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# Porirua Harbour

## Fine Scale Monitoring 2007/08

Prepared for Greater Wellington Regional Council and Porirua City Council

June 2008

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By

Barry Robertson and Leigh Stevens

Cover Photo: Porirua Arm of Porirua Harbour from marina at Mana with Porirua City in background.

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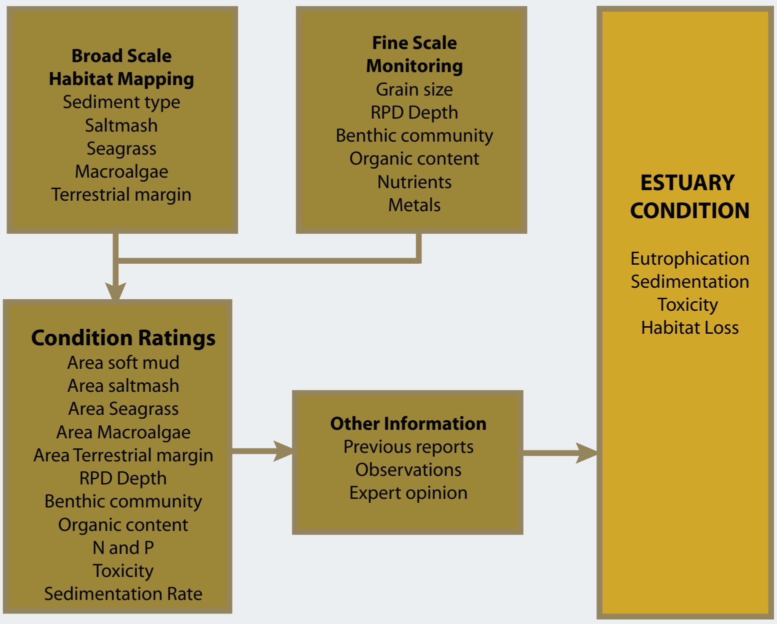
All photos by Wriggle except where noted otherwise.

# PORIRUA HARBOUR - EXECUTIVE SUMMARY

This report summarises the results of the 2008 fine scale monitoring for Porirua Harbour, an 800ha tidal lagoon estuary near the Kapiti coast, and one of the key estuaries in Greater Wellington Regional Council's (GWRC) proposed 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. Although both of these components were recently undertaken in Porirua Harbour the results are presented in two separate reports, the fine scale monitoring component in this report and the broad scale mapping in Stevens and Robertson (2008). Fine scale monitoring is a tool used to assess the condition of estuaries. It 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).

Taken in combination (i.e. the broad and fine scale results), the outcome is a list of detailed physical, chemical and biological data that is used to develop condition ratings for key indicators of estuary condition (e.g. benthic invertebrate community condition rating or organic matter condition rating). These indicator ratings (both broad and fine scale ratings) are then combined with other available data and relevant expert information to assess the overall condition of the estuary in relation to the key issues of sedimentation, eutrophication, toxicity and habitat loss. Disease risk, the other major estuary issue, is monitored and reported separately by GWRC, principally through its recreational water quality monitoring programme. In most cases, both broad and fine scale information is required to assess the extent to which an estuary is manifesting a particular issue. For example, the macroalgal rating (that is derived from broadscale mapping of the percentage macroalgal cover), is combined with a number of fine scale ratings (organic carbon, nutrients, sediment oxygenation, grain size, and benthic community index) and other information (e.g. flushing characteristics) to help assess the extent of eutrophication in the estuary. A summary of the approach is outlined in the figure below.



## 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 Porirua Arm and two in the Pauatahanui Arm) showed:

- **RPD Depth.** RPD Depth, which is a key indicator of sediment oxygenation, was moderately shallow at all sites (2-6cm depth) and therefore sediments were likely to be moderately oxygenated. Such values indicate that the benthic invertebrate community was likely to be either in an unstable "transitional" state or a stable "normal" state.
- **Benthic Macrofauna**. All 4 sites had similar abundance and diversity measures, however, they differed in the types of species making up the community at each site. Overall, the benthic community condition was "unbalanced", giving it a "slightly polluted" classification, i.e. a community with elevated numbers of organisms that tolerate moderate mud and organic enrichment levels.
- **Organic Matter**. The indicator of organic enrichment (TOC) at all 4 sites was at moderate to low concentrations (mean 1.3 % at the two muddier sites in each arm and 0.6% at the other two sites). 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.
- **Nutrients (Nitrogen and Phosphorus**). Total phosphorus (a key nutrient in the eutrophication process) was present in the "low to moderate enrichment" category at the two muddier sites in each arm (mean 440 mg/kg at PorA and PauA), but at the two sandier sites (PorB and PauB), it was in the "very good" category (mean 158 and 150 mg/kg respectively). Like phosphorus, total nitrogen (the other key nutrient in the eutrophication process) was at the "low to moderate enrichment" category at the two muddier sites in each arm (mean 685 mg/kg at PorA and 823 mg/kg at PauA), but at the two sandier sites (PorB and PauB), it was in the "very good" category (mean 504 and 546 mg/kg respectively).
- **Grain Size**. The two fine scale indicators of increased muddiness in the estuary are grain size (% mud, sand, gravel), and sedimentation rate (mm of sediment deposited/yr). In regard to grain size, all sites were dominated by sandy sediments (77-99% sand) but the mud fraction was also significant (1-14% mud content). Sedimentation plates were deployed in the estuary to enable long term monitoring of sedimentation rates.
- **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.

### CONDITION RATINGS

The fine scale monitoring data were then used to determine the fine scale condition ratings for key fine scale indicators. The results were as follows:

| FINE SCALE RATING 2007 | RPD Depth | Benthic Community | Organic Matter | Nutrients | Cadmium | Chromium | Copper | Lead | Nickel | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|
| Pauatahanui Arm Site A | GOOD | UNBALANCED | GOOD | LOW-MOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD | GOOD | VERY GOOD |
| Pauatahanui Arm Site B | GOOD | UNBALANCED | VERY GOOD | LOW-MOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD |
| Porirua Arm Site A | FAIR | UNBALANCED | GOOD | LOW-MOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD | GOOD | GOOD |
| Porirua Arm Site B | GOOD | UNBALANCED | VERY GOOD | LOW-MOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD | GOOD |

## ESTUARY ISSUES

The final step was to use the fine scale results as well as other information (including broad scale results) to provide an understanding of the estuary condition in relation to the key estuary issues that fine scale monitoring addresses, i.e. sedimentation, eutrophication and toxicity.

**ISSUE RATING EUTROPHICATION**

**MODERATELY EUTROPHIC for whole Harbour**

- **Eutrophication.** The major indicators of organic enrichment support the findings of the broad scale report (i.e. the relatively abundant presence of nuisance macroalgal growth - Stevens and Robertson 2008), 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 indicates a need for caution, particularly in relation to factors that could increase nutrient and fine sediment concentrations in the Harbour. Moderately elevated sediment nutrient levels are a particular threat in estuaries where there is a possibility of a shift to sediment anoxia. Under such conditions, both P and N become much more available for nuisance algal growth and a return to oxygenated conditions is difficult to achieve - even if catchment nutrient loads are reduced. Because nutrient loads to the estuary are elevated and localised parts of the estuary are already anoxic (e.g. upper Porirua Harbour), it is recommended that nutrient load management initiatives be supported (as recommended in the recent vulnerability assessment - Robertson and Stevens 2008) and long term monitoring be continued. The TN:TP ratio in the intertidal sediments indicated nitrogen as the key nutrient to target for minimising eutrophication symptoms.

**ISSUE RATING SEDIMENTATION**

**MODERATE SEDIMENTATION for whole Harbour**

- **Sedimentation**. If sediment inputs to an estuary are excessive, the estuary infills quickly with muds, reducing biodiversity and human values and uses. In subtidally-dominated estuaries, like the Porirua Harbour, fine muds tend to settle in three main areas; the subtidal central basin and, to a lesser extent, the unvegetated intertidal area around the central basins; saltmarsh areas; and sheltered estuary arms. It is therefore not unexpected that the 2007 fine scale grain size results (and 2007 broad scale mapping), showed that the intertidal area in both arms was dominated by sandy sediments, and previous studies (Healy 1980) showed that the subtidal basins were dominated by soft muds. Overall, the combined results indicate that sedimentation is an issue in Porirua Harbour and that ongoing monitoring and management is required. Because of the high cost of subtidal monitoring and the fact that soft mud already dominates the subtidal basins, mapping and monitoring of the less impacted intertidal area has been chosen as the preferred approach. In addition, measurement of the sedimentation rate in both intertidal and subtidal areas has been initiated with deployment of sediment plates at 4 intertidal sites and 1 subtidal site. In the future, it is recommended that additional subtidal plates be deployed and subtidal sediment type assessed at a few key sites.

**ISSUE RATING TOXICITY**

**LOW TOXICITY for Pauatahanui Arm**

**LOW -MODERATE for Porirua Arm**

- **Toxicity**. If potentially toxic contaminant inputs (e.g. heavy metals) are excessive, estuary biodiversity is threatened and shellfish and fish may be unsuitable for eating. The concentration of potential toxicants in Porirua Harbour sediments (in this case metals), is likely to be greatest in the subtidal basins. This arises because metals are mostly bound to the mud fraction, and the subtidal area is where most of the mud settles. In addition, the mud fraction is also the main source of food for the dominant sediment-dwelling organisms (i.e., deposit feeders). The results of 2008 intertidal and the 2005 subtidal monitoring both indicate elevated metal concentrations, particularly in the Porirua Arm. Such findings indicate a localised risk of sediment contamination from toxicants in urban stormwater discharges (both directly into this southern end of the harbour from Porirua City and indirectly to the Porirua Stream catchment).

## 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 monitoring results and condition ratings, it is recommended that monitoring continue as outlined as follows:

**Fine Scale Monitoring**.
Complete the three to four years of the proposed annual baseline monitoring in Porirua Harbour but with the following changes to the programme:

- Because of the good condition ratings and the small variation between replicates for most physical and chemical parameters, it is recommended that the number of replicates for physical and chemical parameters be reduced from ten to three composite samples for sites in Porirua Harbour.
- 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 15 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

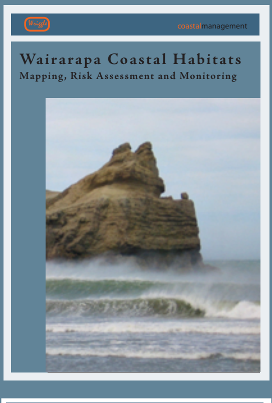
The fine scale monitoring reinforced the need for management of the following inputs to the estuary:

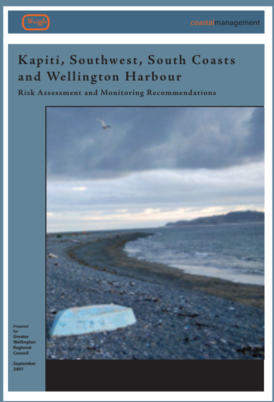
- nutrients,
- fine sediment, and
- toxicants.

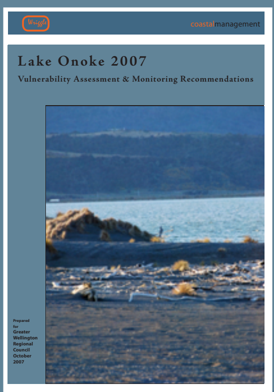
It is understood that GWRC and Porirua City Council, intend to work together to identify catchment nutrient, toxin and sediment sources and "hotspots", and to implement Best Management Practices (BMPs) for reducing nutrient, toxin and sediment mobilisation and runoff to surface and groundwater. The findings 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 (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,** including historical comparisons (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, is the subject of the current report.

Porirua Harbour is a large, shallow, well flushed "tidal lagoon" type estuary consisting of two arms, 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.

Because of the high use of Porirua Harbour and the presence of extensive past modifications that have degraded the estuary condition (e.g. saltmarsh reclamation, loss of vegetated terrestrial margin, increased muddiness, litter and disease risk), there is a high potential for estuary restoration to be undertaken, particularly given high local and regional motivation. In particular, this is likely to involve the following restoration actions;

- Re-establishment of saltmarsh areas in Porirua Harbour through appropriate margin development (in particular decreasing seawall gradients) and further saltmarsh plantings in Pauatahanui Arm.
- Re-establishment of a natural vegetated terrestrial margin around the estuary where possible.
- Litter clean-up in the Porirua Arm.
- Water quality improvements through better management of stormwater and land-runoff.

# 1. Introduction (continued)

**OVERVIEW**

This potential for restoration combined with the documented long term, low-moderate risks to Porirua Harbour from a number of sources (i.e. catchment landuse practices, invasive weeds and pests, margin development, sea level rise, sewer overflows, urban stormwater) (Robertson and Stevens 2007b), indicate a need for a long term monitoring programme. The information gathered in the programme will help guide restoration management actions, allow effectiveness to be monitored, and identify any need for revised actions.

The current report documents the following;

- The results of the fine scale monitoring undertaken in January 2008 of Porirua Harbour intertidal sites (including both the Porirua and Pauatahanui Arms).
- The establishment of sediment plates in Porirua Harbour.
- Condition ratings for the Porirua Harbour 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 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).

**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** Conclusions.
**Section 5** Monitoring recommendations.
**Section 6** Management recommendations.
**Section 7** Acknowledgements.
**Section 8** References.
**Appendix 1:** Details of analytical methods.
**Appendix 2:** Detailed fine scale monitoring results - Porirua Harbour 2008.
**Appendix 3:** Characteristics of the benthic invertebrate community.

# 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. |
| Rocky Shores | Rocky shore vulnerability matrix. Broad scale rocky shore and terrestrial margin mapping. Fine scale rocky shore monitoring. |

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

| Issue | Impact |
|---|---|
| Sedimentation | If sediment inputs are excessive, an estuary infills 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, the ecosystem experiences 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.**

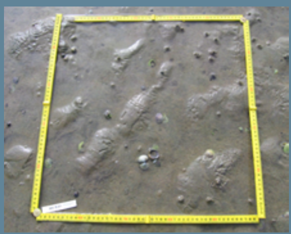
| Issue | Indicator | Method |
|---|---|---|
| Sedimentation | Soft Mud Area | Broad scale mapping - estimates the area and change in soft mud habitat over time. |
| Sedimentation | Sedimentation Rate | Fine scale measurement of sediment deposition. |
| Eutrophication | Nuisance Macroalgal Cover | Broad 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 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. |

Juliet Milne and Summer Warr (GWRC staff) and Barry Robertson (Wriggle) at fine scale monitoring sites in Porirua Harbour.

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 2 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).
- Organic Matter: Ash free dry weight (AFDW) (converted and reported as total organic content - 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), 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 Arm, ten samples from each site of the top 20mm of sediment (each approx. 250gms) were collected adjacent to the infauna cores.
- For the Pauatahanui Arm, 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).
  - Ash Free Dry Weight (AFDW) (as a measure of total organic content).
  - 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.

Counting epifauna.

**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 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.

Five sites (three in the Porirua Arm and two in the Pauatahanui Arm) were established in Porirua Harbour in December 2007 (Figure 1). The sites were located in mud/sand habitat in areas of each estuary arm where sedimentation rates are likely to be elevated. At site "Por A (Railway)" (Porirua Arm) and site "Pau B Upper East", (Pauatahanui Arm), four plates (20cm wide square concrete blocks) were buried approximately 30m apart in a square configuration deep in the sediments where stable substrate is located. At site "Pau A Boatsheds", (Pauatahanui Arm) four plates were buried at 2m intervals along a line between two marker pegs. At site "Por B Polytech", (Porirua Arm) two plates were buried parallel to the river channel. At site "Western Subtidal" (Porirua Arm), 2 wooden pegs were located at right angles to the shoreline either side of large (~750mm) plate buried subtidally. The position of each plate was marked with wooden stakes driven into the sediment, their GPS positions logged, and the depth from the undisturbed mud surface to the top of the sediment plate and the top of the wooden stakes was recorded. In the future, these distances will be measured annually and, over the long term, will provide a measure of rates 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 Porirua Harbour (based on the ratings developed for Southland's estuaries - Robertson & Stevens 2006, 2007). 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)

| | |
|---|---|
| | In most cases the management recommendation is simply that GWRC develop a plan to further evaluate an issue and consider what response actions may be appropriate. At this stage, the interim condition ratings reflect the best guidance able to be provided based on the available information and budget. It is expected that the proposed ratings will continue to be revised and updated as better information becomes available, and new ratings developed for other indicators. |
| 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. The majority of the other eutrophication indicators (e.g. macroalgal blooms, soft muds, sediment organic C, TP, and TN ) are less critical, in that they can be elevated, but not necessarily causing sediment anoxia and adverse impacts on aquatic life. The tendency for sediments to become anoxic is much greater if the sediments are muddy. In sandy porous sediments, the RPD layer is usually relatively deep (>3cm) and is maintained primarily by current or wave action that pumps oxygenated water into the sediments. In finer silt/clay sediments, physical diffusion limits oxygen penetration to <1 cm (Jørgensen and Revsbech 1985) unless bioturbation by infauna oxygenates the sediments. |

**RPD CONDITION RATING (ERP = Evaluation and Response Plan)**

| RATING | DEFINITION | RECOMMENDED RESPONSE |
|---|---|---|
| Very Good | >10cm depth below surface | Monitor at 5 yr intervals after baseline established |
| Good | 3-10cm depth | Monitor at 5 yr intervals after baseline established |
| Fair | 1-3cm depth | Post baseline, monitor at 2 yr intervals. Initiate ERP |
| Poor | <1cm depth | Post baseline, monitor at 2 yr intervals. Initiate ERP |
| Early Warning Trigger | >1.3 x Mean of highest baseline yr | Initiate ERP |

| | |
|---|---|
| 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 | Post baseline, monitor at 2 yr intervals. Initiate ERP |
| Poor | >ISQG-High | Post baseline, monitor at 2 yr intervals. Initiate ERP |
| Early Warning Trigger | >1.3 x Mean of highest baseline year | Initiate ERP |

| | |
|---|---|
| Total Nitrogen | In shallow estuaries like Porirua Harbour, 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 | Post baseline, monitor at 2 yr intervals. Initiate ERP |
| Very Enriched | >4000mg/kg | Post baseline, monitor at 2 yr intervals. Initiate ERP |
| Early Warning Trigger | >1.3 x Mean of highest baseline year | Initiate ERP |

# 2. Methods (Continued)

## Total Phosphorus

In shallow estuaries like Porirua Harbour, 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 | Post baseline, monitor at 2 yr intervals. Initiate ERP |
| Very Enriched | >1000mg/kg | Post baseline, monitor at 2 yr intervals. Initiate ERP |
| Early Warning Trigger | >1.3 x Mean of highest baseline year | Initiate ERP |

## 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% | Post baseline, monitor at 2 yr intervals, manage source |
| Very Enriched | >5% | Post baseline, monitor at 2 yr intervals, manage source |
| Early Warning Trigger | >1.3 x Mean of highest baseline yr | Initiate ERP |

## Sedimentation Rate

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

| SEDIMENTATION RATE CONDITION RATING | | |
|---|---|---|
| RATING | DEFINITION | RECOMMENDED RESPONSE |
| Very Low | <1mm/yr (pre-European) | 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 | Post baseline, monitor yearly, initiate ERP |
| Very High | >20mm/yr | As above. Manage source. |
| Early Warning Trigger | Rate increasing | Initiate ERP |

## 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 yr intervals after baseline established |
| Impoverished | Unpolluted | 1 | Monitor at 5 yr intervals after baseline established |
| Unbalanced | Slightly polluted | 2 | As above plus initiate ERP |
| Transitional to polluted | Moderately polluted | 3 | As above |
| Polluted | Moderately polluted | 4 | Post baseline, monitor yearly, initiate ERP |
| Heavily polluted | Transitional to heavily polluted | 5 | As above |
| Heavily polluted | Heavily polluted | 6 | As above |
| Extremely polluted | Azoic (devoid of life) | 7 | As above |
| Early Warning Trigger | Trend to slightly polluted | | Initiate ERP |

# 3. RESULTS AND DISCUSSION

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 a results summary presented in Tables 4 and 5. Detailed results are presented in Appendix 1.

**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 monitoring results 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 Por A and Pau A). A grain size condition rating has yet to be developed for the Porirua Harbour.

**Figure 2. Porirua Harbour grain size at 4 sites, January 2008.**

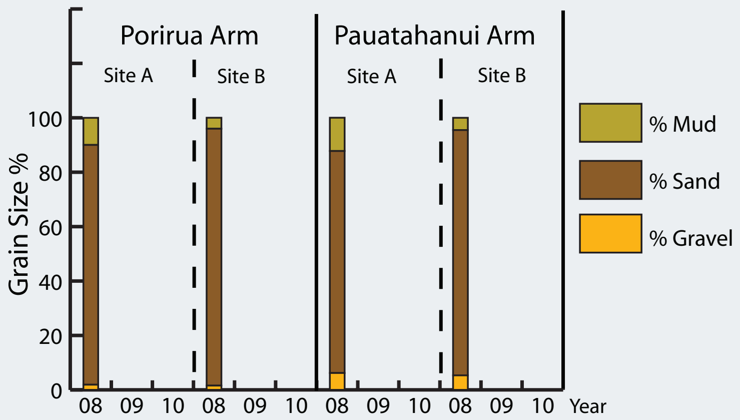



**Table 4. Physical and chemical results (means) for Porirua Harbour, January 2008.**

| Estuary | Site | Reps. | RPD | Salinity | AFDW | TOC | Mud | Sand | Gravel | Cd | Cr | Cu | Ni | Pb | Zn | TN | TP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | cm | ppt | % | | | | | mg/kg | | | | | | | |
| Porirua | Por A | 10 | 2-3 | 30 | 2.53 | 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 | 1.15 | 0.60 | 4.03 | 94.42 | 1.57 | 0.041 | 5.1 | 3.6 | 9.5 | 3.6 | 59.9 | 504 | 158 |
| Pauatahanui | Pau A | 3 | 4 | 30 | 2.50 | 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 | 1.10 | 0.58 | 4.50 | 90.17 | 5.33 | 0.020 | 4.7 | 2.3 | 4.7 | 3.9 | 23.0 | 546 | 150 |

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

| Estuary | Site | Reps. | Infauna | | Epifauna | |
|---|---|---|---|---|---|---|
| | | | Mean Abundance.m$^{-2}$ | Mean No. Species/core | Mean Abundance/quadrat | Mean No. Species/quadrat |
| Porirua | Por A | 10 | 7417 | 11.9 | 3.1 | 1.8 |
| | Por B | 10 | 7222 | 12.6 | 3.3 | 1.6 |
| Pauatahanui | Pau A | 10 | 7012 | 13.1 | 16.0 | 5.0 |
| | Pau B | 10 | 6390 | 13.4 | 27.4 | 4.5 |

# 3. Results and Discussion (Continued)

**RATE OF SEDIMENTATION**

Sedimentation plates were deployed in the estuary in Dec. 2007 to enable long term monitoring of sedimentation rates. The locations of the 15 sedimentation plates buried in soft muddy sediments in Porirua Harbour are shown in Figure 1.

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 are shown in Table 6. Following establishment of this baseline, ongoing monitoring results will be used to determine the sedimentation rate in the estuary, with a sediment condition rating used to assess any changes.

**Table 6. Sedimentation plate locations and height and depth details.**

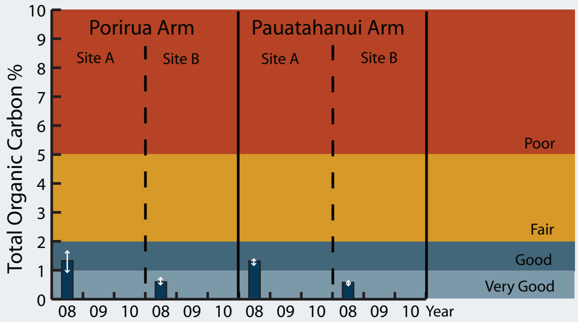
| | Site | No | Date | NZMG East | NZMG North | Plate depth (mm) | Height of stake (mm) | Height of stake (mm) |
|---|---|---|---|---|---|---|---|---|
| Pauatahanui Arm | Upper East Arm | 1 | 13 Dec 07 | 2670354 | 6010091 | 181 | 100 (north) | 100 (south) |
| | Upper East Arm | 2 | 13 Dec 07 | 2670374 | 6010070 | 215 | 100 (north) | 100 (south) |
| | Upper East Arm | 3 | 13 Dec 07 | 2670396 | 6010080 | 282 | 100 (north) | 100 (south) |
| | Upper East Arm | 4 | 13 Dec 07 | 2670385 | 6010106 | 276 | 100 (north) | 100 (south) |
| | Paremata Boatsheds | 1 | 13 Dec 07 | 2667289 | 6010500 | Yet to measure | Yet to measure | Yet to measure |
| | Paremata Boatsheds | 2 | 13 Dec 07 | 2667287 | 6010497 | Yet to measure | Yet to measure | Yet to measure |
| | Paremata Boatsheds | 3 | 13 Dec 07 | 2667286 | 6010500 | Yet to measure | Yet to measure | Yet to measure |
| | Paremata Boatsheds | 4 | 13 Dec 07 | 2667283 | 6010501 | Yet to measure | Yet to measure | Yet to measure |
| Porirua Arm | Lower (Railway) | 1 | 13 Dec 07 | 2666528 | 6009501 | 168 | 100 (west) | 100 (east) |
| | Lower (Railway) | 2 | 13 Dec 07 | 2666499 | 6009497 | 150 | 100 (west) | 100 (east) |
| | Lower (Railway) | 3 | 13 Dec 07 | 2666500 | 6009475 | 152 | 100 (west) | 100 (east) |
| | Lower (Railway) | 4 | 13 Dec 07 | 2666529 | 6009468 | 93 | 100 (west) | 100 (east) |
| | Upper (Polytech d/s) | 1 | 21 Jan 08 | 2664586 | 6007145 | 237 | 180 (west) | 180 (east) |
| | Upper (Polytech u/s) | 2 | 21 Jan 08 | 2664600 | 6007121 | 230 | 180 (west) | 180 (east) |
| | Western Subtidal | 4 | 12 Dec 07 | 2665545 | 6008840 | 120 | no stake | no stake |

**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 3) was at moderate to low concentrations (mean 1.3% at the two muddier sites in each arm and 0.6% at the other two sites) and met the "good" to "very good" condition rating. This reflects the generally well-flushed nature of much of the intertidal area and a likely moderate load of organic matter (sourced primarily from phytoplankton and macroalgae) depositing on the sediments.

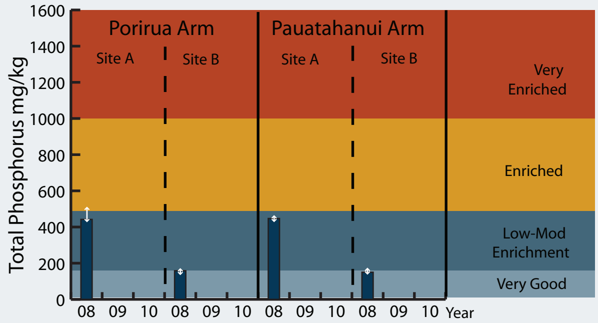
**Figure 3. Total organic carbon (mean and range) at 4 intertidal sites, Jan. 2008.**




## TOTAL PHOSPHORUS

Total phosphorus (a key nutrient in the eutrophication process) was present in the "low to moderate enrichment" category (Figure 4) at the two muddier sites in each arm (mean 440mg/kg at PorA and PauA), but at the two sandier sites (PorB and PauB), it was in the "very good" category (mean 158 and 150mg/kg respectively).

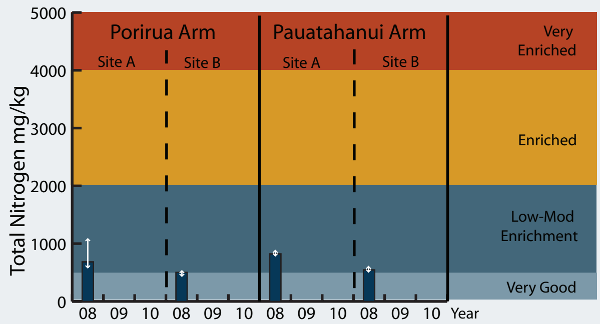
**Figure 4. Total phosphorus (mean and range) at 4 intertidal sites, Jan.2008.**




## TOTAL NITROGEN

Like phosphorus, total nitrogen (the other key nutrient in the eutrophication process) was at the "low to moderate enrichment" category (Figure 5) at the two muddier sites in each arm (mean 685mg/kg at PorA and 823mg/kg at PauA), but at the two sandier sites (PorB and PauB), it was in the "very good" category (mean 504 and 546mg/kg respectively).

**Figure 5. Total nitrogen (mean and range) at 4 intertidal sites, Jan. 2008.**

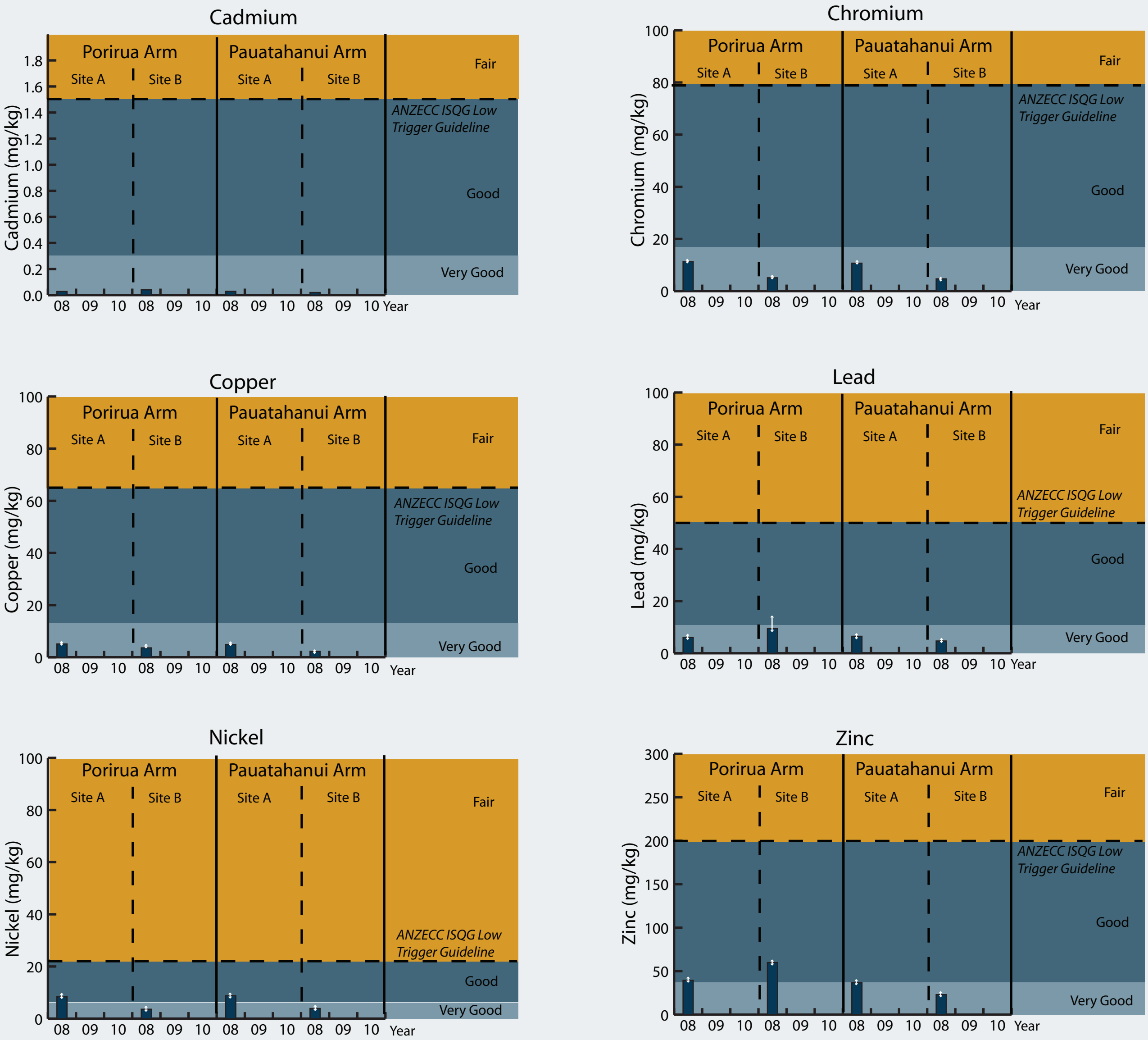


# 3. Results and Discussion (Continued)

**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 well below the ANZECC (2000) ISQG-Low trigger values (Figure 6). Metals met the "very good" condition 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" condition rating for nickel at the two lower estuary sites (PorA and PauB) and zinc at the two Porirua Arm sites.

**Figure 6. Total recoverable metals (mean and range) at 4 intertidal sites, January 2008.**



**REDOX POTENTIAL DISCONTINUITY DEPTH**

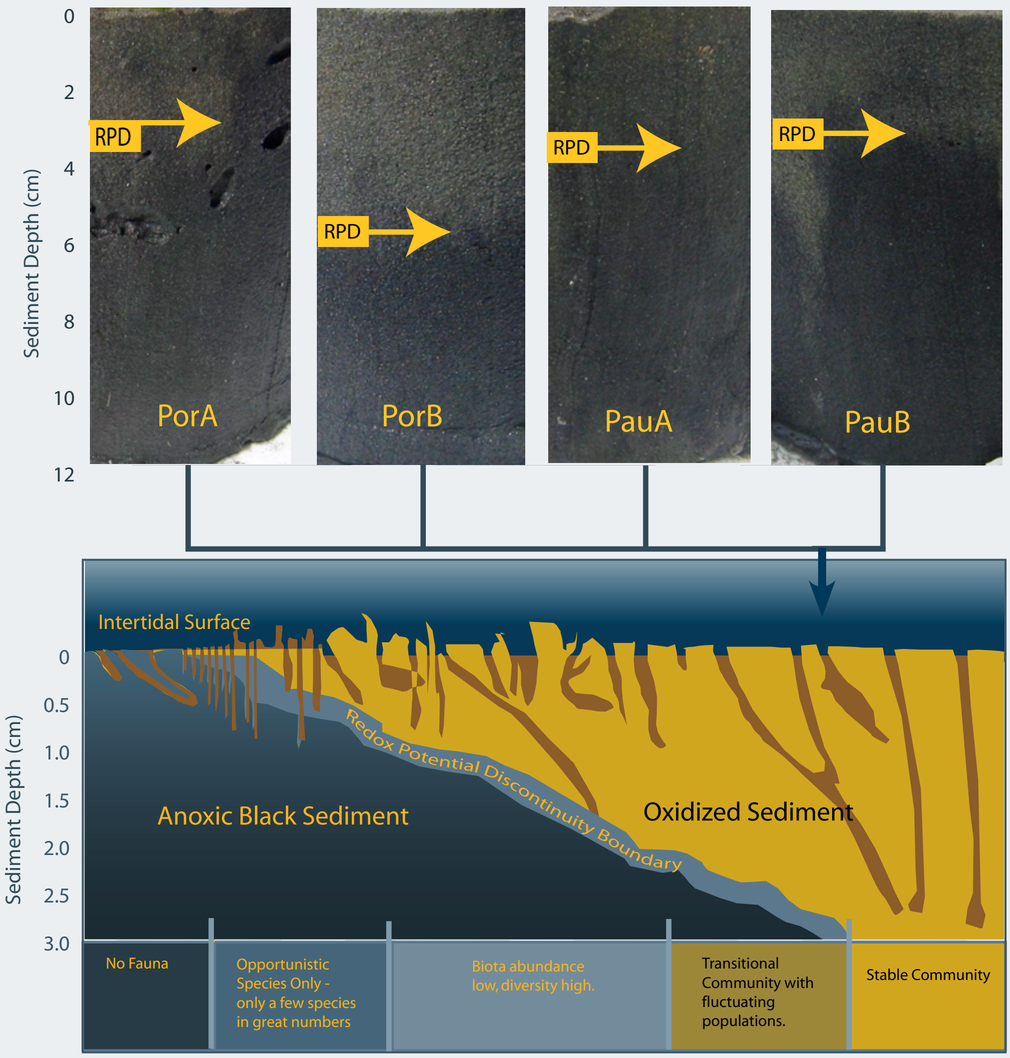
RPD depth, which is a key indicator of sediment oxygenation, was relatively shallow and varied from 2-4cm at PorA (opposite the Plimmerton Railway Station) to 3-6cm at the other sites. The key finding of the RPD profiles was that the sediments were good to moderately oxygenated as inferred from the following observations;

- RPD values were fair to good at all sites (2-6cm)
- 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 7 shows the sediment profiles and RPD depths for each of the four Porirua Harbour sampling sites (also Table 4). 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.

For the Porirua Harbour the results indicated that the benthic invertebrate community was likely to be either in an unstable "transitional" state or a stable "normal" state.

**Figure 7. Porirua Harbour sediment profiles and RPD depths at each of 4 sampling sites.**

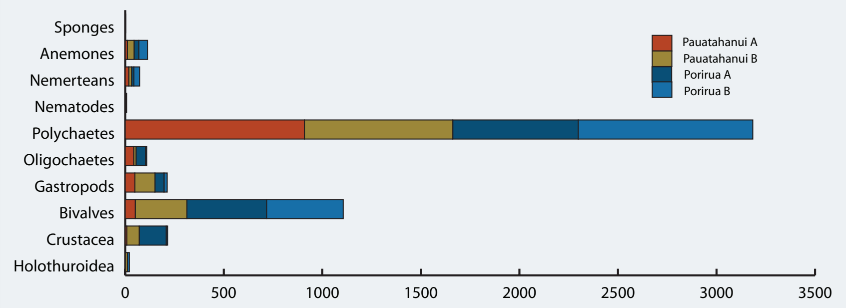


# 3. Results and Discussion (Continued)

**BENTHIC INVERTEBRATE COMMUNITY**

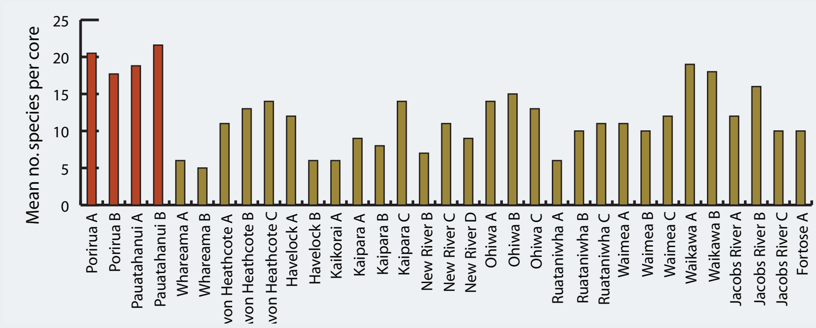
Like other NZ estuaries, the intertidal benthic community at all four sites was dominated in terms of abundance by polychaetes (>50%), followed by bivalves, crustaceans and gastropods (Figure 8).

**Figure 8. Mean total abundance of macrofauna groups in Porirua Harbour.**



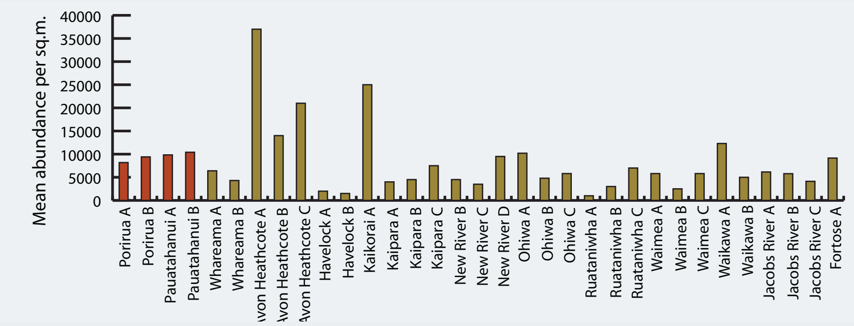

The community at all four sites also included a wide range of species (16-22 species per core or 33-42 species recorded in the 10 cores taken at each site). Compared with the intertidal mudflats in other NZ estuaries that drain developed catchments, the community diversity was relatively high (Figure 9).

**Figure 9. Mean number of infauna species, Porirua Harbour compared with other NZ estuaries (source: Robertson et al. 2002, Robertson and Stevens 2006).**




Similarly, the overall community abundance at all four sites in Porirua Harbour was moderate at 8,000-10,000$m^{-2}$ (Figure 10) compared with other NZ estuaries with developed catchments.

**Figure 10. Mean total abundance of macrofauna in Porirua Harbour compared with other NZ estuaries.**



**SITE DIFFERENCES**

Although all four sites had similar abundance and diversity measures, they differed in the types of species making up the community at each site.

At Pauatahanui Site A, the five most abundant species in the community (Table 7) were all polychaetes, but with varying degrees of tolerance to organic enrichment. *Heteromastus*, the second most abundant organism was very tolerant, the Paraonid and *Perinereis* were moderately tolerant, and *Boccardia* and *Axiothella* were intolerant (see Appendix 3 for details on species tolerance).

At Pauatahanui Site B, the five most abundant species in the community included the very tolerant *Heteromastus* and two very intolerant polychaete species *Boccardia* and *Axiothella*, plus two moderately tolerant bivalves (the cockle *Austrovenus* and the wedge shell *Macomona*).

At Porirua Site A (opposite the railway station near Mana), the five most abundant species in the community included the very tolerant *Heteromastus* (which had the highest abundance of all Porirua Harbour sites), three moderately tolerant bivalves (*Nucula, Arthritica* and the cockle *Austrovenus*), and an enrichment-intolerant amphipod.

At Porirua Site B (opposite the Polytech in Porirua), the five most abundant species in the community included the moderately tolerant cockle (*Austrovenus*), the very tolerant polychaete *Heteromastus filiformis*, the moderately tolerant polychaete *Aonides*, and two very intolerant polychaetes *Orbinia* and *Axiothella*. This site also had the highest numbers of the highly enrichment-tolerant, polychaete *Capitella*.

In terms of feeding preferences, the community at all sites was dominated by a mix of suspension and surface and subsurface deposit feeders that prefer low to moderately enriched sands or muddy sands, and a moderately shallow RPD.

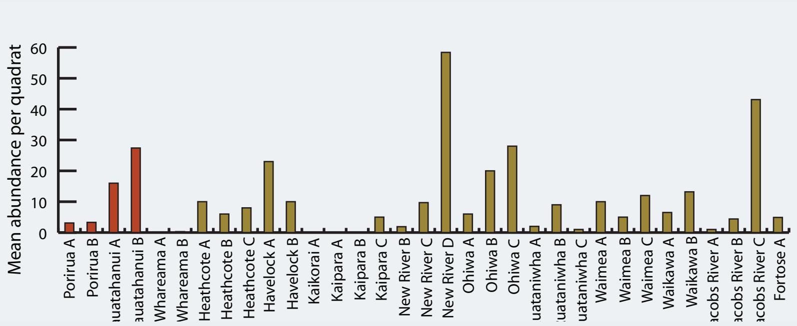
**Table 7. Mean abundance of the 15 most abundant infauna species at Porirua Harbour intertidal sites.**

| Species | Paua A | Species | Paua B | Species | Por A | Species | Por B |
|---|---|---|---|---|---|---|---|
| Paraonidae sp.#1 | 313 | Heteromastus filiformis | 332 | Heteromastus filiformis | 388 | Austrovenus stutchburyi | 309 |
| Heteromastus filiformis | 229 | Boccardia (acus | 123 | Nucula hartvigiana | 164 | Heteromastus filiformis | 195 |
| Boccardia syrtis | 95 | Austrovenus stutchburyi | 110 | Arthritica sp.#1 | 95 | Axiothella serrata | 191 |
| Perinereis vallata | 64 | Macomona liliana | 110 | Phoxocephalidae sp.#1 | 93 | Aonides sp.#1 | 156 |
| Axiothella serrata | 52 | Axiothella serrata | 98 | Austrovenus stutchburyi | 87 | Orbinia papillosa | 135 |
| Oligochaeta | 43 | Orbinia papillosa | 47 | Boccardia acus | 75 | Capitella capitata | 67 |
| Terebellidae sp.#1 | 33 | Spionidae sp.#1 | 46 | Paraonidae sp.#1 | 63 | Macomona liliana | 55 |
| Haminoea zelandiae | 31 | Phoxocephalidae sp.#1 | 43 | Macomona liliana | 58 | Boccardia) acus | 54 |
| Sabellidae sp.#1 | 24 | Haminoea zelandiae | 38 | Oligochaeta | 48 | Edwardsia sp.#1 | 44 |
| Spionidae sp.#1 | 21 | Edwardsia sp.#1 | 34 | Spionidae sp.#1 | 38 | Scoloplos cylindrifer | 41 |
| Macomona liliana | 18 | Notoacmaea helmsi | 27 | Boccardia syrtis | 26 | Spionidae sp.#2 | 25 |
| Capitella capitata | 16 | Arthritica sp.#1 | 24 | Ostracoda sp.#1 | 23 | Nemertea sp.#1 | 21 |
| Orbinia papillosa | 14 | Perinereis vallata | 22 | Gastropoda sp.#1 | 19 | Arthritica sp.#1 | 18 |
| Scolecolepides benhami | 14 | Sphaerosyllis sp.#1 | 21 | Anthozoa sp.#1 | 16 | Perinereis vallata | 10 |
| Sphaerosyllis sp.#1 | 13 | Aonides sp.#1 | 20 | Halicarcinus varius | 14 | Trochodota dendyi | 10 |

**EPIFAUNA**

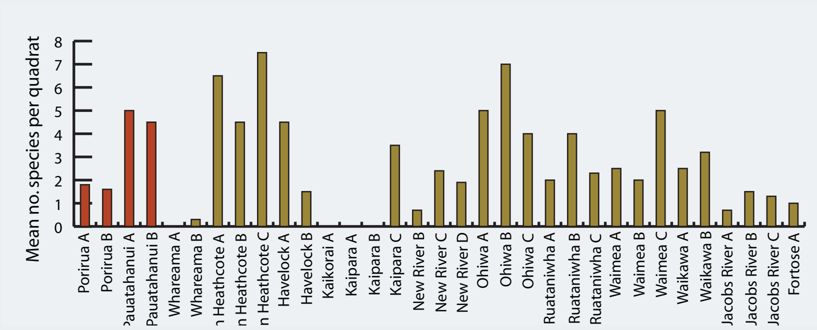
Surface dwelling organisms (epifauna) were also recorded using quadrats rather than the much smaller cores used to sample the whole benthic community (i.e. infauna and epifauna). These results, although not used in the benthic community index, show that surface dwelling organisms were both more abundant and more diverse in the Pauatahanui Arm compared with the Porirua Arm (Figures 11 and 12).

**Figure 11. 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 Porirua Arm it was low.

**Figure 12. Mean number of epifauna species per quadrat - Porirua Harbour and other NZ estuaries (source Robertson et al. 2002, Robertson and Stevens 2006).**



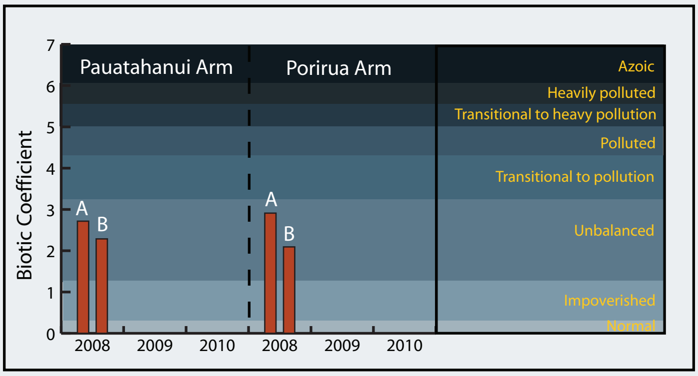

In the Pauatahanui Arm, the epifauna included a typical array of shellfish including cockles , whelks, topshells, limpets, spire shells and bubble shells, as well as the mud-flat anemone. In the Porirua Arm, the epifauna was less diverse and included cockles, whelks, topshells, limpets and spire shells.

## BENTHIC COMMUNITY INDEX

A need for new tools to assess the environmental status of coastal and estuarine systems encouraged Borja et al. (2000) to develop a new benthic community index, the AZTI (AZTI-Tecnalia Marine Research Division, Spain) Marine Benthic Index (AMBI). Results from around the world show that in many cases, the AMBI provides a very good indication of environmental conditions and therefore has become a promising tool for assessing estuary condition. Within NZ, use of the index to date has been low but initial evaluations on estuaries in the Tasman and Wellington regions look promising (Robertson and Stevens 2008, 2008a).

Use of the AMBI in Porirua Harbour to summarise the benthic community health and provide an estuary condition classification (for dominant intertidal areas) also turned out promising. The results (details in Appendix 3) showed that the benthic invertebrate community at all sites in the Porirua Harbour was "unbalanced", indicating a "slightly polluted" classification (Figure 13).

**Figure 13. Benthic community condition rating for 4 sites in Porirua Harbour.**




The unbalanced nature of the community can be 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 2007b).

## CONDITION RATINGS

The fine scale condition ratings for the key fine scale indicators are summarised as follows.

| FINE SCALE RATING 2007 | RPD Depth | Benthic Community | Organic Matter | Nutrients | Cadmium | Chromium | Copper | Lead | Nickel | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|
| Pauatahanui Arm Site A | GOOD | UNBALANCED | GOOD | LOW-MOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD | GOOD | VERY GOOD |
| Pauatahanui Arm Site B | GOOD | UNBALANCED | VERY GOOD | LOW-MOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD |
| Porirua Arm Site A | FAIR | UNBALANCED | GOOD | LOW-MOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD | GOOD | GOOD |
| Porirua Arm Site B | GOOD | UNBALANCED | VERY GOOD | LOW-MOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD | VERY GOOD | GOOD |

# 4. CONCLUSIONS

In conclusion, the first 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 the Porirua Harbour was unvegetated muddy sand and was generally in good to moderate condition. In order to provide a more comprehensive assessment of overall estuary condition, these results, in combination with other relevant information particularly the broad scale mapping results (Stevens and Robertson 2008), are used in the following subsections to provide an understanding of the estuary condition in relation to the key issues addressed by the fine scale monitoring, that is sedimentation, eutrophication and toxicity.

Black anoxic layer (RPD) just below surface in Porirua Arm.

**EUTROPHICATION.**

Eutrophication is the process where water bodies receive excess nutrients that stimulate excessive plant growth. In estuaries like the Porirua Harbour, 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.

In terms of the eutrophication indicators for the intertidal area, the results were in the low-moderate category for nutrients (TN and TP) and organic content, and the sediments were fair to moderately oxygenated as inferred from the relatively shallow RPD layer at all sites (2-6cm). Although the sediment biota results indicated a very diverse and abundant community, the presence of high numbers of pollution tolerant organisms meant that its condition was "unbalanced", giving it a "slightly polluted" classification. Taken in combination with the relatively abundant presence of macroalgae in the estuary (Stevens and Robertson 2008), the results indicated a moderately eutrophic or mesotrophic estuary.

Such enrichment, although not yet a major problem, does indicates a need for caution, particularly in relation to factors that could increase nutrient and fine sediment concentrations in the Harbour. Moderately elevated sediment nutrient levels are a particular threat in estuaries where there is a possibility of a shift to sediment anoxia. Under such conditions, both P and N become much more available for nuisance algal growth and a return to oxygenated conditions is difficult to achieve - even if catchment nutrient loads are reduced.

Another important point, is that the nutrient data identify N as the nutrient most likely to be limiting eutrophication in the Porirua Harbour (i.e. the ratio of TN:TP in the intertidal sediments, which ranged from 1.2 to 3.7, was less than the upper limit of 10 used to define nitrogen limitation). Such data confirm N as the critical nutrient to address in any management actions designed to reduce macroalgal growth in the estuary.

Because nutrient loads to the estuary are elevated and localised parts of the estuary are already anoxic (e.g. upper Porirua Harbour), continuation with nutrient load management options (as recommended in the recent vulnerability assessment - Robertson and Stevens 2007b) and long term monitoring is supported.

**SEDIMENTATION**

Soil erosion is a major issue in New Zealand and the resulting suspended sediment impacts are of particular concern in tidal lagoon estuaries like the Porirua, because they have a central basin which forms a sink for fine sediments.

# 4. Conclusions (continued)

**Mud snails grazing on intertidal mudflats, Pauatahanui Arm.**

The result can cause impacts such as; increased muddiness and turbidity, shallowing, increased nutrients, changes in saltmarsh and seagrass habitats, less oxygen, increased organic matter degradation by anoxic processes (e.g. sulfate reduction), and alterations to fish and invertebrate communities.

In subtidally-dominated estuaries, like the Porirua Harbour, fine muds tend to settle in three main areas; the subtidal central basin and, to a lesser extent, the unvegetated intertidal area around the central basins; salt marsh areas; and sheltered estuary arms. It is therefore not unexpected that the 2008 fine scale grain size results (and 2007 broad scale mapping) showed that the intertidal area in both arms was dominated by sandy sediments and previous studies (Healy 1980) showed that the subtidal basins were dominated by soft muds.

A more recent study of sedimentation in Pauatahanui Arm (Swales et al. 2005) provides further insights into sedimentation patterns in the Harbour. A summary of the study's findings were presented in the June 2005 GWRC "Coastal Investigations Report" as follows:

> *The studies demonstrated that the rate of sediment accumulation in Pauatahanui Inlet has increased over time. Pre-human ("natural") rates are estimated to have averaged 1mm per year. As a result of the impacts of forest removal, conversion to pasture and other human activities the sediment accumulation rate has steadily increased and is estimated to be about 4.6mm per year currently. It was noted that the quantity of sediment entering the Inlet is likely to be higher than this figure. Two processes have worked in the Inlet's favour to prevent the accumulation rate being higher. Firstly, as a result of the strength and frequency of winds experienced at Pauatahanui and the particular depth of the Inlet, there is considerable "stirring up" and re-suspension of sediment. Secondly, the Inlet has strong tidal flushing with the total volume of water in the Inlet changing every 4 days. The scientists suspected that the combination of these two factors resulted in a proportion of sediment being exported from the Inlet. This factor may be the Inlet's "saving grace" that has prevented a more rapid accumulation of sediment. In addition, there had been a sea level rise of about 1.8mm per year in the Wellington Harbour since 1891. It was assumed that a similar rise has taken place at Pauatahanui Inlet and this will have offset the effects of sediment build-up to some degree.*
>
> *The study also showed that the rate of accumulation appeared to be continuing to increase and that there may be variations between sub-catchments.*
>
> *The study concluded that the fact that sediment accumulation rates have increased in recent decades suggested that the rate of sediment input now exceeded the capacity of the estuary to flush sediment.*

Overall, the combined results indicate that sedimentation is an issue in Porirua Harbour and that ongoing monitoring and management is required. Because of the high cost of subtidal monitoring and the fact that soft mud already dominates the subtidal basins, mapping and monitoring of the less impacted and more vulnerable intertidal area has been chosen as the preferred approach. In addition, measurement of the sedimentation rate in both intertidal and subtidal areas has been initiated with deployment of sediment plates at 4 intertidal sites and 1 subtidal site. In the future, it is recommended that additional subtidal plates be deployed and subtidal sediment type assessed at a few key sites.

# 4. Conclusions (continued)

**TOXICITY**

The extent of contamination with toxic substances was rated “very good to good” reflecting the low levels of heavy metals (total recoverable Cd, Cr, Cu, Ni, Pb, Zn) in the intertidal sediments compared with ANZECC (2000) guideline criteria. However, such positive results for the intertidal sediments can be misleading when using the findings to assess overall toxicity within the whole estuary. In the Porirua Harbour, fine sediments tend to deposit mainly in the subtidal basins. Because metals entering the estuary are mostly bound to fine sediments (mud fraction size class), they also tend to end up at the highest concentrations in the subtidal basins. It is also important to consider the proportion of sediments in the mud fraction size class and their associated contaminant concentrations because the mud fraction is the main source of food for the dominant sediment-dwelling organisms (i.e., deposit feeders).

It is therefore not surprising that previous studies (Stephenson and Mills 2006) at five subtidal sites in the Harbour (Table 8) showed higher concentrations (copper, lead and zinc were just below the ANZECC (2000) ISQG-Low trigger values), than measured at the intertidal sites. However, it should be noted that a true comparison of the metal concentrations reported here and those reported by Stephenson and Mills (2006) is not possible because different sediment fractions were analysed; Stephenson and Mills (2006) analysed the sub-500 micron fraction (i.e. muds and fine to medium sands).

**Table 8. Subtidal metal concentrations (mg/kg) (Stephenson and Mills 2006).**

| Subtidal Site (2005) | Cadmium | Chromium | Copper | Lead | Nickel | Zinc | %mud | TOC% |
|---|---|---|---|---|---|---|---|---|
| PAH1 (Pauatahanui Arm) | 0.040 | 15.8 | 12.5 | 20.1 | 11 | 66.4 | 20 | 1.5 |
| PAH2 (Pauatahanui Arm) | 0.060 | 12.4 | 11.4 | 17.5 | 8.5 | 56.9 | 50 | 1.5 |
| PAH3 (Pauatahanui Arm) | 0.040 | 13.3 | 9.3 | 16 | 9.4 | 57.8 | 35 | 1 |
| POR1 (Porirua Arm) | 0.014 | 16.3 | 21 | 42 | 10.4 | 169 | 78 | 2 |
| POR2 (Porirua Arm) | 0.050 | 18.7 | 19.2 | 38.3 | 12.1 | 127 | 90 | 1.8 |

In any case, both intertidal and subtidal surface sediment sampling to date confirm the findings of the recent vulnerability assessment for Porirua Harbour (Robertson and Stevens 2007b) which indicated a localised risk of sediment contamination – particularly in the southern end of the Porirua Arm – from toxicants in urban stormwater discharges.

# 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 monitoring results and condition ratings, it is recommended that monitoring continue as outlined as follows:

**Fine Scale Monitoring**.
Complete the three to four years of the proposed annual baseline monitoring in Porirua Harbour but with the following changes to the programme:

- Because of the good condition ratings and the small variation between replicates for most physical and chemical parameters, it is recommended that the number of replicates for physical and chemical parameters be reduced from ten to three composite samples for sites in Porirua Harbour.
- 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 15 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 reinforced 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, intend to work 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.

# 7. ACKNOWLEDGEMENTS

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# APPENDIX 1. DETAILS ON ANALYTICAL METHODS

| Indicator | Laboratory | Method | Detection Limit |
|---|---|---|---|
| Infauna Sorting and ID | CMES | Coastal Marine Ecology Consultants (Gary Stephenson) * | N/A |
| Grain Size | R.J Hill | Air dry (35 degC, sieved to pass 2mm and 63um sieves, gravimetric - (% sand, gravel, silt) | N/A |
| AFDW (% organic matter) | R.J Hill | 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 | 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. 2008 DETAILED RESULTS

**Physical and chemical results for Porirua Harbour, January 2008.**

| | Site | Rep. | RPD | Salinity | AFDW | Mud | Sands | Gravel | Cd | Cr | Cu | Ni | Pb | Zn | TN | TP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | cm | ppt@15$^0$C | % | | | | mg/kg | | | | | | | |
| Porirua Arm | PorA | 1 | 2.5 | 30 | 2.3 | 11 | 86.3 | 2.7 | 0.03 | 11 | 4.9 | 5.7 | 8.3 | 38 | 650 | 420 |
| | PorA | 2 | 3 | 30 | 2.4 | 6.8 | 92.9 | 0.2 | 0.028 | 12 | 5.1 | 5.8 | 8.5 | 41 | 530 | 440 |
| | PorA | 3 | 4 | 30 | 2.4 | 8.7 | 91 | 0.3 | 0.021 | 11 | 5 | 5.8 | 8.7 | 39 | 540 | 430 |
| | PorA | 4 | 2 | 30 | 3.6 | 13.3 | 85.4 | 1.3 | 0.025 | 12 | 5.9 | 7.7 | 9.1 | 44 | 1100 | 530 |
| | PorA | 5 | 3 | 30 | 2.8 | 13.7 | 80.4 | 5.9 | 0.028 | 12 | 5 | 5.5 | 8.3 | 38 | 580 | 410 |
| | PorA | 6 | 2 | 30 | 2.9 | 9.3 | 89.6 | 1.1 | 0.029 | 11 | 4.9 | 5.8 | 8 | 38 | 590 | 420 |
| | PorA | 7 | 3 | 30 | 2 | 8.1 | 91.2 | 0.7 | 0.031 | 11 | 5 | 6 | 8.2 | 39 | 590 | 410 |
| | PorA | 8 | 3 | 30 | 2.7 | 8.3 | 86.6 | 5.1 | 0.03 | 11 | 5.2 | 6 | 8.5 | 40 | 680 | 440 |
| | PorA | 9 | 3 | 30 | 2.1 | 9.1 | 89.8 | 1.1 | 0.03 | 11 | 4.7 | 6.1 | 8.2 | 38 | 640 | 420 |
| | PorA | 10 | 2 | 30 | 2.1 | 11.3 | 88.1 | 0.6 | 0.031 | 11 | 5.1 | 6.1 | 8 | 39 | 950 | 500 |
| | PorB | 1 | 5 | 27 | 1.6 | 5.8 | 91.7 | 2.5 | 0.046 | 5.3 | 3.7 | 8.5 | 3.6 | 61 | 510 | 160 |
| | PorB | 2 | 4 | 27 | 1.2 | 2.1 | 95.3 | 2.6 | 0.037 | 5 | 3.3 | 8.3 | 3.6 | 57 | 500 | 170 |
| | PorB | 3 | 4 | 27 | 1.3 | 4.4 | 93.3 | 2.3 | 0.051 | 5.5 | 3.7 | 11 | 3.7 | 62 | 500 | 160 |
| | PorB | 4 | 5 | 27 | 0.87 | 3.3 | 95.1 | 1.6 | 0.039 | 4.9 | 4 | 14 | 3.5 | 59 | 530 | 170 |
| | PorB | 5 | 6 | 27 | 0.88 | 9.6 | 89.2 | 1.2 | 0.036 | 5 | 3.4 | 9 | 3.7 | 58 | 500 | 160 |
| | PorB | 6 | 6 | 27 | 0.92 | 3.8 | 94.8 | 1.4 | 0.036 | 4.8 | 3.2 | 8.6 | 3.5 | 57 | 500 | 160 |
| | PorB | 7 | 5 | 27 | 1.3 | 3.8 | 94.7 | 1.5 | 0.044 | 5.3 | 3.7 | 8.9 | 3.8 | 62 | 500 | 150 |
| | PorB | 8 | 4 | 27 | 1 | 5.1 | 93.4 | 1.4 | 0.04 | 5 | 4 | 9 | 3.6 | 60 | 500 | 160 |
| | PorB | 9 | 5 | 27 | 1.2 | 0.1 | 99.6 | 0.6 | 0.038 | 5 | 3.6 | 9.3 | 3.6 | 61 | 500 | 150 |
| | PorB | 10 | 6 | 27 | 1.2 | 2.3 | 97.1 | 0.6 | 0.038 | 5.2 | 3.6 | 8.7 | 3.4 | 62 | 500 | 140 |
| Pautahanui Arm | PauA | 1 | 4 | 30 | 2.6 | 14.1 | 77.2 | 8.7 | 0.029 | 11 | 5.4 | 7.3 | 9.2 | 39 | 880 | 470 |
| | PauA | 2 | 3 | 30 | 2.6 | 13.3 | 81.7 | 5 | 0.028 | 10 | 4.8 | 6.3 | 9.2 | 35 | 850 | 450 |
| | PauA | 3 | 4 | 30 | 2.3 | 9.3 | 85.9 | 4.9 | 0.03 | 11 | 4.6 | 6 | 8.1 | 36 | 740 | 420 |
| | PauB | 1 | 3 | 30 | 0.81 | 2.8 | 90.4 | 6.8 | 0.021 | 4.4 | 2.1 | 4.7 | 3.7 | 22 | 500 | 130 |
| | PauB | 2 | 3 | 30 | 1 | 5.5 | 89.1 | 5.4 | 0.02 | 5.1 | 2.4 | 4.6 | 4.1 | 24 | 500 | 150 |
| | PauB | 3 | 4 | 30 | 1.5 | 5.2 | 91 | 3.8 | 0.02 | 4.5 | 2.4 | 4.7 | 3.8 | 23 | 640 | 170 |

**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 | 2770091 | 2770080 | 2770052 | 2770053 | 2770070 | 2770076 | 2770095 | 2770101 | 2770086 | 2770074 |
| NZMG NORTH | 6017048 | 6017044 | 6017030 | 6017019 | 6017029 | 6017035 | 6017045 | 6017038 | 6017030 | 6017024 |

## Station Locations

| **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 0.25m$^2$ quadrat)

### 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Anthopleura aureoradiata* Mudflat anemone | | | 1 | | | 1 | 1 | | | |
| *Austrovenus stutchburyi* Cockle | 3 | 4 | | 2 | 2 | 4 | 1 | | | |
| *Bulla quoyii* Bubble shell | | 1 | 10 | 3 | 2 | | 3 | | 5 | 2 |
| *Cominella glandiformis* Mudflat whelk | 1 | 5 | | 2 | | 1 | | | | 4 |
| *Diloma subrostrata* Mudflat topshell | 2 | 2 | 3 | 4 | 1 | 2 | 5 | 5 | 6 | 4 |
| *Elminius modestus* Estuarine barnacle | | | | | | | | 1 | | |
| *Micrelenchus huttoni* Top shell | | 1 | | 4 | | 1 | | | 1 | |
| *Notoacmea helmsi* Estuarine limpet | | 3 | 7 | 6 | 3 | 2 | | 3 | 11 | 6 |
| *Zeacumantus lutulentus* Spire shell | 2 | | 2 | | 2 | | 3 | 8 | 3 | |

### 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 | | | | | | | | 4 | 3 | 2 |
| *Bulla quoyii* Bubble shell | 1 | 4 | 3 | 3 | | 2 | | | 3 | 2 |
| *Cominella glandiformis* Mudflat whelk | 1 | 3 | 2 | 2 | 2 | 3 | 17 | 8 | 3 | 5 |
| *Cominella maculosa* Spotted whelk | | 2 | 2 | 5 | | | | | | |
| *Diloma subrostrata* Mudflat topshell | 4 | 7 | 14 | 16 | 19 | 12 | 19 | 16 | 14 | 15 |
| *Micrelenchus huttoni* Top shell | | | 4 | | | | | | | |
| *Notoacmea helmsi* Estuarine limpet | | | | | 2 | | | | | |
| *Zeacumantus lutulentus* Spire shell | 2 | 2 | 3 | 10 | 7 | 5 | 8 | 1 | 5 | 7 |

### 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 | 4 | 3 | 2 | | | | 2 | | 1 | 2 |
| *Cominella glandiformis* Mudflat whelk | | | | 1 | | | | 1 | | |
| *Diloma subrostrata* Mudflat topshell | | | 2 | 2 | | 1 | | 1 | 3 | |
| *Micrelenchus huttoni* Top shell | | | | | | 1 | | | | |
| *Zeacumantus lutulentus* Spire shell | | | | | 1 | | 1 | | 1 | 2 |

### 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 | | 1 | | | | 2 | | | | |
| *Cominella glandiformis* Mudflat whelk | 6 | | | 2 | 2 | | | 1 | | |
| *Diloma subrostrata* Mudflat topshell | 3 | 2 | 2 | 2 | 2 | 4 | | 1 | | |
| *Notoacmea helmsi* Estuarine limpet | | 1 | | | 1 | | | 1 | | |

# APPENDIX 2. 2008 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PORIFERA | Porifera sp.#1 | | | | | | | | | | |
| ANTHOZOA | Anthozoa sp.#1 | 1 | | | | | | | | | |
| | *Edwardsia sp.#1* | 3 | | 1 | | | 4 | | | | 2 |
| NEMERTEA | Nemertea sp.#1 | | 1 | 1 | 1 | 3 | 2 | 2 | | 1 | 1 |
| | Nemertea sp.#2 | | | | 2 | | | 2 | | | |
| | Nemertea sp.#3 | | | | | | 1 | | | | |
| | Nemertea sp.#4 | | | | 1 | | | | | | |
| NEMATODA | Nematoda | | | | 1 | | | | | | |
| POLYCHAETA | *Aonides sp.#1* | | 1 | | | 2 | 1 | 2 | 2 | | |
| | *Armandia maculata* | | 1 | | | | | | | | |
| | *Axiothella serrata* | 1 | 31 | 2 | 1 | 1 | 3 | 2 | 2 | 4 | 5 |
| | *Boccardia (Paraboccardia) acus* | | 3 | | 1 | | | | | | |
| | *Boccardia (Paraboccardia) syrtis* | 8 | 10 | 10 | 13 | 13 | 7 | 14 | 3 | 10 | 7 |
| | *Capitella capitata* | | 1 | 1 | | | | 8 | 2 | 2 | 2 |
| | Dorvilleidae sp.#1 | 1 | | | 3 | | | | | | |
| | Goniada sp.#1 | | | | | | | | | | |
| | Hesionidae sp.#1 | | 1 | | | | | | | | |
| | *Heteromastus filiformis* | 44 | 35 | 13 | 16 | 11 | 20 | 17 | 12 | 29 | 32 |
| | *Nicon aestuariensis* | | | | | | | | 1 | 2 | |
| | *Orbinia papillosa* | | 1 | 4 | 2 | | 1 | | 2 | 2 | 2 |
| | Paraonidae sp.#1 | 6 | 20 | 47 | 18 | 33 | 29 | 74 | 28 | 36 | 22 |
| | *Pectinaria australis* | | | | | | | | | | |
| | *Perinereis vallata* | 8 | 12 | 6 | 4 | 5 | 6 | 10 | 6 | 1 | 6 |
| | *Platynereis australis* | | | | | | | | | | |
| | Polychaeta sp.#1 | | | | | | | | | | |
| | Sabellariidae sp.#1 | | | | | | | | | | |
| | Sabellidae sp.#1 | | | | 1 | | 6 | 3 | 1 | 12 | 1 |
| | *Scolecolepides benhami* | 1 | | 2 | 1 | 2 | 2 | | 1 | 3 | 2 |
| | *Scoloplos (Scoloplos) cylindrifer* | | | | | | | | | | |
| | Sphaerosyllis sp.#1 | 2 | 2 | 2 | 6 | | | | | 1 | |
| | Spionidae sp.#1 | 2 | 2 | 1 | 3 | | 3 | 4 | 4 | 2 | |
| | Spionidae sp.#2 | | | | | | | | | | |
| | Terebellidae sp.#1 | 6 | 5 | 3 | 6 | 4 | 5 | 3 | 1 | | |
| OLIGOCHAETA | Oligochaeta | | 6 | 1 | 5 | 1 | 6 | 24 | | | |
| GASTROPODA | *Cominella glandiformis* | 1 | 1 | | | | 1 | | 1 | 1 | |
| | *Diloma subrostrata* | | | | | | | | | 1 | |
| | Gastropoda sp.#1 | | | | | | | | | 1 | |
| | Gastropoda sp.#2 | | | | | | | | | | |
| | *Haminoea zelandiae* | | 2 | 1 | 15 | 1 | 4 | 2 | 1 | 3 | 2 |
| | *Notoacmaea helmsi* | | | | 1 | | 2 | 2 | 2 | 4 | |
| | *Xymene plebeius* | | | | | | | | | | |
| | *Zeacumantus lutulentus* | | | | | | | | | | |
| BIVALVIA | *Arthritica sp.#1* | 1 | | 2 | 2 | | 1 | 1 | 1 | 1 | |
| | *Austrovenus stutchburyi* | | 1 | | 1 | | 5 | 2 | 1 | 1 | 1 |
| | *Macomona liliana* | 6 | 1 | | 3 | | 2 | | | 3 | 3 |
| | *Nucula hartvigiana* | | 4 | 1 | 2 | | 1 | | | 4 | |
| | *Paphies australis* | | | | | | | | | | |
| | *Solemya parkinsoni* | | | | | | | | | | |
| CRUSTACEA | Amphipoda sp.#1 | | | | | | | | | | |
| | Cephalocarida sp.#1 | | | | | | | | | | |
| | *Halicarcinus varius* | | | | | | | | | | |
| | *Halicarcinus whitei* | | | | | | | | | | |
| | *Hemigrapsus crenulatus* | | | | | | | | | | |
| | *Macrophthalmus hirtipes* | | | | | 1 | | | | | |
| | Mysidacea sp.#1 | | | | | | | | | | |
| | Ostracoda sp.#1 | 1 | 1 | | 1 | 2 | | | 1 | | |
| | Ostracoda sp.#2 | | | | 1 | | | | | | |
| | Phoxocephalidae sp.#1 | | | | | | | | | | |
| HOLOTHUROIDEA | *Trochodota dendyi* | | | | | | | | | | |
| | **Total species in sample** | **16** | **22** | **17** | **26** | **13** | **22** | **17** | **19** | **22** | **14** |
| | **Total individuals in sample** | **92** | **142** | **98** | **111** | **79** | **112** | **172** | **72** | **124** | **88** |

# APPENDIX 2. 2008 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PORIFERA | Porifera sp.#1 | | | | 2 | | | | | | |
| ANTHOZOA | Anthozoa sp.#1 | | | | | | | | | | |
| | *Edwardsia sp.#1* | | 2 | 1 | 2 | 1 | 2 | 4 | 3 | 5 | 14 |
| NEMERTEA | Nemertea sp.#1 | | | | 1 | | 1 | 2 | | | 2 |
| | Nemertea sp.#2 | | 1 | 1 | | 1 | 2 | | 1 | | 1 |
| | Nemertea sp.#3 | | | | 1 | | | | | | |
| | Nemertea sp.#4 | | | | | | | | | | |
| NEMATODA | Nematoda | | | 1 | | | | | | | |
| POLYCHAETA | *Aonides sp.#1* | | 1 | | 6 | 6 | 6 | | | | 1 |
| | *Armandia maculata* | | | 1 | | | 3 | 1 | | 2 | |
| | *Axiothella serrata* | | 1 | 10 | 6 | 18 | 22 | 6 | 5 | 6 | 24 |
| | *Boccardia (Paraboccardia) acus* | 13 | 12 | 13 | 12 | 17 | 10 | 7 | 5 | 18 | 16 |
| | *Boccardia (Paraboccardia) syrtis* | | | 1 | | 1 | | | | | 7 |
| | *Capitella capitata* | | | 2 | | 3 | | | | | |
| | Dorvilleidae sp.#1 | | | | | | | | | | |
| | Goniada sp.#1 | | | 1 | | | 1 | | 1 | | 3 |
| | Hesionidae sp.#1 | | | | | | | | | | |
| | *Heteromastus filiformis* | 33 | 13 | 32 | 45 | 52 | 66 | 27 | 11 | 14 | 39 |
| | *Nicon aestuariensis* | | | | | | | | 1 | | |
| | *Orbinia papillosa* | 4 | 2 | 6 | 7 | 4 | 10 | 2 | 4 | 5 | 3 |
| | Paraonidae sp.#1 | | | | | | | | | | |
| | *Pectinaria australis* | | | | | | | | | | |
| | *Perinereis vallata* | | | 8 | 2 | 8 | | | 2 | | 2 |
| | *Platynereis australis* | | | | 1 | | | 5 | 1 | 1 | 1 |
| | Polychaeta sp.#1 | | | | | 1 | | | | | |
| | Sabellariidae sp.#1 | 1 | | | | | | | | | |
| | Sabellidae sp.#1 | | | | | | | | | | |
| | *Scolecolepides benhami* | | | | | | | | | 1 | |
| | *Scoloplos (Scoloplos) cylindrifer* | | | | | 4 | | | | | |
| | Sphaerosyllis sp.#1 | | 2 | 3 | 4 | 2 | 2 | | 1 | 3 | 4 |
| | Spionidae sp.#1 | 2 | 1 | 13 | 8 | 5 | 1 | 7 | 3 | 4 | 2 |
| | Spionidae sp.#2 | | | | | | | | | | |
| | Terebellidae sp.#1 | | | | | | | | | | |
| OLIGOCHAETA | Oligochaeta | 1 | | 2 | | 3 | 3 | 2 | | | 1 |
| GASTROPODA | *Cominella glandiformis* | 2 | | 5 | | 1 | 3 | 3 | | 2 | 3 |
| | *Diloma subrostrata* | | | 4 | 1 | | | 9 | | 1 | |
| | Gastropoda sp.#1 | | | | | | | | | | |
| | Gastropoda sp.#2 | | | | | | | | | | |
| | *Haminoea zelandiae* | 3 | 6 | 1 | 2 | 3 | 1 | 3 | 7 | 5 | 7 |
| | *Notoacmaea helmsi* | | 1 | 4 | 4 | 3 | 2 | 5 | 2 | 2 | 4 |
| | *Xymene plebeius* | | | | | | | | | 1 | |
| | *Zeacumantus lutulentus* | | | 1 | | | | | | | 1 |
| BIVALVIA | *Arthritica sp.#1* | 3 | | 1 | 8 | | | 2 | 8 | | 2 |
| | *Austrovenus stutchburyi* | 14 | 10 | 13 | 8 | 16 | 10 | 6 | 6 | 13 | 14 |
| | *Macomona liliana* | 11 | 10 | 13 | 7 | 11 | 10 | 9 | 14 | 13 | 12 |
| | *Nucula hartvigiana* | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 4 | 2 | 1 |
| | *Paphies australis* | | | | | | | | | | |
| | *Solemya parkinsoni* | | | | | | | | | | |
| CRUSTACEA | Amphipoda sp.#1 | | 1 | 4 | 1 | | | 4 | | | 1 |
| | Cephalocarida sp.#1 | | | | | | | | | | |
| | *Halicarcinus varius* | | 1 | 1 | 2 | | | | | | 2 |
| | *Halicarcinus whitei* | | | | | | 1 | | | | |
| | *Hemigrapsus crenulatus* | | | | | | | | | | |
| | *Macrophthalmus hirtipes* | | | | | | | | | | |
| | Mysidacea sp.#1 | | 1 | | | | | 1 | | | |
| | Ostracoda sp.#1 | | | | | | | | | | |
| | Ostracoda sp.#2 | | | | | | | | | | |
| | Phoxocephalidae sp.#1 | 4 | 2 | 6 | | 4 | 4 | 4 | 4 | 7 | 8 |
| HOLOTHUROIDEA | *Trochodota dendyi* | 1 | | 2 | 2 | 1 | 2 | 1 | 1 | | 1 |
| | **Total species in sample** | **14** | **18** | **28** | **23** | **23** | **22** | **22** | **20** | **19** | **27** |
| | **Total individuals in sample** | **93** | **69** | **151** | **134** | **166** | **164** | **112** | **84** | **105** | **176** |

# APPENDIX 2. 2008 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PORIFERA | Porifera sp.#1 | | | | | | | | | | |
| ANTHOZOA | Anthozoa sp.#1 | 1 | 1 | 4 | 2 | | 1 | | 4 | 3 | |
| | *Edwardsia sp.#1* | | 1 | 1 | | 3 | | | 1 | 1 | 1 |
| NEMERTEA | Nemertea sp.#1 | | | | | 1 | | 1 | | 1 | 2 |
| | Nemertea sp.#2 | | | 1 | 1 | | 1 | 1 | | 1 | 2 |
| | Nemertea sp.#3 | | | | | | | | | | |
| | Nemertea sp.#4 | | | | | | | | | | |
| NEMATODA | Nematoda | | | | 2 | 1 | | | | | |
| POLYCHAETA | *Aonides sp.#1* | | | | 3 | | | | | | |
| | *Armandia maculata* | | | | | | | | | | |
| | *Axiothella serrata* | | | | 6 | | | | | | |
| | *Boccardia (Paraboccardia) acus* | 8 | 6 | 10 | 13 | 9 | 8 | 1 | 2 | 10 | 8 |
| | *Boccardia (Paraboccardia) syrtis* | | 2 | 1 | 7 | 1 | 3 | 1 | 1 | 9 | 1 |
| | *Capitella capitata* | | | | | | | | | | |
| | Dorvilleidae sp.#1 | | | | | | | | | | |
| | Goniada sp.#1 | | 2 | | | | | | 1 | 1 | |
| | Hesionidae sp.#1 | | | | | | | | | | |
| | *Heteromastus filiformis* | 8 | 93 | 42 | 43 | 17 | 23 | 41 | 35 | 39 | 47 |
| | *Nicon aestuariensis* | | | | | | | | | | |
| | *Orbinia papillosa* | | 1 | | 1 | | 1 | | | | |
| | Paraonidae sp.#1 | | 2 | 1 | 5 | 6 | 3 | 7 | 6 | 4 | 29 |
| | *Pectinaria australis* | | | | | | | | | | 1 |
| | *Perinereis vallata* | | | | 3 | | 2 | | | | 2 |
| | *Platynereis australis* | 1 | | 1 | | 1 | | 2 | 5 | | |
| | Polychaeta sp.#1 | | | | | | | | | | |
| | Sabellariidae sp.#1 | | | | | | | | | | |
| | Sabellidae sp.#1 | | | | | | | | | | |
| | *Scolecolepides benhami* | | | | | | | 1 | | | |
| | *Scoloplos (Scoloplos) cylindrifer* | | | | | | | | | | |
| | Sphaerosyllis sp.#1 | | 1 | 1 | 1 | 1 | 1 | | | 1 | |
| | Spionidae sp.#1 | 1 | 4 | 4 | 9 | 1 | 3 | 2 | 6 | 4 | 4 |
| | Spionidae sp.#2 | | | | | | | | | | |
| | Terebellidae sp.#1 | | | 2 | | 1 | | | 1 | 1 | |
| OLIGOCHAETA | Oligochaeta | 3 | 1 | 2 | 8 | 2 | 1 | 6 | 7 | 15 | 3 |
| GASTROPODA | *Cominella glandiformis* | | 2 | 2 | 3 | 2 | | 1 | | | 1 |
| | *Diloma subrostrata* | | | | | | | | 1 | | 1 |
| | Gastropoda sp.#1 | | 2 | 3 | 2 | 1 | 3 | 1 | 1 | 4 | 2 |
| | Gastropoda sp.#2 | | | | | 1 | | | | | |
| | *Haminoea zelandiae* | | | | 1 | 1 | | | | | 1 |
| | *Notoacmaea helmsi* | | 1 | 1 | 1 | 2 | 2 | | 2 | 1 | |
| | *Xymene plebeius* | | | | | | | | | | |
| | *Zeacumantus lutulentus* | | | | | | | | | | |
| BIVALVIA | *Arthritica sp.#1* | | 3 | 3 | 1 | 1 | 1 | 63 | 16 | | 7 |
| | *Austrovenus stutchburyi* | 7 | 8 | 5 | 8 | 8 | 11 | 6 | 10 | 16 | 8 |
| | *Macomona liliana* | 4 | 11 | 8 | 6 | 4 | 6 | 4 | 4 | 4 | 7 |
| | *Nucula hartvigiana* | 2 | 42 | 12 | 16 | 6 | 12 | 29 | 26 | 7 | 12 |
| | *Paphies australis* | | | | | | | | | | |
| | *Solemya parkinsoni* | | | | | | | | 1 | | |
| CRUSTACEA | Amphipoda sp.#1 | | | | | | | | | 2 | |
| | Cephalocarida sp.#1 | 1 | | | | | | | | | |
| | *Halicarcinus varius* | | | 4 | | 3 | | 1 | 2 | | 4 |
| | *Halicarcinus whitei* | | | | | | | | | | |
| | *Hemigrapsus crenulatus* | | | | | | | | | | |
| | *Macrophthalmus hirtipes* | | | 1 | | | | 1 | 2 | | |
| | Mysidacea sp.#1 | | | | | | | | | | |
| | Ostracoda sp.#1 | 2 | 4 | 6 | 1 | | | 5 | 3 | | 2 |
| | Ostracoda sp.#2 | | | | | | | | | | |
| | Phoxocephalidae sp.#1 | 11 | 21 | 11 | 5 | 4 | 2 | 9 | 11 | 16 | 3 |
| HOLOTHUROIDEA | *Trochodota dendyi* | | | | | | | | | | |
| | **Total species in sample** | **12** | **20** | **23** | **24** | **23** | **18** | **20** | **23** | **20** | **22** |
| | **Total individuals in sample** | **49** | **208** | **126** | **148** | **77** | **84** | **183** | **148** | **140** | **148** |

## APPENDIX 2. 2008 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PORIFERA | Porifera sp.#1 | | | | | | | | | | |
| ANTHOZOA | Anthozoa sp.#1 | | | | | | | | | | |
| | *Edwardsia sp.#1* | 2 | 3 | 6 | 3 | 2 | 5 | 1 | 6 | 11 | 5 |
| NEMERTEA | Nemertea sp.#1 | 1 | 3 | 1 | | 4 | 1 | 2 | 3 | 3 | 3 |
| | Nemertea sp.#2 | 1 | | | | | 4 | | | 2 | 1 |
| | Nemertea sp.#3 | | | | | | | | | | |
| | Nemertea sp.#4 | | | | | | | | | | |
| NEMATODA | Nematoda | | 1 | | | | | | | | 1 |
| POLYCHAETA | *Aonides sp.#1* | 10 | 32 | 45 | 15 | 19 | 9 | 10 | 7 | 4 | 5 |
| | *Armandia maculata* | | | | | | | | | | |
| | *Axiothella serrata* | 6 | 9 | 7 | 5 | 11 | 10 | 10 | 21 | 67 | 45 |
| | *Boccardia (Paraboccardia) acus* | 3 | 3 | 8 | 1 | 11 | 12 | 5 | 2 | 8 | 1 |
| | *Boccardia (Paraboccardia) syrtis* | | | | | | 1 | | | | |
| | *Capitella capitata* | | 7 | 6 | 5 | 18 | 2 | 3 | 6 | 12 | 8 |
| | Dorvilleidae sp.#1 | | | | | | | | | | |
| | Goniada sp.#1 | | | | | | | | | | |
| | Hesionidae sp.#1 | | | | | | | | | | |
| | *Heteromastus filiformis* | 22 | 23 | 18 | 17 | 27 | 13 | 25 | 15 | 13 | 22 |
| | *Nicon aestuariensis* | 1 | 1 | 1 | | | | 2 | | | |
| | *Orbinia papillosa* | 6 | 11 | 8 | 20 | 12 | 22 | 22 | 11 | 14 | 9 |
| | Paraonidae sp.#1 | | | | | 1 | | | | | |
| | *Pectinaria australis* | | | | | | | | | | |
| | *Perinereis vallata* | 1 | | 1 | 1 | | 1 | 1 | 1 | 3 | 1 |
| | *Platynereis australis* | | | | | | | | | | |
| | Polychaeta sp.#1 | | | | | | | | | | |
| | Sabellariidae sp.#1 | | | | | | | | | | |
| | Sabellidae sp.#1 | | | | | | | | | | |
| | *Scolecolepides benhami* | | | | | | | | | | 1 |
| | *Scoloplos (Scoloplos) cylindrifer* | 5 | 6 | 2 | 1 | 5 | 9 | 7 | 4 | 2 | |
| | Sphaerosyllis sp.#1 | | | | | | | | | | |
| | Spionidae sp.#1 | | | 1 | | | | 1 | 2 | | |
| | Spionidae sp.#2 | | 6 | | 1 | 4 | | | 2 | 4 | 8 |
| | Terebellidae sp.#1 | | | | | | | | | | |
| OLIGOCHAETA | Oligochaeta | | 1 | | | 1 | 1 | 2 | 1 | | |
| GASTROPODA | *Cominella glandiformis* | 1 | 1 | | | | 1 | | | | |
| | *Diloma subrostrata* | 1 | | | | | | | | | |
| | Gastropoda sp.#1 | | | | | | | | | | |
| | Gastropoda sp.#2 | | | | | | | | | | |
| | *Haminoea zelandiae* | 1 | | | | | | | | 2 | 1 |
| | *Notoacmaea helmsi* | | 2 | | | | 3 | | 3 | | |
| | *Xymene plebeius* | | | | | | | | | | |
| | *Zeacumantus lutulentus* | | | | | | | | | | |
| BIVALVIA | *Arthritica sp.#1* | 1 | 4 | 1 | 2 | 1 | 1 | 1 | 4 | 2 | 1 |
| | *Austrovenus stutchburyi* | 40 | 29 | 30 | 13 | 25 | 44 | 34 | 27 | 41 | 26 |
| | *Macomona liliana* | 6 | 6 | 4 | 6 | 7 | 5 | 8 | 5 | 4 | 4 |
| | *Nucula hartvigiana* | | | | | | | | | | |
| | *Paphies australis* | 2 | | | | | | | 1 | 2 | 1 |
| | *Solemya parkinsoni* | | | | | | | | | | |
| CRUSTACEA | Amphipoda sp.#1 | | | | | | | | | | |
| | Cephalocarida sp.#1 | | | | | | | | | | |
| | *Halicarcinus varius* | 2 | | | | | | | | | |
| | *Halicarcinus whitei* | 1 | | | | | | | | | |
| | *Hemigrapsus crenulatus* | | 1 | | | | | | | | |
| | *Macrophthalmus hirtipes* | | | | | | | | | | |
| | Mysidacea sp.#1 | | | 1 | | 1 | 1 | | | | |
| | Ostracoda sp.#1 | | | | | | | | | | |
| | Ostracoda sp.#2 | | | | | | | | | | |
| | Phoxocephalidae sp.#1 | | | | | | | | | | |
| HOLOTHUROIDEA | *Trochodota dendyi* | 3 | | | 1 | | | 1 | | 4 | 1 |
| | **Total species in sample** | **21** | **19** | **16** | **14** | **16** | **19** | **17** | **18** | **18** | **19** |
| | **Total individuals in sample** | **116** | **149** | **140** | **91** | **149** | **145** | **135** | **121** | **198** | **144** |

# 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 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 | 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. |

## APPENDIX 3. INFAUNA CHARACTERISTICS

| 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. |

## APPENDIX 3. INFAUNA CHARACTERISTICS

| Group and Species | | AMBI Group | Details |
|---|---|---|---|
| Holothuroidea | *Trochodota dendyi* | I | Small acorn barnacle. Capable of rapid colonisation of any hard surface in intertidal areas including shells and stones. |

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-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 anoxic 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.