coastalmanagement

Porirua Harbour

Intertidal Fine Scale Monitoring 2008/09

Prepared
for
**Greater
Wellington
Regional
Council
June
2009**

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Intertidal Fine Scale Monitoring 2008/09

Prepared for
Greater Wellington Regional Council

By

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Cover Photo: Upper Pauatahanui Arm of Porirua Harbour from mouth of Pautahanui Stream.

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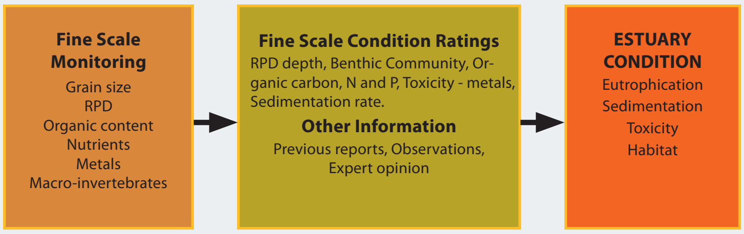
All photos by Wriggle except where noted otherwise.

PORIRUA HARBOUR 2009 - EXECUTIVE SUMMARY

This report summarises the results of the 2009 fine scale monitoring for Porirua Harbour, an 800ha tidal lagoon estuary, and one of the key estuaries in Greater Wellington Regional Council's (GWRC) long-term coastal monitoring programme. This programme uses sediment health as a primary indicator of estuary condition and includes 2 main components, broad scale mapping, and detailed fine scale monitoring. Broad scale mapping is undertaken at 5 yearly intervals and was first undertaken in 2008 and is reported in Stevens and Robertson (2008). Fine scale monitoring was also first undertaken in 2008 (Robertson and Stevens 2008) and subsequently is carried out annually for 3-4 years to establish a baseline and then afterwards at 5 yearly intervals, or as deemed necessary based on estuary condition ratings.

Fine scale monitoring provides detailed information on indicators of chemical and biological condition of the dominant intertidal habitat type in the estuary (i.e. unvegetated intertidal mudflats at low-mid water). The methods used were based on the tools included in the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002), and a number of recent extensions (Robertson and Stevens 2006 and 2008).

This report describes the fine scale results and uses these to apply established estuary "condition ratings" for the major issues facing most NZ estuaries: sedimentation, eutrophication, and toxicity (see diagram below). Disease risk in estuaries, another key issue, is reported on separately by GWRC.



The results of the condition ratings (described in Section 2) are summarised below. These are followed by an overview of the key issues that the ratings raise, and recommendations for future monitoring and management.

SUMMARY OF CONDITION RATINGS - PORIRUA HARBOUR 2008 AND 2009

Issue	Indicator (result)	Porirua (Onepoto) Arm				Pauatahanui Arm			
		Site A		Site B		Site A		Site B	
		2008	2009	2008	2009	2008	2009	2008	2009
Sedimentation	Sedimentation Rate	Baseline Established	VERY LOW	Baseline Established	MODERATE	Baseline Established	Not Measured	Baseline Established	LOW
Eutrophication	Redox Profile	FAIR	FAIR	GOOD	FAIR	GOOD	FAIR	GOOD	GOOD
	Total Organic Carbon (TOC)	GOOD	GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD
	Total Nitrogen	LOW-MOD ENRICHMENT	LOW-MOD ENRICHMENT	VERY GOOD	VERY GOOD	LOW-MOD ENRICHMENT	LOW-MOD ENRICHMENT	VERY GOOD	VERY GOOD
	Total Phosphorus	LOW-MOD ENRICHMENT	LOW-MOD ENRICHMENT	VERY GOOD	VERY GOOD	LOW-MOD ENRICHMENT	LOW-MOD ENRICHMENT	VERY GOOD	VERY GOOD
Toxins	Cadmium	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD
	Chromium	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD
	Copper	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD
	Nickel	GOOD	GOOD	VERY GOOD	VERY GOOD	GOOD	GOOD	VERY GOOD	VERY GOOD
	Lead	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD
	Zinc	GOOD	GOOD	GOOD	GOOD	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD
Range of Issues	Macro-invertebrates	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD

EXECUTIVE SUMMARY (CONTINUED)

FINE SCALE MONITORING RESULTS

The fine scale results of the dominant intertidal habitat in each arm (represented by two sites in the Onepoto (Porirua) Arm and two in the Pauatahanui Arm) showed:

- **RPD Depth.** RPD depth, which is a key indicator of sediment oxygenation, was relatively shallow (<3cm) at most sites in 2009 (i.e. a "fair" condition rating) and tended to be slightly shallower than in 2008.
- **Organic Matter**. The indicator of organic enrichment (TOC) at all four sites was at low concentrations (<1%) at all sites and met the "very good" condition rating. Significantly lower TOC concentrations were measured in 2009 compared with 2008, which are likely to be the result of a change in analytical methods.
- **Nutrients (Total Nitrogen and Phosphorus**). TN and TP (key nutrients in the eutrophication process) were present in 2009 at concentrations similar to those measured in 2008. Concentrations were in the "low to moderate enrichment" category at the two muddier sites (PorA and PauA) but at the two sandier sites (PorB and PauB), they were in the "very good" category.
- **Benthic Macrofauna**. Overall, the benthic community condition was "unbalanced", giving it a "good" classification, i.e. a community with elevated numbers of organisms that tolerate moderate mud and organic enrichment levels.
- **Grain Size**. The two fine scale indicators of increased muddiness in the estuary were grain size (% mud, sand, gravel), and sedimentation rate (mm of sediment deposited/yr). Grain size results showed that all sites in 2009 were dominated by sandy sediments (77-99% sand) but the mud fraction was also significant (1-14% mud content). Similar results were recorded in 2008.
- **Sedimentation Rate**. A mean sedimentation rate of 0.75 to 7mm/13 months was measured at the 4 sites. Such rates fit within the "very low" to "moderate" rating categories. The highest rate (7 mm/yr) was recorded in the upper estuary of the Porirua Arm (opposite the Polytech). However, within this site (which is represented by two sediment plates), the variability was high (0-14mm).
- **Metals** (total recoverable Cd, Cr, Cu, Ni, Pb, Zn). Heavy metals, an indicator of potential toxicants, were at low to very low concentrations at all four intertidal sites, with all values well below the ANZECC (2000) ISQG-Low trigger values and 2009 values similar to those measured in 2008.

ESTUARY ISSUES

ISSUE RATING EUTROPHICATION
MODERATELY EUTROPHIC

ISSUE RATING SEDIMENTATION
LOW TO MODERATE SEDIMENTATION

ISSUE RATING TOXICITY
LOW TOXICITY

A number of conclusions can be made from these results in relation to the key estuary issues that fine scale monitoring addresses, i.e. sedimentation, eutrophication and toxicity.

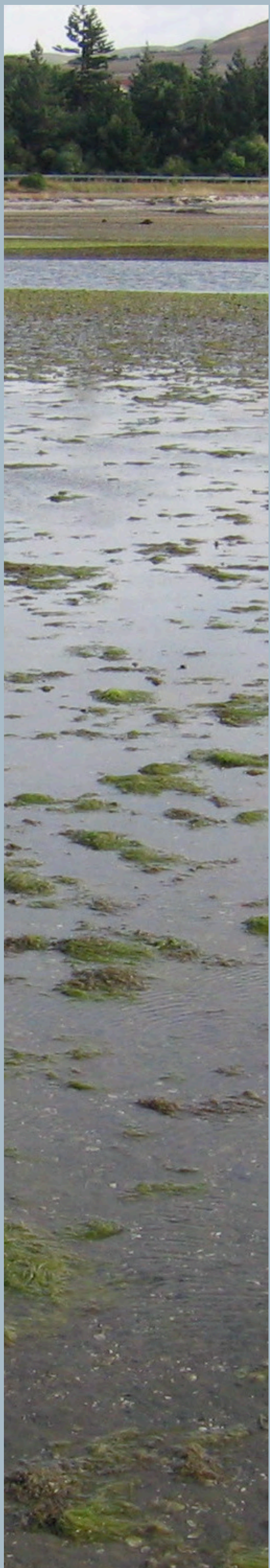
- **Eutrophication.** The major indicators of organic enrichment continue to support the findings of the 2008 broad scale report that the estuary was moderately enriched or in a moderately eutrophic state. Such conclusions were inferred from the relatively shallow RPD (i.e. depth of anoxic layer), the "unbalanced" nature of the benthic invertebrate community, and the low-moderate nutrient concentrations. Such enrichment, although not yet a major problem, does indicate a need for caution, particularly in relation to factors that could increase nutrient and fine sediment concentrations in the Harbour.
- **Sedimentation**. After the first year, sedimentation rates at most sites were low. However, excessive rates (14mm in 13 months) were measured at one of the two plates in the upper Porirua Arm. Such variability indicates a need for more sedimentation plates at this site to more adequately represent this patchiness.
- **Toxicity**. The results of 2008 and 2009 intertidal monitoring indicate relatively low metal concentrations and an overall "low" toxicity rating.

EXECUTIVE SUMMARY (CONTINUED)

MONITORING	Porirua Harbour has been identified by GWRC as a high 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 and 2009 monitoring results and condition ratings, it is recommended that monitoring continue as follows: **Fine Scale Monitoring**. Continue with the current programme; to establish three to four years of annual baseline monitoring in Porirua Harbour followed by monitoring at five yearly intervals or as deemed necessary based on the condition ratings. **Sedimentation Rate Monitoring**. Measure the depths of the existing sediment plates in January 2010 while doing the fine scale monitoring. Following the 2010 monitoring, it is recommended that the depth of all plates be measured annually thereafter or whenever fine scale monitoring is undertaken. In addition, it is recommended that additional sediment plates be deployed in upper Porirua Arm (Polytech site) in 2010 to better account for the patchiness of sediment deposition at this important site.
MANAGEMENT	The combined results of the 2008 and 2009 fine scale monitoring reinforces the need for management of the following inputs to the estuary: • nutrients, • fine sediment, and • toxicants. It is understood that GWRC and Porirua City Council, are currently working together to identify catchment nutrient, toxin and sediment sources and "hotspots", and to implement Best Management Practices (BMPs) for reducing nutrient, toxin and sediment mobilisation and runoff to surface and groundwater. The findings of this report provide support for such management.

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 coastline and estuaries to establish priorities for a long-term coastal monitoring programme for the region (Robertson and Stevens 2007a, 2007b and 2007c). 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 [Onepot (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 Porirua Harbour monitoring programme consists of three components:

1. **Ecological Vulnerability Assessment** of the estuaries to major issues and appropriate monitoring design. This component has been completed for Porirua Harbour and is reported on in Robertson and Stevens (2007b).
2. **Broad scale habitat mapping,** (EMP approach). This component, which documents the key habitats within the estuary and changes to these habitats over time, is reported separately in Stevens and Robertson (2008).
3. **Fine scale physical, chemical and biological monitoring**, including sedimentation plate deployment (EMP approach). This component, which provides detailed information on estuary condition, began in January 2008 (Robertson and Stevens 2008). The second year of monitoring was undertaken in January 2009 and is the subject of the current report.

Porirua Harbour is a large, shallow, well flushed "tidal lagoon" type estuary consisting of two arms, Onepoto (herewith referred to as Porirua) Inlet and Pauatahanui Inlet. It has high uses and ecological values and provides a natural focal point for the thousands of people that live near or visit its shores. The harbour has been extensively modified over the years, particularly the Porirua Inlet where the once vegetated arms have been reclaimed, and now most of the inlet is lined with rockwalls. The Pauatahanui Inlet is much less modified and has extensive areas of saltmarsh, a large percentage of which have been improved through local community efforts. Catchment landuse is dominated by urban use in the Porirua Inlet and by grazing in the steeper Pauatahanui Inlet catchment, although urban (residential) development is significant in some areas.

The current report documents the following;

- The results of the fine scale monitoring undertaken in January 2009.
- Sedimentation rates over the last year in Porirua Harbour.
- Condition ratings for the Porirua Harbour based on the 2009 fine scale results. A suggested monitoring or management response is linked to each condition rating.

This report is the second of a series of three to four, which will characterise the baseline fine scale conditions in the estuary over a 3-4 year period. The results will help determine the extent to which the estuary is affected by major estuary issues (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. Coastal Monitoring Tools (Wriggle Coastal Management).

Resource	Tools for Monitoring and Management
Estuaries	Estuary vulnerability matrix. Broad scale estuary and 200m terrestrial margin habitat mapping. Fine scale estuary monitoring. Sedimentation rate measures (using plates buried in sediment). Historical sedimentation rates (using radio-isotope ageing of sediment cores). Macroalgae and seagrass mapping (reported as separate GIS layers). Condition ratings for key indicators. Georeferenced digital photos (as a GIS layer). Upper estuary monitoring and assessment.
Beaches, Dunes	Beach and dune vulnerability matrix. Broad scale beach, dune and terrestrial margin mapping. Fine scale beach monitoring. Condition ratings for key indicators. Georeferenced digital photos (as a GIS layer).
Rocky Shores	Rocky shore vulnerability matrix. Broad scale rocky shore and terrestrial margin mapping. Fine scale rocky shore monitoring. Georeferenced digital photos (as a GIS layer).

Table 2. Summary of the major issues affecting most NZ river mouth estuaries.

Key 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.
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 *Enteromorpha, 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 gastroenteritis, salmonellosis, hepatitis A, and noroviruses.
Toxic Contamination	In the last 60 years, New Zealand has seen a huge range of synthetic chemicals introduced to estuaries through urban and agricultural stormwater runoff, industrial discharges and air pollution. Many of them are toxic in minute concentrations. Of particular concern are polycyclic aromatic hydrocarbons (PAHs), heavy metals, polychlorinated biphenyls (PCBs), and pesticides. These chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to people and marine life.
Habitat Loss	Estuaries have many different types of habitats including shellfish beds, seagrass meadows, saltmarshes (rushlands, herbfields, reedlands etc.), forested wetlands, beaches, river deltas, and rocky shores. The continued health and biodiversity of estuarine systems depends on the maintenance of high-quality habitat. Loss of habitat negatively affects fisheries, animal populations, filtering of water pollutants, and the ability of shorelines to resist storm-related erosion. Within New Zealand, habitat degradation or loss is common-place with the major causes cited as sea level rise, population pressures on margins, dredging, drainage, reclamation, pest and weed invasion, reduced flows (damming and irrigation), over-fishing, polluted runoff and wastewater discharges.

1. Introduction (Continued)

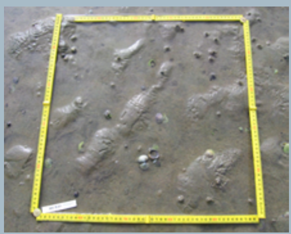
Table 3. Summary of the broad and fine scale EMP indicators.

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 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.

Figure 1. Location of sedimentation and fine scale monitoring sites in Porirua Harbour (Photo Google Earth).

2. METHODS

FINE SCALE MONITORING



Quadrat for epifauna sampling.

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 two per estuary) are selected and sediment samples collected and analysed for the following variables:

- Salinity, Oxygenation (Redox Potential Discontinuity - RPD), Grain size (% mud, sand, gravel).
- Total organic carbon (TOC).
- Nutrients: Total nitrogen (TN), Total phosphorus (TP).
- Heavy metals: total recoverable Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Nickel (Ni) and Zinc (Zn).
- Macroinvertebrate abundance and diversity (infauna and epifauna)

For the Porirua Harbour, four fine scale sampling sites (Figure 1, Appendix 1), were selected in unvegetated, mid-low water habitat of the dominant substrate type (avoiding areas of significant vegetation and channels). At each site, a 60m x 30m 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.
- For the Porirua and Pauatahanui Arms, three samples from each site (each a composite from four plots) of the top 20mm of sediment (each approx. 250gms) were collected adjacent to the infauna cores.
- All samples were kept in a chillybin. Chilled samples were sent to R.J. Hill Laboratories for analysis (details in Appendix 1) for:
    - Grain size/Particle size distribution (% mud, sand, gravel).
    - Nutrients (TN and TP).
    - Total organic carbon (TOC).
    - Trace metal contaminants (total recoverable Cd, Cr, Cu, Ni, Pb, Zn). Analyses were based on whole (sub 2mm) sample fractions which are not normalised to allow direct comparison with ANZECC (2000) sediment quality guidelines.
- 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.
- In addition, salinity of the overlying water was measured at low tide at each site 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)

Sampling RPD layer.

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, plastic bags were transported to a commercial laboratory (Gary Stephenson, Coastal Marine Ecology Consultants) for sieving, counting and identification. Each core was washed through a 0.5mm nylon mesh bag, with the infauna retained and preserved in 70% isopropyl alcohol.

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. Locations (Figure 1) and methods for deployment are presented in the 2008 report (Robertson and Stevens 2008a)

CONDITION RATINGS

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 Porirua Estuary (based on the ratings developed for Southland’s estuaries - Robertson & Stevens 2006, 2008b).

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, 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.

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).

RATING
Very Good
Good
Fair
Poor
Early Warning Trigger

2. Methods (Continued)

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 Porirua, 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

Total Phosphorus

In shallow estuaries like Porirua 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

2. Methods (Continued)

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. However, although the AMBI is particularly useful in detecting temporal and spatial impact gradients care must be taken in its interpretation in some situations. 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. The same can occur when studying low-salinity locations (e.g. the inner parts of estuaries), some naturally-stressed locations (e.g. naturally organic matter enriched bottoms; *Zostera* beds producing dead leaves; etc.), or some particular impacts (e.g. sand extraction, for some locations under dredged sediment dumping, or some physical impacts, such as fish trawling).

The equation to calculate the AMBI Biotic Coefficient (BC) is a s follows;

$$BC = \{(0 \times \%GI) + (1.5 \times \%GII) + (3 \times \%GIII) + (4.5 \times \%GIV) + (6 \times \%GV)\}/100.$$

The characteristics of the above-mentioned ecological groups (GI, GII, GIII, GIV and GV) are summarised in Appendix 3.

BENTHIC COMMUNITY CONDITION RATING			
ECOLOGICAL RATING	DEFINITION	BC	RECOMMENDED RESPONSE
HIGH	Unpolluted	0-1.2	Monitor at 5 year intervals after baseline established
GOOD	Slightly polluted	1.2-3.3	Monitor 5 yearly after baseline established
MODERATE	Moderately polluted	3.3-5.0	Monitor 5 yearly after baseline est. Initiate ERP
POOR	Heavily polluted	5.0-6.0	Post baseline, monitor yearly. Initiate ERP
BAD	Azoic (devoid of life)	>6.0	Post baseline, monitor yearly. Initiate ERP
Early Warning Trigger	Trend to slightly polluted	>1.2	Initiate Evaluation and Response Plan

3. RESULTS AND DISCUSSION

OVERVIEW

The fine scale indicator results for the dominant intertidal habitat in each arm (represented by two sites in the Porirua Arm and two in the Pauatahanui Arm) are presented in the following section, with results summarised in Tables 4 and 5. Detailed results are presented in Appendix 2.

Table 4. Physical and chemical results (means) for Porirua Harbour, January 2008 and 2009.

Year	Site	Reps.	RPD	Salinity	TOC	Mud	Sand	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP
			cm	ppt	%				mg/kg							
2008	Por A	10	2-3	30	1.33	9.96	88.13	1.90	0.028	11.3	5.1	6.1	8.4	39.4	685	442
	Por B	10	5	27	0.60	4.03	94.42	1.57	0.041	5.1	3.6	9.5	3.6	59.9	504	158
	Pau A	3	4	30	1.32	12.23	81.60	6.20	0.029	10.7	4.9	6.5	8.8	36.7	823	447
	Pau B	3	3	30	0.58	4.50	90.17	5.33	0.020	4.7	2.3	4.7	3.9	23.0	546	150
2009	Por A	3	2-3	30	0.39	9.23	89.30	1.47	0.034	12.3	5.0	8.5	6.7	41.0	643	397
	Por B	3	2	28	0.21	5.73	85.80	8.43	0.046	5.6	3.9	3.7	8.9	57.7	<500	147
	Pau A	3	2	30	0.38	9.93	81.47	8.57	0.025	11.0	4.6	7.7	6.1	35.0	700	437
	Pau B	3	4	30	0.23	4.43	87.43	8.17	0.019	4.5	2.0	3.4	4.5	21.0	<553	137

Table 5. Macrofauna results (means) for Porirua Harbour, January 2008 and 2009.

Estuary	Site	Reps.	Infauna				Epifauna			
			Mean Abundance m^{-2}		Mean No. Species/core		Mean Abundance/quadrat		Mean No. Species/quadrat	
			2008	2009	2008	2009	2008	2009	2008	2009
Porirua	Por A	10	7417	10103	11.9	22.1	3.1	40	1.8	3
	Por B	10	7222	7455	12.6	13.3	3.3	3.5	1.6	1.4
Pauatahanui	Pau A	10	7012	7388	13.1	20.7	16.0	9	5.0	2.3
	Pau B	10	6390	9788	13.4	17.8	27.4	6.6	4.5	3.3

SEDIMENTATION

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. 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 Stevens and Robertson 2008).

GRAIN SIZE

Grain size [% mud (<0.063mm fraction), sand (0.063-2mm fraction), gravel (>2mm fraction)] measurements provide a good indication of the muddiness of a particular site. The 2008 and 2009 monitoring results (Figure 2) show that although all sites were dominated by sandy sediments (77-99% sand), the mud fraction was also significant (1-14% mud content), particularly near the mouth at the two lower estuary sites PorA and PauA). A grain size condition rating has yet to be developed for the Porirua Harbour.

Figure 2. Grain size at 4 sites, Jan 2008 and Jan 2009.

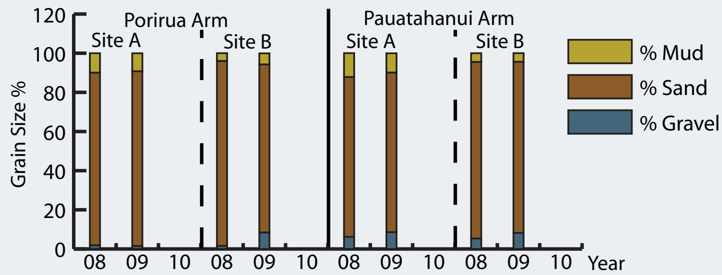
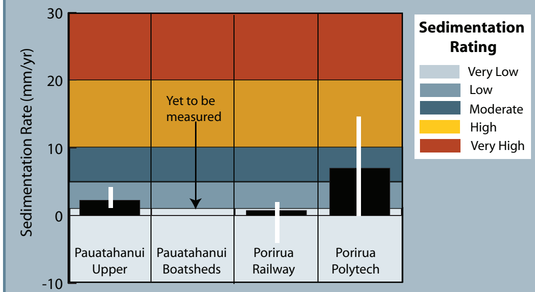


Figure 3. Sedimentation rate (mean and range) December 2007 to January 2009, Porirua Estuary.



RATE OF SEDIMENTATION

Fifteen sedimentation plates were deployed in the estuary in December 2007 to enable long term monitoring of sedimentation rates (Figure 1).

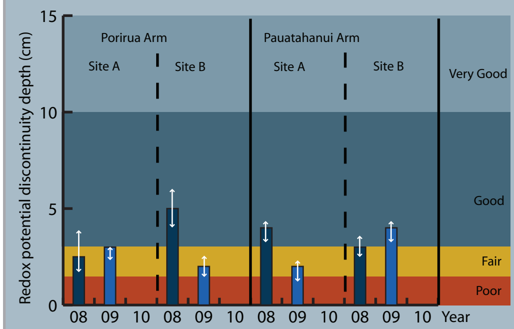
Monitoring of the overlying sediment depth above each plate after thirteen months of burial was undertaken during the period 15-16 January 2009.

The results indicated a mean sedimentation rate of 0.75 to 7mm/13 months (Figure 3). Such rates fit within the "very low to moderate" categories. The highest rate (7mm/yr) was recorded in the upper estuary of the Porirua Arm (opposite the Polytech). However, within this site (which is represented by 2 sediment plates), the variability was high (0-14mm) which indicates a need for deployment of additional sedimentation plates to more adequately represent this patchiness. The lowest rate (0.75 mm/13 months) was recorded in the lower Porirua Arm (opposite the Railway Station at Mana).

EUTROPHICATION

Eutrophication is the process where water bodies receive excess nutrients that stimulate excessive plant growth. In estuaries like the Porirua, 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 depth, sediment organic matter, nitrogen and phosphorus concentrations, and the community structure of certain sediment-dwelling animals. The broad scale indicators (reported in Stevens and Robertson 2008) are the percentages of the estuary covered by macroalgae and soft muds.

Figure 4. RPD depth (mean and range) December 2007 to January 2009, Porirua Estuary.



REDOX POTENTIAL DISCONTINUITY DEPTH

RPD depth, which is a key indicator of sediment oxygenation, was relatively shallow at most sites (Figure 4, and Table 4). In terms of 2009 RPD condition ratings, both the sites in the Porirua Arm and the lower Pauatahanui site (PauA) fitted the "fair" rating. The upper Pauatahanui Arm site (PauB) fitted the "good" rating.

Figure 5 shows the sediment profiles and RPD depths at each of 4 sampling sites. The figure also indicates the likely benthic community (adapted from Pearson and Rosenberg 1978) that is supported at each site based on the measured RPD depth. The results show that RPD averaged 2cm at PauA (opposite the Mana Boatsheds) and PorB (opposite the Polytech in Porirua). Such conditions indicated that the benthic invertebrate community at these sites were likely to have a slightly lower abundance and diversity than normal communities. At PorA (opposite the Mana Railway Station) RPD was 2-3cm and likely to be represented by a transitional benthic community with fluctuating populations. At PauB (upper Pauatahanui Arm) RPD was 4cm and likely to be represented by a stable-normal community.

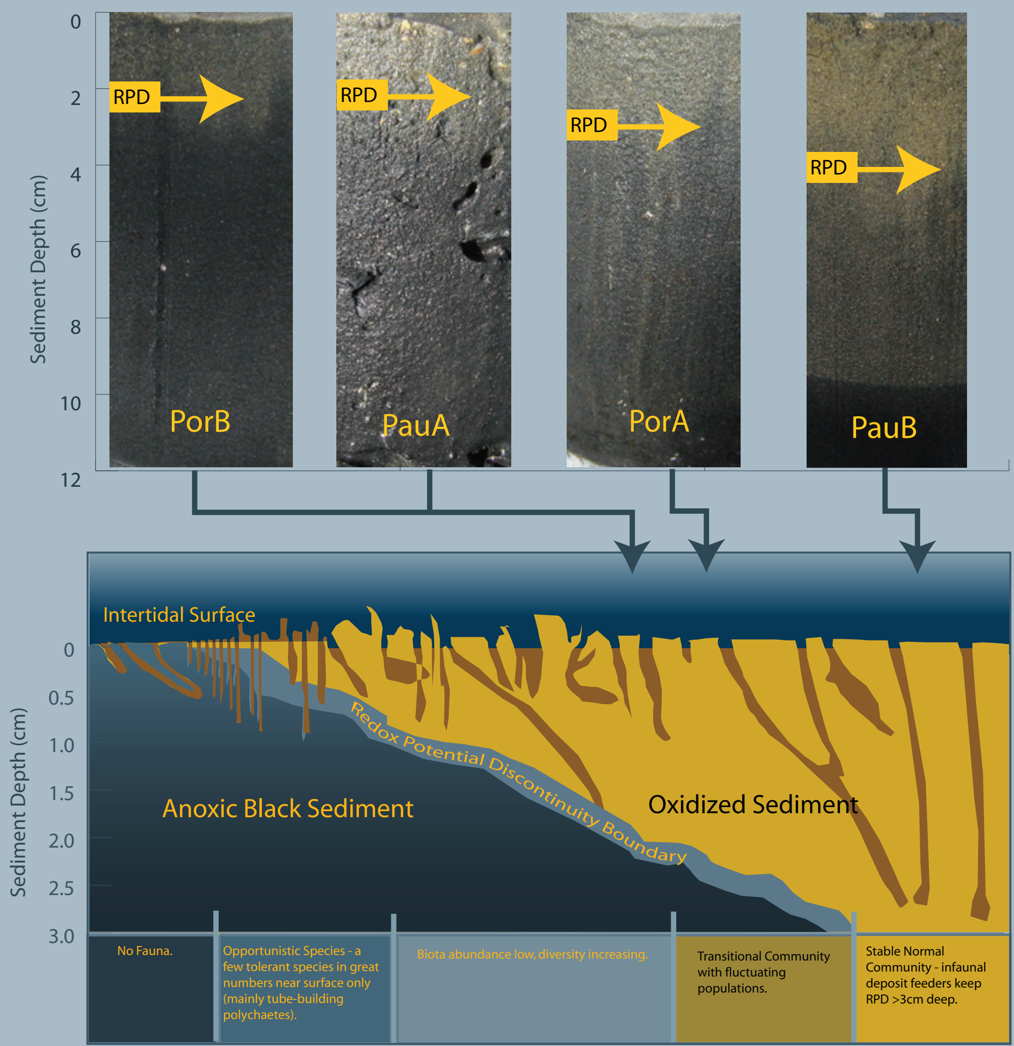
3. Results and Discussion (Continued)

Compared with RPD results in January 2008, the RPD values at PorB and PauA in January 2009 were significantly lower and therefore signified a reduced level of sediment oxygenation at these two sites. 2009 RPD values at the other two sites were similar to those measured in 2008.

Overall, the key finding of the RPD profiles was that the sediments were well to moderately oxygenated as inferred from the following observations;

- RPD values were fair to good at all sites (1-6cm)
- Numerous infauna feeding voids and burrows were present below the RPD.
- The sediments at each of the four sites were dominated by sands (but with a significant mud component).

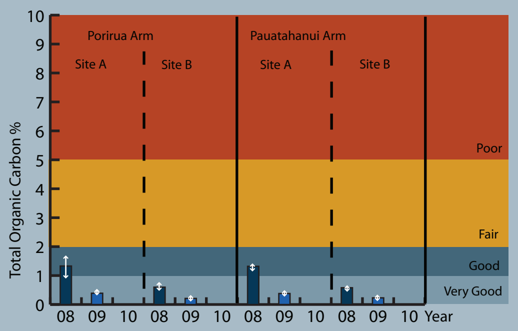
Figure 5. Porirua Harbour sediment profiles and RPD depths at each of 4 sampling sites.



Note. The figure also indicates the likely benthic community (adapted from Pearson and Rosenberg 1978) that is supported at each site based on the measured RPD depth.

3. Results and Discussion (Continued)

Figure 6. Total organic carbon (mean and range) at 4 intertidal sites, Jan 2008 and Jan 2009.



Macroalgal cover PauB 2008 (left) and 2009 (right).

Figure 8. Total phosphorus (mean and range) at 4 intertidal sites, Jan 2008 and Jan 2009.

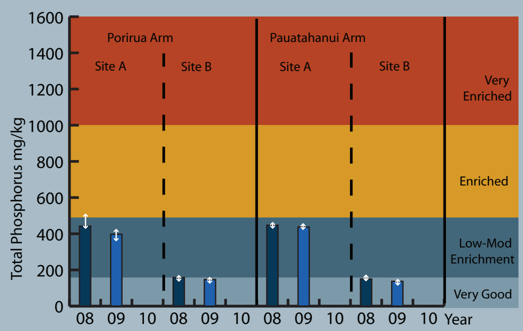
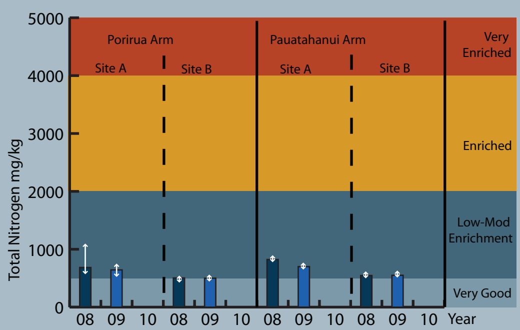


Figure 9. Total nitrogen (mean and range) at 4 intertidal sites, Jan 2008 and Jan 2009.



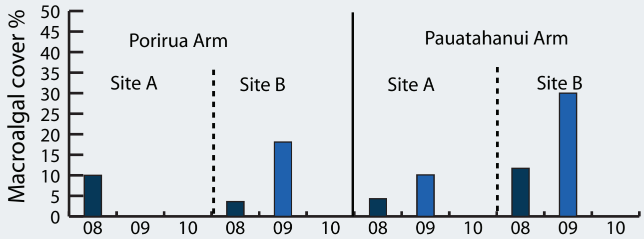
ORGANIC MATTER (TOC)

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

The indicator of organic enrichment (TOC) at all four sites (Figure 6) was at low concentrations (<1%) at all sites and met the "very good" condition rating. Significantly lower TOC concentrations were measured in 2009 compared with 2008, which are likely to be the result of over-estimation in 2008. In 2008, ash free dry weight and a standard conversion factor were used to estimate TOC. In 2009, TOC was measured directly.

Also of interest in relation to the potential for increased sediment organic matter in the future, was the increased cover of surface macroalgae at the fine scale sites in 2009 compared with 2008 (*Enteromorpha* and *Gracilaria* sp.) at all sites except PorA in 2009 (Figure 7 and margin photo).

Figure 7. Percentage macroalgal cover at 4 intertidal sites, Jan 2008 and Jan 2009.



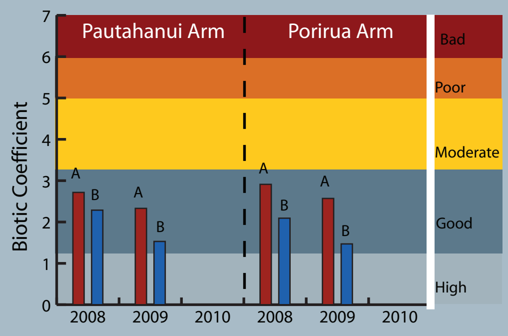
TOTAL PHOSPHORUS

Total phosphorus (a key nutrient in the eutrophication process) was present in the "low to moderate enrichment" category (Figure 8) at the two muddier sites in each arm (mean 397 and 437mg/kg at PorA and PauA), but at the two sandier sites (PorB and PauB), it was in the "very good" category (mean 147 and 137mg/kg respectively). These 2009 results were similar to those measured in 2008.

TOTAL NITROGEN

Like phosphorus, total nitrogen (the other key nutrient in the eutrophication process) was at the "low to moderate enrichment" category (Figure 9) at the two muddier sites in each arm (mean 643mg/kg at PorA and 700mg/kg at PauA), but at the two sandier sites (PorB and PauB), it was in the "very good" category (mean <500 and <550mg/kg respectively).

Figure 10. Macroinvertebrate rating, sites A and B, 2008, 2009.



SEDIMENT BIOTA

The benthic invertebrate community condition (a key indicator of response to both man-made and natural stressors) in the Porirua Harbour showed a consistent small improvement in 2009 compared with 2008. As expected, based on the "good" sediment ratings for nutrients and organic carbon, the macro-invertebrate rating for all sites was "good" (Figure 10), signifying a diverse but unbalanced community. The unbalanced nature is attributed to an increasing abundance of species that tolerate moderate organic enrichment (i.e. surface deposit feeding species such as tube-building spionid polychaetes), as well as those that tolerate high levels of enrichment (mainly small-sized, sub-surface deposit feeding polychaetes such as *Heteromastus*). Such a benthic community rating is not unexpected given the highly developed catchment and the moderate eutrophication risk rating of the harbour (Robertson and Stevens 2008a).

The community at all four sites also included a wide range of species (33-42 species recorded in the 10 cores taken at each site in 2008 and an even wider range, 27-42 species in 2009). Compared with the intertidal mudflats in other NZ estuaries that drain developed catchments, the community diversity was relatively high (Figure 11). Similarly, the overall community abundance at all four sites in Porirua Harbour was moderate at 7,000-10,000m^{-2} for both 2008 and 2009 (Figure 12) compared with other NZ estuaries.

Figure 11. Mean number of macrofauna species, Porirua Harbour (2008 and 2009) compared with other NZ estuaries (Source Robertson et al. 2002, Robertson and Stevens 2006).

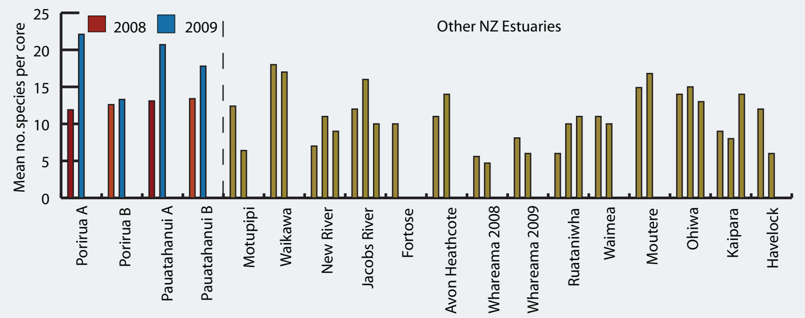
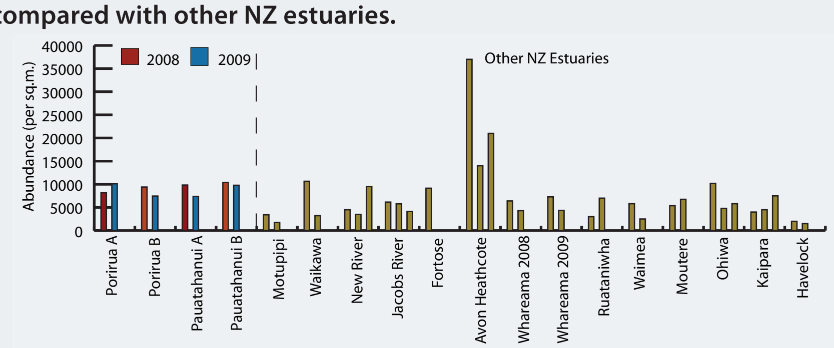
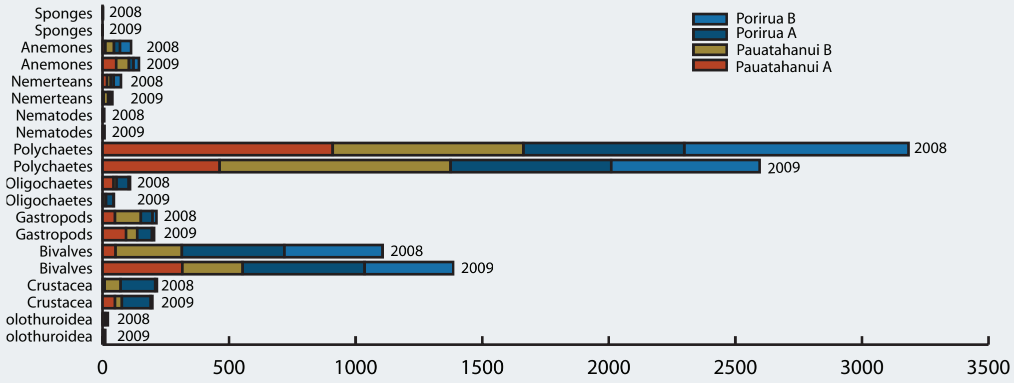


Figure 12. Mean total abundance of macrofauna, Porirua Harbour (2008 and 2009) compared with other NZ estuaries.



Like other NZ estuaries, the intertidal benthic community at all four sites (for both 2008 and 2009) was dominated in terms of abundance by polychaetes (>50%), followed by bivalves, crustaceans and gastropods (Figure 13).

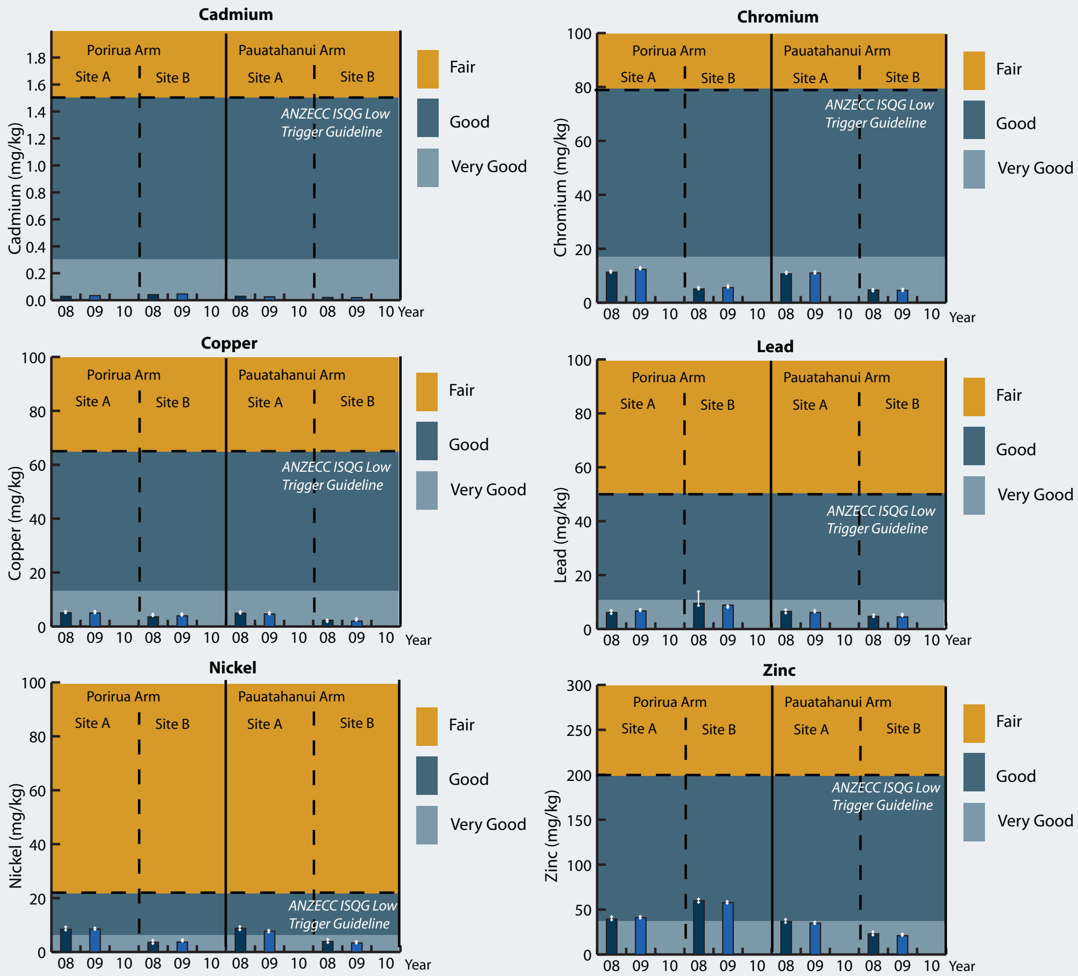
Figure 13. Major macrofauna groups, Porirua Harbour (2008 and 2009)



METALS

Heavy metals (total recoverable Cd, Cr, Cu, Ni, Pb, Zn), used as an indicator of potential toxicants, were at low to very low concentrations at all four intertidal sites, with all values below the ANZECC (2000) ISQG-Low trigger values (Figure 14). Results for 2008 and 2009 were similar at each site. Metals met the "very good" rating for cadmium, chromium, copper and lead at all sites, zinc in the two Pauatahanui sites and nickel at the two upper estuary sites (PorB and PauB). Metals met the "good" rating for nickel at the two lower estuary sites (PorA and PauB) and zinc at the two Porirua Arm sites.

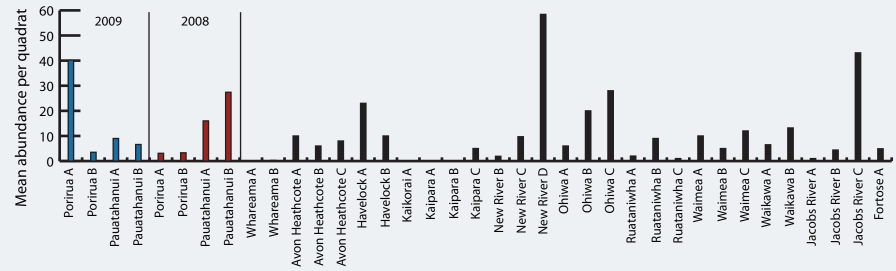
Figure 14. Total recoverable metals (mean and range) at 4 intertidal sites, Jan 2008 and Jan 2009.



EPIFAUNA

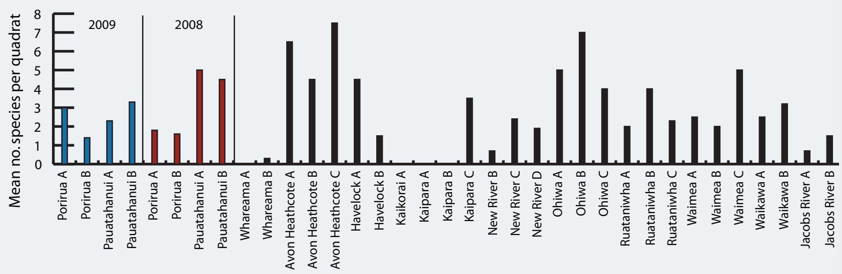
Visible surface dwelling organisms (epifauna) were also recorded using quadrats rather than the much smaller cores used to sample the whole benthic community (i.e. infauna and epifauna). These results, although not used in the benthic community index, demonstrate the typical highly variable nature of epifauna communities. In both 2008 and 2009, epifauna were both more abundant and more diverse in the Pauatahanui Arm compared with the Porirua Arm (Figures 15 and 16), except for the Site PorA (opposite Mana Railway) in 2009 when large numbers of cockles were visible on the surface. Such exposure of cockle beds is a common occurrence in estuaries and can occur as a result of strong winds and bottom currents. Epifauna abundance and species diversity in the Pauatahanui Arm were much less in 2009 than in 2008.

Figure 15. Mean abundance of epifauna per quadrat - Porirua Harbour and other NZ estuaries (source Robertson et al. 2002, Robertson and Stevens 2006).



In addition, the results show that, compared with other NZ estuaries with developed catchments, epifauna abundance and diversity in the Pauatahanui Arm was moderate to high but in the upper Porirua Arm it was more variable.

Figure 16. Mean number of epifauna species per quadrat - Porirua Harbour and other NZ estuaries (source Robertson et al. 2002, Robertson and Stevens 2006).



In the Pauatahanui Arm, the epifauna included a typical array of shellfish including cockles, whelks, topshells, limpets, spire shells and bubble shells, as well as the mudflat anemone. In the Porirua Arm, the epifauna was less diverse and included cockles, whelks, topshells, limpets and spire shells.

4. CONCLUSIONS

In conclusion, the second year of intertidal fine scale monitoring results for a range of physical, chemical and biological indicators of estuary condition show that the dominant intertidal habitat in Porirua Harbour was unvegetated muddy sand and was generally in "good" to "moderate" condition. In relation to the key issues addressed by the fine scale monitoring, that is sedimentation, eutrophication and toxicity, the results are similar to those found in the first year of the baseline (2008).

That is:

- A moderately eutrophic estuary, with low-moderate nutrients (TN and TP) and organic content, and a relatively shallow RPD layer at all sites.
- Low-moderate sedimentation in the intertidal zone.
- Low intertidal sediment toxicity (based on heavy metal data). It must be noted however, that more elevated sediment toxicity may be present in localised areas.

5. MONITORING

Porirua Harbour has been identified by GWRC as a high 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 and 2009 monitoring results and condition ratings, it is recommended that monitoring continue as follows:

Fine Scale Monitoring.

Continue with the current programme; to establish three to four years of annual baseline monitoring in Porirua Harbour, followed by monitoring at five yearly intervals or as deemed necessary based on the condition ratings.

Sedimentation Rate Monitoring.

Measure the depths of the existing sediment plates in January 2010 while doing the fine scale monitoring. Following the 2010 monitoring, it is recommended that the depth of all plates be measured annually thereafter or whenever fine scale monitoring is undertaken. In addition, it is recommended that additional sediment plates be deployed in upper Porirua Arm (Polytech site) in 2010 to better account for the patchiness of sediment deposition at this important site.

6. MANAGEMENT

The combined results of the 2008 and 2009 fine scale monitoring reinforces the need for management of the following inputs to the estuary:

- nutrients,
- fine sediment, and
- toxicants.

It is understood that GWRC and Porirua City Council, are currently working together to identify catchment nutrient, toxin and sediment sources and "hotspots", and to implement Best Management Practices (BMPs) for reducing nutrient, toxin and sediment mobilisation and runoff to surface and groundwater. The findings of this report provide support for such management.

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.

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.M., and Stevens, L. 2006. Southland Estuaries State of Environment Report 2001-2006. Prepared for Environment Southland. 45p plus appendices.

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

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

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

Robertson, B.M, and Stevens, L. 2008. Motupipi Estuary 2008 - Fine Scale Monitoring. Prepared for Tasman District Council. 20p.

Robertson, B.M, and Stevens, L. 2008a. Porirua Harbour - Fine Scale Monitoring 2007/08. Prepared for Greater wellington Regional Council. 32p.

Robertson, B.M., and Stevens, L. 2008b. Waikawa Estuary - Fine scale Monitoring 2007/08. Prepared for Environment Southland. 32p.

Stevens, L. and Robertson, B.M. 2008. Porirua Harbour; Broad Scale Habitat Mapping 2007/08. Prepared for Greater Wellington Regional Council. 29p.

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. 2009 DETAILED RESULTS

Physical and chemical results for Porirua Harbour, 15-16 January 2009.

	Site	Rep.*	RPD	Salinity	TOC	Mud	Sands	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP
			cm	ppt@15^{0}C	%				mg/kg							
Porirua Arm	Por A	1-4	3	30	0.32	10.9	88.6	0.5	0.035	13	5	8.9	6.8	43	540	410
	Por A	5-8	3	30	0.38	10.3	87.1	2.6	0.035	12	5	8.4	6.9	41	650	400
	Por A	9-10	2	30	0.46	6.5	92.2	1.3	0.031	12	5.1	8.2	6.3	39	740	380
	Por B	1-4	2	28	0.27	6.8	82	11.1	0.054	5.8	5.7	3.9	9.6	63	<500	150
	Por B	5-8	3	28	0.17	5.2	90.3	4.5	0.046	5.5	3.1	3.7	8.7	57	<510	150
	Por B	9-10	2	28	0.18	5.2	85.1	9.7	0.039	5.5	3.1	3.5	8.3	53	<510	140
Pautahanui Arm	Pau A	1-4	2	30	0.39	8.9	85.2	5.9	0.022	11	4.7	7.7	6.5	36	680	450
	Pau A	5-8	2	30	0.35	11.5	82.3	6.2	0.03	11	4.6	7.7	6	34	730	430
	Pau A	9-10	1	30	0.41	9.4	76.9	13.6	0.023	11	4.6	7.7	5.8	35	690	430
	Pau B	1-4	4	30	0.2	6.7	90.1	3.2	0.016	4.1	1.8	3.1	4	19	600	120
	Pau B	5-8	4	30	0.24	5.0	80.9	14.1	0.022	4.6	2	3.4	4.5	21	560	130
	Pau B	9-10	3	30	0.25	1.6	91.3	7.2	0.02	5	2.2	3.6	4.9	23	<500	160

* composite samples

Sediment Plate Depths (mm).

Estuary Arm	Site	13/12/07	15/1/09	Sed. Rate (mm/13mths)
Pauatahanui	Upper East Arm	181	182	1
	Upper East Arm	215	218	3
	Upper East Arm	182	186	4
	Upper East Arm	176	177	1
	Paremata Boatsheds	Not measured	171	-
	Paremata Boatsheds	Not measured	213	-
	Paremata Boatsheds	Not measured	232	-
	Paremata Boatsheds	Not measured	234	-
Porirua	Lower (Railway)	168	164	-4
	Lower (Railway)	150	152	2
	Lower (Railway)	152	155	3
	Lower (Railway)	93	95	2
	Upper (Polytech d/s)	237	237	0
	Upper (Polytech u/s)	230	244	14
	Western Subtidal	120	Not measured	-

APPENDIX 2. 2009 DETAILED RESULTS (CONTINUED)

Station Locations

Porirua A	PorA-01	PorA-02	PorA-03	PorA-04	PorA-05	PorA-06	PorA-07	PorA-08	PorA-09	PorA-10
NZMG EAST	2666477	2666482	2666481	2666492	2666500	2666497	2666497	2666489	2666498	2666514
NZMG NORTH	6009488	6009500	6009518	6009534	6009533	6009518	6009505	6009484	6009488	6009525

Porirua B	PorB-01	PorB-02	PorB-03	PorB-04	PorB-05	PorB-06	PorB-07	PorB-08	PorB-09	PorB-10
NZMG EAST	2664635	2664580	2664574	2664565	2664578	2664582	2664588	2664595	2664600	2664607
NZMG NORTH	6007136	6007197	6007212	6007222	6007227	6007219	6007207	6007198	6007200	6007217

Pauatahanui A	PauA-01	PauA-02	PauA-03	PauA-04	PauA-05	PauA-06	PauA-07	PauA-08	PauA-09	PauA-10
NZMG EAST	2667263	2667266	2667265	2667266	2667261	2667261	2667239	2667250	2667255	2667266
NZMG NORTH	6010358	6010383	6010316	6010327	6010341	6010354	6010358	6010334	6010327	6010315

Pauatahanui B	PauB-01	PauB-02	PauB-03	PauB-04	PauB-05	PauB-06	PauB-07	PauB-08	PauB-09	PauB-10
NZMG EAST	2670378	2670377	2670380	2670382	2670386	2670384	2670384	2670386	2670397	2670398
NZMG NORTH	6010057	6010022	6010032	6010014	6010017	6010025	6010043	6010065	6010063	6010055

Epifauna (numbers per 0.25m² quadrat) - 15-16 January 2009

Pauatahanui A

Scientific name	Common name	PauA-01	PauA-02	PauA-03	PauA-04	PauA-05	PauA-06	PauA-07	PauA-08	PauA-09	PauA-10
Austrovenus stutchburyi	Cockle	8	6	3	4	1	4	6			
Haminoea zelandiae	Bubble shell		1								
Cominella glandiformis	Mudflat whelk	11				1			2		3
Diloma subrostrata	Mudflat topshell	8	6	2	1		5	1			3
Zeacumantus lutulentus	Spire shell	1		3	8	2					

Pauatahanui B

Scientific name	Common name	PauB-01	PauB-02	PauB-03	PauB-04	PauB-05	PauB-06	PauB-07	PauB-08	PauB-09	PauB-10
Austrovenus stutchburyi	Cockle	1	5	2	11	1	1		5		1
Haminoea zelandiae	Bubble shell	1					1	1	2		
Cominella glandiformis	Mudflat whelk	1	2			1		3	1	2	2
Diloma subrostrata	Mudflat topshell	2		1	2			2		3	2
Notoacmea helmsi	Estuarine limpet		1	1			1		3		1
Zeacumantus lutulentus	Spire shell			1		1			1		

Porirua A

Scientific name	Common name	PorA-01	PorA-02	PorA-03	PorA-04	PorA-05	PorA-06	PorA-07	PorA-08	PorA-09	PorA-10
Austrovenus stutchburyi	Cockle	22	29	22	36	44	46	31	38	21	23
Haminoea zelandiae	Bubble shell										2
Cominella glandiformis	Mudflat whelk									1	2
Diloma subrostrata	Mudflat topshell	4	4	5	6	15	5	2	5		9
Micrelenchus huttoni	Top shell										
Zeacumantus lutulentus	Spire shell			2	7	3	2	2	2	5	7

Porirua B

Scientific name	Common name	PorB-01	PorB-02	PorB-03	PorB-04	PorB-05	PorB-06	PorB-07	PorB-08	PorB-09	PorB-10
Austrovenus stutchburyi	Cockle	2	2	5	5	2	6	1	4	2	2
Cominella glandiformis	Mudflat whelk			1							
Zeacumantus lutulentus	Spire shell				1	1				1	

Infauna (numbers per 0.0133m² core) - 15-16 January 2009

See following pages

APPENDIX 2. 2009 DETAILED RESULTS (CONTINUED)

GROUP	SPECIES	Paua A-01	Paua A-02	Paua A-03	Paua A-04	Paua A-05	Paua A-06	Paua A-07	Paua A-08	Paua A-09	Paua A-10
ANTHOZOA	Anthozoa sp.#1	7	4	1	1	5	1	1	1		
	Edwardsia sp.#1	2	4	1	5	5	3	1	1	4	7
NEMERTEA	Nemertea *sp.#1*			1	1	1					
	Nemertea sp.#2						1				
NEMATODA	Nematoda										1
POLYCHAETA	*Aglaophamus macroura*										
	Aonides sp.#1										
	Armandia maculata	3				1					
	Axiothella serrata								1		3
	Boccardia (Paraboccardia) acus	12	14	4	3	15	8	5	14	4	
	Boccardia (Paraboccardia) syrtis		1	2	1	1			3	1	
	Capitella sp.#1										1
	Dorvilleidae sp.#1					1					
	Goniada sp.#1										
	Hesionidae sp.#1	1									
	Heteromastus filiformis	39	22	35	35	25	9	31	24	2	19
	Nicon aestuariensis			1		3	1	7	2	3	4
	Orbinia papillosa		1	1	1	4	2	3	2		1
	Paraonidae sp.#1	4	1		7			4	11		2
	Perinereis vallata	1	1		5	5	1	2	4	1	
	Phyllodocidae sp.#1										
	Platynereis australis										
	Sabellidae sp.#1										1
	Scolecolepides benhami		1						1	1	1
	Scoloplos (Scoloplos) cylindrifer										
	Serpulidae sp.#1	1									
	Sphaerosyllis sp.#1	2			3	1	1	1	2		
	Spionidae sp.#1	1	3		4	1	2	3	1		2
	Spionidae sp.#2										
	Terebellidae sp.#1	1					2	1			
	Travisia sp.#1										
OLIGOCHAETA	Oligochaeta		1	1		1					
POLYPLACOPHORA	*Chiton glaucus*	1									
GASTROPODA	*Cominella glandiformis*	1				4		1			
	Diloma subrostrata	1					1	1			
	Eatoniella olivacea										
	Gastropoda sp.#3	3	1	1	2						1
	Haminoea zelandiae	2	3	3	3	1	1	1	4	1	
	Notoacmaea helmsi	11	7		3	10	9			6	
	Xymene plebeius								1		
	Zeacumantus lutulentus	2	1		1	1	1		1		3
BIVALVIA	*Arthritica sp.#1*		3		5	3	3			1	1
	Austrovenus stutchburyi	12	19	1	9	13	7	11	9	11	3
	Macomona liliana	5	6	3	3	4	8	2	4	3	3
	Nucula hartvigiana	14	21	14	16	23	18	13	7	6	30
	Paphies australis										
	Solemya parkinsoni			1							
CRUSTACEA	Amphipoda *sp.#1*	1									
	Amphipoda sp.#2										
	Colurostylis lemurum		1								
	Halicarcinus varius										
	Halicarcinus whitei		1			1					1
	Helice crassa	1									
	Macrophthalmus hirtipes										1
	Mysidacea sp.#1										
	Ostracoda sp.#1	1									
	Ostracoda sp.#2	2	5	2			1		2		
	Ostracoda sp.#3										
	Phoxocephalidae sp.#1	7	6	3	2	3	5	1	1		
	Phoxocephalidae sp.#2	1									
	Sphaeroma quoyanum										
INSECTA	Chironomidae sp.#1										
HOLOTHUROIDEA	*Trochodota dendyi*	1	1				1				
Total species in sample		**29**	**24**	**17**	**20**	**24**	**22**	**18**	**21**	**13**	**19**
Total individuals in sample		**140**	**128**	**75**	**110**	**132**	**86**	**89**	**96**	**44**	**85**

APPENDIX 2. 2009 DETAILED RESULTS (CONTINUED)

GROUP	SPECIES	Paua B-01	Paua B-02	Paua B-03	Paua B-04	Paua B-05	Paua B-06	Paua B-07	Paua B-08	Paua B-09	Paua B-10
ANTHOZOA	Anthozoa sp.#1										
	Edwardsia sp.#1	2	2	4	4	8	5	10	7	7	1
NEMERTEA	Nemertea *sp.#1*		2		2	1	2	1	3	2	
	Nemertea sp.#2					3		1	1		
NEMATODA	Nematoda										
POLYCHAETA	*Aglaophamus macroura*										
	Aonides sp.#1	1	3	1	5	19	4				1
	Armandia maculata					1					
	Axiothella serrata	34	32	25	34	21	26	42	47	58	33
	Boccardia (Paraboccardia) acus	4	14	9	8	8	3	7	13	8	17
	Boccardia (Paraboccardia) syrtis	3	3		1	4	3	4	3		7
	Capitella sp.#1		1			1			1		
	Dorvilleidae sp.#1										
	Goniada sp.#1						1				1
	Hesionidae sp.#1										
	Heteromastus filiformis	38	32	25	28	12	14	40	33	40	56
	Nicon aestuariensis	2		2	2	1		2		5	1
	Orbinia papillosa	2	2	2		3	5	2	2	6	3
	Paraonidae sp.#1						1				
	Perinereis vallata			1	1	1		1	3		1
	Phyllodocidae sp.#1	1			1	1					
	Platynereis australis	1	4		3	2					2
	Sabellidae sp.#1										
	Scolecolepides benhami			1					1		
	Scoloplos (Scoloplos) cylindrifer										
	Serpulidae sp.#1										
	Sphaerosyllis sp.#1		2		1	1				1	
	Spionidae sp.#1		1	2			1		1	1	2
	Spionidae sp.#2										3
	Terebellidae sp.#1										
	Travisia sp.#1										
OLIGOCHAETA	Oligochaeta		1	2			4	2			2
POLYPLACOPHORA	*Chiton glaucus*										
GASTROPODA	*Cominella glandiformis*			1	1	3					1
	Diloma subrostrata										
	Eatoniella olivacea										
	Gastropoda sp.#3										
	Haminoea zelandiae	1	11		2				4	1	
	Notoacmaea helmsi		3	2	4	2	2	1	3		
	Xymene plebeius										
	Zeacumantus lutulentus					2					
BIVALVIA	*Arthritica sp.#1*			1		1	2	3			
	Austrovenus stutchburyi	4	25	14	12	13	9	6	13	13	14
	Macomona liliana	9	9	13	12	11	8	10	8	12	15
	Nucula hartvigiana							1			
	Paphies australis										
	Solemya parkinsoni										
CRUSTACEA	Amphipoda *sp.#1*		1		1	12	3	2	2		
	Amphipoda sp.#2										
	Colurostylis lemurum										
	Halicarcinus varius										
	Halicarcinus whitei		1			1		1	1		1
	Helice crassa										
	Macrophthalmus hirtipes										
	Mysidacea sp.#1										
	Ostracoda sp.#1										
	Ostracoda sp.#2										
	Ostracoda sp.#3										
	Phoxocephalidae sp.#1										
	Phoxocephalidae sp.#2										
	Sphaeroma quoyanum	**1**									
INSECTA	Chironomidae sp.#1		**1**								
HOLOTHUROIDEA	*Trochodota dendyi*			**1**	**1**					**1**	
Total species in sample		**14**	**20**	**17**	**19**	**24**	**17**	**18**	**18**	**13**	**18**
Total individuals in sample		**103**	**150**	**106**	**123**	**132**	**93**	**136**	**146**	**155**	**161**

APPENDIX 2. 2009 DETAILED RESULTS (CONTINUED)

GROUP	SPECIES	Por A-01	Por A-02	Por A-03	Por A-04	Por A-05	Por A-06	Por A-07	Por A-08	Por A-09	Por A-10
ANTHOZOA	Anthozoa sp.#1			1		2	2	3			2
	Edwardsia sp.#1		1	2	1		2			1	1
NEMERTEA	Nemertea *sp.#1*			2	2					2	
	Nemertea sp.#2								1		
NEMATODA	Nematoda				1	1	1			2	
POLYCHAETA	*Aglaophamus macroura*		1								
	Aonides sp.#1				4					1	
	Armandia maculata		1								
	Axiothella serrata										1
	Boccardia (Paraboccardia) acus		6	4	4	1	13	17	3	20	7
	Boccardia (Paraboccardia) syrtis	1	18	3	1	2	6	19	1	6	5
	Capitella sp.#1			2	1	1	1	1			2
	Dorvilleidae sp.#1										
	Goniada sp.#1		1	1						2	
	Hesionidae sp.#1								1	3	
	Heteromastus filiformis	12	18	34	30	22	20	31	39	30	30
	Nicon aestuariensis			1						1	
	Orbinia papillosa		1		1	4	5	1		1	1
	Paraonidae sp.#1	5			5		36	2	3	8	14
	Perinereis vallata	2	1	1	3	5	2	1	3	1	2
	Phyllodocidae sp.#1										
	Platynereis australis	3	7	7	3	9	4	2	7	1	1
	Sabellidae sp.#1						1				
	Scolecolepides benhami					1		1			
	Scoloplos (Scoloplos) cylindrifer										
	Serpulidae sp.#1										
	Sphaerosyllis sp.#1	2	2		1		2	2			
	Spionidae sp.#1	7	2	4	1	6	6	3	2	5	4
	Spionidae sp.#2										
	Terebellidae sp.#1										
	Travisia sp.#1		1								
OLIGOCHAETA	Oligochaeta	2			8	1	8	1	1	7	1
POLYPLACOPHORA	*Chiton glaucus*										
GASTROPODA	*Cominella glandiformis*		2	1	2			2	1	1	3
	Diloma subrostrata			1		3	1	1			1
	Eatoniella olivacea		1								
	Gastropoda sp.#3										1
	Haminoea zelandiae										
	Notoacmaea helmsi	1		2	2	4		6	1	3	6
	Xymene plebeius										
	Zeacumantus lutulentus	1	1	1		3		1		4	1
BIVALVIA	*Arthritica sp.#1*	3	19	10	18		1	4	9	4	3
	Austrovenus stutchburyi	2	7	6	2	4	7	15	3	11	8
	Macomona liliana	4	6	4	5	3	4	6	9	7	5
	Nucula hartvigiana	21	25	54	27	40	22	20	24	21	39
	Paphies australis										
	Solemya parkinsoni										
CRUSTACEA	Amphipoda *sp.#1*										
	Amphipoda sp.#2	1									
	Colurostylis lemurum										
	Halicarcinus varius	1				1					
	Halicarcinus whitei			1				1		4	
	Helice crassa			1		3					
	Macrophthalmus hirtipes										1
	Mysidacea sp.#1										
	Ostracoda sp.#1	10	3	29			2	1	28	1	2
	Ostracoda sp.#2										
	Ostracoda sp.#3			1							
	Phoxocephalidae sp.#1	8	3	4	1			2	3	1	1
	Phoxocephalidae sp.#2										
	Sphaeroma quoyanum										
INSECTA	Chironomidae sp.#1										
HOLOTHUROIDEA	*Trochodota dendyi*										
Total species in sample		**18**	**22**	**25**	**22**	**20**	**21**	**24**	**18**	**26**	**25**
Total individuals in sample		**86**	**127**	**177**	**123**	**116**	**146**	**143**	**139**	**148**	**142**

APPENDIX 2. 2009 DETAILED RESULTS (CONTINUED)

GROUP	SPECIES	Por B-01	Por B-02	Por B-03	Por B-04	Por B-05	Por B-06	Por B-07	Por B-08	Por B-09	Por B-10
ANTHOZOA	Anthozoa sp.#1										
	Edwardsia sp.#1	3		2	4		1	5	3	1	3
NEMERTEA	Nemertea *sp.#1*	1			1		1	4	2	1	
	Nemertea sp.#2										
NEMATODA	Nematoda		1		1						
POLYCHAETA	*Aglaophamus macroura*										
	Aonides sp.#1	24	76	11	11	23	55	50	42	42	58
	Armandia maculata										
	Axiothella serrata	1	3	3	10	3	4	2		2	5
	Boccardia (Paraboccardia) acus	8	2	1	6	1	2	3	6	19	
	Boccardia (Paraboccardia) syrtis				1						
	Capitella sp.#1										
	Dorvilleidae sp.#1										
	Goniada sp.#1										
	Hesionidae sp.#1										
	Heteromastus filiformis	1			5		4	4	2		1
	Nicon aestuariensis		2	1	1		2	1	1		2
	Orbinia papillosa	2	3	3	8	4	4	2	1	7	6
	Paraonidae sp.#1										
	Perinereis vallata										
	Phyllodocidae sp.#1										
	Platynereis australis										
	Sabellidae sp.#1										
	Scolecolepides benhami		1	1							1
	Scoloplos (Scoloplos) cylindrifer	5	4	3	3	4	4	2	4	4	4
	Serpulidae sp.#1										
	Sphaerosyllis sp.#1										
	Spionidae sp.#1	1							1		
	Spionidae sp.#2				1			1	2		
	Terebellidae sp.#1										
	Travisia sp.#1										
OLIGOCHAETA	Oligochaeta				1			1			
POLYPLACOPHORA	*Chiton glaucus*										
GASTROPODA	*Cominella glandiformis*			1			2	2		1	
	Diloma subrostrata				1		1				
	Eatoniella olivacea										
	Gastropoda sp.#3										
	Haminoea zelandiae										
	Notoacmaea helmsi										1
	Xymene plebeius										
	Zeacumantus lutulentus										
BIVALVIA	*Arthritica sp.#1*	1	6		7	1					
	Austrovenus stutchburyi	21	27	25	39	30	18	25	20	34	29
	Macomona liliana	9	5	8	5	9	7	7	4	6	4
	Nucula hartvigiana										
	Paphies australis		2		1						
	Solemya parkinsoni										
CRUSTACEA	Amphipoda *sp.#1*					1					
	Amphipoda sp.#2										
	Colurostylis lemurum	1									
	Halicarcinus varius										
	Halicarcinus whitei			1							
	Helice crassa										
	Macrophthalmus hirtipes										
	Mysidacea sp.#1							1	1	1	1
	Ostracoda sp.#1										
	Ostracoda sp.#2										
	Ostracoda sp.#3										
	Phoxocephalidae sp.#1										
	Phoxocephalidae sp.#2										
	Sphaeroma quoyanum										
INSECTA	Chironomidae sp.#1										
HOLOTHUROIDEA	*Trochodota dendyi*		1	1		1			1	1	
Total species in sample		**13**	**13**	**13**	**18**	**10**	**13**	**15**	**14**	**12**	**12**
Total individuals in sample		**78**	**133**	**61**	**106**	**77**	**105**	**110**	**90**	**119**	**115**

APPENDIX 3. INFAUNA CHARACTERISTICS

Group and Species		AMBI Group	Details (primary source NIWA website (Guide to New Zealand Shore Polychaetes) and Wikipedia.
Porifera	Porifera sp.1	NA	Unidentified sponge.
Anthozoa	Anthozoa sp.1	II	Unidentified anemone. An upright, stout, pale cream-coloured species.
	Edwardsia sp.#1	II	A tiny elongate anemone adapted for burrowing; colour very variable, usually 16 tentacles but up to 24, pale buff or orange in colour. Fairly common throughout New Zealand. Prefers sandy sediments with low-moderate mud. Intolerant of anoxic conditions.
Nemertea	Nemertea sp.1, 2, 3, 4.	III	Ribbon or Proboscis Worms, mostly solitary, predatory, free-living animals. Intolerant of anoxic conditions.
Nematoda	Nematoda sp	III	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	*Aonides sp.1*	III	A small surface deposit-feeding spionid polychaete that lives throughout the sediment to a depth of 10cm. Although Aonides is free-living, it is not very mobile and prefers to live in fine sands. Aonides is very sensitive to changes in the silt/clay content of the sediment. In general, polychaetes are important prey items for fish and birds.
	Armandia maculata	I	Common subsurface deposit-feeding/herbivore. Belongs to Family Dpheliidae. Found intertidally as well as subtidal in bays and sheltered beaches. Prefers fine sand to sandy mud at low water. Does not live in a tube. Depth range: 0-1000m. A good coloniser and explorer. Pollution and mud intolerant.
	Axiothella serrata	I	Subsurface deposit-feeder. Belongs to Family Maldanidae. Found intertidally in enclosed harbours/estuaries only. Prefers fine to very fine sands where it builds a loosely-cemented sand-grain tube or burrow shaped like a J to about 15 cm depth. Pollution and mud intolerant.
	Boccardia (Paraboccardia) syrtis and acus	I	Small surface deposit-feeding spionids. 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. When in dense beds, the community tends to encourage build-up of muds.
	Capitella capitata	V	A blood red capitellid polychaete which is very pollution tolerant. Common in suphide rich anoxic sediments.
	Dorvilleidae sp.1	NA	Active surface-dwelling omnivores with chitinous jaw elements consisting of four longitudinal rows of minute, toothed, black plates, and with two pairs of appendages on the rounded prostomium. Not generally common.
	Goniada sp.1	II	Slender burrowing predators (of other smaller polychaetes) with proboscis tip with two ornamented fangs. The goniadids are often smaller, more slender worms than the glycerids. The small goniadid *Glycinde dorsalis* occurs low on the shore in fine sand in estuaries.
	Hesionidae sp.1	II	Fragile active surface-dwelling predators somewhat intermediate in appearance between nereidids and syllids. The New Zealand species are little known.
	Heteromastus filiformis	IV	Small sized capitellid polychaete. A sub-surface, deposit-feeder that lives throughout the sediment to depths of 15cm, 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.
	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.
	Orbinia papillosa	I	Long, slender, sand-dwelling unselective deposit feeders which are without head appendages. Found only in fine and very fine sands, and can be common. Pollution and mud intolerant.

APPENDIX 3. INFAUNA CHARACTERISTICS

Group and Species		AMBI Group	Details
Polychaeta	Paraonidae sp.#1	III	Slender burrowing worms that are probably selective feeders on grain-sized organisms such as diatoms and protozoans. *Aricidea* sp., a common estuarine paraonid, is a small sub-surface, deposit-feeding worm found in muddy-sands. These occur throughout the sediment down to a depth of 15cm and appear to be sensitive to changes in the mud content of the sediment. Some species of Aricidea are associated with sediments with high organic content.
	Pectinaria australis	I	Subsurface deposit-feeding/herbivore. Lives in a cemented sand grain cone-shaped tube. Feeds head down with tube tip near surface. Prefers fine sands to muddy sands. Mid tide to coastal shallows. Belongs to Family Pectinariidae. Often present in NZ estuaries. Density may increase around sources of organic pollution and eelgrass beds. Intolerant of anoxic conditions.
	Perinereis vallata	III	An intertidal soft shore nereid (which are common and very active, omnivorous worms). Prefers sandy sediments.
	Platynereis australis	III	An intertidal soft shore nereid (which are common and very active, omnivorous worms). Prefers sandy sediments.
	Sabellariidae sp.1	NA	Sabellariids live in thick-walled sand and shell-fragment tubes cemented to rock or to any durable surface. As such they often modify the habitat. Some colonial species form conspicuous hummocks and substantial reefs. Sabellariids are filter feeders and detritus feeders. Pollution and mud intolerant.
	Sabellidae sp.#1	I	Sabellids are not usually present in intertidal sands, though some minute forms do occur low on the shore. They are referred to as fan or feather-duster worms and are so-called from the appearance of the feeding appendages, which comprise a crown of two semicircular fans of stiff filaments projected from their tube.
	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.
	Scoloplos (Scoloplos) cylindrifer	I	Belongs to Family Orbiniidae which are thread-like burrowers without head appendages. Common in intertidal sands of estuaries. Long, slender, sand-dwelling unselective deposit feeders.
	Sphaerosyllis sp.1	II	Belongs to Family Syllidae which are delicate and colourful predators. Very common, often hidden amongst epifauna. Small size and delicate in appearance. Prefers sandy sediments.
	Spionidae sp. 1 and 2	NA	An unknown spionid polychaete. Feed at the sediment-water interface - as either deposit or suspension feeders.
	Terebellidae sp.#1	II	Large tube or crevice dwellers with a confusion of constantly active head tentacles and a few pairs of anterior gills.
Oligochaeta	Oligochaete sp.	NA	Segmented worms - deposit feeders. Classified as very pollution tolerant by AMBI (Borja et al. 2000) but a review of literature suggests that there are some less tolerant species.
Gastropoda	*Cominella glandiformis*	NA	Endemic to NZ. A carnivore living on surface of sand and mud tidal flats. Has an acute sense of smell, being able to detect food up to 30 metres away, even when the tide is out. Intolerant of anoxic surface muds.
	Diloma subrostrata	NA	The mudflat top shell, lives on mudflats, but prefers a more solid substrate such as shells, stones etc. Endemic to NZ and feeds on the film of microscopic algae on top of the mud.
	Gastropoda sp. 1 and 2	NA	Yet to be identified.
	Haminoea zelandiae	NA	The white bubble shell, is a species of medium-sized sea snail or bubble snail, a marine opisthobranch gastropod mollusc in the family Haminoeidae, the bubble snails. This bubble snail is common on intertidal mudflats in sheltered situations associated with eel grass. This species is endemic to New Zealand. It is found around the North Island and the northern part of the South Island.

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Group and Species		AMBI Group	Details
	Notoacmaea helmsi	NA	Endemic to NZ. Small limpet attached to stones and shells in intertidal zone. Intolerant of anoxic surface muds.
	Xymene plebeius	NA	Belongs to the Family Muricidae, or murex snails, which are a large and varied taxonomic family of small to large predatory sea snails
	Zeacumantus lutulentus	NA	A medium-sized mud snail. Endemic to the North Island and the northern half of the South Island of NZ. Very common on intertidal mudflats. On the mudflats, these snails plough their way across the surface, leaving recognizable trails. Each snail passes huge quantities of mud through its gut as it extracts organic matter from the mud.
Bivalvia	*Arthritica sp.1*	III	A small sedentary deposit feeding bivalve, preferring a moderate mud content. Lives greater than 2cm deep in the muds.
Bivalvia	*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.
Bivalvia	*Mocomona liliana*	NA	A deposit feeding wedge shell. This species lives at depths of 5–10cm in the sediment and uses a long inhalant siphon to feed on surface deposits and/or particles in the water column. Rarely found beneath the RPD layer.
Bivalvia	*Nucula hartvigiana*	III	The nut clam of the family Nuculidae, is endemic to New Zealand. It is found intertidally and in shallow water, especially in *Zostera* sea grass flats. It is often found together with the New Zealand cockle, *Austrovenus stutchburyi*, but is not as abundant showing a preference for mud. Like *Arthritica* this species feeds on organic particles within the sediment.
Bivalvia	*Paphies australis*	NA	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.
Bivalvia	*Solemya parkinsoni*	NA	The razor mussel. The elongate cylindrical shell valves have the brown, smooth shining epidermis extending beyond the margin forming a characteristic and distinctive fringe; interior of the shell a dull grey-white; grows up to 5cm in length. A common species on sand banks at depths up to 25cm.
Crustacea	*Amphipoda sp.1*	NA	An unidentified amphipod.
Crustacea	*Cephalocarida sp.1*	NA	Cephalocarida (horseshoe shrimps) is a class of only about nine shrimp-like benthic species. Discovered in 1955. Found from the intertidal zone down to a depth of 1500m, in all kinds of sediments. They feed on marine detritus.
Crustacea	*Halicarcinus varius*	NA	Pillbox crabs are usually found on the sand and mudflats but may also be encountered under stones on the rocky shore. *Halicarcinus varius* (10mm) has a pear-shaped carapace, its upper half covered in small hairs. Males have hairy nippers. Its colour varies from white/green to yellow, found in sheltered areas on brown seaweeds or under stones.
Crustacea	*Halicarcinus whitei*	NA	Another species of pillbox crab. Lives in intertidal and subtidal sheltered sandy environments.
Crustacea	*Hemigrapsus crenulatus*		The hairy-handed crab is commonly found, on mud flats and sand flats, but it may also occur under boulders on the rocky shore intertidal. Is a very effective scavenger and tolerates brackish conditions.
Crustacea	*Macrophthalmus hirtipes*	NA	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.
Crustacea	*Mysidacea sp.1*	II	Mysidacea is a group of small, shrimp-like creatures. They are sometimes referred to as opossum shrimps. Wherever mysids occur, whether in salt or fresh water, they are often very abundant and form an important part of the normal diet of many fishes
Crustacea	*Ostracoda sp.1 and 2.*	NA	Ostracods or seed shrimps, have a body which is encased by two valves.
Crustacea	Phoxocephalidae sp.	I	A family of amphipods.

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Group and Species		AMBI Group	Details
Holothuroidea	*Trochodota dendyi*	I	A sea cucumber, that is soft bodied and worm-like in appearance and burrows up to 20cm into sand - a deposit feeder and sediment disturber.

NA=Not Allocated

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-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 anoxic sediments.

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