coastalmanagement

Waikanae Estuary

Fine Scale Monitoring 2011/12

Prepared for Greater Wellington Regional Council

September 2012

Cover Photo: Waikanae Estuary - Dr Barry Robertson collecting sediment cores.


Fine scale and sediment plate monitoring site, Waikanae Estuary, February 2012.

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Prepared for
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By

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All photos by Wriggle except where noted otherwise.

WAIKANAE ESTUARY - EXECUTIVE SUMMARY

This report summarises the results of the third 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. The following table summarises fine scale monitoring results and condition ratings, overall estuary condition, and monitoring and management recommendations.

FINE SCALE MONITORING RESULTS

- Sediment had high mud concentrations (28-48% mud), and a very high sedimentation rate (+35mm/yr).
- The invertebrate mud tolerance rating was "moderate" - dominated by mud tolerant species.
- Sediment Oxygen: Redox Potential Discontinuity (RPD) depth was 1-3cm indicating "fair" but declining sediment oxygenation.
- The indicator of organic enrichment (Total Organic Carbon) was at moderate concentrations, but increasing.
- Nutrient enrichment indicators (TN and TP) were at low-moderate concentrations, but increasing.
- The invertebrate organic enrichment tolerance rating indicated a slightly polluted or "good" condition.
- Heavy metals were well below the ANZECC (2000) ISQG-Low trigger values.
- Intertidal macroalgal cover was low, but downstream water was stained green (high chlorophyll a).

CONDITION RATINGS	2010	2011	2012
Sedimentation Rate	Plates Deployed	Very High	Very High
Invertebrates: Mud Tolerance	Moderate	Moderate	Moderate
Sediment Oxygenation (RPD)	Fair-Good	Good	Fair
Total Organic Carbon (TOC)	Very Good	Very Good	Good
Total Phosphorus (TP)	Good	Good	Fair
Total Nitrogen (TN)	Good	Good	Good
Invertebrates: Organic Enrichment Tolerance	Low to Moderate	Low	Low
Metals (Cd, Cr, Cu)	Very Good	Very Good	Very Good
Metals (Ni, Pb, Zn)	Good	Good	Good
DDT	Very Good	Not Tested	Not Tested

ESTUARY CONDITION AND ISSUES

The third year of baseline monitoring shows that the dominant intertidal habitat (i.e. unvegetated mud/sand) in the Waikanae Estuary was generally in a fair condition, which reflected a more degraded state than the previous year. Since 2011, metal concentrations had increased by 10-60%, mud and TN had doubled, TOC concentrations had quadrupled, and sediment oxygenation had declined from an RPD of 3-10cm to 1-3cm. The likely explanation for this declining condition was an increase in suspended sediment loads in 2012 to the estuary, which resulted in the nutrient and metal concentration increases. With increasing nutrients, the level of organic matter (TOC) increased to higher levels and caused oxygen depletion as it decayed. The source of these nutrient rich fine sediments is uncertain, but was possibly exacerbated by recent forest harvesting in the catchment.

RECOMMENDED MONITORING AND MANAGEMENT

Baseline conditions in this estuary have now been established for fine scale indicators, but because sedimentation and eutrophication have increased dramatically in the last year, it is recommended that annual monitoring be undertaken for the following key indicators (sedimentation rate, grain size, macroalgal cover, RPD, and water column chlorophyll a and dissolved oxygen). A repeat of the full suite of fine scale monitoring indicators is scheduled for January 2017, and broad scale habitat mapping in 2014.

The 2012 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

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.
Next survey 2014.
Macroalgae undertaken annually.

Fine Scale Monitoring
Grain size, RPD, Organic Content Nutrients, Metals, Invertebrates, Macroalgae,
3-4yr Baseline then 5 yearly
Baseline completed.
Next survey 2017
Sedimentation rate, grain size, RPD, Chlor a, DO 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.**

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

GWRC began monitoring Waikanae Estuary in January 2010 following the process used for estuary monitoring and management outlined in the margin flow diagram. The programme consists of three components developed from the National Estuary Monitoring Protocol (NEMP) (Robertson et al. 2002) as follows:

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** (NEMP approach). This component, which documents key estuary habitats and changes to these habitats over time (Table 2), has been completed for the Waikanae Estuary (Stevens and Robertson 2006).
3. **Fine Scale Monitoring** (NEMP 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 undertaken in January 2010, 2011 and again in February 2012 (the subject of the current report).

In addition, a series of condition ratings, described in Section 2, have been developed to help evaluate overall estuary condition and decide on appropriate monitoring and management actions.

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 *Cladophora, Ulva,* and *Gracilaria* 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 gastro-enteritis, 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. (shading signifies indicators used in the fine scale monitoring assessments).

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.
Sedimentation	Grain Size	Fine scale measurement of sediment type.
Eutrophication	Nuisance Macroalgal Cover	Broad scale mapping - estimates the change in the area of nuisance macroalgal growth (e.g. sea lettuce (*Ulva*), *Gracilaria* and *Enteromorpha*) 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 NEMP (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 1, 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 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 = $0.0133m^2$) 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 $0.25m^2$ 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 1. Waikanae Estuary showing location of fine scale and sediment plate sites.

One site (with 4 plates) was established in upper Waikanae Estuary in muddy habitat adjacent to Site A in January 2010 (Figure 1). 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 (ERP)

2. Methods (Continued)

Benthic Community Mud Tolerance

Soft sediment macrofauna can 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)

Total Phosphorus

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.

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

Total Nitrogen

In shallow estuaries like Waikanae, the sediment compartment is often the largest nutrient pool in the system, and nitrogen exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL NITROGEN CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<500mg/kg	Monitor at 5 year intervals after baseline established
Good	500-2000mg/kg	Monitor at 5 year intervals after baseline established
Fair	2000-4000mg/kg	Monitor at 2 year intervals and manage source
Poor	>4000mg/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

Benthic Community Organic Enrichment Tolerance

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.

BENTHIC COMMUNITY ORGANIC ENRICHMENT TOLERANCE RATING			
ENRICHMENT TOLERANCE 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

Metals

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).

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

3. RESULTS AND DISCUSSION

OUTLINE

A summary of the results of the 20 February 2012 fine scale monitoring of Waikanae Estuary is presented alongside the 2010 and 2011 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 from 2010 to 2012 is presented in the accompanying figures.

Table 3. Physical, chemical and macrofauna results (means) for Waikanae Estuary 2010-12.

Site		RPD	Salinity	TOC	Mud	Sand	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP	Abundance	Species
		cm	ppt	%				mg/kg								No./m^2	No./core
2010	Wkne 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	Wkne 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
2012	Wkne A	1-2	<1	1.7	38.7	60.7	0.5	0.053	14.8	8.7	11.6	10.7	49.3	1433	523	24,847	7.3

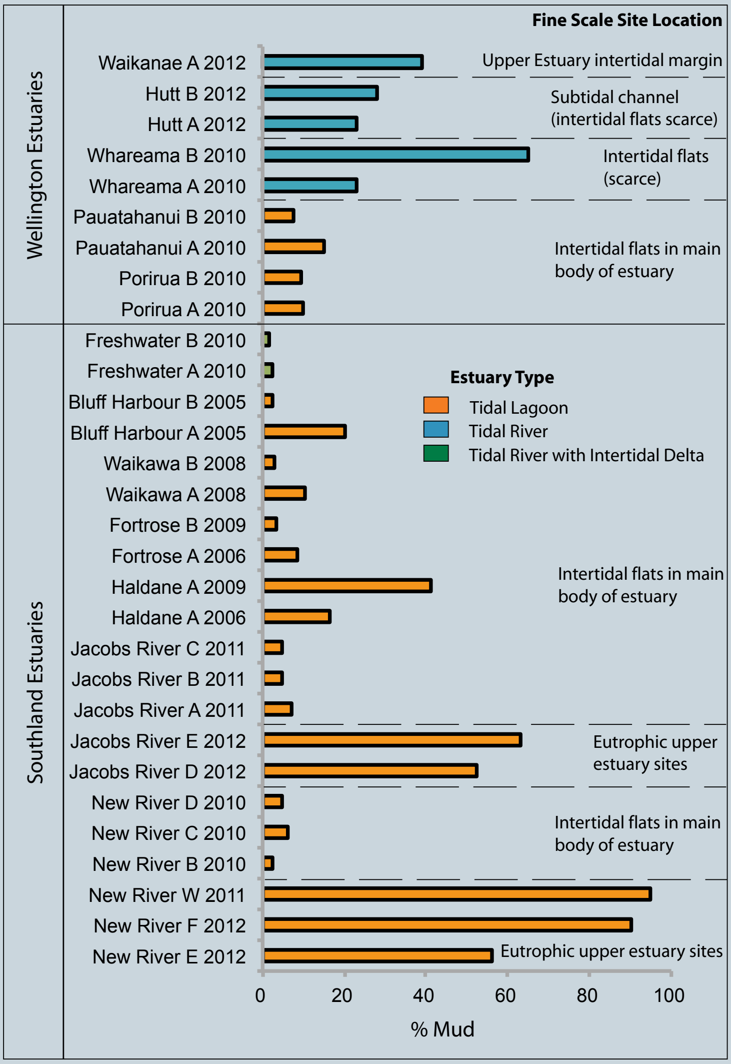

Figure 2. Percentage of mud at fine scale sites in NZ estuaries.

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. In estuaries with undeveloped catchments, the mud content is extremely low e.g. Freshwater Estuary, Stewart Island where the mud content is <1% (Figure 2). However, sediments with a high mud content (i.e. ~30% comprising a grain size <63µm) are now typical in many NZ estuaries that drain developed catchments.

In such mud-impacted estuaries, the muds generally concentrate in the upper estuary reaches where the combined effects of increased salinity and reduced flow velocity promotes sediment flocculation and settlement, or in those parts of the estuary that experience low energy tidal currents and waves e.g. sheltered intertidal arms and margins and subtidal basin areas.

In estuaries with 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).

Even in developed catchment areas however, large intertidal flats in estuaries commonly have sandy sediments with a low mud content, reflecting their regular exposure to wind-wave disturbance (e.g. Porirua Harbour, 2-10% mud - Figure 2).

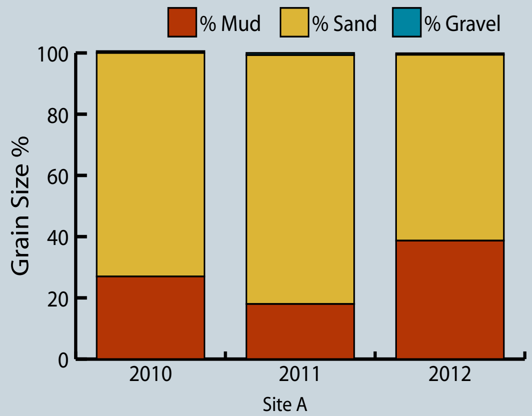

Figure 3. Grain size, Waikanae Estuary A, 2010-12.

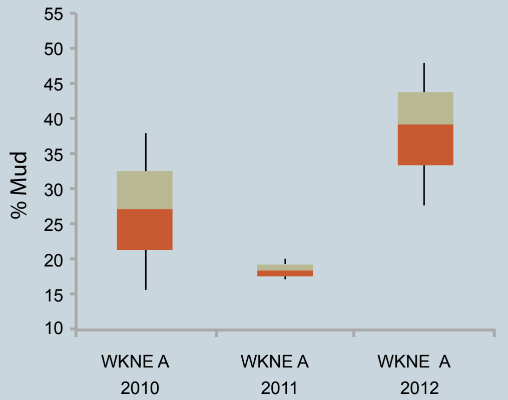

Figure 4. Percent mud (median, upper and lower quartiles, range), Waikanae Estuary A, 2010-12.

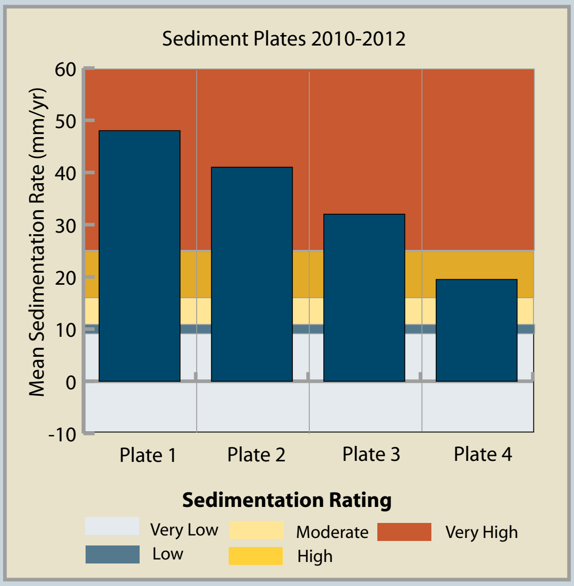

Figure 5. Sedimentation rate from plate data, Waikanae Estuary, 2010-12.

The three indicators used to assess sedimentation in Waikanae Estuary in 2012 were grain size, the presence of mud tolerant macro-invertebrates, and sedimentation rate.

Grain Size

Grain size (% mud, sand, gravel) is a key indicator of both eutrophication and sediment changes. In tidal river estuaries that lack large intertidal flats, mud levels are often elevated along the narrow channel banks. A high or increasing mud content signals a deterioration in estuary condition.

Figures 3 and 4 (see also Table 3) show the Waikanae fine scale site, which is typical of the whole upper estuary, has relatively high mud concentrations (mean 39% mud). Compared with 2011 (18% mud), this was a considerable increase. During sampling, an obvious mud layer was observed overlying the previously much sandy lower reaches of the intertidal flats, with soft muds also present subtidally. The presence of pulsed inputs as observed are usually highly detrimental to the animals living on and in the sediments.

Anecdotal reports from locals suggested recent forest harvesting in the upper catchment, followed by heavy rain, was the probable cause of the increased estuary sedimentation, although GWRC have been unable to confirm sediment sources.

Compared to other tidal river estuaries (e.g. Whareama, Hutt), the Waikanae had a similar mud content. As expected, the mud content was moderately high when compared to fine scale sites in tidal lagoon type estuaries (Figure 2).

Rate of Sedimentation

The depths to four plates buried in Waikanae Estuary (see Robertson and Stevens 2010, 2011) were measured in February 2012 as part of annual long term sedimentation rate monitoring in the estuary (Figures 5 and 6, Table 4).

Mean annual sedimentation rates for the site since 2010 range from +25 to +45mm/yr, with an overall mean annual rate of +35.2mm/yr, and a total increase of +70mm since 2010. This is within the "very high" category and indicates that the intertidal flats in the mid-upper Waikanae Estuary are currently rapidly infilling. Greatest deposition was near the channel edge (Figure 5 - Plate 1).

Such a high sediment deposition rate is likely to be the combined result of a number of factors as follows;

- The relatively small area in the estuary now available for the settling of fine sediments - in the past, the upper estuary was much larger prior to reclamation of the large historical estuarine arm.
- The loss of extensive areas of saltmarsh that naturally filter sediments and nutrients.
- A large catchment sediment potential based on existing land use.
- Recent land disturbance related to forest harvesting and other point source discharges.

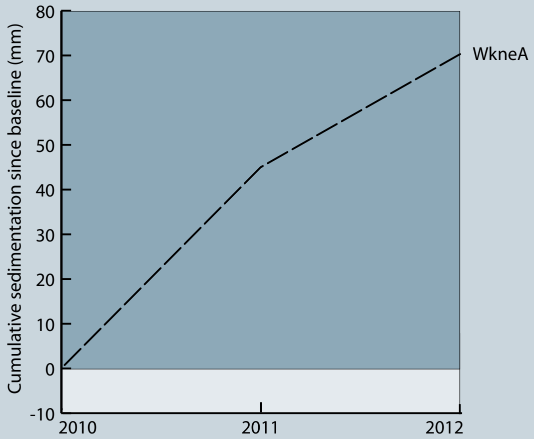

Figure 6. Cumulative change in sediment level at Waikanae Estuary site A from 2010-2012.

Table 4. Sediment plate data, Waikanae Estuary (2010-2012).

SITE	Mean Sediment Depth (mm)			Change (mm)		Site Mean (mm/yr)		2010-2012 Mean Annual Rate (mm/yr)
	20/01/10	16/01/11	20/02/12	2010-2011	2011-2012	2010-2011	2011-2012	
Plate 1	180	238	276	+58	+38	+45.0	+25.3	**+35.2**
Plate 2	213	261	295	+48	+34			
Plate 3	231	270	295	+39	+25			
Plate 4	235	270	274	+35	+4			

2012 SEDIMENTATION RATE CONDITION RATING	VERY HIGH

Macro-invertebrate Tolerance to Muds

Compared with the intertidal mudflats in other NZ estuaries, the community diversity at Site A in 2012 (mean 7.3 species/core) was similar to 2011 (mean 7.9 species/core) but less than 2010 (mean 9.1 species/core - Figure 6). The mean abundance (24,847/m^2) was greater than the 2011 result (18,813/m^2) and closer to the 2010 result (33,150/m^2 - Figure 7). This variation in mean abundance was likely attributable to the varying mud content, with the highest mud contents measured in 2010 and 2012.

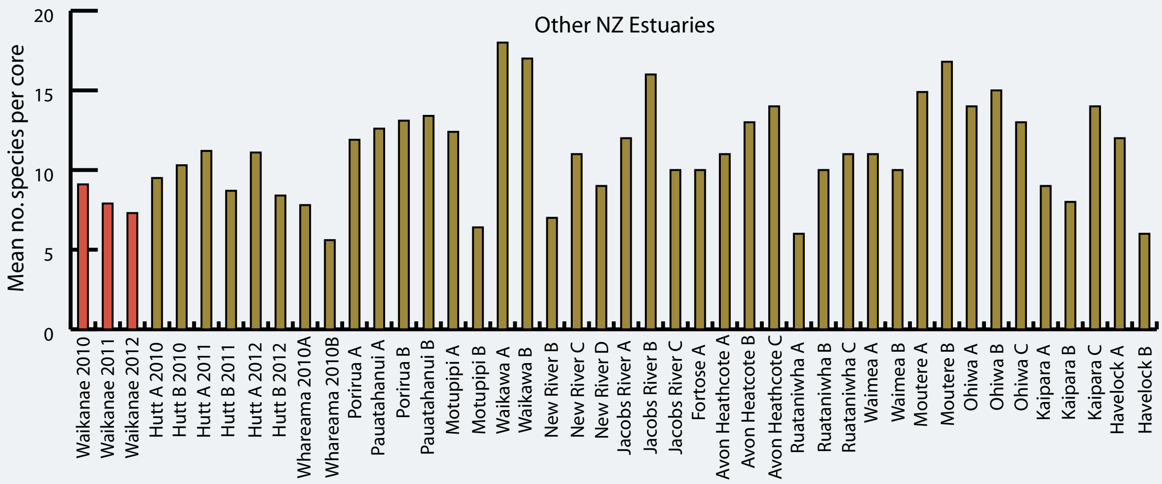

Figure 7. Mean number of infauna species, Waikanae Estuary compared with other NZ estuaries (Source Robertson et al. 2002, Robertson and Stevens 2006, Robertson and Stevens 2010a and b).

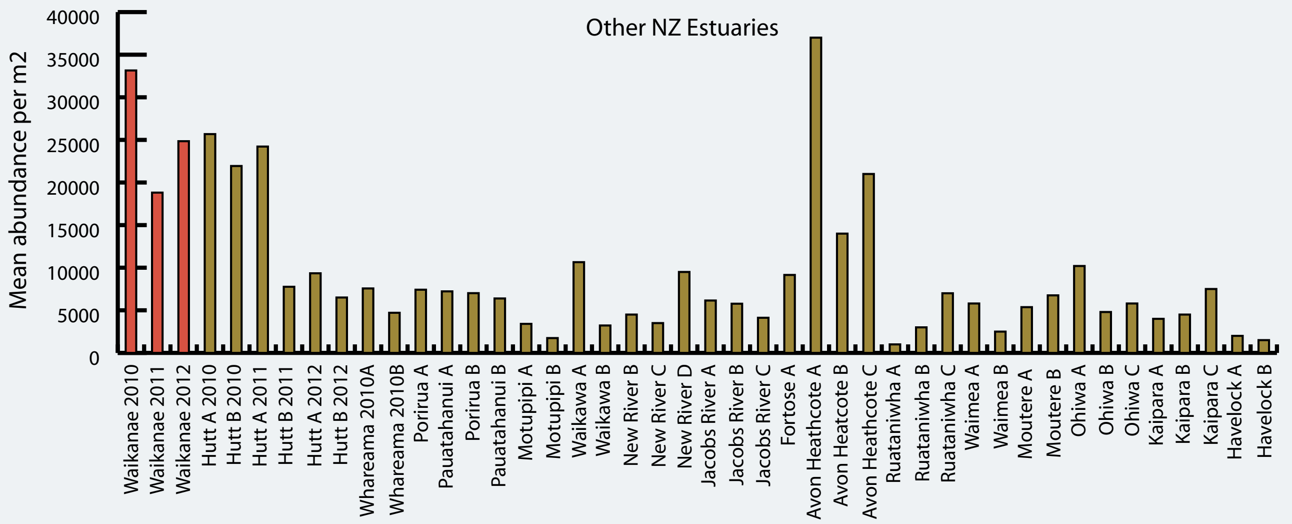

Figure 8. Mean total abundance of macrofauna, Waikanae Estuary compared with other NZ estuaries. (Source Robertson et al. 2002, Robertson and Stevens 2006, Robertson and Stevens 2010a and b).

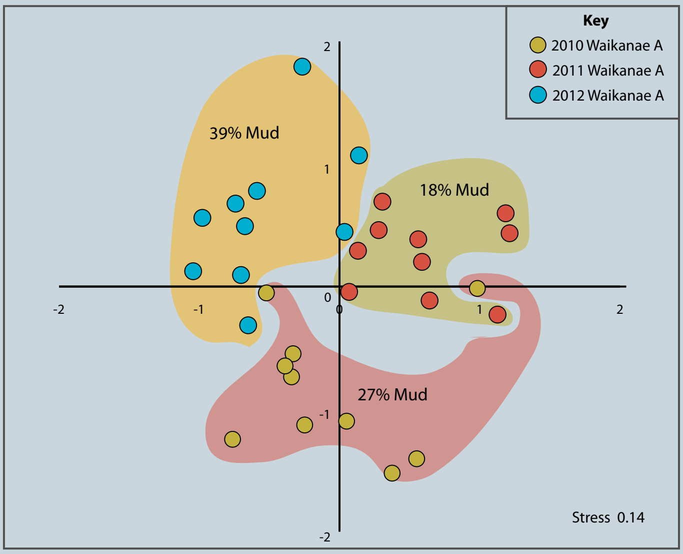

Figure 9. NMDS plot showing the relationship among samples in terms of similarity in macro-invertebrate community composition for Site A for 2010 - 2012. The plot shows each of the 10 replicate samples for each site and is based on Bray Curtis dissimilarity and square root transformed data.

The approach involves multivariate data analysis methods, in this case non-metric multidimensional scaling (NMDS) using PRIMER vers. 6.1.10. The analysis basically plots the site and abundance data for each species as points on a distance-based matrix (a scatterplot ordination diagram). Points clustered together are considered similar, with the distance between points and clusters reflecting the extent of the differences. The interpretation of the ordination diagram depends on how good a representation it is of actual dissimilarities i.e. how low the calculated stress value is. Stress values greater than 0.3 indicate that the configuration is no better than arbitrary and we should not try and interpret configurations unless stress values are less than 0.2.

Multivariate techniques were used to explore whether the macro-invertebrate communities at Site A in the Waikanae Estuary in 2010, 2011 and 2012 were different from each other. The results (Figure 9) show that they were, and that the difference in mud contents between each of the sites was the likely reason.

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 10 and Appendices 2 and 3). The results show the 2012 macro-invertebrate mud tolerance rating was in the "moderate" category (similar to the previous years), indicating that the community was dominated by species that prefer mud rather than those that prefer sand.

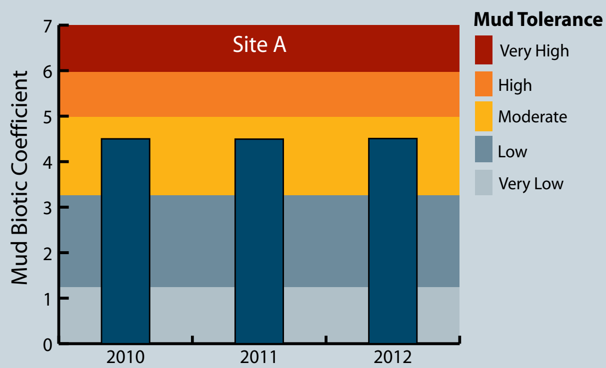

Figure 10. Mud tolerance macro-invertebrate rating, 2010-2012 (Note; updated mud coefficients used for some species which alters previous years ratings).

2012 Benthic Community MUD TOLERANCE RATING	**MODERATE**

3. Results and Discussion (Continued)

The dominant "mud tolerant" species in Waikanae Estuary in 2010-2012 (Figure 11) were:

- The small native estuarine snails *Potamopyrgus* spp. that require brackish conditions for survival and are surface deposit feeders. They are intolerant of anoxic surface muds but tolerant of muds.
- The native tube-dwelling corophioid amphipod *Paracorophium excavatum* which has a very strong mud preference, is a sub-surface deposit feeder, and is tolerant of low salinities.
- The ubiquitous surface deposit feeding spionid polychaete *Scolecolepides benhami* that often occurs in a dense zone high on the shore. It is tolerant of brackish conditions, and has a strong mud preference.
- The nereid polychaete *Nicon aestuariensis* is also tolerant of freshwater and is a surface deposit feeding omnivore. It prefers to live in moderate to high mud content sediments.

The abundance of mud tolerant species was varied between the years, but with no clear pattern. In addition, there continued to be small numbers of previously absent sand preferring species (i.e. pipi *Paphies australis* and the spionid polychaete *Boccardia syrtis*).

Overall, the three years of monitoring indicates predominantly muddy conditions that favour a macro-invertebrate community dominated by mud-tolerant species. Combined with the elevated sedimentation rate, such conditions indicates excessive catchment loads of fine sediment are detrimentally affecting the upper/middle estuary.

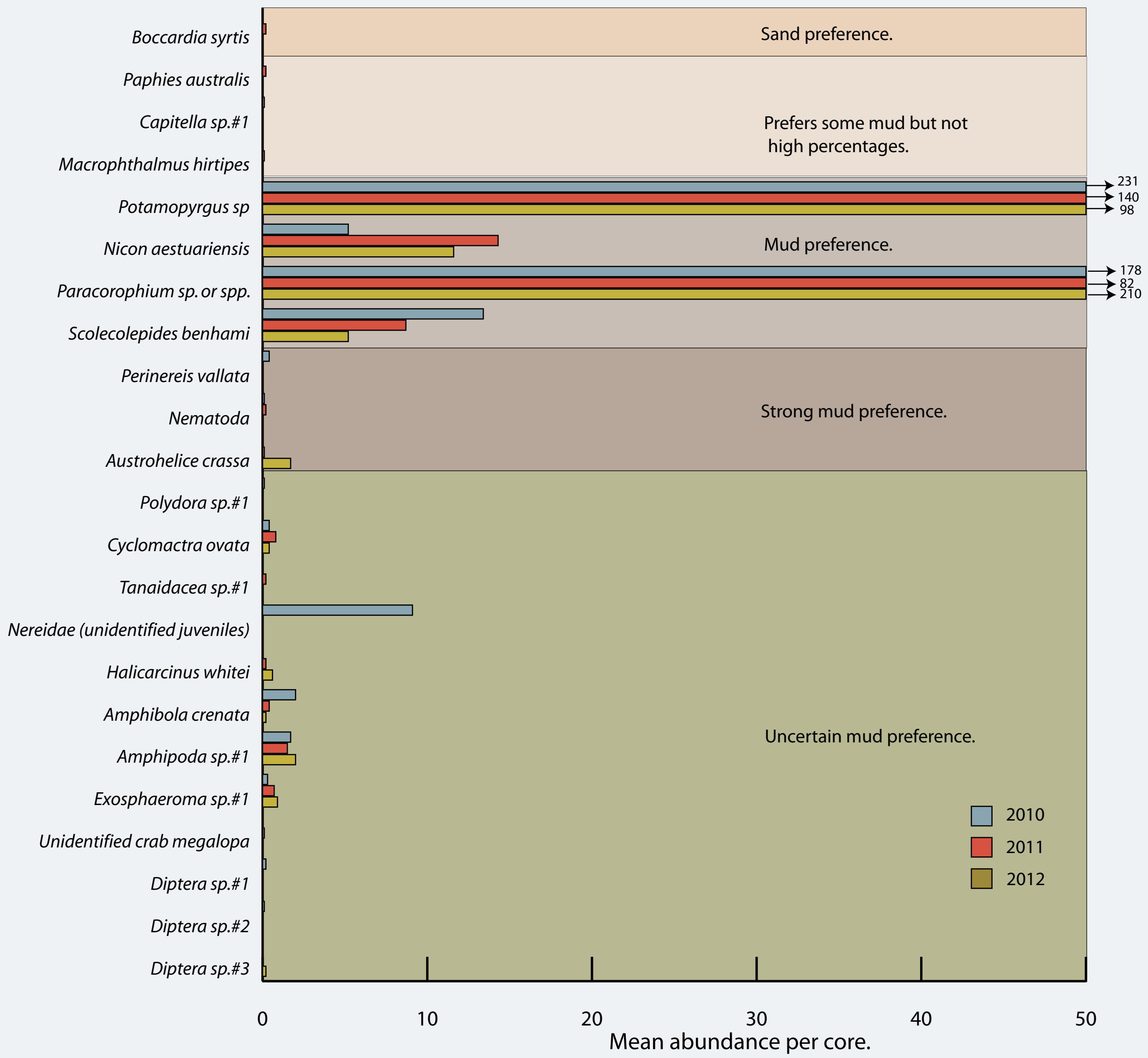

Figure 11. Waikanae Estuary 2012 - mud sensitivity of macro-invertebrates (see Appendix 3 for sensitivity details).

3. Results and Discussion (Continued)

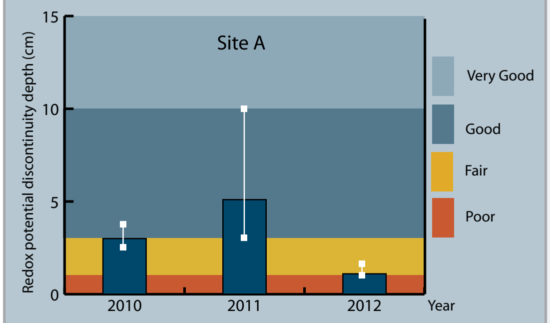

Figure 12. RPD depth (mean, range), Waikanae Estuary 2010-12.

EUTROPHICATION

Excessive organic input, sourced either from outside the estuary or growing within it in response to high nutrient loads, is a principal cause of physical and chemical degradation and of faunal change in estuarine and near-shore benthic environments. As organic input to the sediment increases the sediments become deoxygenated, nuisance algal growth becomes abundant, the number of suspension-feeders (e.g. bivalves and certain polychaetes) declines, and deposit-feeders (e.g. opportunistic polychaetes) increase (Pearson and Rosenberg 1978). The primary fine scale indicators of eutrophication are grain size, RPD depth, sediment organic matter, nitrogen and phosphorus concentrations, and the community structure of certain sediment-dwelling animals. The broad scale indicators are the percentages of the estuary covered by macroalgae and soft muds (Stevens and Robertson, 2006).

2012 RPD RATING
FAIR

Redox Potential Discontinuity (RPD)

Figures 12 and 13 (also Table 3) 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 2012 results show a decline in RPD depth (2.5-4cm in 2010, 3-10cm in 2011 and 1-2cm in 2012) indicating sediments in 2012 were less well oxygenated than in the previous two surveys. Such RPD values fit the "fair" condition rating and indicate that the benthic invertebrate community is likely to be in a stable state.

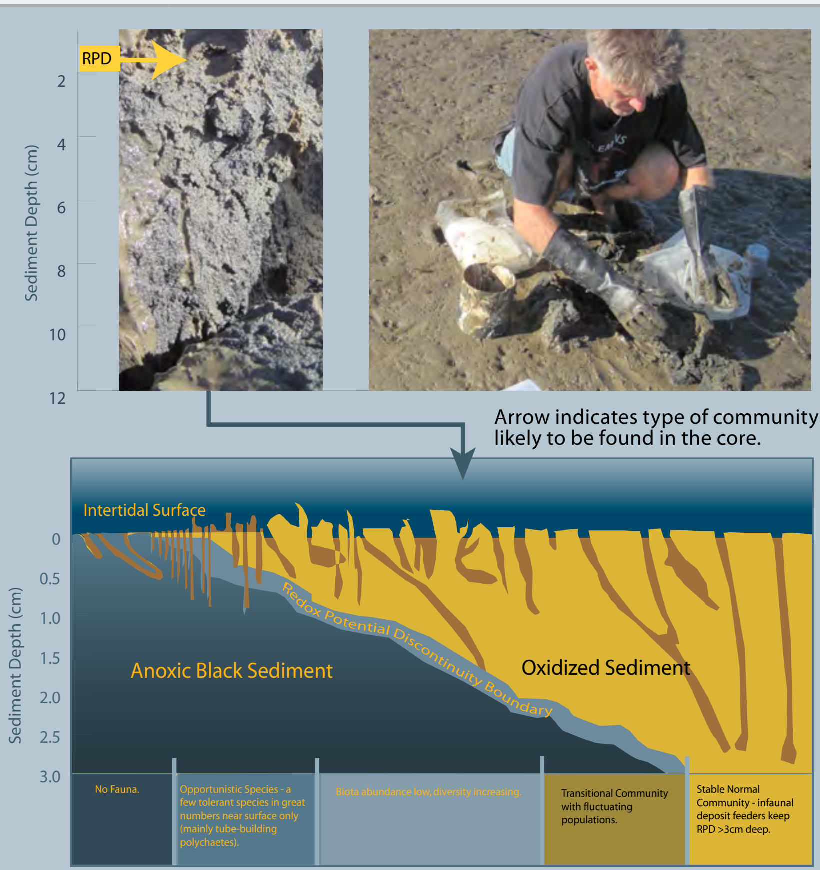

Figure 13. Sediment profiles, RPD depths, and predicted benthic community type, Waikanae Estuary 2012.

3. Results and Discussion (Continued)

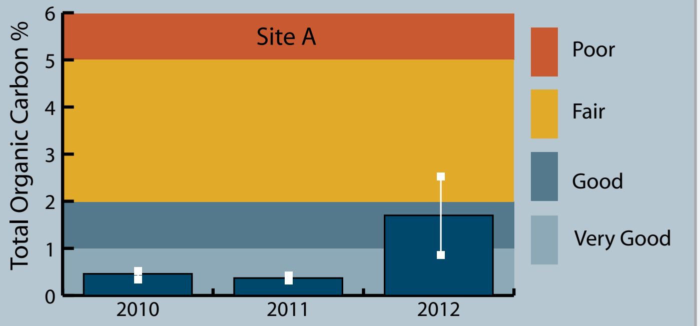

Figure 14. Total organic carbon (mean, range), Waikanae Estuary 2010-12.

2012 TOC RATING	**GOOD-FAIR**

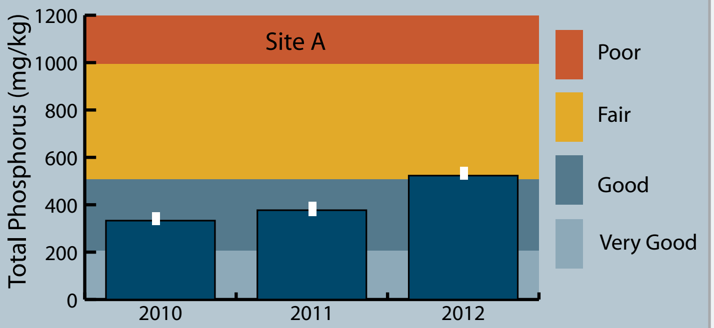

Figure 15. Total phosphorus (mean, range), Waikanae Estuary 2010-12.

2012 TP RATING	**FAIR**

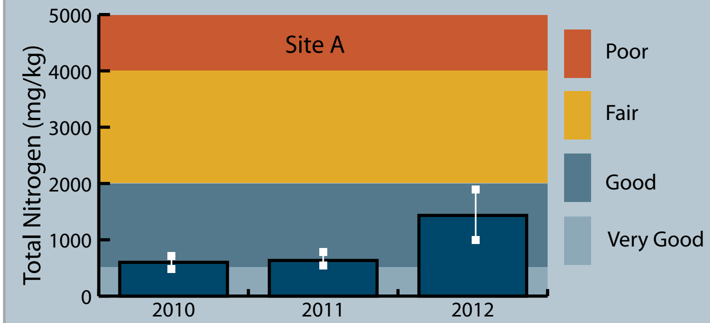

Figure 16. Total nitrogen (mean, range), Waikanae Estuary 2010-12.

2012 TN RATING	**GOOD**

Total Organic Carbon and Nutrients

The concentrations of sediment nutrients (total nitrogen - TN and phosphorus - TP) and organic matter (total organic carbon - TOC) also provide valuable trophic state information. In particular, if concentrations are elevated, and eutrophication symptoms are present (i.e. shallow RPD, excessive algal growth, low biotic index), then TN, TP and TOC concentrations provide a good indication of loadings exceeding the assimilative capacity of the estuary. However, a low TOC, TN or TP concentration does not necessarily indicate an absence of eutrophication symptoms. It maybe that the estuary, or part of an estuary, has reached a eutrophic condition and exhausted the available nutrient supply. Obviously, the latter case is likely to better respond to input load reduction than the former.

In relation to Waikanae Estuary Site A, the 2012 results (Figures 14-16) indicate elevated concentrations of TOC, TP and TN compared with results measured in the two previous years. These results indicate excessive nutrient loads have entered the estuary in 2012 and have settled within the intertidal sediments in the upper estuary. Decomposition of the organic component results in a high sediment oxygen demand, and a consequent movement of the RPD closer to the surface. The elevated sediment nutrients provide fuel for algal growth, which was present in the estuary mainly as benthic microalgae growing on the surface of the estuary mudflats, and as phytoplankton, evident by a strong green colouration in the downstream estuarine waters - particularly in temperature/salinity stratified bottom waters.

Overall, the combined results for the eutrophication indicators show an increasing presence of eutrophication symptoms in the Waikanae Estuary in 2012 as follows:

- Moderate concentrations of TN, TP and TOC,
- "Fair" (but declining) condition rating for RPD (sediment oxygenation),
- Increased phytoplankton and microalgal-growth, and
- Low but increasing cover of macroalgae (see Stevens and Robertson 2012).

To better assess these symptoms of eutrophication, it is recommended that annual monitoring be continued, but only for low cost key indicators (i.e. RPD, macroalgal cover, chlorophyll a concentration in bottom water).

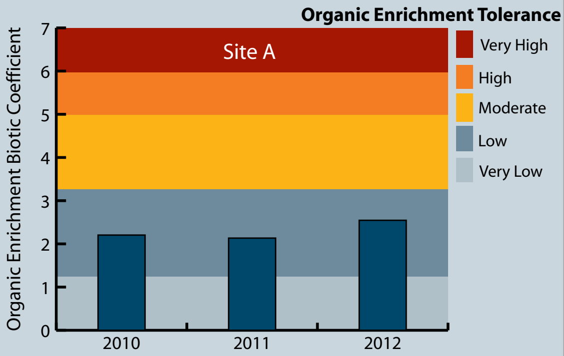

Figure 17. Macro-invertebrate organic enrichment tolerance rating, Site A, 2010-2012.

2012 MACROINVERTEBRATE ORGANIC ENRICHMENT TOLERANCE RATING	LOW

Macro-invertebrate Organic Enrichment Tolerance Index

The benthic invertebrate organic enrichment tolerance index shows that the rating in the Waikanae Estuary fitted the “low” category in all three years (Figure 17). Such a rating indicated that the site was moderately enriched and characterised by organisms tolerant of slight enrichment. This dominance of such species is demonstrated more clearly in Figure 18 which shows very low abundance of Type I (“very sensitive” organisms), but increasing concentrations of Type II (“indifferent to organic enrichment”) and Types III (“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 *Scolecolepides 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.

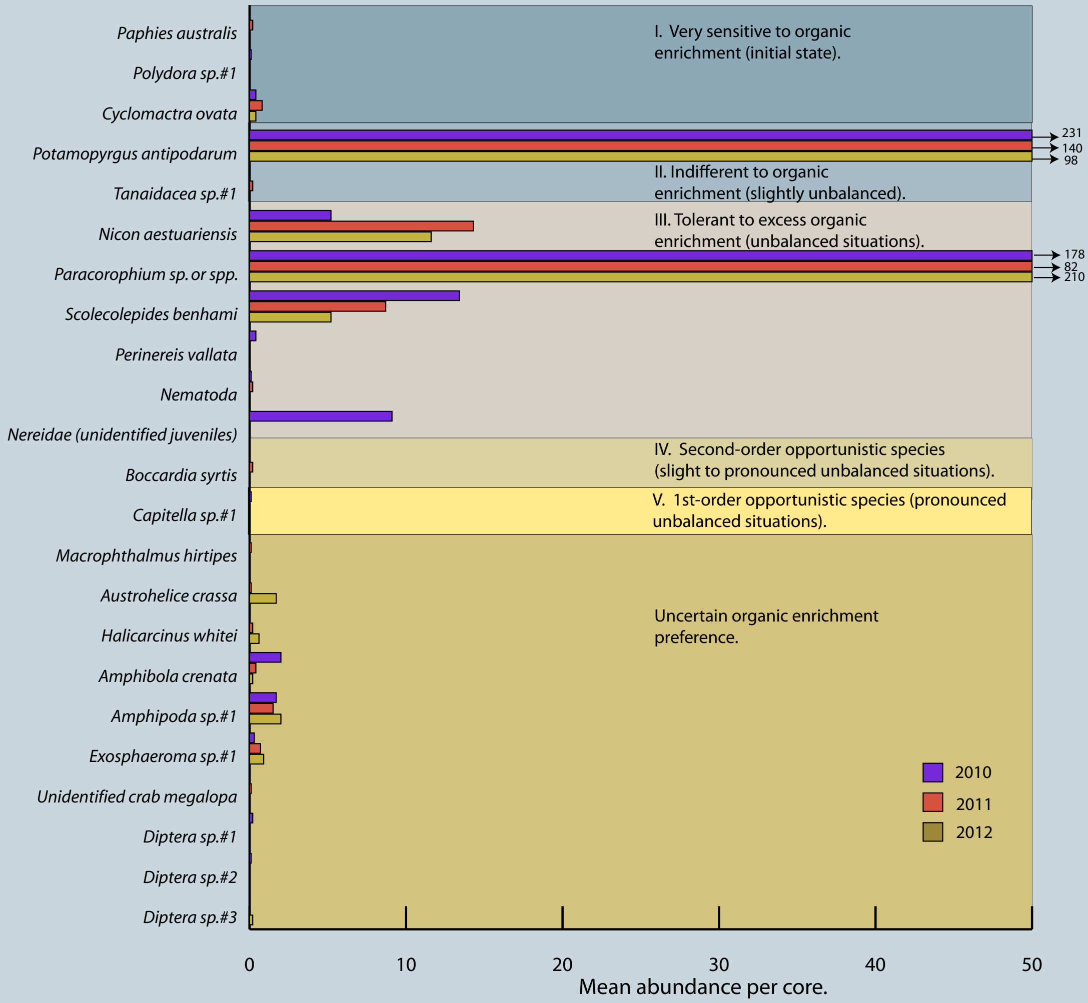

Figure 18. Organic enrichment sensitivity of macroinvertebrates, Waikanae Estuary, 2010-2012 (see Appendix 3 for sensitivity details).

2012 TOXICITY RATING

GOOD
(Ni, Pb, Zn)

VERY GOOD
(Cd, Cr, Cu)

TOXICITY

Heavy metals (Cd, Cr, Cu, Ni, Pb, Zn), used as an indicator of potential toxicants, were at low to very low concentrations in 2012, with all values well below the ANZECC (2000) ISQG-Low trigger values (Figure 19). However, the concentrations of all six metals in 2012 had increased. This increase (ranging from 13% to 61% of the 2011 values) is attributed to the two-fold increase in the percentage of mud at this site. Fine grained sediments are known to be the depositories of particulate contaminants (e.g. particle-bound organic materials, nutrients and metals), and increased metal concentrations are expected with the increased mud content at the site. Despite the increase in 2012, as in 2010 and 2011, the metals met the "good" condition rating for nickel lead and zinc, and the "very good" condition rating for cadmium, chromium, and copper.

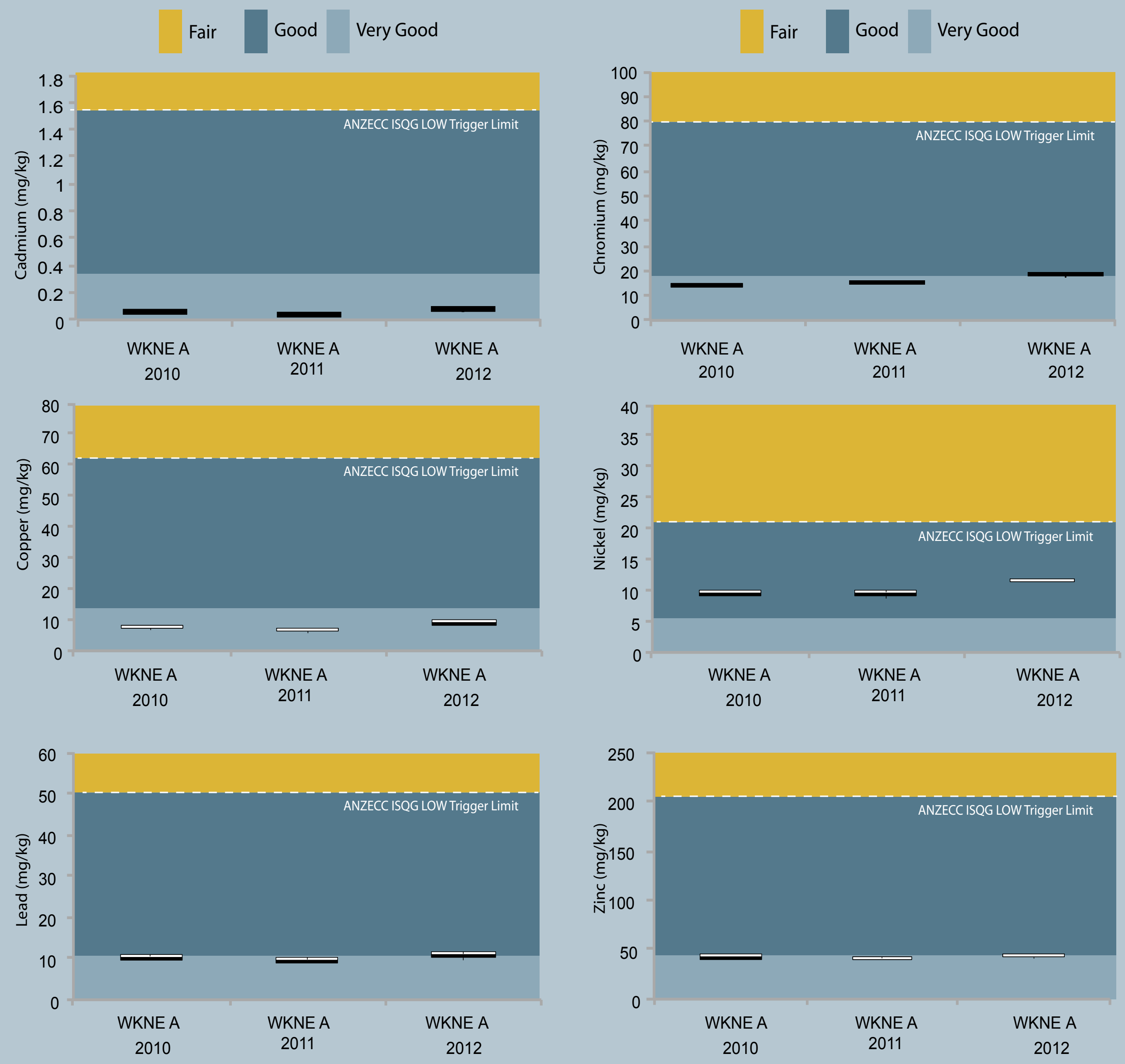

Figure 19. Total recoverable metals (median, upper and lower quartiles, range), Waikanae Estuary 2010-12.

4. SUMMARY AND CONCLUSIONS

The third year of baseline monitoring shows that the dominant intertidal habitat (i.e. unvegetated mud/sand) in the Waikanae Estuary was generally in a fair condition, which reflected a more degraded state than the previous year. Since 2011, metal concentrations had increased by 10-60%, mud and TN had doubled, TOC concentrations had quadrupled, and sediment oxygenation had declined from an RPD of 3-10cm to 1-3cm.

The likely explanation for this declining condition was an increase in suspended sediment loads in 2012 to the estuary, which resulted in the nutrient and metal concentration increases. With increasing nutrients, the level of organic matter (TOC) increased to higher levels and caused oxygen depletion as it decayed.

The source of these nutrient rich fine sediments is uncertain, but was possibly exacerbated by recent forest harvesting in the catchment.

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. Following completion of 3 years of baseline monitoring, and based on the results and condition ratings from this, it is recommended that monitoring continue as outlined below:

Fine Scale, Macroalgal and Sedimentation Rate Monitoring. Continue fine scale monitoring at five yearly intervals (next monitoring scheduled for 2017) or as deemed necessary based on the condition ratings.

Annual Eutrophication and Sedimentation Monitoring. To better assess current symptoms of excessive eutrophication and sedimentation, it is recommended that annual monitoring be continued, but only for low cost key indicators of RPD, sedimentation rate and grain size at Site A, macroalgal cover of the whole estuary, and chlorophyll a concentration in surface water and bottom water (downstream pool).

Broad Scale Habitat Mapping. Habitat mapping be undertaken at 10 year intervals. It was last undertaken in 2003 with the next mapping scheduled for 2013.

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 (note the estuary has not been artificially opened for flood control purposes in the past 10 years).

The historical northeast arm of the estuary, now separated from the main estuary by a floodgate and managed as a lake, is having the floodgate replaced in September 2012 to increase water exchange and allow fish passage. This will increase the potential for high value estuarine habitat to expand in this area. Ongoing initiatives such as this are encouraged.

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 and Megan Oliver (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. 2012 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 February 2012.

Site	Reps*	RPD	Salinity	TOC	Mud	Sands	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP
		cm	ppt	%				mg/kg							
Waik A	1-4	1-3	<1	1.69	41.2	58.4	0.4	0.052	15	8.9	11.8	11.5	50	1400	530
Waik A	5-8	1-3	<1	2.5	47.7	51.4	0.9	0.058	14.2	9.1	11.5	11.2	50	1900	540
Waik A	9-10	1-3	<1	0.9	27.3	72.4	0.3	0.049	15.2	8	11.4	9.5	48	1000	500

*** composite samples**

Sediment Plate Locations and Depths (mm)

Site	NZGD2000 NZTM East	NZGD2000 NZTM North	Sediment Depth (mm)			Change (mm)		Site Mean (mm/yr)		Overall Rate (mm/yr)	2010-2012 SEDIMENTATION RATE CONDITION RATING
			Jan 2010	Jan 2011	Feb 2012	2010-2011	2011-2012	2010-2011	2011-2012	2010-2012	
Plate 1	1769247	5473369	180	238	276	58	38	+45.0	+25.3	**+35.2**	**VERY HIGH**
Plate 2	1769249	5473370	213	261	295	48	34				
Plate 3	1769252	5473371	231	270	295	39	25				
Plate 4	1769253	5473371	235	270	274	35	4				

2011 NOTE: A large fresh down the river in the weeks preceding Jan 2011 had deposited layer of clean muds over the site. Baseline measures from 21/1/2010 can be used to show impact of this deposition, although deposited mud is likely to erode relatively quickly.
2012 NOTE: Obvious deposition of recent mud layer present over sand - consequently, counting epifauna was very difficult as most were buried in mud. Muds most pronounced at the river edge of site. Forest harvesting evident in the upper catchment. GWRC trying to locate info on timing and extent of harvesting, and any storms within the sampling period.

APPENDIX 2. 2012 DETAILED RESULTS (CONTINUED)

Infauna (numbers per 0.01327m² core) **(Note NA = Not Assigned)**

Waikanae Estuary Site A 20 February 2012

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
POLYCHAETA	*Nicon aestuariensis*	III	4	9	11	9	13	5	21	7	13	13	15
	Scolecolepides benhami	III	4	5	3	5	3	7	4	1	13	8	3
GASTROPODA	*Amphibola crenata*	NA	NA							1			1
	Potamopyrgus sp. or spp.	II	4	70	85	45	133	91	12	80	46	271	144
BIVALVIA	*Cyclomactra ovata*	I	NA	1	1	1						1	
CRUSTACEA	Amphipoda sp.#1	NA	NA	5		1	4	1	5	2	1		1
	Austrohelice crassa	NA	5		5				1	4	2	3	2
	Exosphaeroma planulum	NA	NA		3		2	1	1			1	1
	Halicarcinus whitei	NA	NA	2	1		1			1			1
	Paracorophium sp. or spp.	III	4	224	230	102	426	122	117	162	212	251	262
INSECTA	Diptera sp.#3	NA	NA		1								1
Total individuals in sample				316	340	163	582	227	161	258	287	548	431
Total species in sample				7	9	6	7	6	7	8	6	7	10

AMBI and MUD Group details see page 22

Epifauna (numbers per 0.25m² quadrat)

Waikanae Estuary Site A 20 February 2012

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
RPD depth (cm)	2	1	1	1	1	1	1	1	1	1
Amphibola crenata	400	80	150	30	90	180	120	400	360	120
Potamopyrgus sp.							1	2	2	
No. species/quadrat	1	1	1	1	1	1	2	2	2	1
No. individuals/quadrat	400	80	150	30	90	180	121	402	362	120

APPENDIX 3. INFAUNA CHARACTERISTICS

Group	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.
Polychaeta	*Boccardia (Paraboccardia) syrtis and acus*	4	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. Reletively insensitive 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 *Heteromastus filiformis*.	Subsurface deposit feeder, occurs down to about 10cm sediment depth. Common indicator of organic enrichment. Bio-turbator. Prey for fish and birds.
Polychaeta	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 *Nereis diversicolor* 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.
Polychaeta	*Nicon aestuariensis*	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.
Polychaeta	*Perinereis vallata*	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.
Polychaeta	*Polydora* 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. *Boccardia acus* bores into the upper exposed shell of the cockle *Austrovenus stutchburyi*. Several other Polydora group species live free in tubes in the sand. The tubes of the most widely-occurring species, *Boccardia syrtis*, 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	*Scolecolepides benhami*	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 *Scolecolepides freemani* occurs upstream in some rivers, usually in sticky mud in near freshwater conditions. e.g. Waihopai arm, New River estuary.
Gastropoda	*Amphibola crenata*	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.
	Potamopyrgus antipodarum	II	M Tolerant of muds.	Endemic to NZ. Small snail that can live in freshwater as well as brackish conditions. In estuaries *P. antipodarum* 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.
	Potamopyrgus estuarinus	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	*Cyclomactra ovata*	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.
	Paphies australis	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.
	Exosphaeroma sp.	NA	Uncertain.	Small seaweed dwelling isopod.
	Halicarcinus whitei	NA	NA	Another species of pillbox crab. Lives in intertidal and subtidal sheltered sandy environments.
	Macrophthalmus hirtipes	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.
	Paracorophium sp.	III	MM Optimum Range 95-100% mud (found in 40-100% mud)*.	A tube-dwelling corophioid amphipod. Two species in NZ, *Paracorophium excavatum* and *Paracorophium lucasi* and both are endemic to NZ. *P. lucasi* occurs on both sides of the North Island, but also in the Nelson area of the South Island. *P. excavatum* 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.