Wriggle

coastalmanagement

Whareama Estuary

Fine Scale Monitoring 2007/08

Prepared for Greater Wellington Regional Council

May 2008

Cover Photo: Whareama Estuary. Inside Photo: Upper Estuary sampling site WhaB.

Whareama Estuary

Fine Scale Monitoring 2007/08

Prepared for
Greater Wellington Regional Council

By

Barry Robertson and Leigh Stevens

Wriggle Limited, PO Box 1622, Nelson 7040, Ph 0275 417935, 021 417 936, www.wriggle.co.nz

Contents

List of Figures

List of Tables

All photos by Wriggle except where noted otherwise.

WHAREAMA ESTUARY - EXECUTIVE SUMMARY

This report summarises the results of the 2008 fine scale monitoring for Whareama Estuary, a 12km long, tidal river estuary on the Wairarapa coast. It is one of the key estuaries in Greater Wellington Regional Council's (GWRC) proposed long-term coastal monitoring programme and uses sediment health as a primary indicator of estuary condition. The report describes the following work:

- Fine scale monitoring of sediment grain size and chemistry.
- Fine scale monitoring of sediment dwelling plants and animals.
- Establishment of sediment rate monitoring plates.

The methods used are based on the tools included in the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002), and a number of extensions to the EMP and its monitoring outputs developed by Wriggle Coastal Management (see Robertson & Stevens 2006, 2007a).

The following table summarises monitoring results for the two intertidal sites at Whareama Estuary:

Indicator	Rating	Result
RPD Depth (Sediment oxygenation)	**Fair**	The Redox Potential Discontinuity (RPD) layer was relatively shallow (1-3cm depth) at both sites and therefore sediments were likely to be poorly oxygenated. Such low RPD values fit the "fair" condition rating and indicate that the benthic invertebrate community is likely to be in an unbalanced "transitional" state. This was confirmed by intensive macrofauna sampling at each site (see below).
Macrofauna (Infauna and epifauna)	**Slight to Moderate Pollution**	The benthic community condition was "unbalanced", giving it a "slightly to moderately polluted" classification. These conditions resulted in a community dominated by organisms that prefer moderate mud and organic enrichment levels, primarily small subsurface deposit-feeders.
Organic Matter (TOC)	**Good**	The indicator of organic enrichment (TOC) at both sites was at low concentrations. This reflects the well-flushed nature of the estuary and a likely low-moderate load of organic matter (sourced from phytoplankton and macroalgae) depositing on the sediments.
Nutrients (Total Nitrogen and Phosphorus)	**Low-Moderate Enrichment**	The indicators of nutrient enrichment (TN and TP) at both sites were low to moderate. Such findings reflect the well-flushed nature of this shallow estuary. This means that the Whareama Estuary sediments have a low-moderate store of P and N in the sediments (derived from both recent and historical catchment inputs).
Sediment (Grain Size, Rate of Sedimentation)	**No baseline established**	The two fine scale indicators of increased muddiness in the estuary are grain size (% mud, sand, gravel of surface sediment), and sedimentation rate (mm of sediment deposited/yr). In regard to grain size, both sites were dominated by muddy sediments (75% mud). A grain size condition rating has yet to be developed for the Whareama Estuary. Sedimentation plates have been deployed in the estuary to enable long term monitoring of sedimentation rates. The rate of sedimentation has yet to be determined.
Metals and Pesticides (Cd, Cr, Cu, Ni, Pb, Zn & DDT)	**Good-Very Good**	Heavy metals, used as an indicator of potential toxicants, were at very low concentrations at both sites with all values well below the ANZECC (2000) ISQG-Low trigger values. Synthetic organic contaminants (including DDT) were also below detection limits and ANZECC (2000) ISQG-Low trigger values.

Overall, the results showed that the dominant intertidal habitat (i.e. unvegetated tidal-flat) in the Whareama Estuary was generally in good to fair condition. Of concern was the very muddy and poorly oxygenated nature of the sediments which create poor conditions for biota and, as a consequence, the benthic community condition was "unbalanced" giving it a "slight to moderately polluted" classification.

The cause of the unbalanced benthic community was likely attributable to the following:

- excessive inputs of fine sediment,
- periodic exposure to low salinity and
- organic enrichment from excessive phytoplankton growth in the estuary (rather than macroalgae), that at times settle to the sediment surface and decay, causing deoxygenation.

The shallow nature of the RPD and muddy sediments indicate a need for caution. If organic enrichment continues (particularly in combination with an increased mud content), sediment anoxia could get worse and result in sediment nutrients becoming much more available for nuisance algal growth. Under such conditions, a return to oxygenated sediment conditions is difficult to achieve - even if catchment nutrient loads are reduced.

Currently, nutrient loads to the estuary are in the moderate category (based on GWRC monthly monitoring data (2003-2007) and outputs from the NIWA Sparrow model). Such loads are typical of developed catchments with moderate stock loadings. Once these loads enter an estuary the typical response is enrichment and symptoms of moderate eutrophication (i.e. similar to the conditions measured in the Whareama Estuary). To maintain long-term estuary condition it is therefore recommended that areas of intensive landuse in the catchment be identified and assessed for elevated nutrient runoff. The TN:TP ratio in the intertidal sediments indicated N as the key nutrient to target for minimising eutrophication symptoms.

In relation to sedimentation, several factors combine to indicate a need to encourage catchment sediment runoff management; the muddy nature of the Whareama Estuary, the natural soft-rock type and very erosion-prone nature of the catchment and the fact that much of the natural vegetative cover has been cleared.

MONITORING

Whareama Estuary has been identified by GWRC as a priority for monitoring, and is a key part of GWRC's proposed coastal monitoring programme being undertaken in a staged manner throughout the Greater Wellington region. Based on the 2008 monitoring results and condition ratings, it is recommended that monitoring continue as outlined below:

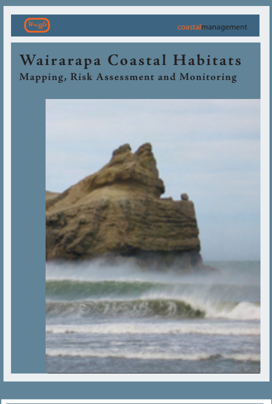
- **Fine Scale Monitoring**. Complete the three to four years of the scheduled baseline monitoring in Whareama Estuary to Jan-Feb 2011. After the three to four year baseline is completed, reduce monitoring to five yearly intervals or as deemed necessary based on the condition ratings.
- **Sedimentation Rate Monitoring**. Measure the depths of the existing 4 sediment plates in January-March 2009 while doing the fine scale monitoring. Following the 2009 monitoring, it is recommended that the depth of all plates be measured annually thereafter or whenever fine scale monitoring is undertaken.

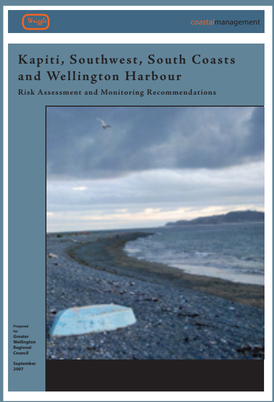
MANAGEMENT

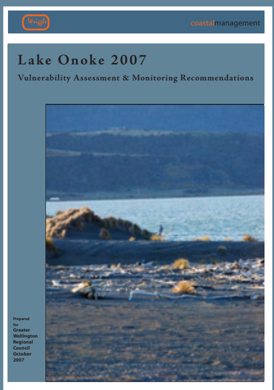
The fine scale monitoring results reinforce the need for management of nutrient and fine sediment sources entering the estuary. It is recommended that options be considered to identify sources and to develop plans to minimise their adverse effects on estuary uses (e.g. fishing, boating, swimming, shellfish collection) and values.

1. INTRODUCTION

OVERVIEW







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 2007b, 2007c and 2007d). These assessments identified the following estuaries as immediate priorities for monitoring: Porirua Harbour, Whareama Estuary, Lake Onoke, Hutt Estuary and Waikanae Estuary. In late 2007, GWRC chose to begin estuary monitoring in a staged manner, with the Porirua Harbour (Porirua and Pauatahanui Arms) and Whareama Estuary (Wairarapa Coast) as the first estuaries. Wriggle Coastal Management were contracted to undertake the work using the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002) plus recent extensions (Table 1).

The Whareama Estuary monitoring programme consists of three components:

1. **Ecological Vulnerability Assessment** of the estuary to major issues and appropriate monitoring design. This component has been completed for Whareama 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 Whareama Estuary (Robertson and Stevens 2007b).
3. **Fine scale physical, chemical and biological monitoring** (EMP approach), including sedimentation plate deployment. This component, which provides detailed information on the condition of the Whareama Estuary, is the subject of the current report.

Whareama Estuary is a long, narrow, "tidal river" type estuary on the Wairarapa coast. The estuary is relatively shallow (1-3m deep) and enclosed within a steep valley. The estuary margin is dominated by grassland and is generally devoid of saltmarsh vegetation except for a narrow strip in the lower section. The bed of the estuary is dominated by muddy sediments except for the very lowest reaches where firm sands dominate. Saltwater extends up to 12km inland and the waters are particularly turbid. There is an indication of moderate macroalgal blooms and the waters have a distinctive green colouration, probably from high levels of chlorophyll in the water.

The current report documents the following;

- The results of the fine scale monitoring of Whareama Estuary intertidal sites (undertaken in January 2008).
- The establishment of sediment plates in Whareama Estuary.
- Condition ratings for Whareama Estuary based on the 2008 fine scale results. A suggested monitoring or management response is linked to each condition rating.

This report is the first of a proposed series of three or four, which will characterise the baseline fine scale conditions in the estuary over a 4 year period. The results will help determine the extent to which the estuary is affected by major estuary issues or problems (Table 2), both in the short and long term. The survey focuses on providing detailed information on indicators of chemical and biological condition (Table 3) of the dominant habitat type in the estuary (i.e. unvegetated intertidal mudflats at low-mid water).

1. Introduction (continued)

Table 1. Extensions to the EMP (developed by Wriggle Coastal Management)

Extensions to Estuary Monitoring Protocol
Development of an Estuary Vulnerability Matrix.
Establishment of sedimentation rate measures (using plates buried in sediment).
Estimation of historical sedimentation rates (using radio-isotope ageing of sediment cores).
Assessment of the percentage cover of macroalgae and seagrass (reported as separate GIS layers).
Broad scale mapping of the 200m terrestrial margin surrounding the estuary.
Establishment of condition ratings for key indicators.
Provision of georeferenced digital photos (as a GIS layer).
Development of an Upper Estuary Monitoring and Assessment Protocol.

Table 2. Summary of the major issues or problems affecting most NZ estuaries.

Issue	Impact
Sedimentation	If sediment inputs are excessive, they infill quickly with muds, reducing biodiversity and human values and uses.
Eutrophication	Eutrophication is an increase in the rate of supply of organic matter to an ecosystem. If nutrient inputs are excessive, they experience macroalgal and/or phytoplankton blooms, anoxic sediments, lowered biodiversity and nuisance effects for local residents.
Disease Risk	If pathogen inputs are excessive, the disease risk from bathing, wading or eating shellfish increases to unacceptable levels.
Toxins	If potentially toxic contaminant inputs (e.g. heavy metals, pesticides) are excessive, estuary biodiversity is threatened and shellfish and fish may be unsuitable for eating.
Habitat Loss	If habitats (such as saltmarsh) are lost or damaged through drainage, reclamation, building of structures, stock grazing or vehicle access, biodiversity and estuary productivity declines.
	If the natural terrestrial margin around the estuary is modified by forest clearance or degraded through such actions as roading, stormwater outfalls, property development and weed growth, the natural character is diminished and biodiversity reduced.

Table 3. 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 (*Ulva*), *Gracilaria* and *Enteromorpha*) over time.
Eutrophication	Organic and Nutrient Enrichment	Chemical analysis of total nitrogen, total phosphorus, and total organic carbon (calculated from ash free dry weight) in replicate samples from the upper 2cm of sediment.
Eutrophication	Redox Profile	Measurement of depth of redox potential discontinuity (RPD) in sediment estimates likely presence of deoxygenated, reducing conditions.
Toxins	Contamination in Bottom Sediments	Chemical analysis of indicator metals (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.

1. INTRODUCTION (CONTINUED)

STRUCTURE

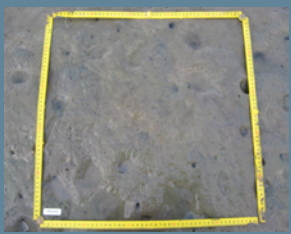
The report is structured in the following general sections:

Section 1 Introduction to the scope and structure of the study.
Section 2 Methods for the fine scale assessment, sedimentation rate, and the estuary condition ratings.
Section 3 Results and discussion.
Section 4 Summary.
Section 5 Monitoring recommendations.
Section 6 Management recommendations.
Section 7 Acknowledgements.
Section 7 References.
Appendix 1: Details of analytical methods.
Appendix 2: Detailed fine scale monitoring results - Whareama Estuary 2008.
Appendix 3: Characteristics of the benthic invertebrate community.

Figure 1 Location of sediment plates and fine scale monitoring sites in Whareama Estuary (Photo; Google)

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 indicators of chemical and biological condition of the dominant habitat type in the estuary. This is most commonly unvegetated intertidal mudflats at low-mid water. Using the outputs of the broad scale habitat mapping, representative sampling sites (usually 2 per estuary) are selected and samples collected and analysed for the following variables:

- Salinity, Oxygenation (Redox Potential Discontinuity - RPD), Grain size (% mud, sand, gravel).
- Organic Matter: Ash free dry weight (AFDW) (converted and reported as total organic content - TOC).
- Nutrients: Total nitrogen (TN), Total phosphorus (TP).
- Heavy metals: Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Nickel (Ni) and Zinc (Zn).
- Macroinvertebrate abundance and diversity (infauna and epifauna)

For the Whareama Estuary, two fine scale sampling sites (Figure 1), were selected in unvegetated, mid-low water mudflats (avoiding areas of significant vegetation and channels). At the upper site, a 60m x 21m area (and at the lower site a 60m x 15m area), in the lower intertidal was marked out and divided into 12 equal sized plots. Within each area, ten plots were selected, a random position defined within each, and the following sampling undertaken:

Physical and chemical analyses:

- Within each plot, one random 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 RPD depth recorded.
- At each site, three samples (each a composite from four plots) of the top 20mm of sediment (each approx. 250gms) were collected adjacent to the core. All samples were kept in a chillybin in the field.
- Chilled samples were sent to R.J. Hill Laboratories for analysis (details in Appendix 1):
  - * Grain size/Particle size distribution (% mud, sand, gravel).
  - * Nutrients (TN and TP).
  - * Ash free dry weight (AFDW) (as a measure of total organic content).
  - * Trace metal contaminants (Cd, Cr, Cu, Ni, Pb, Zn). Analyses were based on whole sample fractions which are not normalised to allow direct comparison with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality produced by Australian and New Zealand Environment and Conservation Council (ANZECC 2000).
  - * Synthetic organic contaminants (polychlorinated biphenyls and pesticides)
- 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.
- In addition, salinity measurements of the overlying water have been included at each site during low tide periods in order to provide a better definition of habitat type.

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.

2. METHODS (CONTINUED)

FINE SCALE MONITORING (CONTINUED)

Infauna (animals within sediments):

- One randomly placed sediment core was taken from each of ten plots using a 130mm diameter (area = $0.0133m^2$) PVC tube.
- The core tube 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 nearby source of seawater and the contents of the core washed through a 0.5mm nylon mesh bag. The infauna remaining were carefully emptied into a plastic container with a waterproof label and preserved in 70% isopropyl alcohol.
- The samples were then transported to a commercial laboratory for counting and identification (Gary Stephenson, Coastal Marine Ecology Consultants).

Sedimentation Plate Deployment:

Determining the sedimentation rate from now 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.

One site (with 4 plates) was established in Whareama Estuary during January 2008 (Figure 1). The site was located in muddy habitat in an area of the lower estuary where sedimentation rates are likely to be elevated. At the site (Site B), four plates (20cm wide square concrete blocks) were buried approximately 2m apart in a line on the edge of the fine scale site. The line began at the downstream site marker peg nearest the water and the plates were buried between two marker pegs located at 5m and 10m distances inland and at right angles to the estuary channel (see Figure 1). The GPS positions of each plate was logged, and the depth from the undisturbed mud surface to the top of the sediment plate recorded. In the future, these depths will be measured annually and, over the long term, will provide a measure of rate of sedimentation in the estuary.

CONDITION RATINGS

RATING
Very Good
Good
Fair
Poor
Early Warning Trigger

At present, there are no formal criteria for rating the overall condition of estuaries in NZ, and development of scientifically robust and nationally applicable condition ratings requires a significant investment in research and is unlikely to produce immediate answers. Therefore, to help GWRC interpret their monitoring data, a series of interim broad and fine scale estuary "condition ratings" (presented below) have been proposed for the Whareama Estuary (based on the ratings developed for Southland's estuaries - Robertson & Stevens 2006, 2007a).

The condition ratings are designed to be used in combination with each other (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management responses.

The ratings are based on a review of monitoring data, use of existing guideline criteria (e.g. ANZECC (2000) sediment guidelines), and expert opinion. They indicate whether monitoring results reflect good or degraded conditions, and also include an "early warning trigger" so that GWRC is alerted where rapid or unexpected change occurs. For each of the condition ratings, a recommended monitoring frequency is proposed and a recommended management response is suggested.

2. Methods (Continued)

OVERVIEW

In most cases the management recommendation is simply that GWRC develop a plan to further evaluate a problem and consider what response actions may be appropriate. It is expected that the proposed ratings will continue to be revised and updated as better information becomes available, and that new ratings will be developed for other indicators. Note that only fine scale ratings are presented in this section. Broad scale ratings are included in Stevens and Robertson (2008).

Redox Potential Discontinuity

The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. The RPD marks the transition between oxygenated and reduced conditions and 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. In addition, nutrient availability in estuaries is generally much greater where sediments are anoxic, with consequent exacerbation of the eutrophication process.

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 Evaluation & Response Plan
Poor	<1cm depth below sediment surface	Monitor at 2 year intervals. Initiate Evaluation & Response Plan
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Metals

Heavy metals provide a low cost preliminary assessment of toxic contamination in sediments and are a starting point for contamination throughout the food chain. Sediments polluted with heavy metals (poor condition rating) should also be screened for the presence of 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

Total Nitrogen

In shallow estuaries like Whareama, 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
Low-Mod Enrichment	500-2000mg/kg	Monitor at 5 year intervals after baseline established
Enriched	2000-4000mg/kg	Monitor at 2 year intervals and manage source
Very Enriched	>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

2. Methods (Continued)

Total Phosphorus

In shallow estuaries like Whareama 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
Low-Mod Enrichment	200-500mg/kg	Monitor at 5 year intervals after baseline established
Enriched	500-1000mg/kg	Monitor at 2 year intervals and manage source
Very Enriched	>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 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
Low-Mod Enrichment	1-2%	Monitor at 5 year intervals after baseline established
Enriched	2-5%	Monitor at 2 year intervals and manage source
Very Enriched	>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

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	<1mm/yr (typical pre-European rate)	Monitor at 5 year intervals after baseline established
Low	1-5mm/yr	Monitor at 5 year intervals after baseline established
Moderate	5-10mm/yr	Monitor at 5 year intervals after baseline established
High	10-20mm/yr	Monitor yearly. Initiate Evaluation & Response Plan
Very High	>20mm/yr	Monitor yearly. Manage source
Early Warning Trigger	Rate increasing	Initiate Evaluation and Response Plan

Macrofauna Biotic Index

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 successfully in relation to a large set of environmental impact sources (Borja, 2005) and geographical areas (in both northern and southern hemispheres) and so is used here.

BENTHIC COMMUNITY CONDITION RATING			
RATING	DEFINITION	INDEX	RECOMMENDED RESPONSE
Normal	Unpolluted	0	Monitor at 5 year intervals after baseline established
Impoverished	Unpolluted	1	Monitor at 5 year intervals after baseline established
Unbalanced	Slightly polluted	2	Monitor 5 yearly after baseline est. Initiate Evaluation & Response Plan
Transitional to polluted	Moderately polluted	3	Monitor 5 yearly after baseline est. Initiate Evaluation & Response Plan
Polluted	Moderately polluted	4	Monitor yearly. Initiate Evaluation & Response Plan
Heavily polluted	Transitional to heavily polluted	5	Monitor yearly. Initiate Evaluation & Response Plan
Heavily polluted	Heavily polluted	6	Monitor yearly. Initiate Evaluation & Response Plan
Extremely polluted	Azoic (devoid of life)	7	Monitor yearly. Initiate Evaluation & Response Plan
Early Warning Trigger	Trend to slightly polluted		Initiate Evaluation and Response Plan

3. RESULTS AND DISCUSSION

OUTLINE

A summary of the results of the fine scale monitoring of Whareama Estuary are presented in Tables 4 and 5 and Figures 2 to 15. Detailed results are presented in Appendix 1. In order to facilitate understanding, this results and discussion section is divided into 3 subsections based on the key estuary problems that the fine scale monitoring is addressing:

- eutrophication,
- sedimentation, and
- toxicity.

Within each subsection, the results for each of the relevant fine scale indicators are presented (e.g. total nitrogen is presented under the issue of eutrophication). A summary of the condition ratings for each of the two sites is presented in the accompanying figures.

Table 4 Physical and chemical results (means) for Whareama Estuary, 18 January 2008.

Estuary	Site	Reps.	RPD	Salinity	AFDW	TOC	Mud	Sands	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP
			cm	ppt	%					mg/kg							
Whareama	Wha A	3	1.5	30	2.57	1.35	67.77	32.07	0.23	0.048	9.17	8.03	6.87	9.90	42.67	780	417
	Wha B	3	2.5	30	2.23	1.18	73.43	26.50	0.17	0.050	9.97	8.73	7.70	10.33	47.00	817	430

Table 5 Macrofauna results (means) for Whareama Estuary, 18 January 2008.

Estuary	Site	Reps.	Mean Total Abundance/m^2	Mean Number of Species/Core
Whareama	Wha A	10	6,400	5.6
	Wha B	10	4,300	4.7

EUTROPHICATION

Eutrophication is the process where water bodies receive excess nutrients that stimulate excessive plant growth. In estuaries like the Whareama, macroalgal (e.g. sea lettuce) and microalgal blooms are the main threat which can lead to sediment anoxia, elevated organic matter and nutrients, increasing muddiness, lowered clarity and benthic community changes. The primary fine scale indicators are therefore 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 Robertson and Stevens 2007b) are the percentages of the estuary covered by macroalgae and soft muds.

2008 RPD RATING
Fair

The Redox Potential Discontinuity (RPD)

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 the trigger leading to 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 2 main reasons:

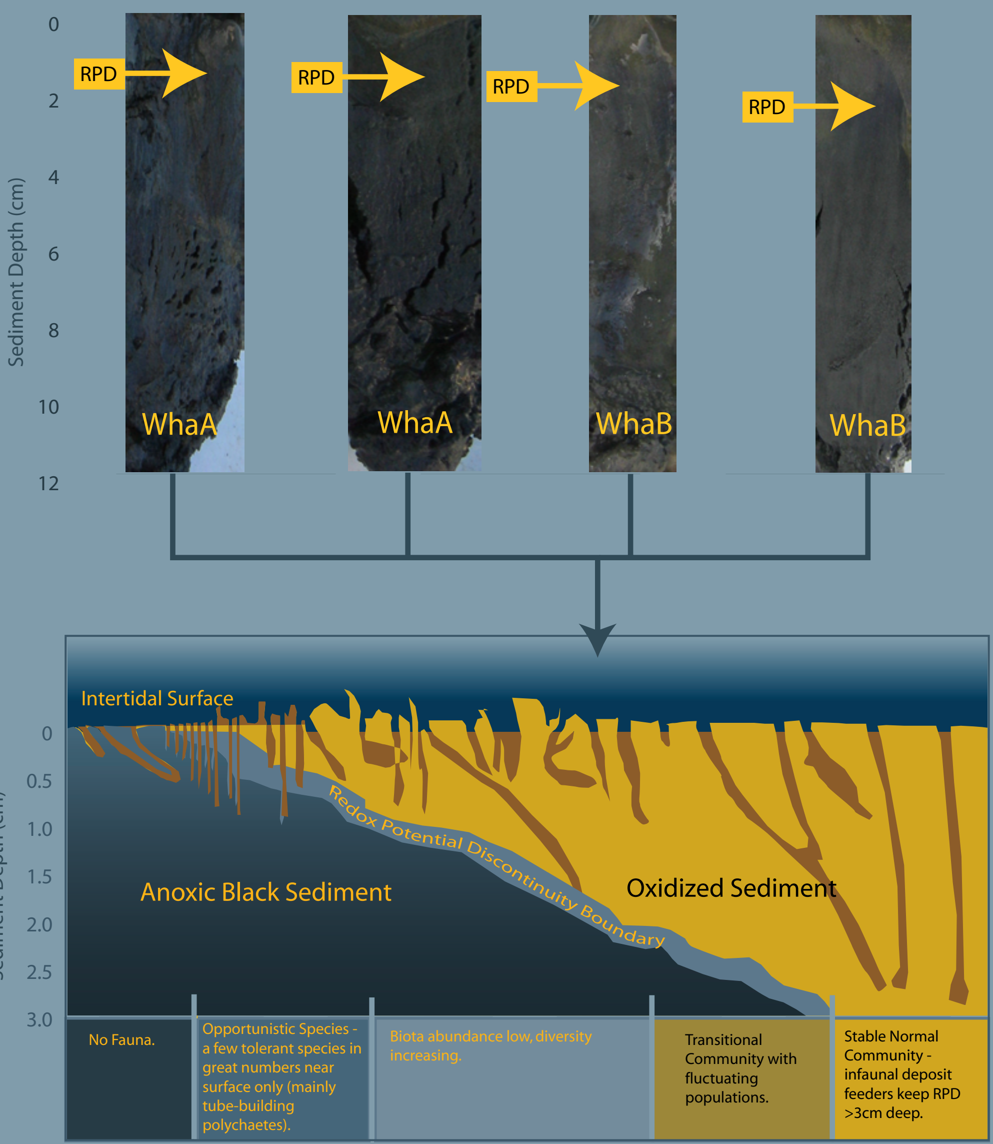
1. As the RPD layer gets close to the surface, a "tipping point" is reached where the pool of sediment nutrients (which can be large), suddenly becomes available to fuel algal blooms and to worsen sediment conditions.
2. Anoxic sediments contain toxic sulphides and very little aquatic life.

3. Results and Discussion (Continued)

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. Figure 2 shows the sediment profiles and RPD depths for each of the two Whareama sampling sites (also Table 4) and indicates the likely benthic community that is supported at each site based on the measured RPD depth (adapted from Pearson and Rosenberg 1978). The RPD results showed that the depth of the RPD in Whareama Estuary was relatively shallow at 1-3cm depth at both sites and therefore likely to be poorly oxygenated (which was further supported by the facts that infauna feeding voids and burrows were uncommon below the RPD and that sediments were dominated by muds.

Such low RPD values fit the “fair” condition rating and indicate that the benthic invertebrate community was likely to be in an unstable “transitional” state. In addition, because the sediments were dominated by muds but with a significant sand component, it is inferred that sediment aeration was relatively poor [being maintained primarily by bioturbation by benthic invertebrate organisms (subsurface deposit-feeders)].

Figure 2 Sediment profiles, depths of RPD and predicted benthic community type, Whareama Estuary. Arrows below cores relate to the type of community likely to be found in each core. (Note: photo and core quality were poor which means RPD depth is difficult to discern on photos) .



3. Results and Discussion (Continued)

2008 TOC RATING
Good

Organic Matter (TOC) (Figure 3)

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 Rosenburg, 1978). The indicator of organic enrichment (TOC) at both sites was at moderate to low concentrations (mean 1.2%) and met the "good" condition rating. This reflects the generally well-flushed nature of much of the estuary area and a likely moderate load of organic matter (sourced primarily from phytoplankton and macroalgae) depositing on the sediments.

2008 TP RATING
Low-Mod Enrichment

Total Phosphorus (TP) (Figure 4)

Total phosphorus (a key nutrient in the eutrophication process) was present in the "low to moderate enrichment" category at the two sites (mean 420 mg/kg). This means that the Whareama Estuary sediments have a low-moderate store of P in the sediments (sourced from both recent and historical catchment inputs). Fortunately, this store of P is primarily unavailable for fertilising nuisance algal growth. Estuary sediments store P generally as iron (Fe) bound P which is only released to the water column at slow rates, unless the shallow sediments turn anoxic. Because anoxia is not common in the estuary at present, sediment P is likely to remain bound unless conditions change. Excessive algal growth is the main threat leading to anoxic sediments. If a shift to widespread sediment anoxia occurred (e.g. from excessive catchment nutrient loads), the sediment P reservoir would be released to fuel even higher levels of nuisance algal growth and cause a major detrimental impact on estuarine ecology.

2008 TN RATING
Low-Mod Enrichment

Total Nitrogen (TN) (Figure 6)

Like phosphorus, total nitrogen (the other key nutrient in the eutrophication process) was at the "low to moderate enrichment" category at the two sites (mean 800 mg/kg). This means that the Whareama sediments have a low-moderate store of N in the sediments (sourced from both recent and historical catchment inputs). Also as with phosphorus, this store of N is primarily unavailable for fertilising nuisance algal growth, but the reason is different. In contrast with P, N is more mobile and in a healthy estuary a large amount of the N load is converted to N gas and liberated to the atmosphere. However, when the sediments become anoxic, the efficiency of this process is lowered and causes most of the nitrogen to stay within the estuary. So like P, N is suddenly much more available for nuisance algal growth when the sediment turns anoxic. The large increase in nuisance algal growth, in turn provides elevated organic matter to the sediments (i.e. rotting algae), which further exacerbates the anoxic condition.

Clearly, once the "tipping point" to anoxic conditions occurs, a return to oxygenated conditions is difficult to achieve - even if catchment nutrient loads are reduced. In order to provide an early warning of such a threat, long term broad scale monitoring of macroalgae, phytoplankton and RPD are being undertaken. Another important point, is that the nutrient data identifies N as the nutrient most likely limiting eutrophication in the Whareama Estuary (i.e. the ratio of TN:TP in the intertidal sediments was close to 1:1, which was less than the upper limit of 10 used to define nitrogen limitation). Such data confirms N as the critical nutrient to address in any management actions designed to reduce macroalgal growth in the estuary.

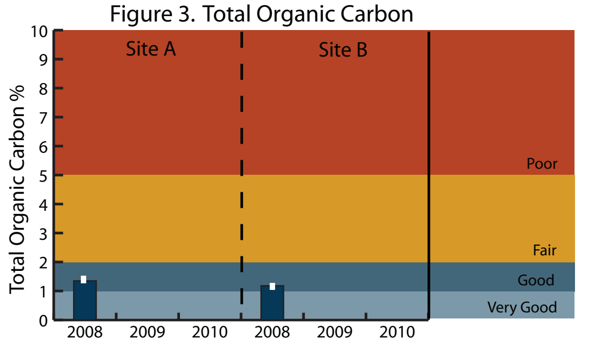


Figure 3. Total Organic Carbon

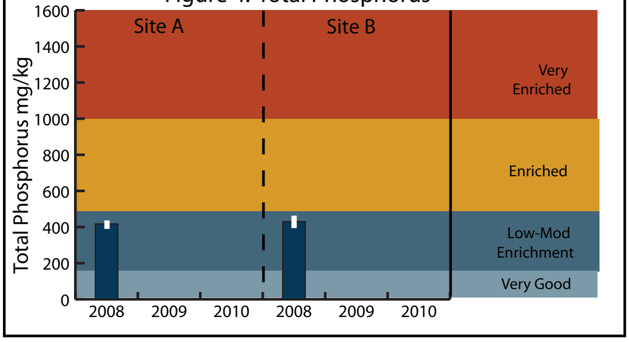


Figure 4. Total Phosphorus

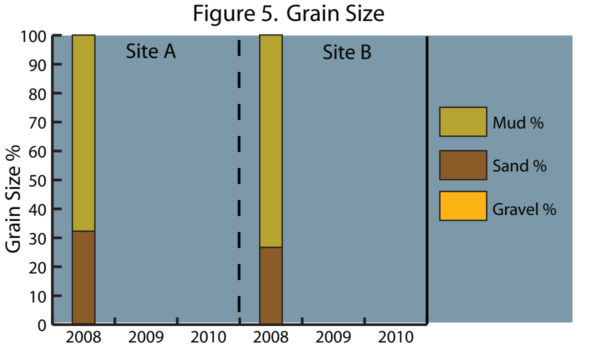


Figure 5. Grain Size

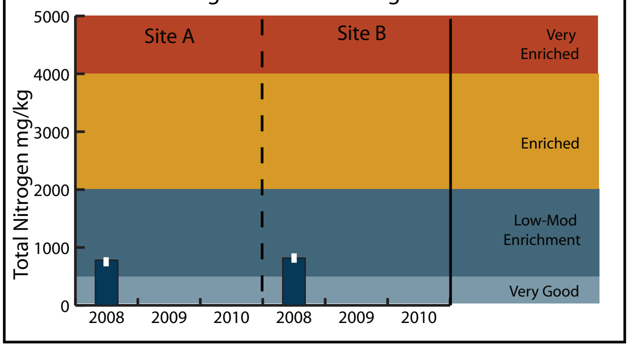


Figure 6. Total Nitrogen

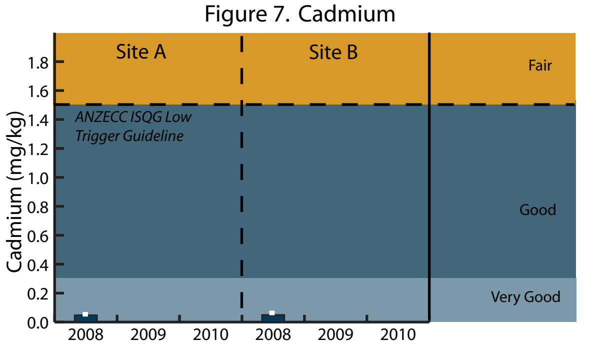


Figure 7. Cadmium

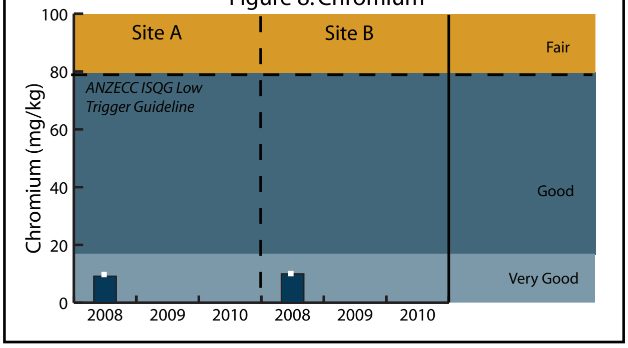


Figure 8. Chromium

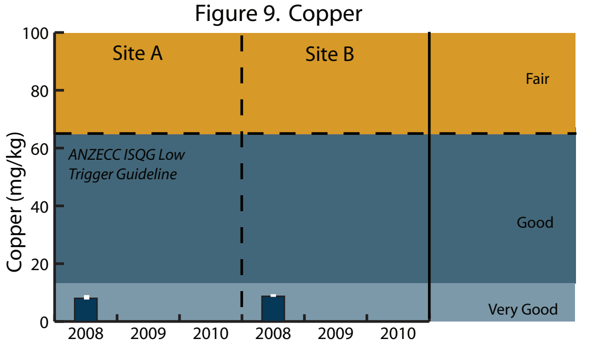


Figure 9. Copper

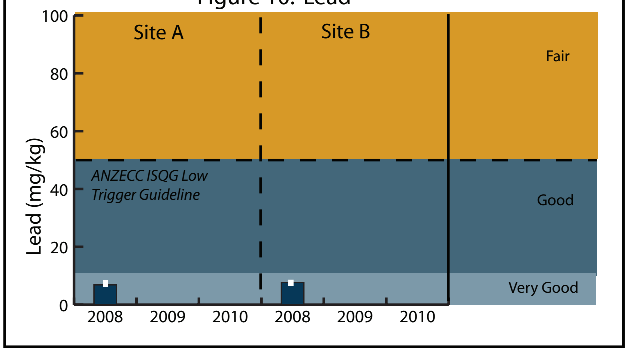


Figure 10. Lead

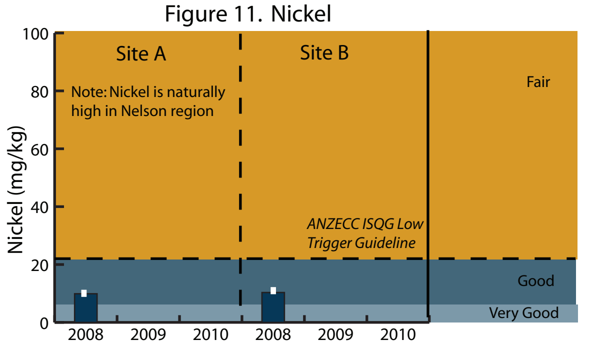


Figure 11. Nickel

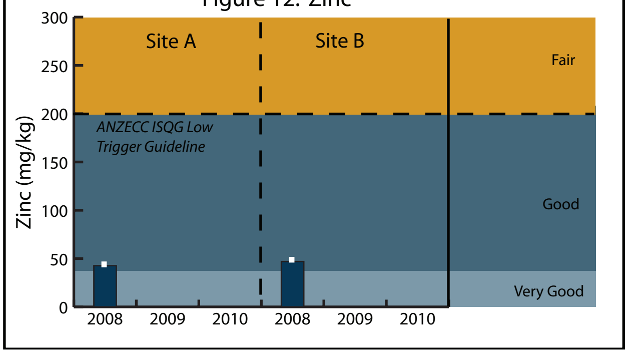


Figure 12. Zinc

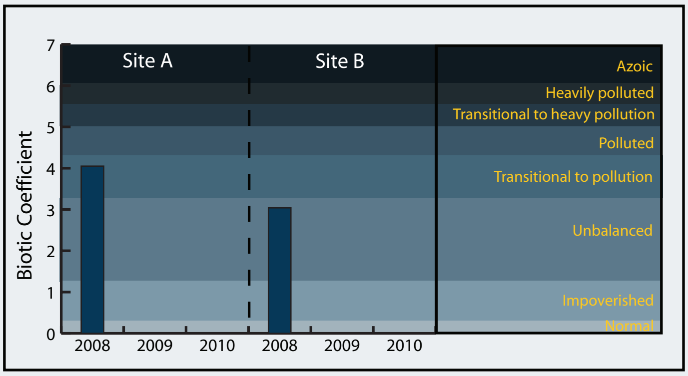
2008 Benthic Community RATING

Unbalanced Transitional to Pollution

Sediment Biota

The benthic invertebrate community condition (a key indicator of response to both man-made and natural stressors) in the Whareama Estuary was "unbalanced" at Site B, indicating a "slightly polluted" classification for that site (Figure 13) and "transitional to pollution" at Site A, indicating a "moderately polluted" classification at that site.

Figure 13 Benthic community condition rating for sites A and B Whareama Estuary



Such findings are expected given the high mud content, the shallow RPD (i.e. poor oxygenation) of the sediments and the fact that the Whareama is a tidal river type estuary which experiences relatively extreme salinity fluctuations. These conditions resulted in a community dominated by organisms that prefer moderate mud, shallow RPD and moderate organic enrichment levels, primarily small subsurface deposit-feeders (i.e. the bivalve *Arthritica bifurca*, the capitellid polychaete *Heteromastus filiformis* and the spionid polychaete *Scolecolepides benhami*) (Borja et al. 2000, and Thrush et al. 2003).

However, the conditions were not poor enough to encourage the dominance of opportunistic highly pollution-tolerant species, e.g. *Capitella*, that proliferate in anoxic sediments. In fact, other more sensitive organisms (i.e. those that prefer low mud contents and low levels of organic enrichment) were also present, but in low numbers. In particular,

- the small tube-building, surface deposit feeding, spionid polychaete *Boccardia*,
- the surface selective deposit feeding ragworm, *Simplisetia*, and
- the suspension feeding cockle, *Austrovenus stutchburyi*.

Compared with the intertidal mudflats in other NZ estuaries, the community diversity was relatively impoverished (mean 5-6 species per core - Figure 14). Mean abundance at each site was low-moderate at 4-6,000 /m^2 (Figure 15).

***Amphibola*, the mudflat snail was the only visible epifauna at the Whareama Sites**

Figure 14. Mean total abundance of macrofauna at Whareama Estuary compared with other NZ estuaries (Source Robertson et al. 2002, Robertson and Stevens 2006)

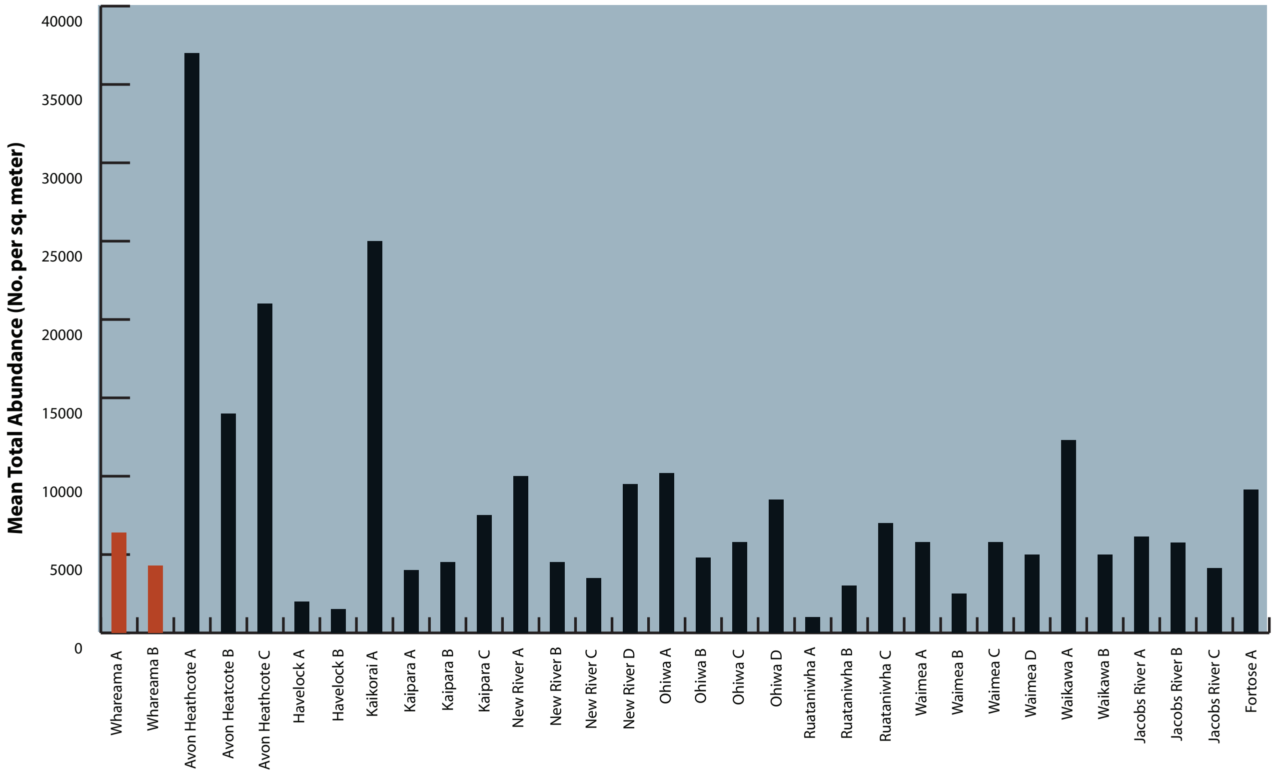
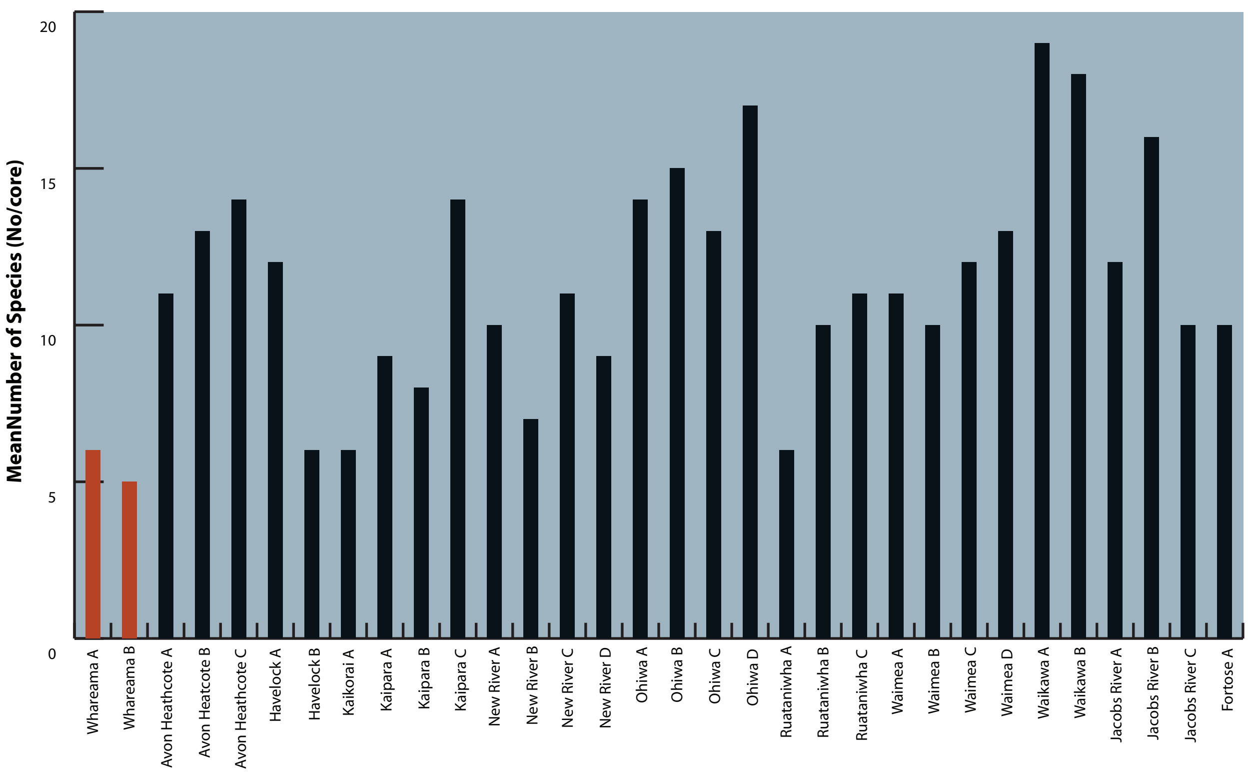


Figure 15. Mean number of infauna species, Whareama Estuary compared with other NZ estuaries



3. Results and Discussion (Continued)

TOXICITY

2008 TOXICITY RATING
Good
Very Good

Heavy metals (Cd, Cr, Cu, Ni, Pb, Zn), used as an indicator of potential toxicants, were at low to very low concentrations at both intertidal sites, with all values well below the ANZECC (2000) ISQG-Low trigger values (Figures 7 to 12). Metals met the "very good" condition rating for cadmium, chromium, copper and lead at all sites, and nickel and zinc met the "good" condition rating. Organochlorine pesticide and polychlorinated biphenyls (PCB's) were also measured and were all below detection limits and ANZECC (2000) criteria (Appendix 2).
These results indicate that there is no widespread toxicity in the Whareama Estuary.

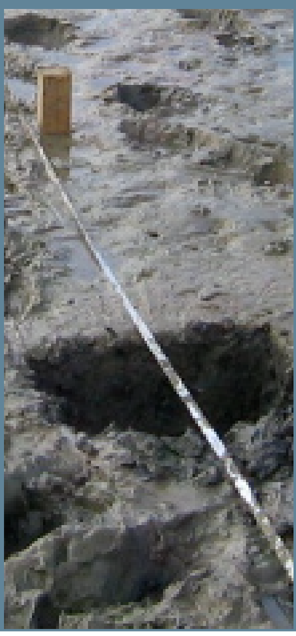
SEDIMENTATION OF FINE SEDIMENT

Soil erosion is a major issue in New Zealand and the resulting suspended sediment impacts are of particular concern in "tidal lagoon" estuaries because they have a central basin which forms a sink for fine sediments. However in "tidal river" estuaries like the Whareama, which is narrow and shallow, there are few sheltered areas for mud to accumulate. High river flows tend to wash most of the suspended solid load out to sea, but because the catchment is particularly erosion-prone, much of the estuary bed is muddy and water clarity is low. The primary fine scale indicators of fine sediment deposition are grain size and sedimentation rate. The broad scale indicator is the area of soft mud (see Robertson and Stevens 2007b).

Grain Size (Figure 5)
Grain size (% mud, sand, gravel) measurements provide a good indication of the muddiness of a particular site. The 2008 monitoring results show that all sites were dominated by muddy sediments (approximately 70% mud).

Rate of Sedimentation
The rate of sedimentation for the Whareama Estuary has yet to be determined. Sedimentation plates were deployed in the estuary in January 2008 to enable long term monitoring of sedimentation rates.

SEDIMENTATION PLATE DEPLOYMENT

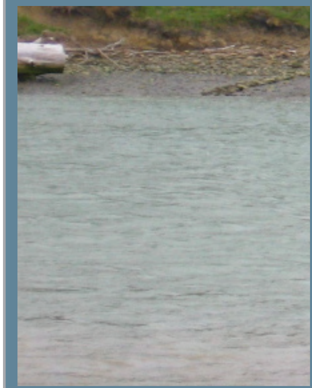


The location of the 4 sedimentation plates buried in soft muddy sediments in Whareama Estuary are shown in Figure 1, while the distance (mm) from the sediment surface to the buried plate, and the height of any marker stakes (mm) either side of each plate above the sediment surface is shown in Table 6. Following establishment of this baseline, ongoing monitoring results can be used to determine the sedimentation rate in the estuary, with a sediment condition rating developed and used to assess any changes.

Table 6. Sedimentation plate locations and height and depth details

Site	No	Date	NZMG East	NZMG North	Plate depth (mm)	Peg Height (mm)
Upstream (2m from Peg Corner)	1	18/1/08	2770097	6017055	182	
Upstream (4m from Peg Corner)	2	18/1/08	2770098	6017054	156	
Upstream (6m from Peg Corner)	3	18/1/08	2770098	6017053	215	
Upstream (8m from peg corner)	4	18/1/08	2770100	6017051	216	
Peg - site corner		18/1/08	2770098	6017056		100
Peg - 5 metre		18/1/08	2770101	6017049		100
Peg - 10 m		18/1/08	2770099	6017052		100

4. SUMMARY



The first year of fine scale monitoring results for a range of physical, chemical and biological indicators of estuary condition show that the dominant intertidal habitat (i.e. unvegetated tidal-flat) in the Whareama Estuary was generally in good to fair condition.

In terms of the eutrophication indicators, the results were in the low-moderate category for nutrients (TN and TP) and organic content, however the sediments were very muddy (70% mud) and poorly oxygenated as inferred from the relatively shallow RPD layer at all sites (1-3cm). Such conditions provided unfavourable habitat for biota and as a consequence the benthic community condition was "unbalanced", giving it a "slight to moderately polluted" classification. The cause of the unbalanced benthic community was probably from a combination of excessive inputs of fine sediment, periodic exposure to low salinity waters during floods, and organic enrichment from excessive phytoplankton and macroalgal growth in the estuary that at times collect on the sediment surface and decay, causing deoxygenation.

The shallow nature of the RPD and muddy sediments indicate a need for caution. If organic enrichment continues (particularly in combination with an increased mud content), sediment anoxia could get worse and result in sediment nutrients becoming much more available for nuisance algal growth. Under such conditions, a return to oxygenated sediment conditions is difficult to achieve - even if catchment nutrient loads are reduced. Currently, nutrient loads to the estuary are in the moderate category (based on GWRC monthly monitoring data (2003-2007) and outputs from the NIWA Sparrow model). Such loads are typical of developed catchments with moderate stock loadings. Once these loads enter an estuary the typical response is enrichment and symptoms of moderate eutrophication (i.e. similar to the conditions measured in the Whareama Estuary). To maintain long-term estuary condition it is therefore recommended that areas of intensive landuse in the catchment be identified and assessed for elevated nutrient runoff. The TN:TP ratio in the intertidal sediments indicated N as the key nutrient to target for minimising eutrophication symptoms.

In relation to sedimentation, several factors combine to indicate a need to encourage catchment sediment runoff management; the muddy nature of the Whareama Estuary, the natural soft-rock type and very erosion-prone nature of the catchment and the fact that much of the natural vegetative cover has been cleared.

5. MONITORING

Whareama Estuary has been identified by GWRC as a priority for monitoring, and is proposed as a key part of GWRC's coastal monitoring programme being undertaken in a staged manner throughout the greater Wellington region. Based on the 2008 monitoring results and condition ratings, it is recommended that monitoring continue as outlined below:

Fine Scale Monitoring. Complete the 3 to 4 years of the scheduled baseline monitoring in Whareama Estuary to Jan-Feb 2010. After the three year baseline is completed, reduce monitoring to five yearly intervals or as deemed necessary based on the condition ratings.

Sedimentation Rate Monitoring. Measure the depths of the existing 4 sediment plates in January-March 2009 while doing the fine scale monitoring. Following the 2009 monitoring, it is recommended that the depth of all plates be measured annually thereafter or whenever fine scale monitoring is undertaken.

6. MANAGEMENT

The fine scale monitoring results reinforced the need for management of nutrient and fine sediment sources entering the estuary. It is recommended that options be considered to identify sources of elevated loads and to develop plans to minimise their adverse effects on estuary uses and values.

7. ACKNOWLEDGEMENTS

This survey and report has been undertaken with help from various people, local residents (particularly Glen Meredith from Orui Station) who provided access to the estuary, Maz Robertson for editing, and lastly the staff of Greater Wellington Regional Council who made it all happen. In particular, the support and feedback of Juliet Milne, Piotr Swierczynski and Paul Denton (all from GWRC) was much appreciated.

8. REFERENCES

ANZECC, 2000. Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

Borja, A., Franco, J., Perez, V., 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Mar. Poll. Bull. 40, 1100–1114.

Borja A., H. Muxika. 2005. Guidelines for the use of AMBI (AZTI's Marine Biotic Index) in the assessment of the benthic ecological quality. Marine Pollution Bulletin 50: 787-789.

Jørgensen, N. and N.P. Revsbech, 1985. Diffusive boundary layers and the oxygen uptake of sediments and detritus. Limnology and Oceanography 30:111-122.

Pearson, T.H. and. Rosenberg, R., 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceangraph and Marine Biology Annual Review 16, 229–311.

Robertson, B.M., Gillespie, P.A., Asher, R.A., Frisk, S., Keeley, N.B., Hopkins, G.A., Thompson, S.J., Tuckey, B.J. 2002. Estuarine Environmental Assessment and Monitoring: A National Protocol. Part A. Development, Part B. Appendices, and Part C. Application. Prepared for supporting Councils and the Ministry for the Environment, Sustainable Management Fund Contract No. 5096. Part A. 93p. Part B. 159p. Part C. 40p plus field sheets.

Robertson, B., and Stevens, L. 2006. Southland Estuaries State of Environment Report 2001-2006. Prepared for Environment Southland.

Robertson, B., and Stevens, L. 2007a. Waikawa Estuary 2007a, Monitoring, Macroalgal Mapping & Historical Sediment Coring. Prepared for Environment Southland.

Robertson, B.M. and Stevens, L. 2007b. Wairarapa Coastal Habitats: Mapping, Risk Assessment and Monitoring. Prepared for Greater Wellington Regional Council. 120p.

Robertson, B.M. and Stevens, L. 2007c. Wellington Harbour, Kapiti, Southwest and South Coasts - Risks and Monitoring. Prepared for Greater Wellington Regional Council. 57p.

Robertson, B.M. and Stevens, L. 2007d. Lake Onoke 2007 - Vulnerability Assessment & Monitoing Recommendations. Prepared for Greater Wellington Regional Council. 57p.

Thrush S.F., Hewitt J.E., Norkko A., Nicholls P.E., Funnell G.A., Ellis .J.I., 2003. Habitat change in estuaries: predicting broad-scale responses of intertidal macrofauna to sediment mud content. Marine Ecology Progress Series 263:101-112.

Stevens, L. and Robertson, B., 2008. Porirua Harbour 2007 Broad Scale Habitat Mapping. Prepared for Greater Wellington Regional Council.

APPENDIX 1. DETAILS ON ANALYTICAL METHODS

Indicator	Analytical Laboratory	Method	Detection Limit
Infauna Sorting and Identification	Gary Stephenson*	Coastal Marine Ecology Consultants	N/A
Grain Size (% sand, gravel, silt)	R.J Hill Laboratories	Air dry (35 degC, sieved to pass 2mm and 63um sieves, gravimetric.	N/A
AFDW (% organic matter)	R.J. Hill Laboratories	Ignition in muffle furnace 550degC, 1 hr, gravimetric. APHA 2540 G 20th ed 1998.	0.04 g/100g dry wgt
Total recoverable cadmium	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.01 mg/kg dry wgt
Total recoverable chromium	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable copper	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable nickel	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable lead	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.04 mg/kg dry wgt
Total recoverable zinc	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.4 mg/kg dry wgt
Total recoverable phosphorus	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	40 mg/kg dry wgt
Total nitrogen	R.J. Hill Laboratories	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	500 mg/kg dry wgt
Organochlorine Pesticides and PCBs			
Environmental Solids Sample Preparation	R.J Hill Laboratories	Air dried at 35°C and sieved, <2mm fraction	
Organochlorine/Polychlorinated biphenyls Trace in Soil	R.J Hill Laboratories	Sonication extraction, SPE cleanup, GC & GC-MS analysis	0.001 mg/kg dry wgt
Organochlorine Pesticides Trace in Soil	R.J Hill Laboratories	Sonication extraction, SPE cleanup, GPC cleanup (if required), dual column GC-ECD analysis	0.001 mg/kg dry wgt
Polychlorinated Biphenyls Trace in Soil	R.J Hill Laboratories	Sonication extraction, SPE cleanup, GPC cleanup (if required), GC-MS analysis	0.001 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. 2008 DETAILED RESULTS

Station Locations

Whareama A	1	2	3	4	5	6	7	8	9	10
NZMGEAST	2770710	2770694	2770682	2770668	2770661	2770673	2770685	2770702	2770698	2770691
NZMGNORTH	6017073	6017081	6017087	6017089	6017088	6017083	6017077	6017070	6017065	6017068

Whareama B	1	2	3	4	5	6	7	8	9	10
NZMGEAST	2770091	2770080	2770052	2770053	2770070	2770076	2770095	2770101	2770086	2770074
NZMGNORTH	6017048	6017044	6017030	6017019	6017029	6017035	6017045	6017038	6017030	6017024

APPENDIX 2. 2008 DETAILED RESULTS (CONTINUED)

Physical and chemical results for Whareama Estuary, 18 January 2008.

Site	Reps.	RPD	Salinity	AFDW	TOC	Mud	Sands	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP
		cm	ppt	%					mg/kg							
WhaA	1	1.5	30	2.8	1.5	76.5	23.5	0.1	0.049	10.0	9.2	7.2	11.0	46	860	420
WhaA	2	1.5	30	2.6	1.4	67.7	31.8	0.5	0.044	8.3	7.4	6.7	9.3	41	720	400
WhaA	3	1.5	30	2.3	1.2	59.1	40.9	0.1	0.050	9.2	7.5	6.7	9.4	41	760	430
WhaB	1	3.5	30	2.0	1.1	70.6	29.4	0.1	0.053	10.0	9.2	7.9	11.0	48	890	460
WhaB	2	2.5	30	2.6	1.4	78.5	21.3	0.3	0.045	9.9	8.5	7.6	10.0	46	770	420
WhaB	3	2.5	30	2.1	1.1	71.2	28.8	0.1	0.051	10.0	8.5	7.6	10.0	47	790	410

Parameter	Whareama A	Whareama B
Polychlorinated Biphenyls Trace in Soil (mg/kg dry wgt)		
PCB-101	< 0.0010	< 0.00099
PCB-105	< 0.0010	< 0.00099
PCB-110	< 0.0010	< 0.00099
PCB-114	< 0.0010	< 0.00099
PCB-118	< 0.0010	< 0.00099
PCB-121	< 0.0010	< 0.00099
PCB-123	< 0.0010	< 0.00099
PCB-126	< 0.0010	< 0.00099
PCB-128	< 0.0010	< 0.00099
PCB-138	< 0.0010	< 0.00099
PCB-141	< 0.0010	< 0.00099
PCB-149	< 0.0010	< 0.00099
PCB-151	< 0.0010	< 0.00099
PCB-153	< 0.0010	< 0.00099
PCB-156	< 0.0010	< 0.00099
PCB-157	< 0.0010	< 0.00099
PCB-159	< 0.0010	< 0.00099
PCB-167	< 0.0010	< 0.00099
PCB-169	< 0.0010	< 0.00099
PCB-170	< 0.0010	< 0.00099
PCB-180	< 0.0010	< 0.00099
PCB-189	< 0.0010	< 0.00099
PCB-194	< 0.0010	< 0.00099
PCB-206	< 0.0010	< 0.00099
PCB-209	< 0.0010	< 0.00099
PCB-28 + PCB-31	< 0.0010	< 0.00099
PCB-44	< 0.0010	< 0.00099
PCB-49	< 0.0010	< 0.00099
PCB-52	< 0.0010	< 0.00099
PCB-60	< 0.0010	< 0.00099
PCB-77	< 0.0010	< 0.00099
PCB-81	< 0.0010	< 0.00099

Parameter	Whareama A	Whareama B
Organochlorine Pesticides Trace in Soil (mg/kg dry wgt)		
Aldrin	< 0.0010	< 0.00099
alpha-BHC	< 0.0010	< 0.00099
beta-BHC	< 0.0010	< 0.00099
delta-BHC	< 0.0010	< 0.00099
gamma-BHC (Lindane)	< 0.0010	< 0.00099
cis-chlordane	< 0.0010	< 0.00099
trans-chlordane	< 0.0010	< 0.00099
2,4'-DDD	< 0.0010	< 0.00099
4,4'-DDD	< 0.0010	< 0.00099
2,4'-DDE	< 0.0010	< 0.00099
4,4'-DDE	< 0.0010	0.00099
2,4'-DDT	< 0.0010	< 0.00099
4,4'-DDT	< 0.0010	< 0.00099
Dieldrin	< 0.0010	< 0.00099
Endosulfan I	< 0.0010	< 0.00099
Endosulfan II	< 0.0010	< 0.00099
Endosulfan sulphate	< 0.0010	< 0.00099
Endrin	< 0.0010	< 0.00099
Endrin aldehyde	< 0.0010	< 0.00099
Endrin Ketone	< 0.0010	< 0.00099
Heptachlor	< 0.0010	< 0.00099
Heptachlor epoxide	< 0.0010	< 0.00099
Hexachlorobenzene	< 0.0010	< 0.00099
Methoxychlor	< 0.0010	< 0.00099
Total Chlordane [(cis+trans)* 100/42]	< 0.0020	< 0.0020

APPENDIX 2. 2008 DETAILED RESULTS (CONTINUED)

Epifauna (numbers per 0.25m² quadrat)

Whareama A										
Station	WhaA-01	WhaA-02	WhaA-03	WhaA-04	WhaA-05	WhaA-06	WhaA-07	WhaA-08	WhaA-09	WhaA-10
No. species/quadrat	0	0	0	0	0	0	0	0	0	0
No. individuals/quadrat	0	0	0	0	0	0	0	0	0	0

Whareama B										
Station	WhaB-01	WhaB-02	WhaB-03	WhaB-04	WhaB-05	WhaB-06	WhaB-07	WhaB-08	WhaB-09	WhaB-10
Amphibola crenata Mud snail			1				1	1		
No. species/quadrat	0	0	1	0	0	0	1	1	0	0
No. individuals/quadrat	0	0	1	0	0	0	1	1	0	0

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

Group	Species	AMBI Group	Wha A-01	Wha A-02	Wha A-03	Wha A-04	Wha A-05	Wha A-06	Wha A-07	Wha A-08	Wha A-09	Wha A-10
POLYCHAETA	*Boccardia (Paraboccardia) syrtis*	I	1	3	3					1		
	Simplisetia sp.#1	II	1	1	1			1				
	Cirratulidae sp.#1	IV						1		1		
	Heteromastus filiformis	IV	51	87	80	55	35	32	34	23	10	3
	Nicon aestuariensis	III										
	Scolecolepides benhami	III	2	6	4	13	15	12	12	20	16	34
	Spionidae sp.#1	NA	17	14	6	8	15	9	15	6	4	1
GASTROPODA	*Amphibola crenata*	NA										
BIVALVIA	*Arthritica sp.#1*	NA	10	65	10	4	5	46	3	26	14	4
	Austrovenus stutchburyi	NA										
CRUSTACEA	*Macrophthalmus hirtipes*	NA				4	1	1	2	1		4
INSECTA	Diptera sp.#1	NA										
Total species in sample			6	6	6	5	5	7	5	7	4	5
Total individuals in sample			82	176	104	84	71	102	66	78	44	46

Group	Species	AMBI Group	Wha B-01	Wha B-02	Wha B-03	Wha B-04	Wha B-05	Wha B-06	Wha B-07	Wha B-08	Wha B-09	Wha B-10
POLYCHAETA	*Boccardia (Paraboccardia) syrtis*	I										
	Simplisetia sp.#1	II							1	1		
	Cirratulidae sp.#1	IV										
	Heteromastus filiformis	IV	2	2	1				1			
	Nicon aestuariensis	III	1	1	1							
	Scolecolepides benhami	III	3	20	12	9	7	19	17	17	13	20
	Spionidae sp.#1	NA										
GASTROPODA	*Amphibola crenata*	NA								1		1
BIVALVIA	*Arthritica sp.#1*	NA	67	51	43	29	88	14	47	3	20	37
	Austrovenus stutchburyi	NA	3		1		2	2		1	1	
CRUSTACEA	*Macrophthalmus hirtipes*	NA	1		1	1	2		2			2
INSECTA	Diptera sp.#1	NA			1			1		1		2
Total species in sample			6	4	7	3	4	4	5	6	3	5
Total individuals in sample			77	74	60	39	99	36	68	24	34	62

APPENDIX 3. INFAUNA CHARACTERISTICS

Group and Species		AMBI Group	Details
Polychaeta	*Boccardia (Paraboccardia) syrtis*	I	A small surface deposit-feeding spionid. Prefers low-mod mud content but found in a wide range of sand/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.
	Simplisetia sp.#1 (previously *Ceratonereis*)	II	A scavenger and selective deposit feeding nereid polychaete. Avoids ingesting fine particles. Preyed on by flounders.
	Nicon aestuariensis	III	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.
	Scolecolepides benhami	III	A 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. Prefers low-moderate mud content (<50% mud). A close relative, the larger *Scolecolepides freemani* occurs upstream in some rivers, usually in sticky mud in near freshwater conditions.
	Spionidae sp.#1	?	An unknown spionid polychaete.
	Cirratulidae sp.#1	IV	Subsurface deposit feeder that prefers muddy sands. Small sized, tolerant of slight to unbalanced situations.
	Heteromastus filiformis	IV	Small sized capitellid polychaete. A sub-surface deposit-feeder that lives throughout the sediment to depths of 15 cm, and prefers a muddy-sand substrate. Despite being a capitellid, *Heteromastus* is not opportunistic and does not show a preference for areas of high organic enrichment as other members of this polychaete group do.
Gastropoda	*Amphibola crenata*	NA	A pulmonate gastropod endemic to New Zealand. 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.
Bivalvia	*Arthritica sp.#1*	III	A small sedentary deposit feeding bivalve, preferring a moderate mud content. Lives greater than 2cm deep in the muds.
	Austrovenus stutchburyi	NA	The cockle is a suspension feeding bivalve with a short siphon - lives a few cm from sediment surface at mid-low water situations. Can live in both mud and sand but is sensitive to increasing mud - prefers low mud content. Rarely found below the RPD layer.
Crustacea	*Macrophthalmus hirtipes*	NA	The stalk-eyed mud crab is endemic to New Zealand and prefers water-logged 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 tunneling mud crab, it feeds from the nutritious mud.
Insecta	Diptera sp.#1	NA	Fly or midge larvae - species unknown.

AMBI Sensitivity to Stress 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-signicant 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 eight levels, from 0 to 7.