of a freshwater layer on top of saline bottom water. Plant and animal life is therefore restricted to those that tolerate such regular salinity extremes.

Human and ecological use of the estuary is high. It is one of the few estuary/wetland areas of any size in the southwestern North Island, and is a nationally significant wetland habitat for waders, seabirds and waterfowl, both local and migratory. More wild birds visit Waikanae Estuary Scientific Reserve than any other area in the Wellington province. In terms of human use, the estuary is a local focal point and is used for conservation, walking, picnicking, boating, fishing, paddling, bird watching, bathing, and white-baiting. The estuary receives moderate inputs of nutrients and sediment from the large catchment and tertiary treated wastewater from the Paraparaumu Treatment Plant (via the Mazengarb Drain) (Robertson and Stevens 2007b).

1. Introduction (Continued)

Table 1. Summary of the major issues affecting most NZ estuaries.

Major Estuary Issues	
Sedimentation	Because estuaries are a sink for sediments, their natural cycle is to slowly infill with fine muds and clays. Prior to European settlement they were dominated by sandy sediments and had low sedimentation rates (<1 mm/year). In the last 150 years, with catchment clearance, wetland drainage, and land development for agriculture and settlements, New Zealand's estuaries have begun to infill rapidly. Today, average sedimentation rates in our estuaries are typically 10 times or more higher than before humans arrived.
Eutrophication (Nutrients)	Increased nutrient richness of estuarine ecosystems stimulates the production and abundance of fast-growing algae, such as phytoplankton, and short-lived macroalgae (e.g. sea lettuce). Fortunately, because most New Zealand estuaries are well flushed, phytoplankton blooms are generally not a major problem. Of greater concern is the mass blooms of green and red macroalgae, mainly of the genera <i>Enteromorpha</i> , <i>Cladophora</i> , <i>Ulva</i> , and <i>Gracilaria</i> which are now widespread on intertidal flats and shallow subtidal areas of nutrient-enriched New Zealand estuaries. They present a significant nuisance problem, especially when loose mats accumulate on shorelines and decompose. Blooms also have major ecological impacts on water and sediment quality (e.g. reduced clarity, physical smothering, lack of oxygen), affecting or displacing the animals that live there.
Disease Risk	Runoff from farmland and human wastewater often carries a variety of disease-causing organisms or pathogens (including viruses, bacteria and protozoans) that, once discharged into the estuarine environment, can survive for some time. Every time humans come into contact with seawater that has been contaminated with human and animal faeces, we expose ourselves to these organisms and risk getting sick. Aside from serious health risks posed to humans through recreational contact and shellfish consumption, pathogen contamination can also cause economic losses due to closed commercial shellfish beds. Diseases linked to pathogens include gastroenteritis, salmonellosis, hepatitis A, and noroviruses.
Toxic Contamination	In the last 60 years, New Zealand has seen a huge range of synthetic chemicals introduced to estuaries through urban and agricultural stormwater runoff, industrial discharges and air pollution. Many of them are toxic in minute concentrations. Of particular concern are polycyclic aromatic hydrocarbons (PAHs), heavy metals, polychlorinated biphenyls (PCBs), and pesticides. These chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to people and marine life.
Habitat Loss	Estuaries have many different types of habitats including shellfish beds, seagrass meadows, saltmarshes (rushlands, herbfields, reedlands etc.), forested wetlands, beaches, river deltas, and rocky shores. The continued health and biodiversity of estuarine systems depends on the maintenance of high-quality habitat. Loss of habitat negatively affects fisheries, animal populations, filtering of water pollutants, and the ability of shorelines to resist storm-related erosion. Within New Zealand, habitat degradation or loss is common-place with the major causes cited as sea level rise, population pressures on margins, dredging, drainage, reclamation, pest and weed invasion, reduced flows (damming and irrigation), over-fishing, polluted runoff and wastewater discharges.

Table 2. Summary of the broad and fine scale EMP indicators.

Issue	Indicator	Method
Sedimentation	Soft Mud Area	Broad scale mapping - estimates the area and change in soft mud habitat over time.
Sedimentation	Sedimentation Rate	Fine scale measurement of sediment deposition.
Eutrophication	Nuisance Macroalgal Cover	Broad scale mapping - estimates the change in the area of nuisance macroalgal growth (e.g. sea lettuce (<i>Ulva</i>), <i>Gracilaria</i> and <i>Enteromorpha</i>) over time.
Eutrophication	Organic and Nutrient Enrichment	Chemical analysis of total nitrogen, total phosphorus, and total organic carbon in replicate samples from the upper 2cm of sediment.
Eutrophication	Redox Profile	Measurement of depth of redox potential discontinuity profile (RPD) in sediment estimates likely presence of deoxygenated, reducing conditions.
Toxins	Contamination in Bottom Sediments	Chemical analysis of indicator metals (total recoverable cadmium, chromium, copper, nickel, lead and zinc) in replicate samples from the upper 2cm of sediment.
Toxins, Eutrophication, Sedimentation	Biodiversity of Bottom Dwelling Animals	Type and number of animals living in the upper 15cm of sediments (infauna in 0.0133m ² replicate cores), and on the sediment surface (epifauna in 0.25m ² replicate quadrats).
Habitat Loss	Saltmarsh Area	Broad scale mapping - estimates the area and change in saltmarsh habitat over time.
Habitat Loss	Seagrass Area	Broad scale mapping - estimates the area and change in seagrass habitat over time.
Habitat Loss	Vegetated Terrestrial Buffer	Broad scale mapping - estimates the area and change in buffer habitat over time.

2. METHODS

FINE SCALE MONITORING



Fine scale monitoring is based on the methods described in the EMP (Robertson et al. 2002) and provides detailed information on the condition of the estuary. Using the outputs of the broad scale habitat mapping, representative sampling sites (usually two per estuary) are selected and samples collected and analysed for physical, chemical and biological variables.

For the Waikanae Estuary, one fine scale sampling site (Figure 2, Appendix 1) was selected in the dominant upper estuary habitat (i.e. intertidal mudflat). At the site, a 60m x 15m area in the lower intertidal was marked out and divided into 12 equal sized plots. Within the area, ten plots were selected, a random position defined within each, and the following sampling undertaken:

Physical and chemical analyses

- Within each sampling location, one core was collected to a depth of at least 100mm and photographed alongside a ruler and a corresponding label. Colour and texture were described and average redox potential discontinuity (RPD) depth recorded.
- At each site, three samples (two a composite from four plots and one a composite from two plots) of the top 20mm of sediment (each approx. 250gms) were collected adjacent to each core. All samples were kept in a chillybin in the field.
- Chilled samples were sent to R.J. Hill Laboratories for analysis of the following (details in Appendix 1):
 - * Grain size/Particle size distribution (% mud, sand, gravel).
 - * Nutrients - total nitrogen (TN), total phosphorus (TP) and total organic carbon (TOC).
 - * Trace metal contaminants {total recoverable cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn)}. Analyses were based on whole (sub 2mm) sample fractions which are not normalised to allow direct comparison with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000).
- Samples were tracked using standard Chain of Custody forms and results are checked and transferred electronically to avoid transcription errors.
- Photographs were taken to record the general site appearance.
- Salinity of the overlying water was measured at low tide.

Infauna (animals within sediments)

- One sediment core was taken from each of ten sampling locations using a 130mm diameter (area = 0.0133m²) PVC tube.
- The core was manually driven 150mm into the sediments, removed with the core intact and inverted into a labelled plastic bag.
- Once all replicates had been collected at a site, the plastic bags were transported to a commercial laboratory (Gary Stephenson, Coastal Marine Ecology Consultants, see Appendix 1) for sieving, counting and identification. Each core was washed through a 0.5mm nylon mesh bag or sieve with the infauna retained and preserved in 70% isopropyl alcohol.

Epifauna (surface-dwelling animals)

Epifauna were assessed from one random 0.25m² quadrat within each of ten plots. All animals observed on the sediment surface were identified and counted, and any visible microalgal mat development noted. The species, abundance and related descriptive information were recorded on specifically designed waterproof field sheets containing a checklist of expected species. Photographs of quadrats were taken and archived for future reference.

Sedimentation Rate (Plate Deployment)

Determining the sedimentation rate from the present and into the future involves a simple method of measuring how much sediment builds up over a buried plate over time. Once a plate has been buried, levelled, and the elevation measured, probes are pushed into the sediment until they hit the plate and the penetration depth is measured. A number of measurements on each plate are averaged to account for irregular sediment surfaces, and a number of plates are buried to account for small scale variance. In the future, these depths will be measured every 1-5 years and, over the long term, will provide a measure of the rate of sedimentation in representative parts of the estuary.

2. Methods (Continued)



Figure 2. Sediment plate and fine scale sites, Waikanae Estuary.

One site (with 4 plates) was established in upper Waikanae Estuary in muddy habitat adjacent to Site A in January 2010 (Figure 2). At the site, four plates (20cm wide square concrete blocks) were buried in a line on the downstream edge of the fine scale site (i.e. at right angles to the stream channel).

The distance of each plate from the fine scale marker peg closest to the estuary channel were as follows: Plate 1 @2m, Plate 2 @4m, Plate 3 @6m and Plate 4 @8m. In addition pegs were located at 5m and at 10m. Both pegs were inserted to 40mm above the ground.

The GPS position of each plate was logged, and the depth from the undisturbed mud surface to the top of the sediment plate recorded (Appendix 2).

CONDITION RATINGS

A series of interim fine scale estuary “condition ratings” (presented below) have been proposed for Waikanae Estuary (based on the ratings developed for Southland’s estuaries - e.g. Robertson & Stevens 2006). The ratings are based on a review of estuary monitoring data, guideline criteria, and expert opinion. They are designed to be used in combination with each other (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management. The condition ratings include an “early warning trigger” to highlight rapid or unexpected change, and each rating has a recommended monitoring and management response. In most cases initial management is to further assess an issue and consider what response actions may be appropriate (e.g. develop an Evaluation and Response Plan - ERP).

Sedimentation Rate

Elevated sedimentation rates are likely to lead to major and detrimental ecological changes within estuary areas that could be very difficult to reverse, and indicate where changes in land use management may be needed.

SEDIMENTATION RATE CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Low	0-1mm/yr (typical pre-European rate)	Monitor at 5 year intervals after baseline established
Low	1-2mm/yr	Monitor at 5 year intervals after baseline established
Moderate	2-5mm/yr	Monitor at 5 year intervals after baseline established
High	5-10mm/yr	Monitor yearly. Initiate ERP
Very High	>10mm/yr	Monitor yearly. Manage source
Early Warning Trigger	Rate increasing	Initiate Evaluation and Response Plan

2. Methods (Continued)

Benthic Community Index (Mud Tolerance)

Soft sediment macrofauna can also be used to represent benthic community health in relation to the extent of mud tolerant organisms compared with those that prefer sands. Using the response of typical NZ estuarine macro-invertebrates to increasing mud content (Gibbs and Hewitt 2004) a “mud tolerance” rating has been developed similar to the “organic enrichment” rating identified above. The equation to calculate the Mud Tolerance Biotic Coefficient (MTBC) is as follows;

$$MTBC = \{(0 \times \%SS) + (1.5 \times \%S) + (3 \times \%I) + (4.5 \times \%M) + (6 \times \%MM)\}/100.$$

The characteristics of the above-mentioned mud tolerance groups (SS, S, I, M and MM) are summarised in Appendix 3.

BENTHIC COMMUNITY MUD TOLERANCE RATING			
MUD TOLERANCE RATING	DEFINITION	MTBC	RECOMMENDED RESPONSE
Very Low	Strong sand preference dominant	0-1.2	Monitor at 5 year intervals after baseline established
Low	Sand preference dominant	1.2-3.3	Monitor 5 yearly after baseline established
Moderate	Some mud preference	3.3-5.0	Monitor 5 yearly after baseline established. Initiate ERP
High	Mud preferred	5.0-6.0	Post baseline, monitor yearly. Initiate ERP
Very High	Strong mud preference	>6.0	Post baseline, monitor yearly. Initiate ERP
Early Warning Trigger	Some mud preference	>1.2	Initiate Evaluation and Response Plan

Redox Potential Discontinuity

The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. It is an effective ecological barrier for most but not all sediment-dwelling species. A rising RPD will force most macrofauna towards the sediment surface to where oxygen is available. The depth of the RPD layer is a critical estuary condition indicator in that it provides a measure of whether nutrient enrichment in the estuary exceeds levels causing nuisance anoxic conditions in the surface sediments. The majority of the other indicators (e.g. macroalgal blooms, soft muds, sediment organic carbon, TP, and TN) are less critical, in that they can be elevated, but not necessarily causing sediment anoxia and adverse impacts on aquatic life. Knowing if the surface sediments are moving towards anoxia (i.e. RPD close to the surface) is important for two main reasons:

1. As the RPD layer gets close to the surface, a “tipping point” is reached where the pool of sediment nutrients (which can be large), suddenly becomes available to fuel algal blooms and to worsen sediment conditions.
2. Anoxic sediments contain toxic sulphides and very little aquatic life.

The tendency for sediments to become anoxic is much greater if the sediments are muddy. In sandy porous sediments, the RPD layer is usually relatively deep (>3cm) and is maintained primarily by current or wave action that pumps oxygenated water into the sediments. In finer silt/clay sediments, physical diffusion limits oxygen penetration to <1 cm (Jørgensen and Revsbech 1985) unless bioturbation by infauna oxygenates the sediments.

RPD CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	>10cm depth below surface	Monitor at 5 year intervals after baseline established
Good	3-10cm depth below sediment surface	Monitor at 5 year intervals after baseline established
Fair	1-3cm depth below sediment surface	Monitor at 5 year intervals. Initiate ERP
Poor	<1cm depth below sediment surface	Monitor at 2 year intervals. Initiate ERP
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Organic Carbon

Estuaries with high sediment organic content can result in anoxic sediments and bottom water, release of excessive nutrients, and adverse impacts to biota - all symptoms of eutrophication.

TOTAL ORGANIC CARBON CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<1%	Monitor at 5 year intervals after baseline established
Good	1-2%	Monitor at 5 year intervals after baseline established
Fair	2-5%	Monitor at 2 year intervals and manage source
Poor	>5%	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

2. Methods (Continued)

<p>Total Phosphorus</p>	<p>In shallow estuaries like Waikanae the sediment compartment is often the largest nutrient pool in the system, and phosphorus exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.</p> <table border="1" data-bbox="360 383 1444 656"> <thead> <tr> <th colspan="3">TOTAL PHOSPHORUS CONDITION RATING</th> </tr> <tr> <th>RATING</th> <th>DEFINITION</th> <th>RECOMMENDED RESPONSE</th> </tr> </thead> <tbody> <tr> <td>Very Good</td> <td><200mg/kg</td> <td>Monitor at 5 year intervals after baseline established</td> </tr> <tr> <td>Good</td> <td>200-500mg/kg</td> <td>Monitor at 5 year intervals after baseline established</td> </tr> <tr> <td>Fair</td> <td>500-1000mg/kg</td> <td>Monitor at 2 year intervals and manage source</td> </tr> <tr> <td>Poor</td> <td>>1000mg/kg</td> <td>Monitor at 2 year intervals and manage source</td> </tr> <tr> <td>Early Warning Trigger</td> <td>>1.3 x Mean of highest baseline year</td> <td>Initiate Evaluation and Response Plan</td> </tr> </tbody> </table>	TOTAL PHOSPHORUS CONDITION RATING			RATING	DEFINITION	RECOMMENDED RESPONSE	Very Good	<200mg/kg	Monitor at 5 year intervals after baseline established	Good	200-500mg/kg	Monitor at 5 year intervals after baseline established	Fair	500-1000mg/kg	Monitor at 2 year intervals and manage source	Poor	>1000mg/kg	Monitor at 2 year intervals and manage source	Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan											
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<p>Benthic Community Index (Organic Enrichment)</p>	<p>Soft sediment macrofauna can be used to represent benthic community health and provide an estuary condition classification (if representative sites are surveyed). The AZTI (AZTI-Tecnalia Marine Research Division, Spain) Marine Benthic Index (AMBI) (Borja et al. 2000) has been verified in relation to a large set of environmental impact sources (Borja, 2005) and geographical areas (in N and S hemispheres) and so is used here. However, although the AMBI is particularly useful in detecting temporal and spatial impact gradients care must be taken in its interpretation. In particular, its robustness can be reduced: when only a very low number of taxa (1–3) and/or individuals (<3 per replicate) are found in a sample, in low-salinity locations and naturally enriched sediments. The equation to calculate the AMBI Biotic Coefficient (BC) is as follows; $BC = \{(0 \times \%GI) + (1.5 \times \%GII) + (3 \times \%GIII) + (4.5 \times \%GIV) + (6 \times \%GV)\}/100$. The characteristics of the ecological groups (GI, GII, GIII, GIV and GV) are summarised in Appendix 3.</p> <table border="1" data-bbox="360 1330 1444 1648"> <thead> <tr> <th colspan="4">BENTHIC COMMUNITY ORGANIC ENRICHMENT RATING</th> </tr> <tr> <th>ECOLOGICAL RATING</th> <th>DEFINITION</th> <th>BC</th> <th>RECOMMENDED RESPONSE</th> </tr> </thead> <tbody> <tr> <td>Very Low</td> <td>Intolerant of enriched conditions</td> <td>0-1.2</td> <td>Monitor at 5 year intervals after baseline established</td> </tr> <tr> <td>Low</td> <td>Tolerant of slight enrichment</td> <td>1.2-3.3</td> <td>Monitor 5 yearly after baseline established</td> </tr> <tr> <td>Moderate</td> <td>Tolerant of moderate enrichment</td> <td>3.3-5.0</td> <td>Monitor 5 yearly after baseline est. Initiate ERP</td> </tr> <tr> <td>High</td> <td>Tolerant of high enrichment</td> <td>5.0-6.0</td> <td>Post baseline, monitor yearly. Initiate ERP</td> </tr> <tr> <td>Very High</td> <td>Azoic (devoid of invertebrate life)</td> <td>>6.0</td> <td>Post baseline, monitor yearly. Initiate ERP</td> </tr> <tr> <td>Early Warning Trigger</td> <td>Trend to slight enrichment</td> <td>>1.2</td> <td>Initiate Evaluation and Response Plan</td> </tr> </tbody> </table>	BENTHIC COMMUNITY ORGANIC ENRICHMENT RATING				ECOLOGICAL RATING	DEFINITION	BC	RECOMMENDED RESPONSE	Very Low	Intolerant of enriched conditions	0-1.2	Monitor at 5 year intervals after baseline established	Low	Tolerant of slight enrichment	1.2-3.3	Monitor 5 yearly after baseline established	Moderate	Tolerant of moderate enrichment	3.3-5.0	Monitor 5 yearly after baseline est. Initiate ERP	High	Tolerant of high enrichment	5.0-6.0	Post baseline, monitor yearly. Initiate ERP	Very High	Azoic (devoid of invertebrate life)	>6.0	Post baseline, monitor yearly. Initiate ERP	Early Warning Trigger	Trend to slight enrichment	>1.2	Initiate Evaluation and Response Plan
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<p>Metals</p>	<p>Heavy metals provide a low-cost preliminary assessment of toxic contamination, and are a starting point for contamination throughout the food chain. Sediments polluted with heavy metals (poor condition rating) should also be screened for other major contaminant classes: pesticides, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs).</p> <table border="1" data-bbox="360 1778 1444 2051"> <thead> <tr> <th colspan="3">METALS CONDITION RATING</th> </tr> <tr> <th>RATING</th> <th>DEFINITION</th> <th>RECOMMENDED RESPONSE</th> </tr> </thead> <tbody> <tr> <td>Very Good</td> <td><0.2 x ISQG-Low</td> <td>Monitor at 5 year intervals after baseline established</td> </tr> <tr> <td>Good</td> <td><ISQG-Low</td> <td>Monitor at 5 year intervals after baseline established</td> </tr> <tr> <td>Fair</td> <td><ISQG-High but >ISQG-Low</td> <td>Monitor at 2 year intervals and manage source</td> </tr> <tr> <td>Poor</td> <td>>ISQG-High</td> <td>Monitor at 2 year intervals and manage source</td> </tr> <tr> <td>Early Warning Trigger</td> <td>>1.3 x Mean of highest baseline year</td> <td>Initiate Evaluation and Response Plan</td> </tr> </tbody> </table>	METALS CONDITION RATING			RATING	DEFINITION	RECOMMENDED RESPONSE	Very Good	<0.2 x ISQG-Low	Monitor at 5 year intervals after baseline established	Good	<ISQG-Low	Monitor at 5 year intervals after baseline established	Fair	<ISQG-High but >ISQG-Low	Monitor at 2 year intervals and manage source	Poor	>ISQG-High	Monitor at 2 year intervals and manage source	Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan											
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3. RESULTS AND DISCUSSION

OUTLINE

A summary of the results of the 20 January 2011 fine scale monitoring of Waikanae Estuary is presented alongside the 2010 results in Table 3, with detailed results presented in Appendices 2 and 3. The results and discussion section is divided into three subsections based on the key estuary problems that the fine scale monitoring is addressing: sedimentation, eutrophication, and toxicity. Within each subsection, the results for each of the relevant fine scale indicators are presented. A summary of the condition ratings for the Waikanae site is presented in the accompanying figures.

Table 3. Physical, chemical and macrofauna results (means) for Waikanae Estuary 2010-11.

	Site	RPD	Salinity	TOC	Mud	Sand	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP	Abundance	No. Species
		cm	ppt	%				mg/kg								No./m ²	No./core
2010	Waik A	2-3.5	<1	0.46	26.7	72.7	0.6	0.036	11.3	7.0	9.4	10.0	44.3	600	333	33,150	9.1
2011	Waik A	3-10	<1	0.4	18.0	81.3	0.7	0.033	12.3	6.3	9.5	9.5	40.7	633	377	18,813	7.9

SEDIMENTATION

Soil erosion is a major issue in New Zealand and the resulting suspended sediment impacts are of particular concern in estuaries because they act as a sink for fine sediments or muds. Sediments containing high mud content (i.e. around 30% with a grain size <63µm) are now typical in many NZ estuaries that drain developed catchments. In such mud-impacted estuaries, the muds generally occur in the areas that experience low energy tidal currents and waves [i.e. the intertidal margins of the upper reaches of estuaries (e.g. Waikanae Estuary), and in the deeper subtidal areas in the main body of the estuary (e.g. Hutt Estuary)] (Figure 3).

In contrast, the main intertidal flats of developed estuaries (e.g. Porirua Harbour) are usually characterised by sandy sediments reflecting their exposure to wind-wave disturbance and are hence low in mud content (2-10% mud). In estuaries where there are no large intertidal flats, the presence of mud along the narrow channel banks in the lower estuary can also be elevated (e.g. Hutt Estuary and Whareama Estuary, Wairarapa Coast). In estuaries with undeveloped catchments the mud content is extremely low (e.g. Freshwater Estuary, Stewart Island where the mud content is <1%).

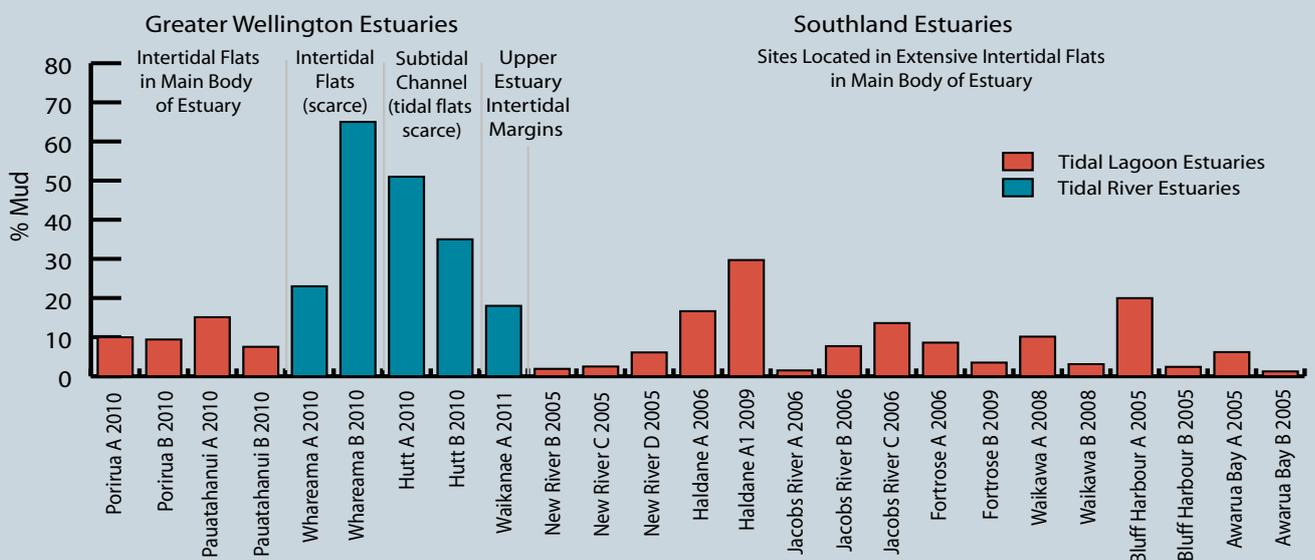


Figure 3. Percentage of mud at fine scale sites in NZ estuaries. Location of fine scale sites within each estuary type are also shown.

3. Results and Discussion (Continued)

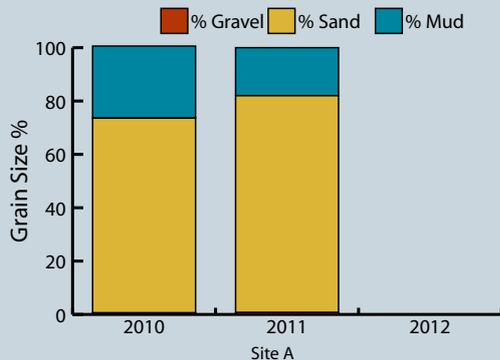


Figure 4. Grain size, Waikanae Estuary, 2010-2011.

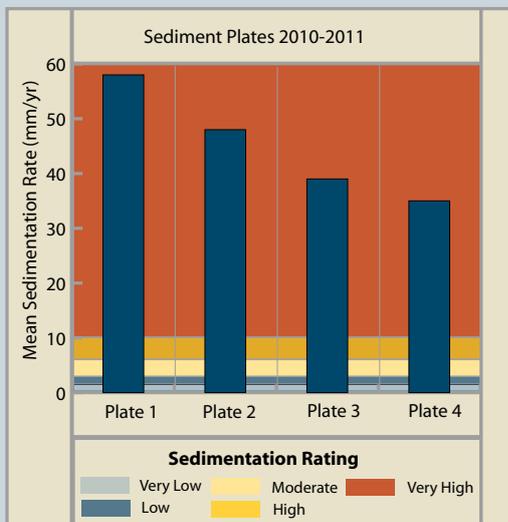


Figure 5. Sedimentation rate from plate data, Waikanae Estuary, 2011.



In order to assess sedimentation in the Waikanae Estuary, a number of indicators have been used: grain size, the presence of mud tolerant macro-invertebrates and sedimentation rate.

Grain Size

Grain size (% mud, sand, gravel) measurements provide a good indication of the muddiness of a particular site. The 2011 monitoring results (Figure 4) show that Site A, which is typical of the whole upper estuary, had moderate to high mud concentrations (mean 18% mud). Compared with the previous year (27% mud), this was a considerable reduction and is likely attributable to recent flooding in the catchment favouring short term high deposition and coarser sediment types.

In relation to other tidal river estuaries (e.g. Whareama and Hutt), the Waikanae had a similar mud content but, as expected, was moderately high compared with fine scale sites in tidal lagoon type estuaries (Figure 3). The source of these muds is almost certainly from the surrounding catchment.

Rate of Sedimentation

To address the potential for ongoing sedimentation within the estuary, and to measure its magnitude, four sedimentation plates were deployed in January 2010 (Figure 5). Monitoring of the overlying sediment depth above each plate after one year of burial indicated a mean sedimentation rate of 45mm/yr (range 35 - 58mm/yr).

Such short term findings indicate that the intertidal flat in the mid Waikanae Estuary is currently infilling at a "very-high" rate. However, such a high rate is not expected to be maintained in the long term because it was likely attributable to recent flooding in the catchment. Instead, gradual erosion of this layer and a much lower sedimentation rate are expected in the future.

Macro-invertebrate Tolerance to Muds

Compared with the intertidal mudflats in other NZ estuaries, the community diversity at Site A in 2011 was less (mean 7.9 species/core) than 2010 (mean 9.1 species/core - Figure 6) and the mean abundance (18,813/m²) was almost half the 2010 result (ie 33,150/m² - Figure 7). This reduction in mean abundance was likely attributable to the decrease in mud content in 2011 as indicated in the following sections.

In order to assess the mud tolerance of the Waikanae Estuary macro-invertebrate community, the response of typical NZ estuarine macro-invertebrates to increasing mud content (Gibbs and Hewitt 2004) was used (Figure 8 and Appendices 2 and 3). The results show the 2011 macro-invertebrate mud tolerance rating was in the "moderate-high" category (slightly down on the previous year), indicating that the community was dominated by species that prefer mud rather than those that prefer sand.

3. Results and Discussion (Continued)

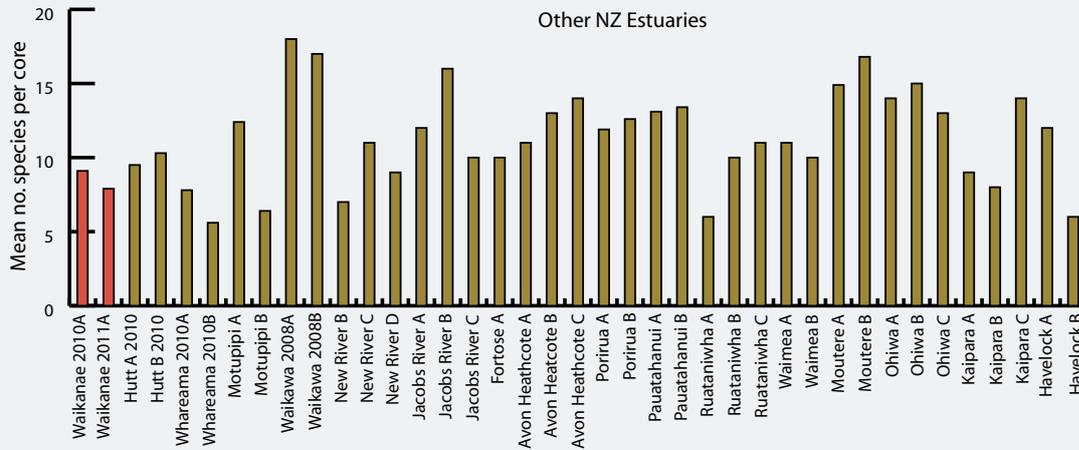


Figure 6. Mean number of infauna species, Waikanae Estuary compared with other NZ estuaries (Source Robertson et al. 2002, Robertson and Stevens 2006, Robertson and Stevens 2010b and c).

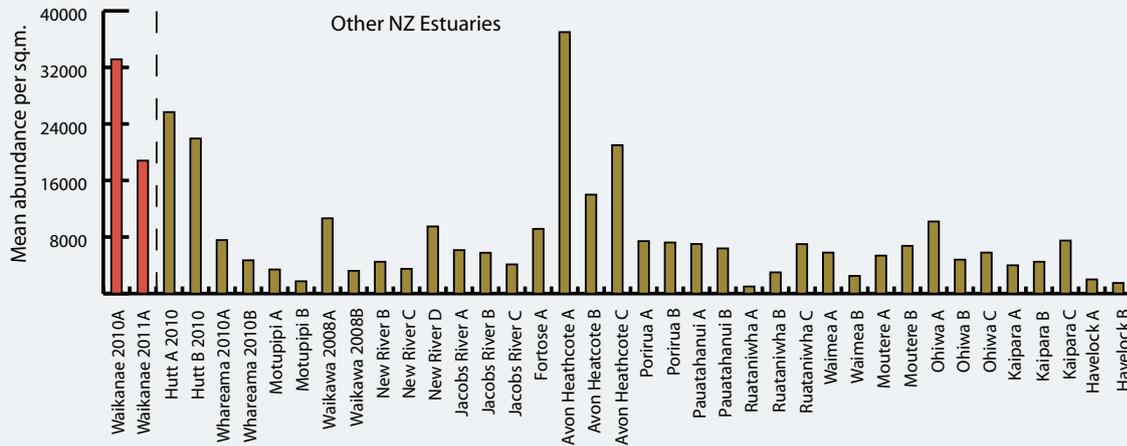


Figure 7. Mean total abundance of macrofauna, Waikanae Estuary compared with other NZ estuaries. (Source Robertson et al. 2002, Robertson and Stevens 2006, Robertson and Stevens 2010b and c).

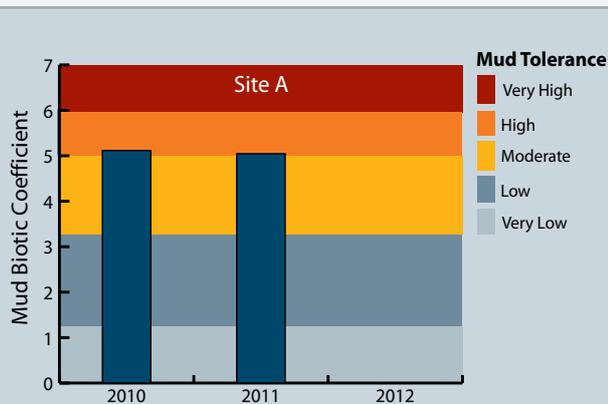


Figure 8. Mud tolerance macro-invertebrate rating, 2010-2011.

2011 Benthic Community
MUD TOLERANCE RATING

Mod-High

The dominant “mud tolerant” species in Waikanae Estuary in both 2010 and 2011 (Figure 9) were:

- The native tube-dwelling corophioid amphipod *Paracorophium excavatum* which is found mainly in east coast habitats of both the South and North Islands. It is sensitive to heavy metals, has a very strong mud preference (optimum range 95-100% mud, but found in 40-100% mud) and is tolerant of low salinities.
- The nereid (ragworm) *Nicon aestenariensis* that is a surface deposit feeding omnivore. It prefers to live in moderate to high mud content sediments.
- The ubiquitous surface deposit feeding spionid polychaete *Scolecoides benhami* that often occurs in a dense zone high on the shore, although large adults tend to occur further down towards low water mark. It is tolerant of brackish conditions, has a strong mud preference and its optimum range is 25-30% mud content, but can be found in mud contents from 0-100%. It is a prey item for fish and birds.

3. Results and Discussion (Continued)



- The small native estuarine snails *Potamopyrgus estuarinus* and *P. antipodarum* that require brackish conditions for survival. They feed on decomposing animal and plant matter, bacteria and algae, and are intolerant of anoxic surface muds but tolerant of muds. However, in 2011 a relatively consistent reduction in the abundance of mud tolerant species was apparent (likely attributable to decreased mud content in 2011). In addition, there was an introduction of small numbers of previously absent sand preferring species (i.e. pipi *Paphies australis* and spionid polychaete *Boccardia syrtis*).

Overall, this indicates an improvement in sediment conditions in 2011, but the macro-invertebrate community was still adversely affected showing that fine sediment inputs are having an impact on the upper/middle estuary.

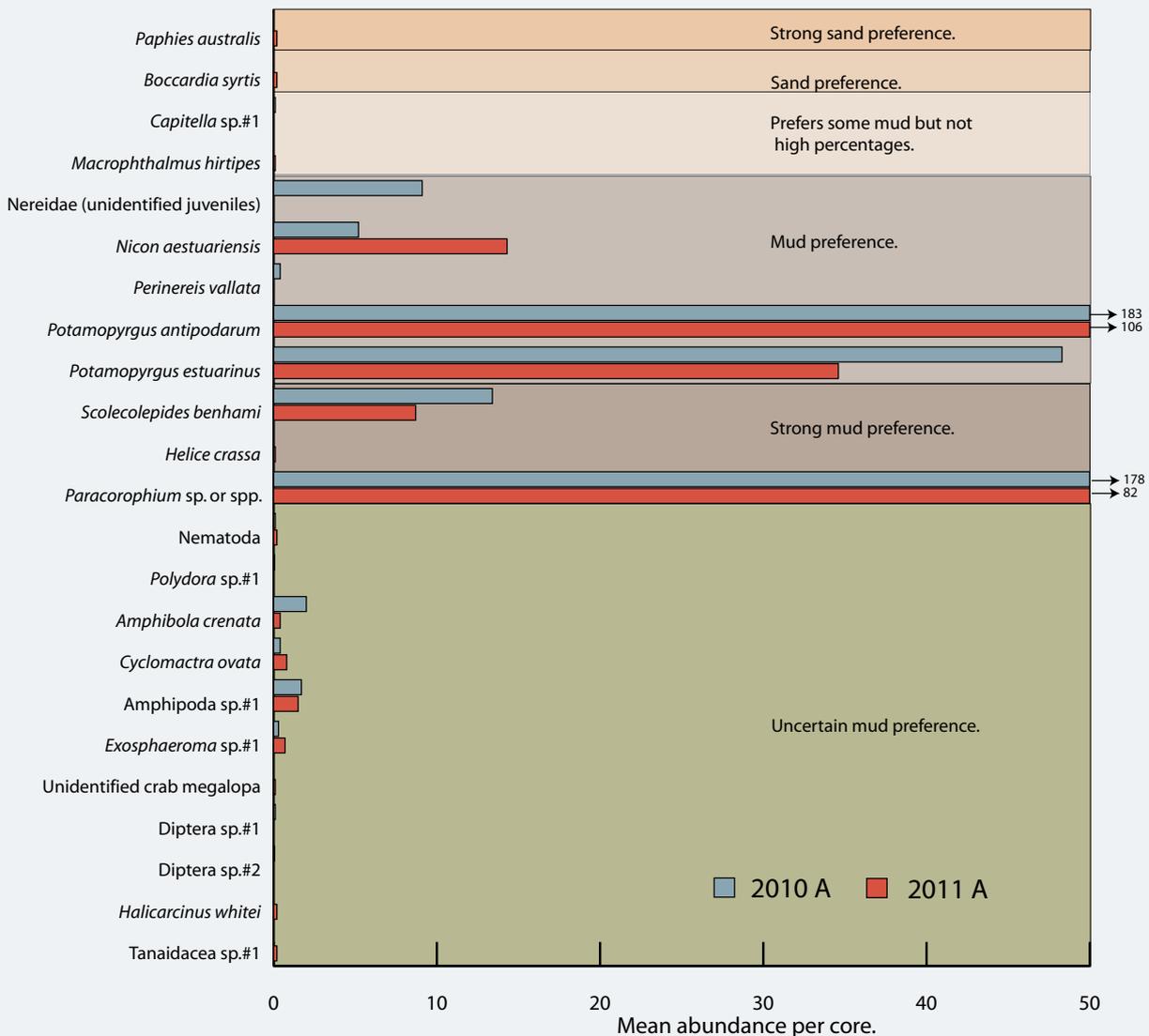
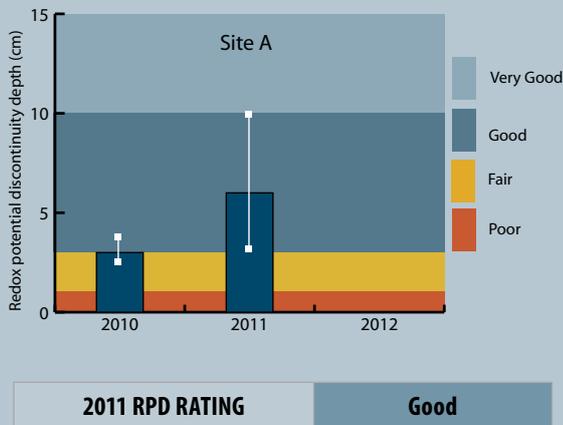


Figure 9. Waikanae Estuary 2011 - mud sensitivity of macro-invertebrates (see Appendix 3 for sensitivity details).

3. Results and Discussion (Continued)

EUTROPHICATION



The primary fine scale indicators of eutrophication are grain size, RPD boundary, sediment organic matter, nitrogen and phosphorus concentrations, and the community structure of certain sediment-dwelling animals. The broad scale indicators (reported in Stevens and Robertson 2010, 2011 and 2004) are the percentages of the estuary covered by macroalgae and soft muds.

Redox Potential Discontinuity (RPD)

Figures 10 and 11 (also Table 4) show the RPD depth and sediment profile for Site A, and indicate the likely benthic community that is supported at the site based on the measured RPD depth (adapted from Pearson and Rosenberg 1978).

The 2011 results show a considerable improvement in RPD depth (2.5-4cm in 2010 and 3-10cm in 2011) and therefore sediments in 2011 were likely to be moderately well oxygenated. Such RPD values fit the “good” condition rating and indicate that the benthic invertebrate community is likely to be in a stable state.

Figure 10. RPD depth (mean and range), Waikanae Estuary 2010-2011.

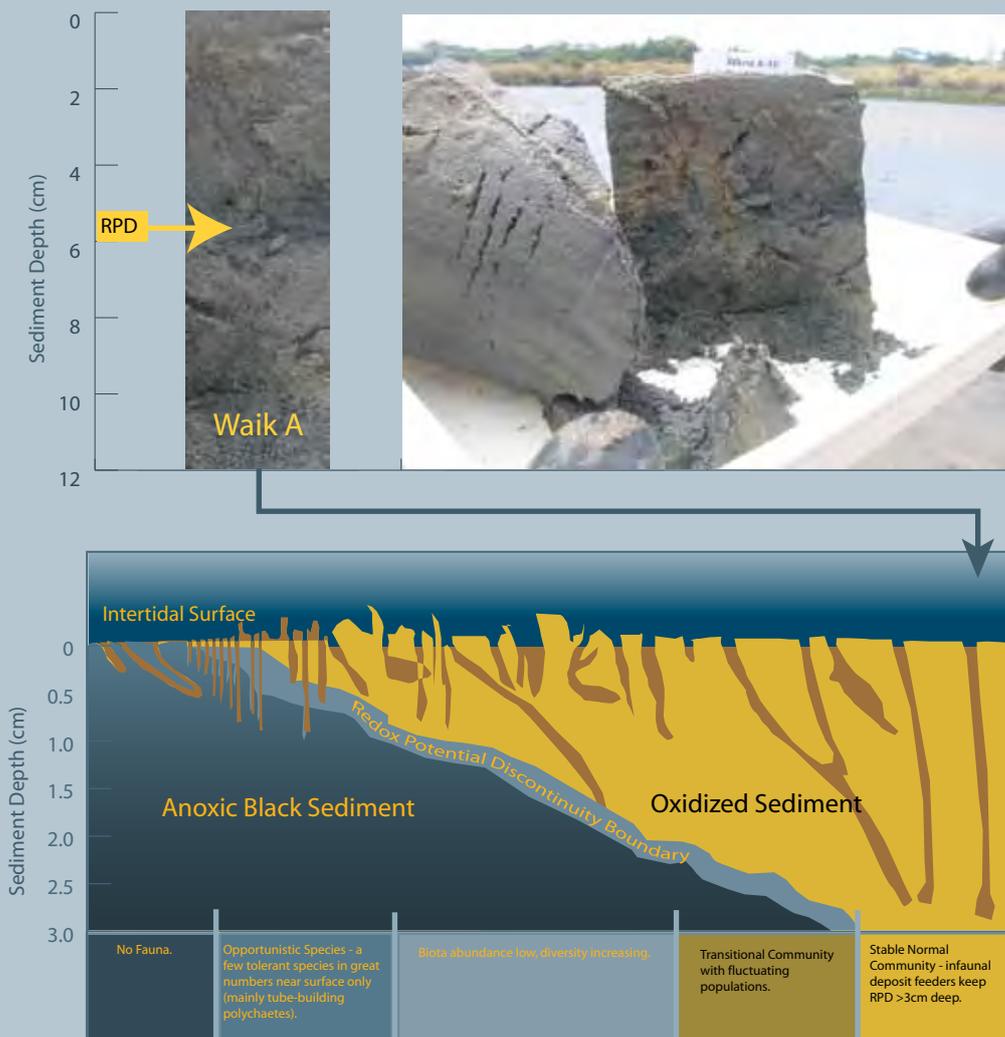


Figure 11. Sediment profiles, depths of RPD and predicted benthic community type, Waikanae Estuary 2011. Arrow below core relates to the type of community likely to be found in the core.

3. Results and Discussion (Continued)

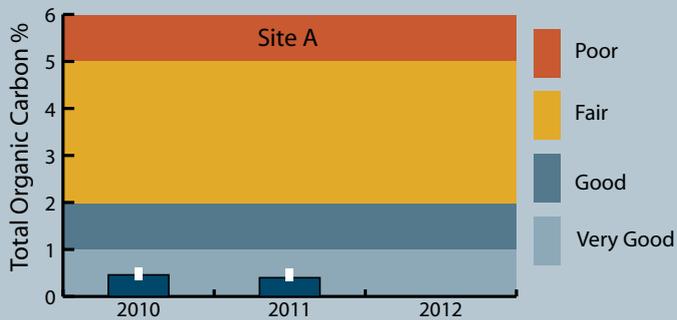


Figure 12. Total organic carbon (mean and range).

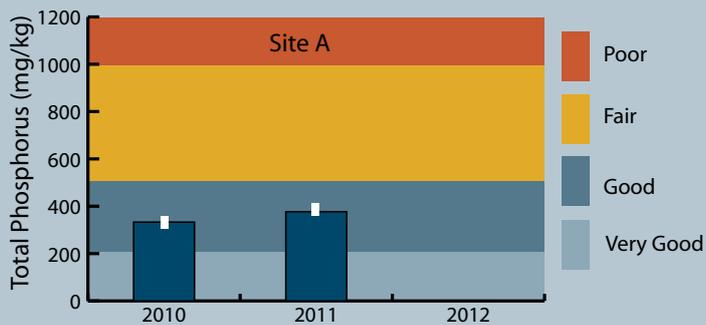
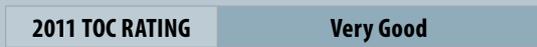


Figure 13. Total phosphorus (mean and range).

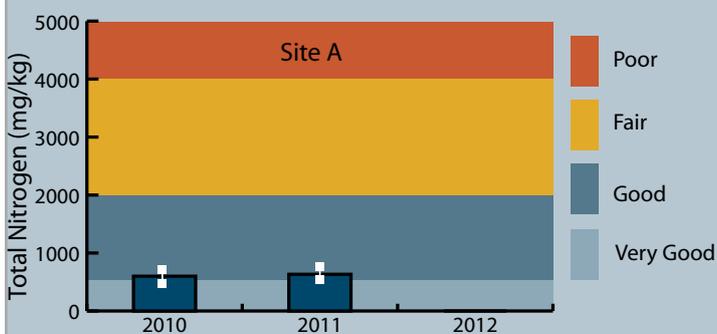


Figure 14. Total nitrogen (mean and range).



ORGANIC MATTER (TOC)

Fluctuations in organic input are considered to be one of the principal causes of faunal change in estuarine and near-shore benthic environments. Increased organic enrichment results in changes in physical and biological parameters, which in turn have effects on the sedimentary and biological structure of an area. The number of suspension-feeders (e.g. bivalves and certain polychaetes) declines and deposit-feeders (e.g. opportunistic polychaetes) increase as organic input to the sediment increases (Pearson and Rosenberg 1978).

The indicator of organic enrichment (TOC) at Site A in 2010 and 2011 (Figure 12) was at low concentrations (<1%) and met the “very good” condition rating.

TOTAL PHOSPHORUS

Total phosphorus (a key nutrient in the eutrophication process) was present in 2010 and 2011 at moderate concentrations and was rated in the “good” category (Figure 13).

This means that the Waikanae Estuary sediments have a moderate store of P in the sediments (sourced from both recent and historical catchment inputs).

TOTAL NITROGEN

Like phosphorus, total nitrogen (the other key nutrient in the eutrophication process) was present in 2010 and 2011 at moderate concentrations and was rated in the “good” category (Figure 14).

This means that the Waikanae sediments have a moderate store of N in the sediments (sourced from both recent and historical catchment inputs).

Overall, the combined results for the indicators of eutrophication indicate a low-moderate presence of eutrophication symptoms in the Waikanae Estuary in 2011, that is:

- low-moderate concentrations of N, P and TOC,
- “good” condition rating for RPD or sediment oxygenation, and
- very low cover of macroalgae as measured in the 2011 survey of macroalgal cover in the Waikanae Estuary (Stevens and Robertson 2011).

3. Results and Discussion (Continued)

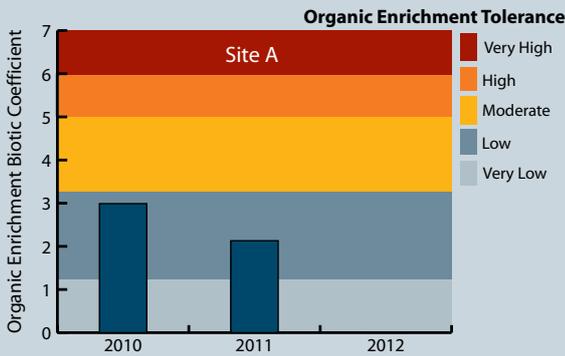


Figure 15. Organic enrichment macro-invertebrate rating, Site A, 2010-2011.

2011 Benthic Community ORGANIC ENRICHMENT RATING **Good**

Macro-invertebrate Organic Enrichment Index

The benthic invertebrate organic enrichment index shows that the rating in the Waikanae Estuary fitted the “low” or “tolerant of slight enrichment” category in both 2010 and 2011 (Figure 15). Such a rating indicated that the organisms were dominated by enrichment tolerant species and that the site was moderately enriched. This dominance is demonstrated more clearly in Figure 16 which shows very low abundance of Type I (“very sensitive” organisms), but increasing concentrations of Type II (“indifferent to organic enrichment”) and Types III and IV (“tolerant”) organisms.

The dominant organisms were the enrichment indifferent and salinity and mud tolerant snails *Potamopyrgus antipodarum* and *P. estuarinus*, the opportunistic tube-dwelling amphipod *Paracorophium excavatum*, and the spionid polychaete *Scolecopides benhami*. However, low numbers of a few other polychaetes, nemerteans, crustaceans and bivalves were also present.

In overview, this rather limited community assemblage was dominated by high numbers of organisms that can tolerate low salinities, muddy conditions, and low to moderate organic enrichment levels, i.e. the conditions present at Site A.

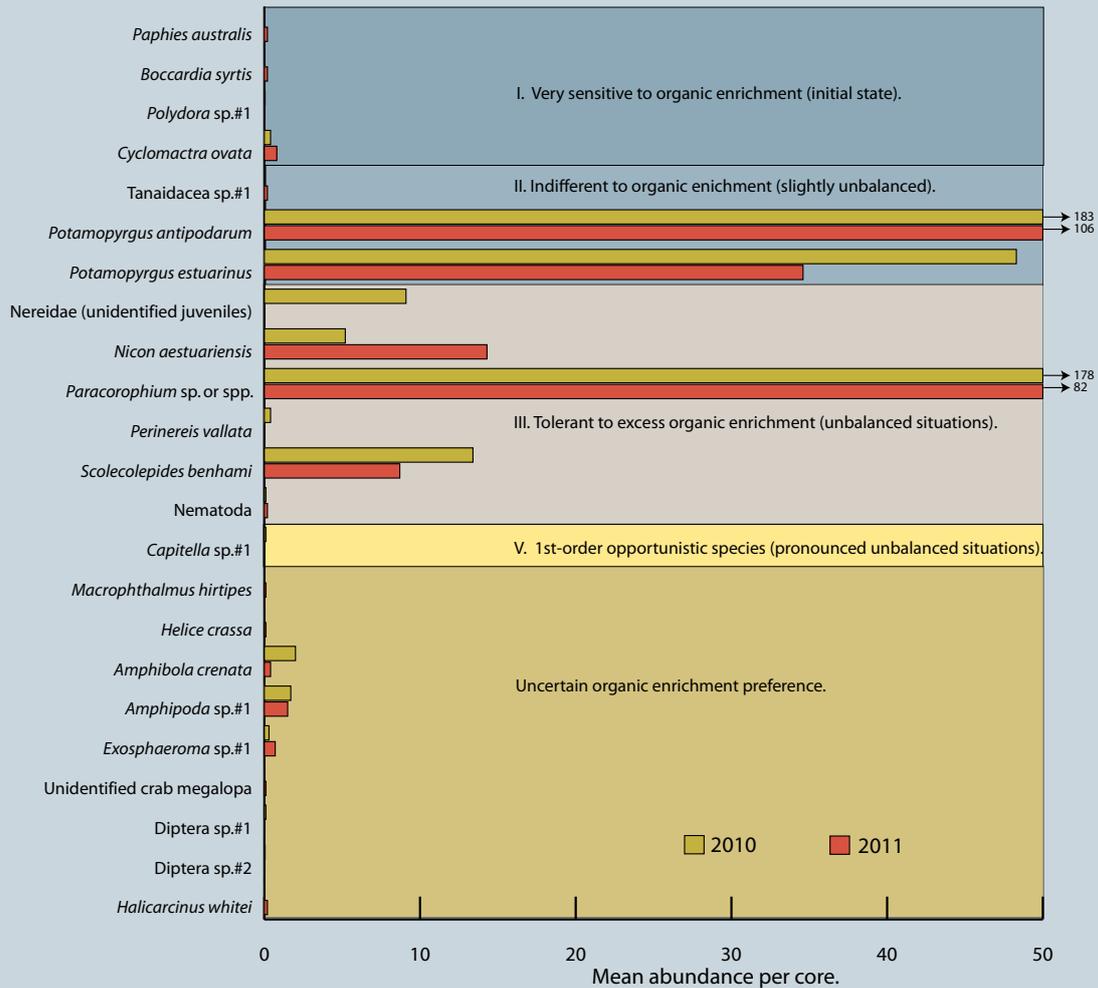


Figure 16. Organic enrichment sensitivity of macroinvertebrates, Waikanae Estuary, 2010-2011 (see Appendix 3 for sensitivity details).

3. Results and Discussion (Continued)

TOXICITY

2011 TOXICITY RATING

Good

Very Good

METALS

Heavy metals (Cd, Cr, Cu, Ni, Pb, Zn), used as an indicator of potential toxicants, were at low to very low concentrations in 2011, with all values well below the ANZECC (2000) ISQG-Low trigger values (Figure 17). As in 2010, in 2011 metals met the "good" condition rating for nickel and and the "very good" condition rating for cadmium, chromium, copper, zinc and lead.

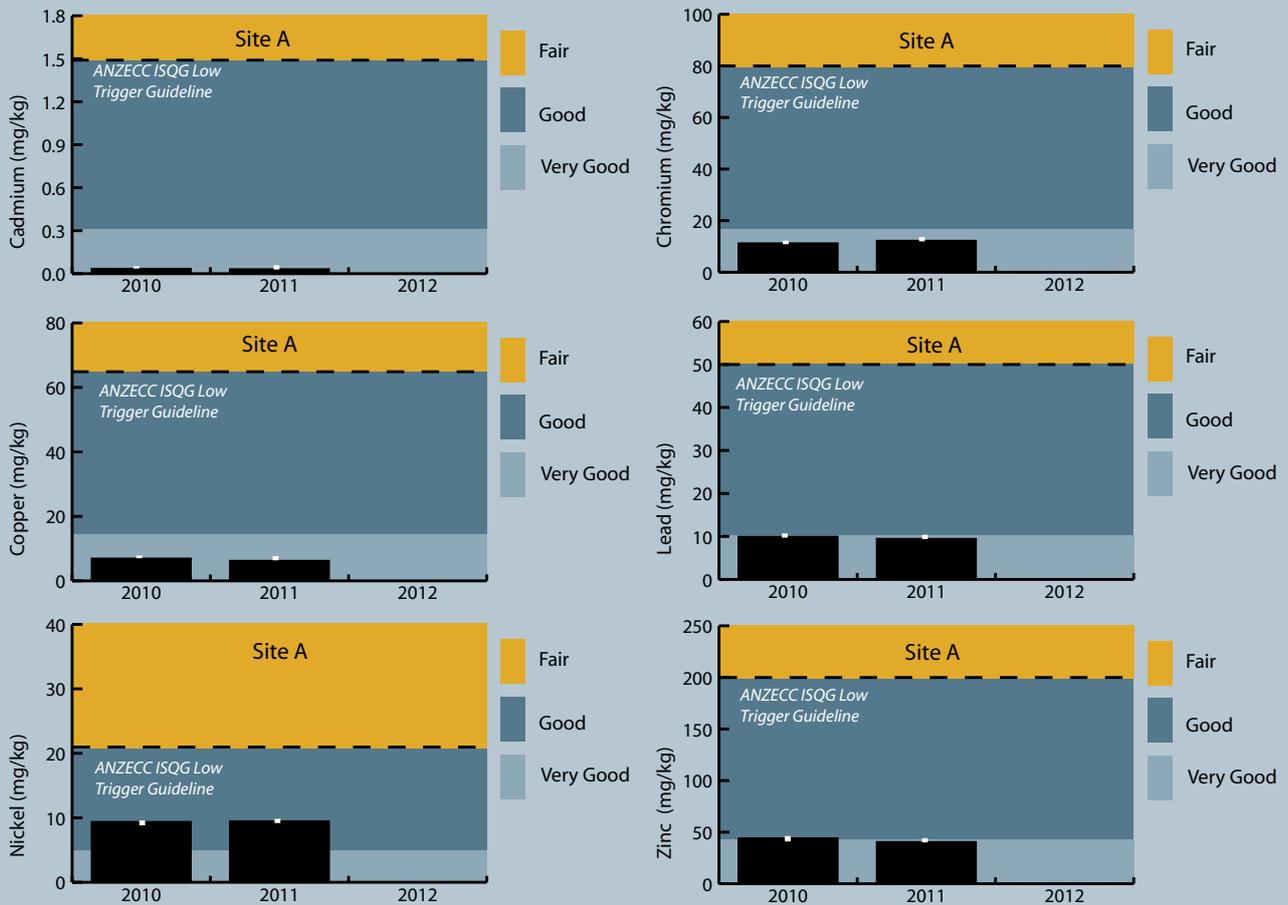


Figure 17. Total recoverable metals (mean and range) at Site A, Waikanae Estuary, 2010-2011.



4. SUMMARY AND CONCLUSIONS

Both the 2010 and 2011 fine scale results showed that the existing condition of the intertidal sediments from the Waikanae Estuary were in good to fair condition, with a relatively high concentration of muds, but low to moderate levels of sediment oxygenation, organic carbon, nitrogen and phosphorus. Concentrations of potential toxicants (heavy metals) were at low to very low concentrations and all below ANZECC ISQG-low trigger criteria. In addition, the animals living in the sediments (i.e. the benthic invertebrate community) were dominated by organisms indicative and tolerant of muddy and slight to moderately enriched conditions.

Overall the findings from the two surveys to date indicate that the estuary:

- is moderately enriched with nutrients (mesotrophic),
- has excessive muds and possibly has elevated sedimentation rates,
- has low levels of toxicity, and
- has been damaged by loss of habitat through artificial mouth opening and the introduction of floodgates.

5. FUTURE MONITORING

Waikanae Estuary is a key part of GWRC's coastal monitoring programme being undertaken in a staged manner throughout the Wellington region. Based on the second year of baseline monitoring results and condition ratings, it is recommended that monitoring continue as outlined below:

Fine Scale, Macroalgal and Sedimentation Rate Monitoring. Continue fine scale baseline monitoring for a further 1 to 2 years. Subsequently, monitor at five yearly intervals or as deemed necessary based on the condition ratings. Baseline monitoring should include measuring the depths of the existing four sediment plates, and broad scale intertidal macroalgal growth. The next monitoring is scheduled for January 2012.

6. MANAGEMENT

The fine scale monitoring results reinforce the need for management of nutrient and especially fine sediment sources entering the estuary. It is recommended that sources of elevated loads ("hot spots") in the catchment be identified and management undertaken to minimise their adverse effects on estuary uses and values. In order to improve estuary function and available habitat, it is also recommended that steps be taken to minimise impacts of artificial openings on the estuary ecosystem and expand high value estuarine habitat through - if possible - removal of existing floodgates. It is understood that GWRC's Flood Protection Department is currently completing a review of its Waikanae River Environmental Strategy. The findings and recommendations of this report should be considered in this review.



7. ACKNOWLEDGEMENTS

This survey and report has been undertaken with help from the staff of Greater Wellington Regional Council, in particular, the support and feedback of Juliet Milne (GWRC) was much appreciated.

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APPENDIX 1. DETAILS ON ANALYTICAL METHODS

Indicator	Laboratory	Method	Detection Limit
Infauna Sorting and ID	CMES	Coastal Marine Ecology Consultants (Gary Stephenson) *	N/A
Grain Size	R.J Hill	Air dry (35 degC, sieved to pass 2mm and 63um sieves, gravimetric - (% sand, gravel, silt)	N/A
Total Organic Carbon	R.J Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	0.05g/100g dry wgt
Total recoverable cadmium	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.01 mg/kg dry wgt
Total recoverable chromium	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable copper	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable nickel	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable lead	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.04 mg/kg dry wgt
Total recoverable zinc	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.4 mg/kg dry wgt
Total recoverable phosphorus	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	40 mg/kg dry wgt
Total nitrogen	R.J Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	500 mg/kg dry wgt

* Coastal Marine Ecology Consultants (established in 1990) specialises in coastal soft-shore and inner continental shelf soft-bottom benthic ecology. Principal, Gary Stephenson (BSc Zoology) has worked as a marine biologist for more than 25 years, including 13 years with the former New Zealand Oceanographic Institute, DSIR. Coastal Marine Ecology Consultants holds an extensive reference collection of macroinvertebrates from estuaries and soft-shores throughout New Zealand. New material is compared with these to maintain consistency in identifications, and where necessary specimens are referred to taxonomists in organisations such as NIWA and Te Papa Tongarewa Museum of New Zealand for identification or cross-checking.

APPENDIX 2. 2011 DETAILED RESULTS

Station Locations (NZGD2000 NZTM)

Waikanae Site A	Wkne A-01	Wkne A-02	Wkne A-03	Wkne A-04	Wkne A-05	Wkne A-06	Wkne A-07	Wkne A-08	Wkne A-09	Wkne A-10
NZTM East	1769248	1769251	1769253	1769260	1769262	1769260	1769257	1769252	1769257	1769261
NZTM North	5473364	5473346	5473337	5473317	5473319	5473333	5473345	5473364	5473368	5473355

Physical and chemical results for Waikanae Estuary, 20 January 2011.

Site	Reps*	RPD	Salinity	TOC	Mud	Sands	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP
		cm	ppt	%			mg/kg								
Waik A	1-4	8	<1	0.4	17.5	82.0	0.5	0.031	12.4	6.5	9.7	9.7	41.0	600	380
Waik A	5-8	3	<1	0.4	19.9	79.4	0.7	0.035	12.8	6.7	10.0	10.0	42.0	700	390
Waik A	9-10	4	<1	0.3	16.7	82.5	0.9	0.033	11.6	5.7	8.7	8.8	39.0	600	360

* composite samples

Sediment Plate Locations and Depths (mm)

Estuary	Site	NZGD2000 NZTM East	NZGD2000 NZTM North	Jan 2010	Jan 2010	Jan 2011	Jan 2011 (change in mm)
Waikanae	Plate 1	1769247	5473369	Plates deployed. Surface sediments settling.	180	238	58
	Plate 2	1769249	5473370		214	262	48
	Plate 3	1769252	5473371		231	270	39
	Plate 4	1769253	5473371		237	272	35

APPENDIX 2. 2011 DETAILED RESULTS (CONTINUED)

Inf fauna (numbers per 0.01327m² core) (Note NA = Not Assigned)

Waikanae A Site A 20 January 2011

Group	Species	AMBI Group	MUDBI Group	Wkne A-01	Wkne A-02	Wkne A-03	Wkne A-04	Wkne A-05	Wkne A-06	Wkne A-07	Wkne A-08	Wkne A-09	Wkne A-10
NEMATODA	Nematoda	III	?					1			1		
POLYCHAETA	<i>Boccardia syrtis</i>		2	1			1						
	<i>Capitella</i> sp.#1	V	3										
	<i>Nereidae</i> (unidentified juveniles)	III	4										
	<i>Nicon aestuariensis</i>	III	4	12	14	15	8	14	20	18	15	16	11
	<i>Perinereis vallata</i>	III	4										
	<i>Polydora</i> sp.#1	I	?										
	<i>Scolecopides benhami</i>	III	5	14	14	15	5	14	8	6	6	2	3
	GASTROPODA	<i>Amphibola crenata</i>	NA	?	1			1			2		
	<i>Potamopyrgus antipodarum</i>	II	4	86	86	74	115	150	99	118	125	87	121
	<i>Potamopyrgus estuarinus</i>	II	4	25	29	42	60	33	32	51	23	35	16
BIVALVIA	<i>Cyclomactra ovata</i>	I	?		4	1				1	1	1	
	<i>Paphies australis</i>	II	1										2
CRUSTACEA	<i>Amphipoda</i> sp.#1	NA	?			3		1	2	5	4		
	<i>Exosphaeroma</i> sp.#1	NA	?		2	1		1	2		1		
	<i>Halicarcinus whitei</i>	NA	?					1			1		
	<i>Helice crassa</i>	NA	5									1	
	<i>Macrophthalmus hirtipes</i>	NA	3		1								
	<i>Paracorophium</i> sp. or spp.	III	5	94	40	66	44	64	118	137	108	106	41
	Tanaidacea sp.#1	II	3								2		
	Unidentified crab megalopa	NA	?								1		
INSECTA	Diptera sp.#1	NA	?										
	Diptera sp.#2	NA	?										
Total species in sample				7	8	8	7	9	7	8	12	7	6
Total individuals in sample				233	190	217	234	279	281	338	288	248	194

AMBI and MUD Group details see page 21

Epifauna (numbers per 0.25m² quadrat)

Waikanae Estuary Site A 20 January 2011

Station	Wkne A-01	Wkne A-02	Wkne A-03	Wkne A-04	Wkne A-05	Wkne A-06	Wkne A-07	Wkne A-08	Wkne A-09	Wkne A-10
<i>Potamopyrgus</i> sp.	22	4	17	2	1	0	3	1	13	3
No. species/quadrat	1	1	1	1	1	0	1	1	1	1
No. individuals/quadrat	22	4	17	2	1	0	3	1	13	3

APPENDIX 3. INFAUNA CHARACTERISTICS

Group and Species		Tolerance to Organic Enrichment - AMBI Group ***	Tolerance to Mud	Details
Nematoda	Nematoda sp.	III	M Mud tolerant.	Small unsegmented roundworms. Very common. Feed on a range of materials. Common inhabitant of muddy sands. Many are so small that they are not collected in the 0.5mm mesh sieve. Generally reside in the upper 2.5cm of sediment. Intolerant of anoxic conditions.
	<i>Boccardia (Paraboccardia) syrtis and acus</i>	I	S Optimum range 10-15% mud,* distribution range 0-50%*	Small surface suspension-feeding spionids (also capable of detrital feeding). Prefers sand with low-mod mud content but found in a wide range of sand/mud. Prefers 10-15% mud but can live in 0-50% mud. It lives in flexible tubes constructed of fine sediment grains, and can form dense mats on the sediment surface. Very sensitive to organic enrichment and usually present under unenriched conditions. When in dense beds, the community tends to encourage build-up of muds.
Polychaeta	Capitellidae	V or IV	I Optimum range 10-15%* or 20-40% mud**, distribution range 0-95%** based on <i>Heteromastus filiformis</i> .	Subsurface deposit feeder, occurs down to about 10cm sediment depth. Common indicator of organic enrichment. Bio-turbator. Prey for fish and birds.
	Nereidae	III	M Optimum range 55-60%* or 35-55% mud**, distribution range 0-100%**. Sensitive to large increases in sedimentation.	Active, surface deposit feeder, scavenger, predator. Prefers reduced salinities. Usually green or brown in colour. There are a large number of New Zealand nereids. Rarely dominant in numbers compared to other polychaetes, but they are conspicuous due to their large size and vigorous movement. The tube-dwelling nereid polychaete <i>Nereis diversicolor</i> is usually found in the innermost parts of estuaries and fjords in different types of sediment, but it prefers silty sediments with a high content of organic matter (Rasmussen 1973, Kristensen 1988). Blood, intestinal wall and intestinal fluid of this species catalyzed sulfide oxidation, which means it is tolerant of high sulphide concentrations. Prey items for fish and birds.
	<i>Nicon aestuariensis</i>	III	M Optimum range 55-60%* or 35-55% mud**, distribution range 0-100%**.	A nereid (ragworm) that is tolerant of freshwater and is a surface deposit feeding omnivore. Prefers to live in moderate to high mud content sediments.
	<i>Perinereis vallata</i>	III	M Optimum range 55-60%* or 35-55% mud**, distribution range 0-100%**.	An intertidal soft shore nereid (common and very active, omnivorous worms). Prefers sandy sediments. Prey items for fish and birds. Sensitive to large increases in sedimentation.
	<i>Polydora</i> sp.	IV	Uncertain	A Spionid. Polydora-group have many NZ species. Difficult to identify unless complete and in good condition. The Polydora group of species specialise in boring into shells. <i>Boccardia acus</i> bores into the upper exposed shell of the cockle <i>Austrovenus stutchburyi</i> . Several other Polydora group species live free in tubes in the sand. The tubes of the most widely-occurring species, <i>Boccardia syrtis</i> , form a visible fine turf on sandstone reefs and on some sand flats.

APPENDIX 3. INFAUNA CHARACTERISTICS

Group and Species		Tolerance to Organic Enrichment - AMBI Group ***	Tolerance to Mud	Details
Polychaeta	<i>Scolecopides benhami</i>	III	MM Optimum range 25-30% mud,* distribution range 0-100%*	A Spionid, surface deposit feeder. Is rarely absent in sandy/mud estuaries, often occurring in a dense zone high on the shore, although large adults tend to occur further down towards low water mark. Strong Mud Preference. Prey items for fish and birds. Rare in Freshwater Estuary (<1% mud) and Porirua Estuary (5-10% mud). Common in Whareama (35-65% mud), Fortrose Estuary (5% mud), Waikanae Estuary 15-40% mud. Moderate numbers in Jacobs River Estuary (5-10% muds) and New River Estuary (5% mud). A close relative, the larger <i>Scolecopides freemani</i> occurs upstream in some rivers, usually in sticky mud in near freshwater conditions. e.g. Waihopai arm, New River estuary.
Gastropoda	<i>Amphibola crenata</i>	NA	Uncertain.	A pulmonate gastropod endemic to NZ. Common on a variety of intertidal muddy and sandy sediments. A detritus or deposit feeder, it extracts bacteria, diatoms and decomposing matter from the surface sand. It egests the sand and a slimy secretion that is a rich source of food for bacteria.
	<i>Potamopyrgus antipodarum</i>	II	M Tolerant of muds.	Endemic to NZ. Small snail that can live in freshwater as well as brackish conditions. In estuaries <i>P. antipodarum</i> can tolerate up to 17-24% salinity. Shell varies in color (gray, light to dark brown). Feeds on decomposing animal and plant matter, bacteria, and algae. Intolerant of anoxic surface muds but can tolerate organically enriched conditions. Tolerant of muds. Populations in saline conditions produce fewer offspring, grow more slowly, and undergo longer gestation periods.
	<i>Potamopyrgus estuarinus</i>	II	M Tolerant of muds.	Endemic to NZ. Small estuarine snail, requiring brackish conditions for survival. Feeds on decomposing animal and plant matter, bacteria, and algae. Intolerant of anoxic surface muds. Tolerant of muds and organic enrichment.
Bivalvia	<i>Cyclomactra ovata</i>	1	Uncertain	Trough shell of the family Mactridae, endemic to NZ. It is found intertidally and in shallow water, deeply buried in soft mud in estuaries and tidal flats. The shell is large, thin, roundly ovate and inflated, without a posterior ridge. The surface is almost smooth. It makes contact with the surface through its breathing tubes which are long and fused. It feeds on minute organisms and detritus floating in the water when the tide covers the shell's site.
Bivalvia	<i>Paphies australis</i>	II	SS (adults) S or M (Juveniles) Strong sand preference (adults optimum range 0-5% mud*, distribution range 0-5% mud**). Juveniles often found in muddier sediments.	The pipi is endemic to New Zealand. Pipi are tolerant of moderate wave action, and commonly inhabit coarse shell sand substrata in bays and at the mouths of estuaries where silt has been removed by waves and currents. They have a broad tidal range, occurring intertidally and subtidally in high-current harbour channels to water depths of at least 7m. Optimum mud range 0-5% mud and very restricted to this range. Common at mouth of Motupipi Estuary, Freshwater Estuary (<1% mud), a few at Porirua B (polytech) 5% mud.

APPENDIX 3. INFAUNA CHARACTERISTICS

Group and Species		Tolerance to Organic Enrichment - AMBI Group ***	Tolerance to Mud	Details
Crustacea	Amphipoda	NA	Uncertain.	An intertidal soft shore nereid (common and very active, omnivorous worms). Prefers sandy sediments. Prey items for fish and birds. Sensitive to large increases in sedimentation.
	<i>Exosphaeroma</i> sp.	NA	Uncertain.	Small seaweed dwelling isopod.
	<i>Halicarcinus whitei</i>	NA	NA	Another species of pillbox crab. Lives in intertidal and subtidal sheltered sandy environments.
	<i>Macrophthalmus hirtipes</i>	NA	I Optimum range 45-50% mud, distribution range 0-95%*.	The stalk-eyed mud crab is endemic to NZ and prefers waterlogged areas at the mid to low water level. Makes extensive burrows in the mud. Tolerates moderate mud levels. This crab does not tolerate brackish or fresh water (<4ppt). Like the tunnelling mud crab, it feeds from the nutritious mud.
	<i>Paracorophium</i> sp.	III	MM Optimum Range 95-100% mud (found in 40-100% mud)*.	A tube-dwelling corophioid amphipod. Two species in NZ, <i>Paracorophium excavatum</i> and <i>Paracorophium lucasi</i> and both are endemic to NZ. <i>P. lucasi</i> occurs on both sides of the North Island, but also in the Nelson area of the South Island. <i>P. excavatum</i> has been found mainly in east coast habitats of both the South and North Islands. Sensitive to metals. Also very strong mud preference. Optimum Range 95-100% mud (found in 40-100% mud) in upper Nth. Is. estuaries. In Sth. Is. and lower Nth. Is. common in Waikanae Estuary (15-40% mud), Haldane Estuary (25-35% mud) and in Fortrose Estuary (4% mud). Often present in estuaries with regular low salinity conditions. In muddy, high salinity sites like Whareama A and B (30-70% mud) we get very few.
Diptera	Diptera sp.	NA	Uncertain.	Fly or midge larvae - species unknown.

* Preferred and distribution ranges based on findings from the Whitford Embayment in the Auckland Region (Norkko et al. 2001).

** Preferred and distribution ranges based on findings from 19 North Island estuaries (Gibbs and Hewitt 2004).

*** Preferred and distribution ranges based on findings from Thrush et al. (2003)

**** Tolerance to Mud Codes are as follows (from Gibbs and Hewitt 2004, Norkko et al. 2001) :

1 = SS, strong sand preference.

2 = S, sand preference.

3 = I, prefers some mud but not high percentages.

4 = M, mud preference.

5 = MM, strong mud preference.

***** AMBI Sensitivity to Organic Enrichment Groupings (from Borja et al. 2000)

Group I. Species very sensitive to organic enrichment and present under unpolluted conditions (initial state). They include the specialist carnivores and some deposit-feeding tubicolous polychaetes.

Group II. Species indifferent to enrichment, always present in low densities with non-significant variations with time (from initial state, to slight unbalance). These include suspension feeders, less selective carnivores and scavengers.

Group III. Species tolerant to excess organic matter enrichment. These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalance situations). They are surface deposit-feeding species, as tubicolous spionids.

Group IV. Second-order opportunistic species (slight to pronounced unbalanced situations). Mainly small sized polychaetes: subsurface deposit-feeders, such as cirratulids.

Group V. First-order opportunistic species (pronounced unbalanced situations). These are deposit-feeders, which proliferate in reduced sediments.

The distribution of these ecological groups, according to their sensitivity to pollution stress, provides a Biotic Index with 5 levels, from 0 to 6.