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# Clifton Wastewater Treatment Plant Discharge

## Consent Monitoring - New River Estuary Sediments 2013

Prepared for

**Invercargill City Council**

**July 2013**

**Cover Photo: Clifton wastewater treatment plant discharge channel where it enters New River Estuary.**


Sunset sampling of intertidal sediments adjacent to the Clifton wastewater treatment plant.

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Prepared for
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by

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# EXECUTIVE SUMMARY

This report summarises the results of the third year of baseline estuary sediment consent monitoring undertaken by the Invercargill City Council (ICC) as a condition of their resource consent to discharge treated wastewater to the New River Estuary adjacent to the Clifton wastewater treatment plant.

An outline of the estuary monitoring undertaken by ICC is presented in the margin flow diagram, with monitoring results for nine intertidal sites situated adjacent to the treated wastewater discharge channel within the estuary. These sites were first sampled in 2000, followed by a 3 year baseline survey undertaken in 2006, 2011, and 2013. The following sections summarise the estuary sediment monitoring results, condition ratings, overall estuary condition, and monitoring and management recommendations.

## SEDIMENT MONITORING RESULTS

- All sites were dominated by sand. Since 2000, mud content has declined.
- Mud, organic-enrichment and freshwater tolerant invertebrates dominated the infauna community.
- Sediment nitrogen and organic carbon concentrations have declined since 2000.
- Sediment Redox Potential Discontinuity (RPD) has deepened (i.e. more oxygenated).
- Heavy metals, semi volatile organic compounds (SVOCs) and total petroleum hydrocarbons (TPHs) were well below the ANZECC (2000) ISQG-Low trigger values (i.e. low toxicity).

## CONDITION RATINGS

Key To Ratings: High/Poor; Fair; Good; Very Good

| | 2000 | | | 2006 | | | 2011 | | | 2013 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1A | 2A | 3A | 1A | 2A | 3A | 1A | 2A | 3A | 1A | 2A | 3A |
| Invertebrates: Mud Tolerance | Fair High | Fair High | Good Fair | High | Fair High | Good Fair | High | High | Fair | High | High | Fair High |
| Sediment Oxygenation (RPD) | | | | | | | | | | | | |
| Total Organic Carbon (TOC) | | | | | | | | | | | | |
| Total Nitrogen | | | | | | | | | | | | |
| Invertebrates: Organic Enrichment Tolerance | Fair High | Fair High | Good High | Fair High | High | Good Fair | High | Fair High | Fair | Fair High | High | Fair High |
| Metals (Cd, Cu, Cr, Ni, Pb, Zn) | | | | | | | | | | | | |
| SVOCs and TPHs | | | | | | | | | | | | |

## ESTUARY CONDITION AND ISSUES

In relation to the key issues addressed by the fine scale monitoring (sedimentation, eutrophication and toxicity), the 2006-2013 results indicate that the treated wastewater discharge is having a relatively low impact on the estuary in the vicinity of the discharge channel, and is therefore unlikely to be causing problems to the wider ecosystem. The results also demonstrate a trend of improving conditions following a treatment upgrade in 2004, with reductions in mud content and sediment organic matter, and increased sediment oxygenation. The data also suggests that the dominance by mud and organic enrichment tolerant species was likely attributable to influences from the catchment as well as the wastewater discharge.

## RECOMMENDED MONITORING AND MANAGEMENT

Given the low impact of the ICC discharge to the estuary in the vicinity of the discharge outfall, it is recommended that:

- Monitoring should continue as required by consent, with the next monitoring scheduled for 2018.
- Management focus should be on continuing to maintain a stable and well-treated effluent that meets estuary guidelines for the main estuary issues of sedimentation, eutrophication, disease risk, toxicity, and habitat loss.

**New River Estuary**

**ICC Monitoring**

**Estuary Water Quality Monitoring**

Salinity, NO3, NH3, TP, DRP, chlor a, DO, pH, temp, FCs, Enterococci.

**High & Low Tide Monthly since 1991**

**Undertaken by ICC staff**

**Estuary Sediment Monitoring**

Grain size, RPD, TOC, TN, SVOCs, TPH's, Metals, Invertebrates, Macroalgae.

**3yr Baseline then 5 yearly**

Baseline completed 2013.
Next survey 2018.

**Undertaken by Wriggle Coastal Management**

**ICC Water Quality Information**

Recorded and used internally or provided to other agencies for use in reviewing estuary condition.

**Condition Ratings**

**Sedimentation:** Invertebrate mud tolerance, grain size.
**Eutrophication:** RPD depth, TN, TOC, invertebrate organic enrichment rating.
**Toxicity:** Metals, SVOCs, TPHs.

**Other Information**

Previous reports, Observations, Expert opinion.

**ESTUARY CONDITION NEAR OUTFALL**

Low Sedimentation
Moderate Eutrophication
Low Toxicity
Habitat Improving

**Recommended Management**

As current discharge impact is low: Maintain a stable and well-treated effluent that meets estuary guidelines for:
Sedimentation,
Eutrophication,
Ddisease risk,
Toxicity, and
Habitat loss.

# 1. INTRODUCTION

## OVERVIEW

| New River Estuary Summary Details | |
|---|---|
| **Estuary Type** | Tidal Lagoon estuary - area 4,600ha |
| **Catchment Area** | 1,527km$^2$ |
| **Landuse** | 13% native forest, 60% high producing pasture, 17% low producing pasture, 8% exotic forest.<br>Dairy cow numbers = 180,000 cows |
| **Catchment Geology** | Gravel, sandstone/siltstone, igneous, peat. |
| **Freshwater Inputs** | Oreti 44m$^3$/s and Waihopai 2.8m$^3$/s mean flows |
| **High Value Habitats** | Saltmarsh, 2012: 464ha primarily jointed wire rush<br>Seagrass (>50%cover);<br>2001: 94ha (3.1% of estuary)<br>2012: 53ha (1.7% of estuary)<br>200m terrestrial margin, 2012: 29% forest/scrub, 56% pasture, 13% residential/industrial.<br>Intertidal sand flats, 2012: 75% of estuary |
| **Salinity** | Well mixed, sea water dominated |
| **Depth** | Mean 1-2m |
| **Residence Time** | Less than 1 day |
| **Uses/Values** | Walking, shellfish collection, birds, scenic, fishing, water sports, duckshooting, whitebaiting, bathing. |
| **Issues** | **Eutrophication**: nuisance macroalgal growth rating "fair".<br>**Sedimentation**: excessive mud deposition in natural settling areas.<br>**Disease Risk**: exceedance of bathing and shellfish guidelines particularly during high rainfall events.<br>**Toxins**: heavy metals (used as an indicator of toxicity)low in main estuary flats. Moderate concentrations in sediment deposition zones. Likely to be moderately elevated near stormwater outfalls.<br>**Habitat Loss**: historical reclamations have significantly reduced area of estuary, particularly saltmarsh. |

**Major Input Loads to New River Estuary**

| Source | Oreti* | Waihopai* | ICC Discharge** | ICC Discharge % of total |
|---|---|---|---|---|
| **Nitrogen (t/yr)** | 2322 | 320 | 181 | 6.9% |
| **Phosphorus (t/yr)** | 192 | 13.3 | 37.4 | 18.2% |
| **Suspended Sediment (kt/yr)** | 151 | 2.7 | 0.15 | 0.1% |
| **Faecal Coliforms ($x10^{15}$ e.coli/yr)** | 49 | 19 | 0.095 | 0.14% |

*NIWA CLUES model outputs (2011). **ICC monitoring data 2011.

The Invercargill City wastewater treatment plant (WTP) is operated by the Invercargill City Council (ICC) and is located at Clifton, approximately one kilometre south of the Invercargill township adjacent to the New River Estuary (Figures 1 and 2). The plant is used to treat domestic and industrial wastewater. ICC was granted resource consent for the discharge of treated wastewater to New River Estuary from the upgraded plant in 2004 by the Southland Regional Council (Discharge Permit No. 200749). Condition 6 in this consent sets monitoring requirements for benthic sediments and biota in the vicinity of the outfall as follows:

> *"The consent holder shall commission surveys of the benthic sediments and biota in the vicinity (Site A in the Cawthron Report) of the effluent discharge by suitably qualified persons. The surveys are to be carried out once each year for the first three years from the date of commencement of this resource consent, and at 5 yearly intervals thereafter. The survey design and parameters will be the same as for the baseline study undertaken by Cawthron Institute in June 2000 (Cawthron Report No.580)."*

The first of the three baseline surveys was undertaken In January 2006 (Robertson and Stevens 2006). Due to an oversight, baseline surveys were not undertaken in the following two years as required by the consent. To rectify this and provide an appropriate baseline for measuring future trends, the ICC commissioned Wriggle Coastal Management to undertake the additional two baseline surveys in 2011 and 2013. This report presents the findings of the 2013 survey.

## BACKGROUND

New River Estuary is a large "tidal lagoon" type estuary (area 4,600ha), discharging to the east end of Oreti Beach. Situated at the confluence of the Oreti and Waihopai Rivers, it drains a primarily agricultural catchment (see estuary characteristics in margin table). This shallow estuary (mean depth ~2m) is bordered by a mix of vegetation and land uses (urban, bush and grazed pasture). It has a wide range of habitats (extensive mudflats, seagrass and saltmarsh areas) but has also lost large areas through drainage and reclamation, particularly in the Waihopai Arm. Currently the estuary receives excessive nutrients, sediment and faecal bacteria which cause a number of problems (Robertson and Stevens 2010) as follows:

- Nuisance blooms of macroalgae (*Ulva* and *Gracilaria*).
- Exceedance of faecal bacterial guidelines for bathing and shellfish.
- Rapid infilling with sediment in certain areas of the estuary.

The treated wastewater from the Clifton outfall is expected to contribute to the nutrient and disease risk issues given its elevated nutrient and bacterial loads. However, because total loads of these contaminants are low in comparison to catchment non-point inputs (see margin table), and are only discharged on an ebb tide, the Clifton wastewater discharge is not likely to be a major contributor to these estuary problems. Despite the presence of these issues, human use and ecological values of large parts of the estuary are high.

# 1. Introduction (Continued)

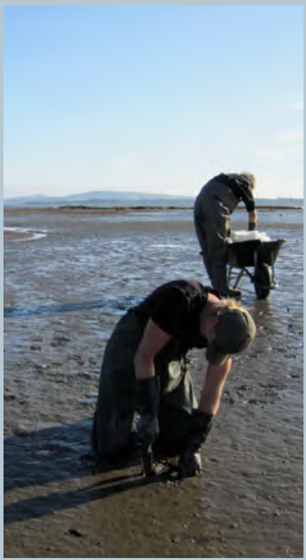
**Table 1. Summary of the major issues affecting most NZ estuaries.**

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

**Table 2. Summary of the broad and fine scale EMP indicators** (shading signifies indicators used in the current report).

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

# 2. METHODS



Sampling at site 1A1.

The fine scale monitoring of sediments around the outfall discharge point is based on the methods described in Robertson and Stevens (2006) which provides detailed information on the condition of the estuary at this location. The monitoring is designed to identify whether the discharge is causing adverse impacts to the estuary in the area adjacent to the discharge channel in relation to eutrophication, sedimentation and toxicity.

The survey design involves monitoring nine sites located in unvegetated intertidal habitat (avoiding areas of significant vegetation and channels) adjacent to the Clifton outfall (Figure 1). Treated wastewater discharges on the ebb tide into a 0.25m deep drainage channel that meanders across the estuary as a well defined channel at low water, with sampling sites positioned at three tidal heights within the channel and on either side of it. The positions of sampling sites in relation to the drainage channel are depicted in Figure 1 and Table 3. Site coordinates are presented in Appendix 2.

**Table 3. Location of ICC Clifton wastewater outfall monitoring sites.**

| Sites | Tidal Level | Sediment Type |
|---|---|---|
| 1A1, 1A2, 1A3 | Between mid and high water | Mud sand - fine sand |
| 2A1, 2A2, 2A3 | Mid water | Mud sand - fine sand |
| 3A1, 3A2, 3A3 | Low water | Mud sand - fine sand |

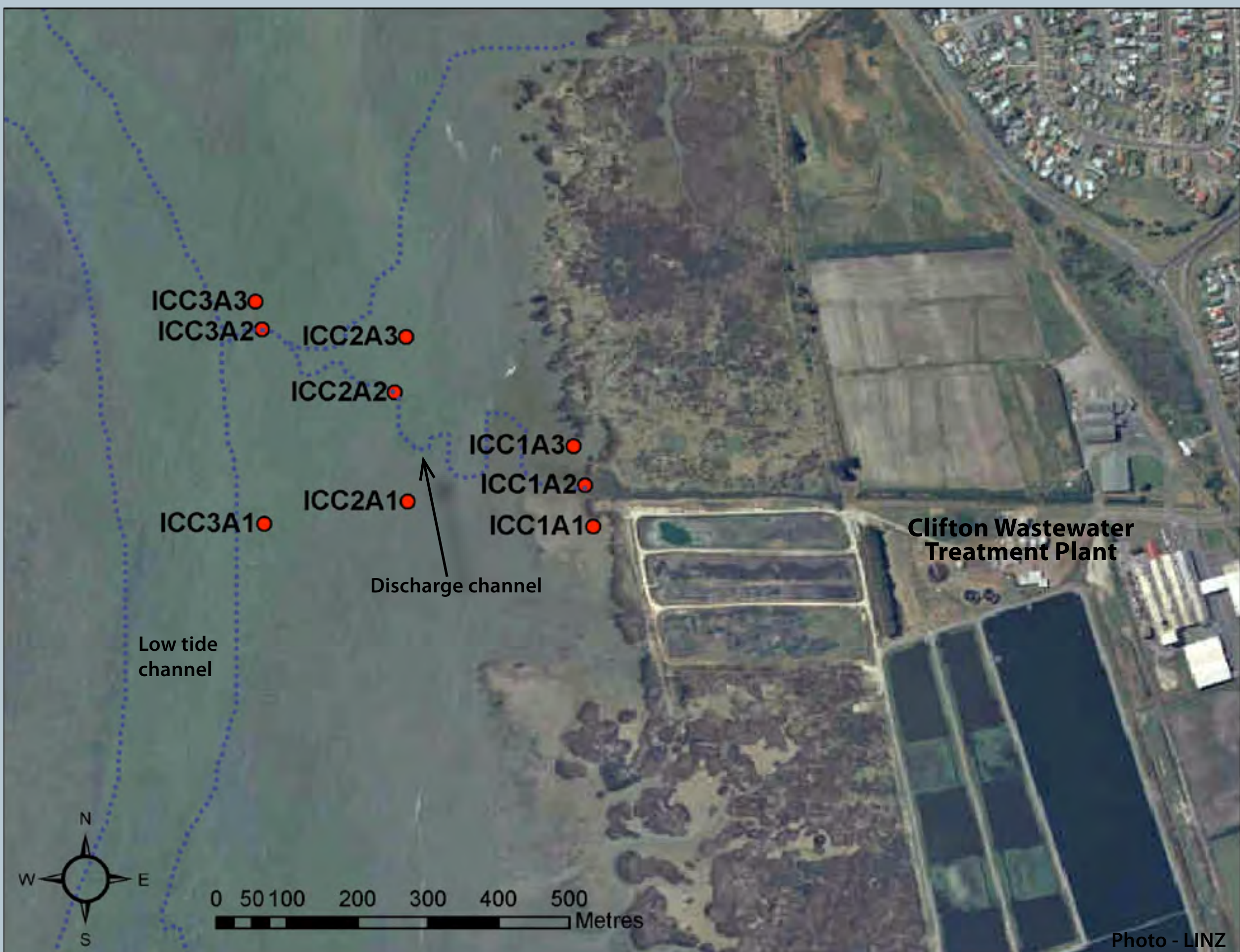



**Figure 1. Location of the ICC Clifton wastewater discharge monitoring sites in New River Estuary.**

# 2. Methods (Continued)


**Figure 2. Location of ICC Clifton wastewater discharge and Environment Southland (ES) long term monitoring sites in New River Estuary.**

# 2. Methods (Continued)

Quadrat for epifauna sampling.

Sediment surface.

Placing sediment core into 0.5mm sieve bag.

At each of the nine monitoring sites the following sampling was undertaken:

**Physical and chemical analyses**

- Within each site three random cores were collected to a depth of at least 100mm and representative samples photographed alongside a ruler and a corresponding label. Colour and texture were described and average Redox Potential Discontinuity (RPD) depth (i.e. depth to light grey/black anoxic layer) recorded.
- At each site, one sample (each a composite from 3 replicates) of the top 20mm of sediment (each approx. 250gms) was collected adjacent to each core. All samples were kept in a chilly bin in the field.
- Chilled samples were sent for analysis of the following (details in Appendix 1):
  - * Grain size/Particle size distribution (% mud, sand, gravel).
  - * Nutrients - total nitrogen (TN), and total organic carbon (TOC).
  - * Trace metal contaminants (total recoverable Cd, Cr, Cu, Ni, Pb, Zn). Analyses were based on whole sample fractions which were not normalised to allow direct comparison with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000).
  - * Total Petroleum Hydrocarbons - This method assesses the relative concentrations of eight different groups of aliphatic hydrocarbons. Aliphatic (straight chain) hydrocarbons are a major constituent of petroleum products but are also common biological components. These groups are separated by the number of carbon atoms contained within the chain and ordered from shortest chain (C7-C9) to longest chain (C25-C36).
  - * Semi Volatile Organic Compounds (SVOCs) - The major groups of SVOCs include a host of two - through six-ring polycyclic aromatic hydrocarbons (PAHs), phthalates, furans and pesticides.
- 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.

**Epifauna (surface-dwelling animals)**

Epifauna were assessed from one random 1m$^2$ quadrat within each of nine sites. All animals observed on the sediment surface were identified and counted, and any visible micro-algal 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.

**Infauna (animals within sediments)**

- Three randomly placed sediment cores was taken from each of the nine sites using a 130mm diameter (area = 0.0133m$^2$) PVC tube.
- The core tube was manually driven 150mm into the sediments, removed with the core intact and inverted into a labelled plastic bag.
- Once all replicates had been collected at a site, the plastic bags were transported to a nearby source of seawater and the contents of the core were washed through a 0.5mm nylon mesh bag. The infauna remaining were carefully emptied into a plastic container with a waterproof label and preserved in 70% isopropyl alcohol - seawater solution.
- The samples were then transported to a commercial laboratory for counting and identification (Gary Stephenson, Coastal Marine Ecology Consultants, Appendix 1).

# 2. Methods (Continued)

## CONDITION RATINGS

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

### Sedimentation Rate

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

**SEDIMENTATION RATE CONDITION RATING**

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

### Benthic Community Index (Mud Tolerance)

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

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

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

**BENTHIC COMMUNITY MUD TOLERANCE RATING**

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

### Total Organic Carbon

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

**TOTAL ORGANIC CARBON CONDITION RATING**

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

# 2. Methods (Continued)

| | |
|---|---|
| Redox Potential Discontinuity | The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. It is an effective ecological barrier for most but not all sediment-dwelling species. A rising RPD will force most macrofauna towards the sediment surface to where oxygen is available. The depth of the RPD layer is a critical estuary condition indicator in that it provides a measure of whether nutrient enrichment in the estuary exceeds levels causing nuisance anoxic conditions in the surface sediments. The majority of the other indicators (e.g. macroalgal blooms, soft muds, sediment organic carbon, TP, and TN) are less critical, in that they can be elevated, but not necessarily causing sediment anoxia and adverse impacts on aquatic life. Knowing if the surface sediments are moving towards anoxia (i.e. RPD close to the surface) is important for two main reasons:<br>1. As the RPD layer gets close to the surface, a "tipping point" is reached where the pool of sediment nutrients (which can be large), suddenly becomes available to fuel algal blooms and to worsen sediment conditions.<br>2. Anoxic sediments contain toxic sulphides and very little aquatic life.<br>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 <1cm (Jørgensen and Revsbech 1985) unless bioturbation by infauna oxygenates the sediments. |

**RPD CONDITION RATING**

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

| | |
|---|---|
| Total Phosphorus | In shallow estuaries like New River, the sediment compartment is often the largest nutrient pool in the system, and phosphorus exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae. |

**TOTAL PHOSPHORUS CONDITION RATING**

| RATING | DEFINITION | RECOMMENDED RESPONSE |
|---|---|---|
| Very Good | <200mg/kg | Monitor at 5 year intervals after baseline established |
| Good | 200-500mg/kg | Monitor at 5 year intervals after baseline established |
| Fair | 500-1000mg/kg | Monitor at 2 year intervals and manage source |
| Poor | >1000mg/kg | Monitor at 2 year intervals and manage source |
| Early Warning Trigger | >1.3 x Mean of highest baseline year | Initiate Evaluation and Response Plan |

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

**TOTAL NITROGEN CONDITION RATING**

| RATING | DEFINITION | RECOMMENDED RESPONSE |
|---|---|---|
| Very Good | <500mg/kg | Monitor at 5 year intervals after baseline established |
| Good | 500-2000mg/kg | Monitor at 5 year intervals after baseline established |
| Fair | 2000-4000mg/kg | Monitor at 2 year intervals and manage source |
| Poor | >4000mg/kg | Monitor at 2 year intervals and manage source |
| Early Warning Trigger | >1.3 x Mean of highest baseline year | Initiate Evaluation and Response Plan |

# 2. Methods (Continued)

**Benthic Community Index (Organic Enrichment)**

Soft sediment macrofauna can be used to represent benthic community health and provide an estuary condition classification (if representative sites are surveyed). The AZTI (AZTI-Tecnalia Marine Research Division, Spain) Marine Benthic Index (AMBI) (Borja et al. 2000) has been verified in relation to a large set of environmental impact sources (Borja, 2005) and geographical areas (in N and S hemispheres) and so is used here. However, although the AMBI is particularly useful in detecting temporal and spatial impact gradients, care must be taken in its interpretation. In particular, its robustness can be reduced: when only a very low number of taxa (1–3) and/or individuals (<3 per replicate) are found in a sample, in low-salinity locations and naturally enriched sediments. The equation to calculate the AMBI Biotic Coefficient (BC) is as follows; $BC = \{(0 \times \%GI) + (1.5 \times \%GII) + (3 \times \%GIII) + (4.5 \times \%GIV) + (6 \times \%GV)\}/100$. The characteristics of the ecological groups (GI, GII, GIII, GIV and GV) are summarised in Appendix 3.

| BENTHIC COMMUNITY ORGANIC ENRICHMENT RATING | | | |
|---|---|---|---|
| ENRICHMENT TOLERANCE | DEFINITION | BC | RECOMMENDED RESPONSE |
| Very Low | Intolerant of enriched conditions | 0-1.2 | Monitor at 5 year intervals after baseline established |
| Low | Tolerant of slight enrichment | 1.2-3.3 | Monitor 5 yearly after baseline established |
| Moderate | Tolerant of moderate enrichment | 3.3-5.0 | Monitor 5 yearly after baseline est. Initiate ERP |
| High | Tolerant of high enrichment | 5.0-6.0 | Post baseline, monitor yearly. Initiate ERP |
| Exceeded | Azoic (devoid of invertebrate life) | >6.0 | Post baseline, monitor yearly. Initiate ERP |
| Early Warning Trigger | Trend to slight enrichment | >1.2 | Initiate Evaluation and Response Plan |

**Metals**

Heavy metals provide a low-cost preliminary assessment of toxic contamination, and are a starting point for contamination throughout the food chain. Sediments polluted with heavy metals (poor condition rating) should also be screened for other major contaminant classes: pesticides, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs).

| METALS CONDITION RATING | | |
|---|---|---|
| RATING | DEFINITION | RECOMMENDED RESPONSE |
| Very Good | <0.2 x ISQG-Low | Monitor at 5 year intervals after baseline established |
| Good | <ISQG-Low | Monitor at 5 year intervals after baseline established |
| Fair | <ISQG-High but >ISQG-Low | Monitor at 2 year intervals and manage source |
| Poor | >ISQG-High | Monitor at 2 year intervals and manage source |
| Early Warning Trigger | >1.3 x Mean of highest baseline year | Initiate Evaluation and Response Plan |

**Site 3A2 adjacent to where the Clifton discharge channel meets the main Waihopai channel.**

# 3. RESULTS AND DISCUSSION

## OUTLINE

A summary of the 25 February 2013 Clifton fine scale wastewater discharge monitoring results is presented in Table 4, with detailed results presented in Appendix 2. The results are presented alongside the results of three earlier surveys:

- April 2000 (prior to 2004 treatment plant upgrade) (Robertson and Jensen 2000),
- February 2006, the first of the baseline monitoring surveys (Robertson and Stevens 2006), and
- February 2011, the second of the baseline monitoring surveys (Robertson and Stevens 2011).

**Table 4. Physical, chemical and macrofauna results for New River Estuary (2000, 2006, 2011 and 2013).**

| Date | Site | RPD | TOC | Mud | Sand | Gravel | Cd | Cr | Cu | Ni | Pb | Zn | TN | Abundance | No. of Species |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cm | % | | | | mg/kg | | | | | | | Mean No./m2 | Mean No./core |
| 25 February 2013 | ICC 1A1 | >5 | 0.4 | 7.4 | 92.2 | 0.3 | 0.017 | 9.7 | 5.4 | 7.8 | 3 | 31 | <500 | 8575 | 7 |
| | ICC 1A2 | 0.5 | 0.35 | 3.1 | 96.8 | < 0.1 | 0.018 | 8.6 | 4.9 | 6.8 | 2.6 | 28 | <500 | 7825 | 6 |
| | ICC 1A3 | >5 | 0.39 | 5.9 | 94 | 0.2 | 0.026 | 8.9 | 4.9 | 6.9 | 2.6 | 26 | <500 | 10700 | 6 |
| | ICC 2A1 | 4 | 0.25 | 1.9 | 97.7 | 0.3 | 0.013 | 8.5 | 3.9 | 6.2 | 1.92 | 22 | <500 | 13775 | 6 |
| | ICC 2A2 | 1-2 | 0.41 | 5.7 | 93.8 | 0.5 | 0.017 | 11.4 | 6 | 8.9 | 2.6 | 33 | <500 | 18075 | 6 |
| | ICC 2A3 | 4 | 0.37 | 5.8 | 93.9 | 0.3 | 0.014 | 10.1 | 5.1 | 8 | 2.5 | 29 | <500 | 17525 | 6 |
| | ICC 3A1 | 7 | 0.26 | 1.7 | 98.1 | 0.3 | 0.012 | 8.2 | 3.8 | 6 | 1.9 | 21 | <500 | 18350 | 6 |
| | ICC 3A2 | 2 | 0.43 | 7.5 | 92.3 | 0.2 | 0.026 | 10.5 | 6.2 | 8.8 | 2.7 | 34 | <500 | 21350 | 6 |
| | ICC 3A3 | 4 | 0.29 | 2.1 | 97.9 | < 0.1 | 0.012 | 7.9 | 4.2 | 6.2 | 2 | 24 | <500 | 23625 | 7 |
| 14 February 2011 | ICC 1A1 | 6 | 0.19 | 5 | 95 | < 0.1 | 0.02 | 9.1 | 4.6 | 6.6 | 2.6 | 27 | 290 | 20925 | 8 |
| | ICC 1A2 | 1 | 0.46 | 8.3 | 91.3 | 0.4 | 0.023 | 11.4 | 6.8 | 8.4 | 3.3 | 38 | 520 | 17850 | 8 |
| | ICC 1A3 | 3 | 0.21 | 3.4 | 95.9 | 0.7 | 0.02 | 8 | 4 | 5.6 | 2 | 23 | 250 | 40200 | 7 |
| | ICC 2A1 | 3 | 0.16 | 0.8 | 98.9 | 0.4 | 0.017 | 8.3 | 3.8 | 5.7 | 1.79 | 22 | 180 | 20050 | 8 |
| | ICC 2A2 | 10 | 0.21 | 3.2 | 96.4 | 0.4 | 0.017 | 9.7 | 4.7 | 7 | 2.2 | 30 | 250 | 17550 | 10 |
| | ICC 2A3 | 5 | 0.23 | 6.2 | 93.2 | 0.6 | 0.021 | 10.5 | 5 | 7.2 | 2.4 | 30 | 280 | 40225 | 9 |
| | ICC 3A1 | 6 | 0.15 | 1.1 | 98.4 | 0.5 | 0.018 | 10.2 | 4.5 | 7 | 2.2 | 27 | 200 | 18475 | 8 |
| | ICC 3A2 | 10 | 0.15 | 1.6 | 98.2 | 0.2 | 0.022 | 9 | 4.6 | 6.6 | 2.1 | 29 | 200 | 21350 | 8 |
| | ICC 3A3 | 5 | 0.17 | 1.8 | 98.2 | < 0.1 | 0.022 | 9.4 | 4.9 | 7.2 | 2.2 | 32 | 190 | 9400 | 7 |
| 2 February 2006 | ICC 1A1 | 0.5 | 0.8 | 16.2 | 83.6 | 0.2 | 0.03 | 14.3 | 8.1 | 11 | 3.89 | 43.4 | 590 | 3025 | 5 |
| | ICC 1A2 | 0.5 | 0.5 | 4.8 | 95.2 | 0.1 | 0.02 | 8.4 | 4.6 | 6.6 | 2.19 | 25.8 | 430 | 7100 | 6 |
| | ICC 1A3 | 3 | 0.5 | 3.1 | 96.3 | 0.6 | 0.02 | 7.9 | 3.9 | 5.6 | 1.93 | 22.6 | 300 | 47150 | 7 |
| | ICC 2A1 | 3 | 0.5 | 2.3 | 97.1 | 0.5 | 0.02 | 9.5 | 4.5 | 6.9 | 1.95 | 24.8 | 310 | 45600 | 10 |
| | ICC 2A2 | 0.5 | 0.9 | 9 | 90.6 | 0.4 | 0.04 | 13.2 | 7.3 | 10.2 | 3.11 | 38.5 | 410 | 20475 | 7 |
| | ICC 2A3 | 2 | 0.7 | 7.1 | 92.4 | 0.5 | 0.03 | 10.3 | 5.7 | 7.9 | 2.59 | 31.3 | 480 | 50175 | 11 |
| | ICC 3A1 | 3 | 0.5 | 3.7 | 96.2 | 0.1 | 0.02 | 10 | 5 | 7.4 | 2.28 | 28 | 280 | 15425 | 14 |
| | ICC 3A2 | 0.5 | 0.4 | 2.6 | 97.4 | 0.1 | 0.02 | 9.2 | 5 | 7 | 2.11 | 28.6 | 210 | 30000 | 11 |
| | ICC 3A3 | 3 | 0.5 | 2.9 | 97 | 0.1 | 0.03 | 8.7 | 4.6 | 6.5 | 2.03 | 27.1 | 230 | 22575 | 11 |
| 11 April 2000 | ICC 1A1 | 5 | 7.0 | 17.8 | 82.2 | 0 | 0.04 | 14 | 9 | 11 | 3.9 | 57 | 1000 | 30375 | 9 |
| | ICC 1A2 | 4 | 1.8 | 3.1 | 96.9 | 0 | 0.02 | 9.3 | 5.1 | 7 | 2.1 | 34 | 300 | 2025 | 6 |
| | ICC 1A3 | 5 | 2.4 | 4.2 | 95.8 | 0 | 0.02 | 8.7 | 4.9 | 6.7 | 2.2 | 32 | 300 | 12650 | 11 |
| | ICC 2A1 | 4 | 3.0 | 6.7 | 93.3 | 0 | 0.03 | 7.2 | 5.4 | 6 | 2.2 | 30 | 400 | 3000 | 7 |
| | ICC 2A2 | 1 | 2.1 | 3.4 | 96.6 | 0 | 0.03 | 9.9 | 5.5 | 7.8 | 2.3 | 32 | 300 | 16475 | 9 |
| | ICC 2A3 | 4 | 4.2 | 9.7 | 90.3 | 0 | 0.07 | 14 | 11 | 12 | 5.3 | 70 | 500 | 26700 | 9 |
| | ICC 3A1 | 4 | 1.8 | 1.8 | 98.2 | 0 | 0.02 | 6.8 | 3.8 | 5.1 | 2 | 24 | 300 | 20550 | 8 |
| | ICC 3A2 | <10 | 2.7 | 6 | 94 | 0 | 0.03 | 11 | 6.7 | 8.9 | 3.4 | 39 | 400 | 49325 | 8 |
| | ICC 3A3 | 7 | 3.5 | 9.1 | 90.9 | 0 | 0.03 | 11 | 6.4 | 8.5 | 3.3 | 39 | 400 | 17050 | 10 |

| SITE 1A2 | Semi-volatile Organic Compounds | | | | | | | Total Petroleum Hydrocarbons | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Organochlorine Pesticides | Nitrogen containing compounds | Plasticisers | PCB's | PAH's | Halo-ethers | Phenols | C7 - C9 | C10 - C14 | C15 - C36 | Total hydrocarbons (C7 - C36) |
| 2013 | ND | ND | ND | Not Measured | ND | ND | ND | <19 | <40 | <80 | <140 |
| 2011 | ND | ND | ND | Not Measured | ND | ND | ND | <11 | <30 | <50 | <80 |
| 2006 | ND | ND | ND | ND | ND | ND | ND | <10 | <20 | <40 | Not reported |
| 2000 | ND | ND | ND | ND | ND | ND | ND | <5 | 7 | 62 | Not reported |

ND = Not detected at trace levels (see Appendix 2 for detailed results). PCB's = polychlorinated biphenyls. PAH's = polycyclic aromatic hydrocarbons.

# 3. Results and Discussion (Continued)

The results and discussion section is divided into three subsections based on the key estuary problems that the fine scale monitoring is addressing: sedimentation, eutrophication and toxicity. Within each subsection, the results for each of the relevant fine scale indicators are presented. A summary of the condition ratings for each of the nine sites is presented in the accompanying figures. In addition, the results are at times compared with data from other Environment Southland (ES) long term monitoring sites (NRE B, C, D, E, and F, Figures 2, 4, 5, and 6).

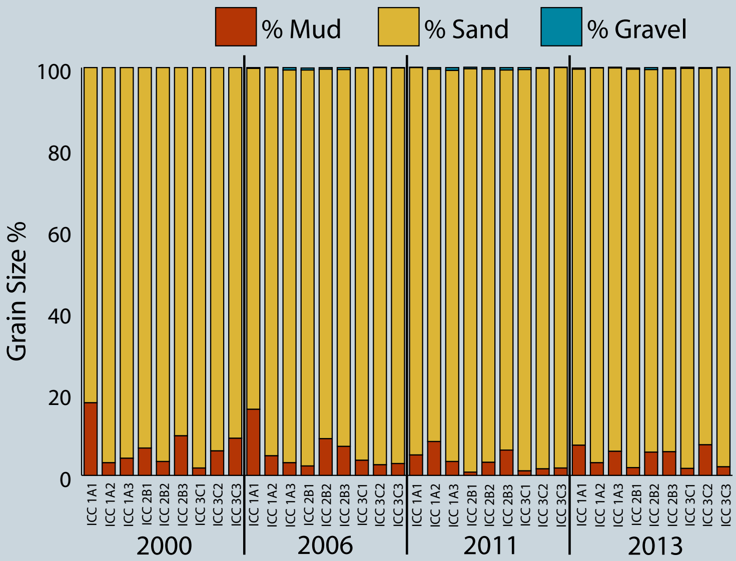



**Figure 3. Grain size, ICC Clifton wastewater discharge monitoring sites (2000, 2006, 2011 and 2013).**

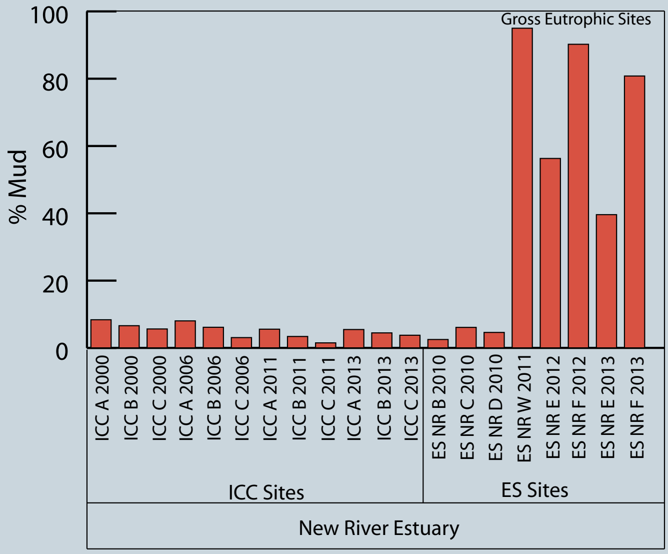



**Figure 4. Percentage mud at ICC Clifton sites in 2000, 2006, 2011 and 2013, compared with ES sites in New River Estuary** **(Source Robertson and Stevens 2010, Robertson and Stevens 2012).**

**1. SEDIMENTATION**

Accelerated soil erosion from developed catchments is a major issue for tidal lagoon estuaries in New Zealand as they form a sink for fine suspended sediments. NZ estuaries are particularly sensitive to increased muddiness given that they are generally sand dominated, have a diverse and healthy biology, and a short history of catchment development. Increased muddiness results in reduced sediment oxygenation, production of toxic sulphides, increased nuisance macroalgal growth, and a shift towards a degraded invertebrate and plant community. In order to assess the extent of potential sedimentation effects from the ICC wastewater discharge, grain size and the macro-invertebrate community have been used.

**(a) Grain Size.** Grain size (% mud, sand, gravel) measurements provide a good indication of the muddiness of a particular site. Because sediments adjacent to the Clifton discharge are dominated by fine, mud-sized particles, any shift towards a higher mud content, or elevated concentrations compared to background ES monitoring sites, could indicate that the discharge was causing adverse sedimentation effects in the estuary.

The 2013 monitoring results (Figure 3) showed that all nine ICC sites at Clifton were dominated by sandy sediments (>92% sand) with a relatively low mud content (1.7-7.5% mud). The results also showed that in 2013, the mud content (mean 4.6% mud) was lower than in 2000 (mean 6.9% mud) and 2006 (mean 5.7% mud), but slightly higher than in 2011 (mean 3.5% mud). The mud contents at the ICC Clifton sites were similar to the three ES long term monitoring sites in the main body of New River Estuary (NRE B, NRE C and NRE D - Figure 4). Compared with the gross eutrophic sites at Waihopai Arm and Daffodil Bay in the estuary (NR W, NR E, NR F), mud contents at Clifton were low (Figure 4).

These results indicate that the ICC discharge causes little sedimentation of fine sediments within the estuary, which is to be expected given the relatively low suspended sediment content of the discharge (mean 20 mg/l in 2011).

# 3. Results and Discussion (Continued)

**(b) Macro-invertebrate Tolerance to Muds**

Sediment mud content is a major determinant of the structure of the benthic invertebrate community. This section examines this relationship in New River Estuary in three steps:

- Comparing the mean abundance and species diversity data at ICC Clifton sites with other sites in the main body of the estuary to see if there are any major differences (Figures 5 and 6).
- Using multivariate techniques to explore whether the macro-invertebrate communities at the nine sites differ between the four monitoring surveys since 2000 (Figure 7).
- Using the response of typical NZ estuarine macro-invertebrates to increasing mud content (Gibbs and Hewitt 2004) to assess the mud tolerance of the invertebrate community at the ICC sites over the four monitoring surveys since 2000 (Figures 8 and 9).

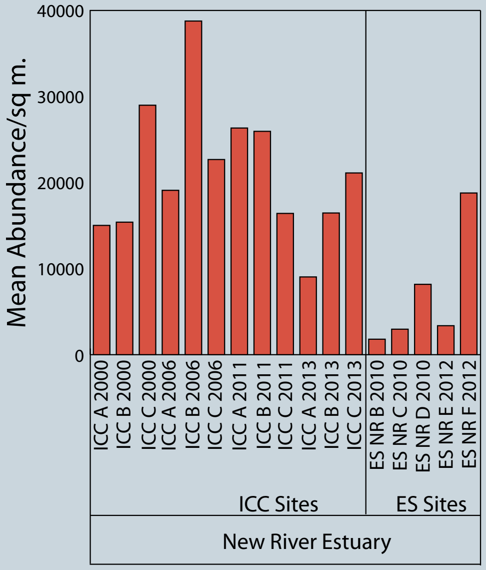



**Figure 5. Mean total abundance of infauna, New River Estuary** (Source Robertson and Stevens 2010, Robertson and Stevens 2012).

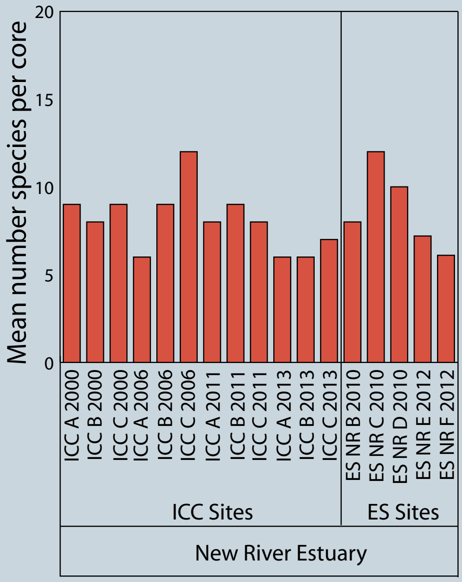



**Figure 6. Mean number of infauna species, New River Estuary** (Source Robertson and Stevens 2010, Robertson and Stevens 2012).

As in previous years, the first step showed that the total abundance of macro-invertebrates at all nine ICC sites in 2013 was relatively elevated (4,425 - 37,425m$^{-2}$) and was generally greater than the three ES long term monitoring sites in the main body of New River Estuary (NRE B, NRE C and NRE D) (Figure 5). On the other hand, the species richness at the ICC sites was similar (6-7 species/core) to all the ES sites (Figure 6).

In the second step, the results of the multi-variate analysis (Figure 7) showed the following:

- A difference in the benthic invertebrate communities between each of the sites for all the four monitoring surveys in 2000, 2006, 2011 and 2013.
- A progressive increase in the difference between communities over years between 2000 and 2013.
- A progressive decrease in the inter-site difference between communities in each year between 2000 and 2013.

The third step identified the likely cause of these differences as an increase in mud-tolerant species at the ICC sites in recent years as follows. In this step, the species present at each site were divided into six groups based on their tolerance to mud, and the results used to calculate a mud tolerance rating for each year and site. The results show that all sites were dominated by mud tolerant species in each of the four monitoring surveys (i.e. "fair" to "high" ratings - Figure 8). In addition, the results showed that the rating increased from 4.4 in 2000 to 5.3 in 2013 (i.e. an increase in mud tolerant species in 2013) which is likely to partially explain the differences between community compositions over time. These results almost certainly reflect the elevated suspended sediment load in the water column rather than the sediment mud concentration, given that the latter was relatively low (mean 4.6% mud in 2013) and that the sites are exposed to wind turbulence and are nearby to the very muddy Waihopai Arm.


**Figure 7. NMDS plot showing the relationship among mean samples in terms of similarity in macro-invertebrate community composition at nine ICC Clifton wastewater discharge monitoring sites in 2000, 2006, 2011 and 2013. The plot shows the mean of each of the 3 replicate samples for each site and is based on Bray Curtis dissimilarity and square root transformed data.**

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

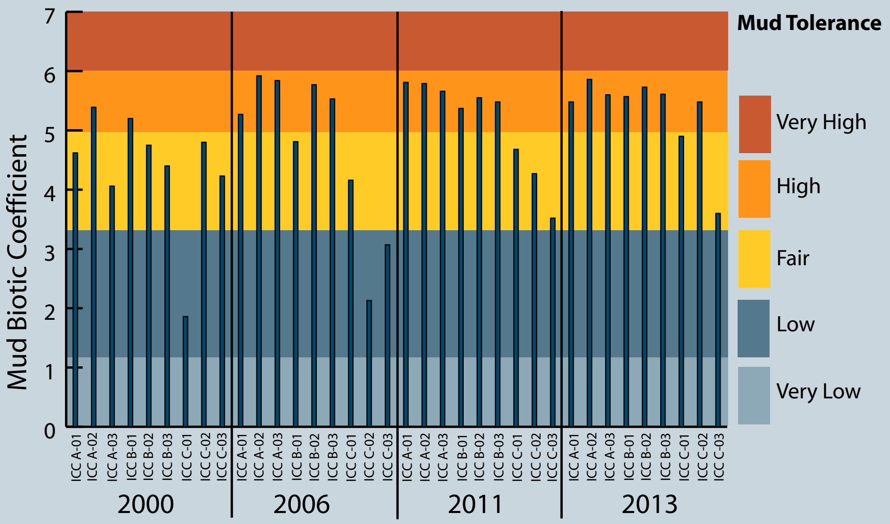



**Figure 8. Mud tolerance macro-invertebrate rating, ICC Clifton wastewater discharge monitoring sites (2000, 2006, 2011 and 2013).**

# 3. Results and Discussion (Continued)

The dominance of mud tolerant species is further portrayed in Figure 9. This plot shows that for 2013, the benthic invertebrate community was dominated by gastropod snails, amphipods, polychaete and oligochaete worm species. The important findings were as follows:

- **Low Numbers of Sand Preference Species.** Although the sediments were dominated by sand with relatively low mud contents at all the nine sites, there were low numbers of "sand preference" species, in particular, cockles and pipis. However, *Microspio maori*, a small, common, intertidal spionid which prefers sand dominated sites and can handle low mud content and moderately enriched situations, was present at three sites in 2013. The reason for the absence of shellfish from the ICC sites is possibly a combination of the following:
    - their intolerance to the relatively constant influence of freshwater at the ICC sites, given that both species are intolerant to low salinity for long periods (McLeod and Wing 2008).
    - relatively high turbidity at the sites resulting from high wind induced resuspension of estuary sediments, and close proximity to the turbid Waihopai Arm of the estuary. Although they feed on suspended food particles, excessive turbidity can clog the filtering system and eventually kill the cockles and pipis.

  The oval trough shell (*Cyclomactra ovata*) and the polychaete worm, *Aglaophomus* sp. were present in very low numbers at two sites in 2013. These species prefer sandy environments with low mud (0-10% mud).

- **Elevated numbers of species that prefer some mud.** In particular, elevated numbers of:
    - the small, sedentary deposit feeding bivalve, *Arthritica bifurca* which prefers 20-40% mud and is also found at lower mud contents. It lives at depths >2cm in the sediment.
    - the small native estuarine snail, *Potamopyrgus sp*. It feeds on decomposing animal and plant matter, bacteria and algae, and is intolerant to anoxic surface muds but is tolerant to muds and brackish water.

- **High abundance of mud tolerant amphipods.** Organisms that prefer "high mud contents" were also found at the sites. These mud-tolerant species included:
    - the tube-dwelling amphipod *Paracorophium excavatum*, which is the dominant corophioid amphipod in the South Island. *Paracorophium* is well-known as a major primary coloniser (and hence indicator) of disturbed estuarine intertidal flats (Ford et al. 1999). Examples of common disturbances are, macroalgal mats settling on the tidal flats as a result of coastal eutrophication, and mud deposition after mobilisation of fine sediments from exposed soil surfaces in the catchment. In these situations, *Paracorophium* can become very abundant and, through its burrowing activities, increases oxygen exchange which in turn mitigates the effect of the disturbance. Given the relatively low mud content at the ICC sites, it is likely that the high numbers of *Paracorophium* was a response to disturbance caused by elevated turbidity, low salinity and elevated organic loadings.
    - the surface-deposit feeding spionid polychaete *Scolecolepides benhami*. This spionid is very tolerant of mud, fluctuating salinities, organic enrichment and toxicants (e.g. heavy metals). It 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.

**2. EUTROPHICATION**

The primary indicators of over-enrichment of nutrients or eutrophication are the RPD boundary, sediment organic matter, nitrogen and phosphorus concentrations, and the community structure of certain sediment-dwelling animals. The broad scale indicators are the percentages of the estuary covered by macroalgae and soft muds.

**(a) Redox Potential Discontinuity (RPD) depth**

The 2013 results show a moderately deep RPD (>2cm) at all sites except for ICC 1A2 (0.5cm) and ICC 2A2 (1cm) (Figure 10). This indicates that ICC 1A2 and ICC 2A2 were likely to be poorly oxygenated (i.e. "poor" rating) whereas the other sites were moderately to well oxygenated (i.e. "fair-good" rating). These RPD ratings were similar to those measured at the sites in 2006, but a moderate deterioration on those measured in 2011.

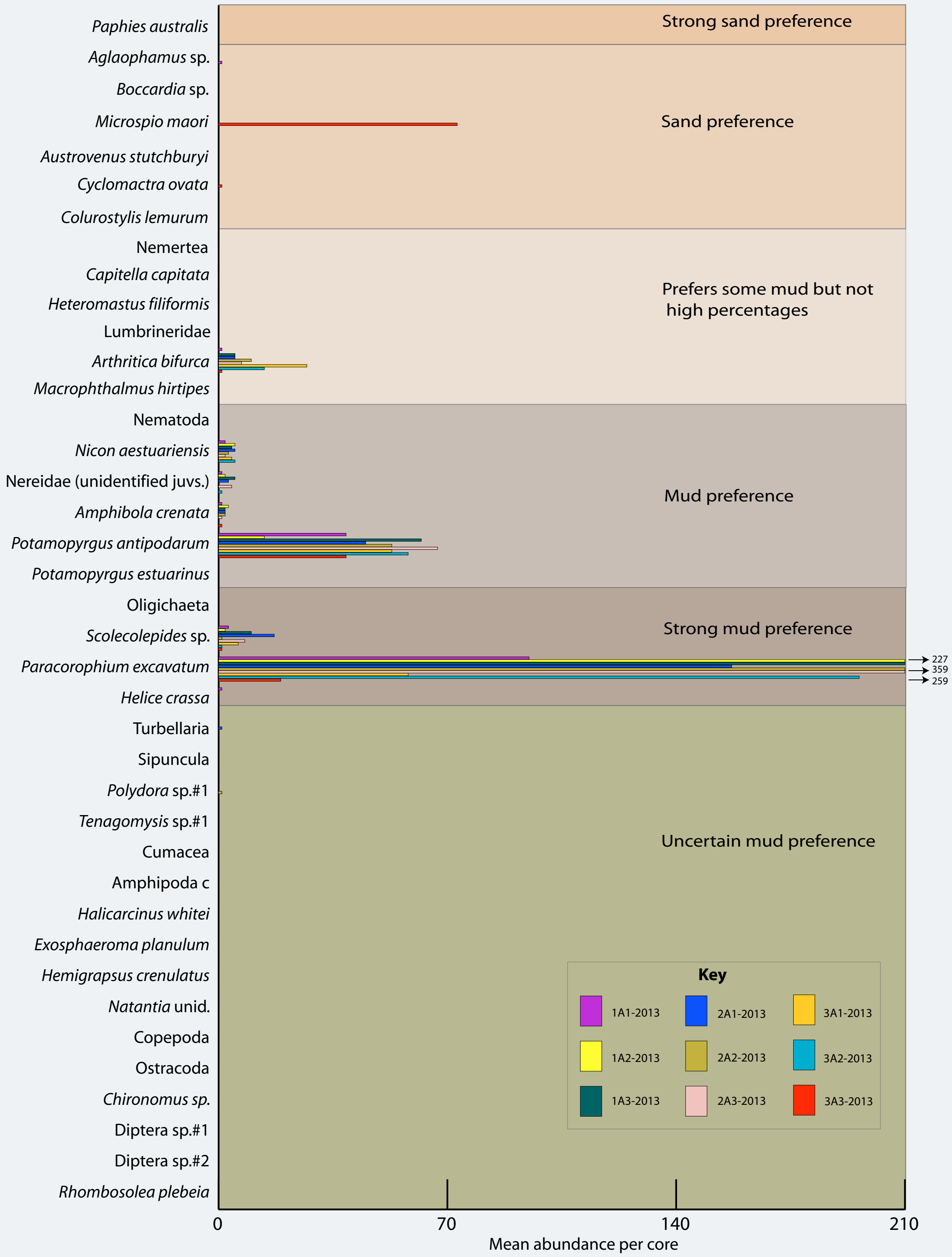



**Figure 9. Mud sensitivity of macro-invertebrates at nine ICC Clifton sites (2013). Sensitivity details in Appendix 3.**

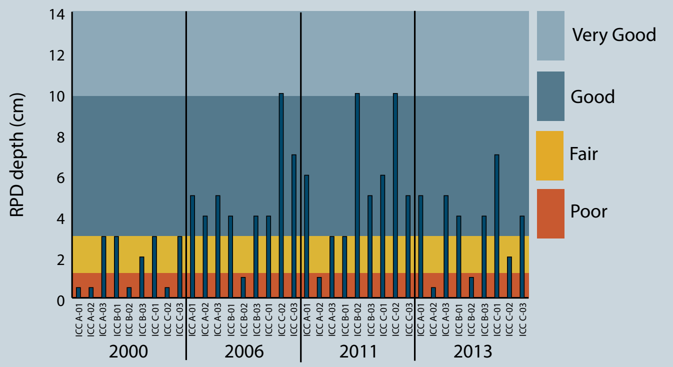



**Figure 10. Redox Potential Discontinuity depth (mean and range), ICC Clifton wastewater discharge monitoring sites (2000, 2006, 2011, 2013).**

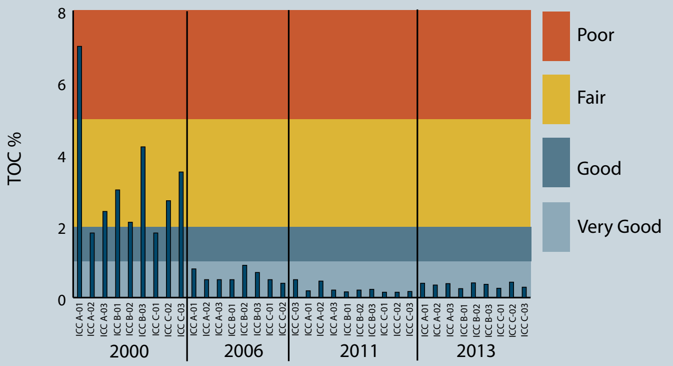



**Figure 11. Total Organic Carbon (mean and range), ICC Clifton wastewater discharge monitoring sites (2000, 2006, 2011, 2013).**

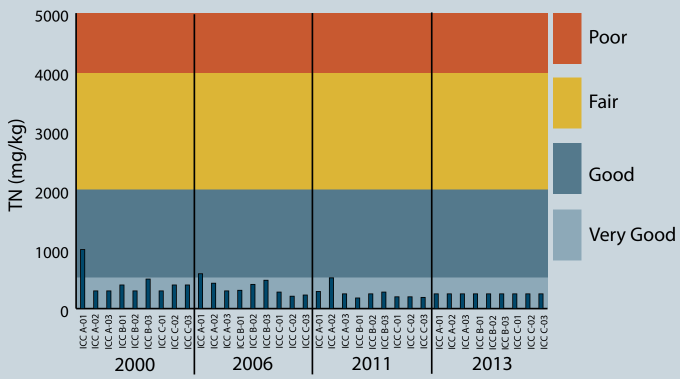



**Figure 12. Total Nitrogen (mean and range), ICC Clifton wastewater discharge monitoring sites (2000, 2006, 2011, 2013).** Note that the 2013 concentrations were all below the detection limit of 500mg/kg. They are plotted as 50% of the detection limit in order to reflect the likely actual concentrations (i.e. similar to the 2011 results).

**(b) Total Organic Carbon (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 nine sites in 2013 (Figure 11) was at low concentrations (<1%) and met the "very good" condition rating. These conditions were similar to those measured in 2006 and 2011, but a large improvement compared with 2000 (mean 0.4% in 2013, 0.2% in 2011, 0.6% in 2006 and 3.2% in 2000). The 2013 results were similar to those reported for the ES background monitoring sites in the main basin of the estuary (Robertson and Stevens 2010). Such conditions currently indicate low sediment organic enrichment in the vicinity of the ICC discharge channel which reflects the relatively low organic content of the discharge (5-20mg/l BOD) and the relatively exposed nature of the site.

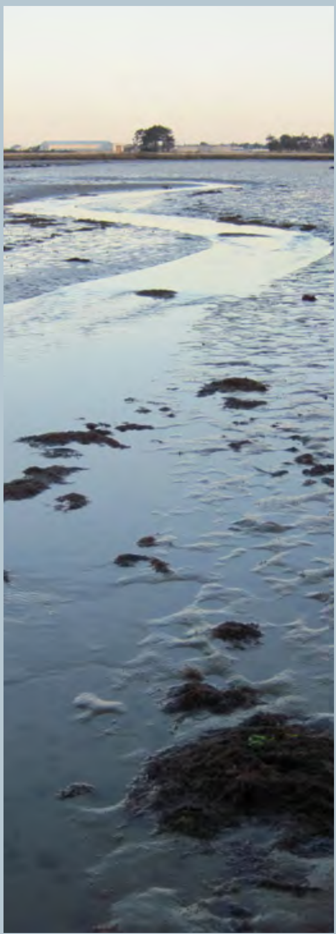
**(c) Total Nitrogen (TN)**

Total nitrogen (the key nutrient in the eutrophication process in tidal lagoon estuaries) was in the "low enrichment" category (Figure 12) at all nine sites in 2013 and met the "very good" condition rating. A method change required in 2013 resulted in the detection limit increasing to 500mg/kg, with all the 2013 results below the detection limit.

Like TOC, TN results have shown a steady improvement since 2000 (mean 433mg/kg in 2000, 360mg/kg in 2006, and 262mg/kg in 2011). The 2013 TN results (mean<500mg/kg) were similar to those reported for the ES background monitoring sites in the main basin of the estuary (Robertson and Stevens 2010).

These results indicate sediment nitrogen concentrations in the vicinity of the ICC discharge channel are currently low and are not expected to support excessive growths of nuisance algae. This is consistent with recent measured low levels of nuisance macroalgal growth in this section of the estuary (Stevens and Robertson 2013). The reduction in past extensive growths previously apparent in the area can likely be attributed to:

- reduced discharges of landfill leachate from the now closed ICC landfill just upstream of the Clifton WTP plant and,
- improved treatment of the Clifton WTP discharge.



**(d) Macro-invertebrate Organic Enrichment Index**

The 2013 benthic invertebrate organic enrichment rating for the ICC Clifton sites showed similar results to the previous years, with almost all sites classified in the "fair" to "high" categories, indicating moderate to high organic enrichment (Figure 13). Such a rating likely reflects the high catchment nutrient loads to the estuary (see Introduction) stimulating algal growth and providing food for infauna. The low sediment nutrient concentrations reflect the exposed nature of this central part of the estuary. These conditions are reflected in the composition of the invertebrate community as shown for 2013 in Figure 14 and summarised below.

- No species very sensitive to organic enrichment were present.
- Only two species indifferent to organic enrichment (slightly unbalanced) were present, and with very low abundances e.g. the bivalve *Cyclomactra ovata* and the large, carnivorous, nephtyid polychaete *Aglaophamous* sp.
- Moderate numbers and elevated abundances of species that are tolerant to excess organic enrichment (unbalanced situation) e.g. the spionid polychaete *Microspio maori*, the small native estuarine snails *Potamopyrgus estuarinus* and *P. antipodarum,* and the surface deposit feeding spionid polychaete *Scolecolepides benhami.*
- Low abundances and diversity of species that are very tolerant to organic enrichment (slight to pronounced unbalanced situations) e.g. the polychaete *Polydora* sp.
- High abundances of 1st order opportunistic species that are highly tolerant to organic enrichment (pronounced unbalanced situations) e.g. the tube-dwelling amphipod *Paracorophium excavatum.*

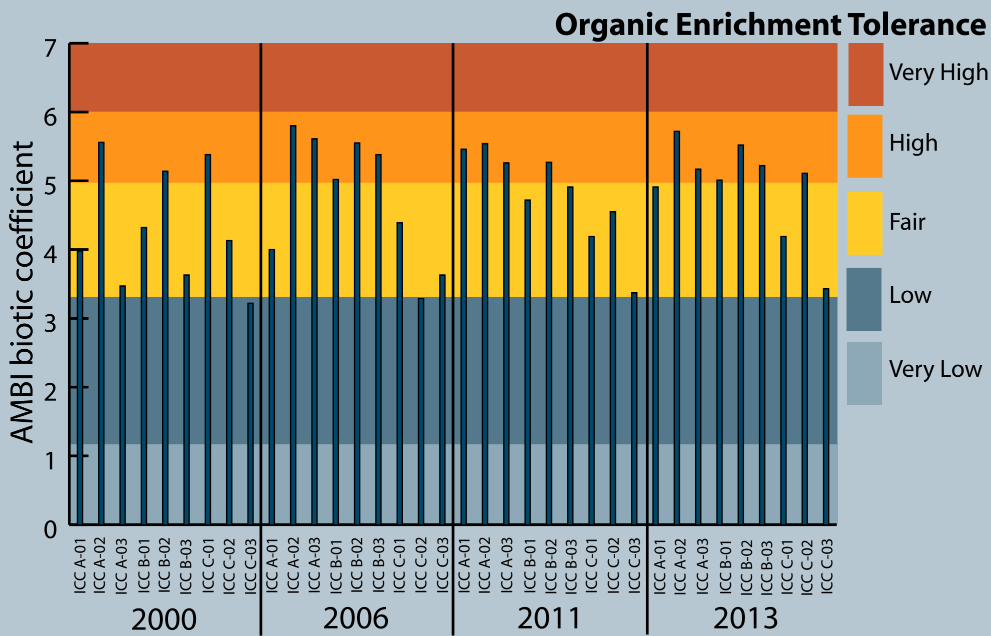



**Figure 13. Benthic invertebrate organic enrichment rating, ICC Clifton wastewater discharge monitoring sites (2000, 2006, 2011, 2013).** Note that this rating has been modified since 2011 to better reflect the response of NZ estuary infauna to enrichment indicators (based on Wriggle data for 21 NZ estuaries).

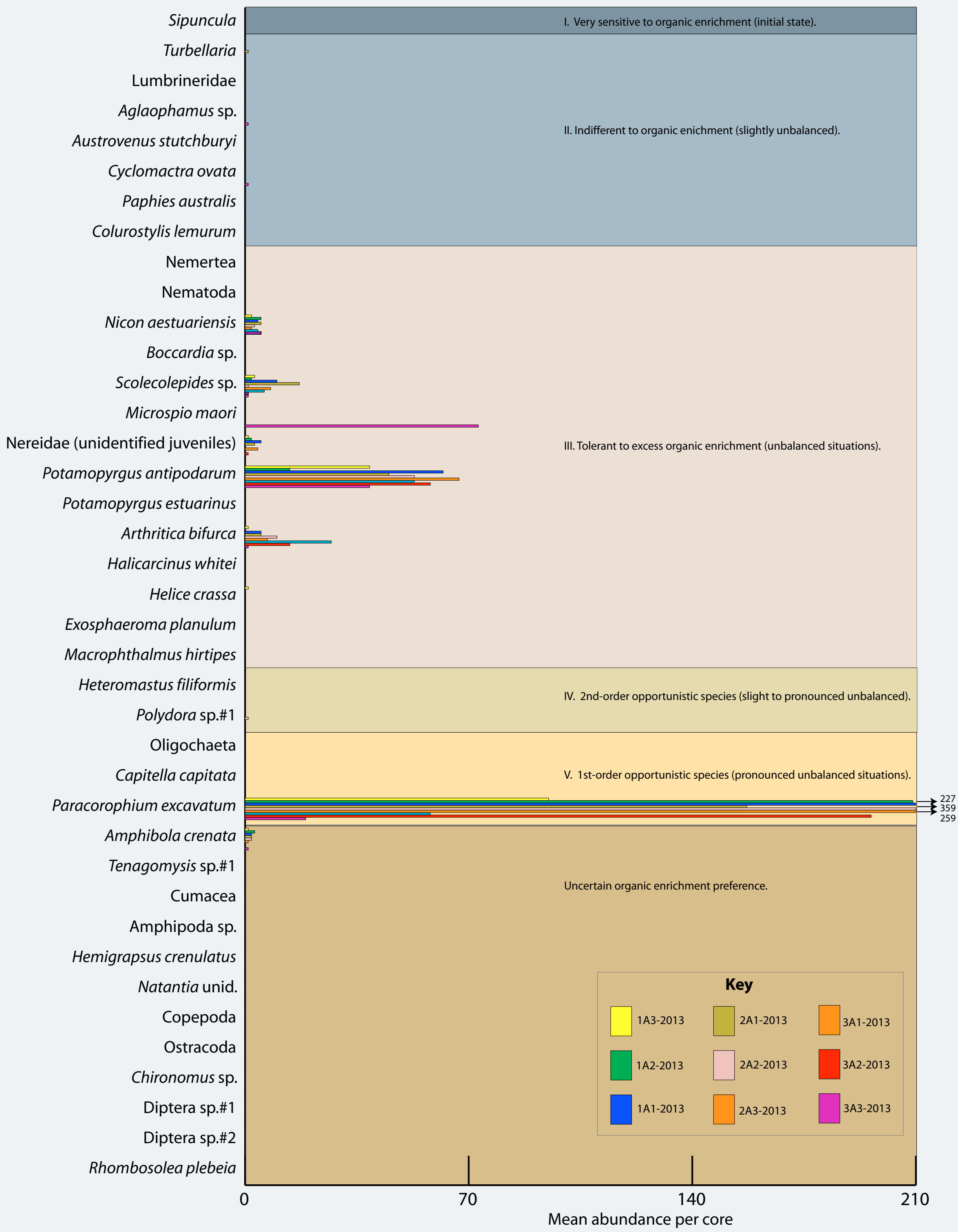



**Figure 14. Organic enrichment sensitivity of macro-invertebrates at nine ICC Clifton sites (2013). Sensitivity details in Appendix 3.**

# 3. Results and Discussion (Continued)

**3. TOXICITY**

**(a) Metals.** Heavy metals (Cd, Cr, Cu, Ni, Pb, Zn), used as an indicator of potential toxicants, were at low to very low concentrations in all years, with all values well below the ANZECC (2000) ISQG-Low trigger values (Figure 15). In 2013, metals met the "good-very good" condition rating at all sites.

**(b) Semi-Volatile Organic Compounds.** SVOC's collected at Site 1A2 in 2013 (and also in 2000, 2006 and 2011) yielded no detectable concentrations at trace levels as summarised in Table 1 (detailed results in Appendix 2). Values were therefore well below ANZECC (2000) ISQG-Low trigger values.

**(c) Total Petroleum Hydrocarbons.** TPH's collected at Site 1A2 in 2013 yielded no detectable concentrations at trace levels as summarised in Table 1 (detailed results in Appendix 2). These results represented an improvement on the levels that were recorded in 2000.

Overall, the results for the various toxicants indicate that toxicity in the vicinity of the Clifton discharge channel of the New River Estuary is low.

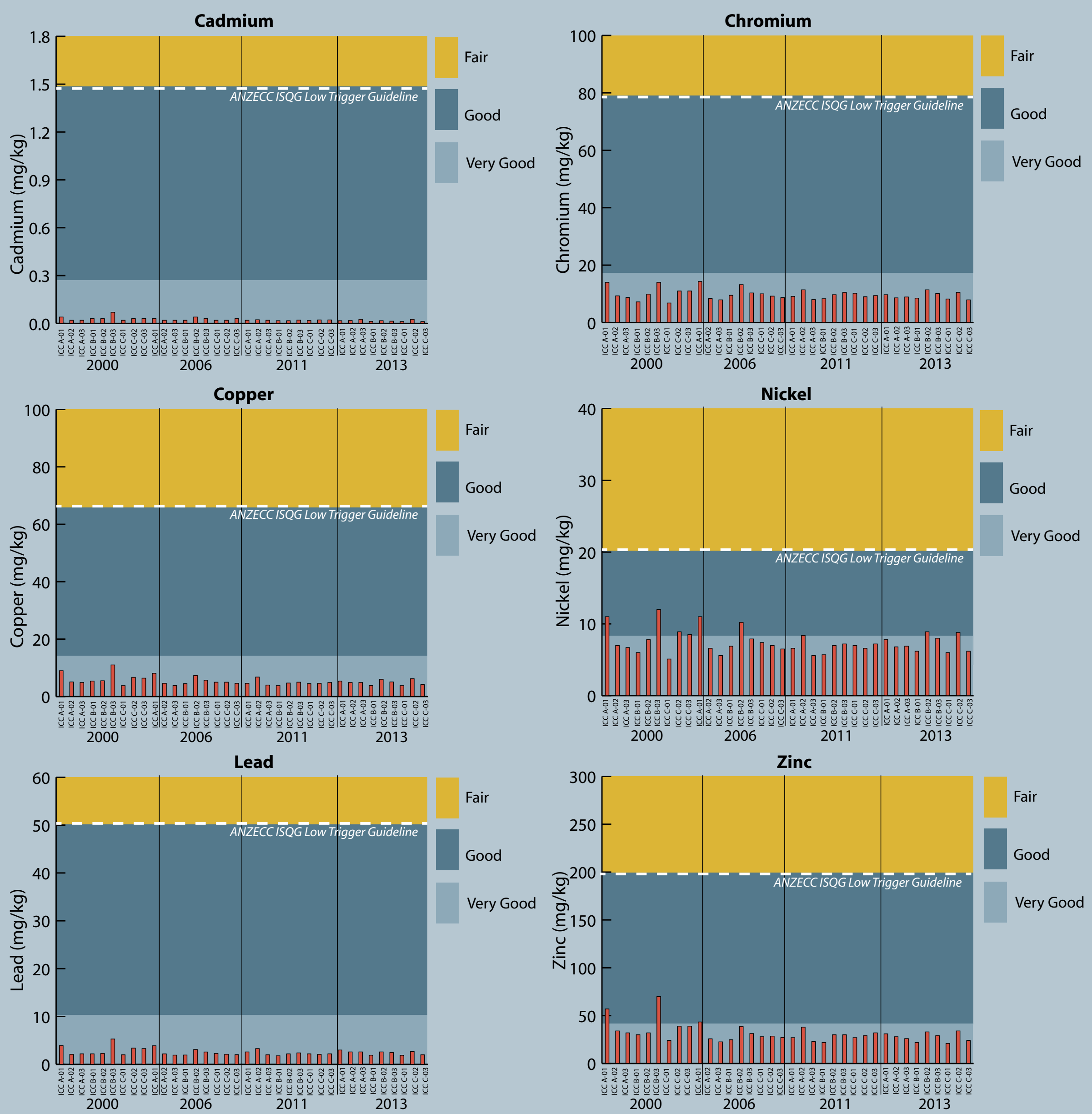
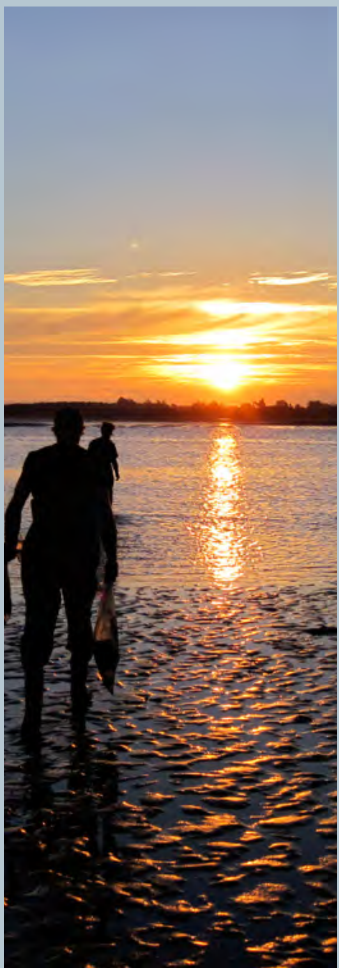



**Figure 15. Total recoverable metals (mean and range), ICC Clifton wastewater discharge monitoring sites (2000, 2006, 2011 and 2013).**

# 4. CONCLUSIONS



This report presents the results of the third year of baseline sediment monitoring of nine New River Estuary sites in the vicinity of the ICC Clifton WTP outfall undertaken following a significant treatment upgrade in 2004.

The 2013 results indicate low-moderate sediment contamination in relation to mud content, nutrients, organic matter, and metals. However, the results, particularly for the sediment dwelling macro-invertebrate community, indicated that the ICC sites were dominated by mud and organic enrichment tolerant species. The cause was likely attributable to:

1. Elevated water column concentrations of nutrients and suspended sediment sourced primarily from very high diffuse catchment inputs, and to a lesser extent from the diluted ICC wastewater effluent, and
2. Their additional tolerance to brackish water, driven by the proximity to river influences, and the increased volume of freshwater discharged from the Clifton WTP in recent years.

The results indicated a substantial improvement since 2000 in the main indicators of organic enrichment (nitrogen, total organic carbon, and RPD) in the sediments, and a decrease in sediment muddiness:

| Indicator | 2000 | 2006 | 2011 | 2013 |
|---|---|---|---|---|
| TOC (mean %) | 3.2 | 0.6 | 0.2 | 0.4 |
| TN (mean mg/kg) | 433 | 360 | 262 | <500* |
| RPD depth (mean cm) | 1.8 | 4.9 | 5. | 33.7 |
| Mud content (%) | 6.5 | 5.7 | 3.5 | 4.6 |

*likely to be approximately 250mg/kg) in 2013

Concentrations of sediment toxicants (heavy metals, semi-volatile organic compounds and petroleum hydrocarbons) were also low and similar to, or slightly lower, than those measured in 2000.

In summary, the studies to date indicate the following in relation to the localised effects of the discharge on the estuary sediments in the vicinity of the outfall:

- Low-moderate sediment organic enrichment.
- Low toxicity.
- Low mud content.
- A stable benthic invertebrate community, dominated by mud and organic enrichment tolerant species.

# 5. FUTURE MONITORING

The current consent for the discharge of the ICC treated wastewater to New River Estuary requires three years of baseline monitoring, with subsequent monitoring undertaken at five yearly intervals. The first year was undertaken in 2006, the second year in 2011, with the third year of baseline monitoring undertaken in February 2013. The next monitoring is scheduled to be undertaken in February 2018.

# 6. ACKNOWLEDGEMENTS

This survey and report has been undertaken with assistance from Peter Arnott and Adrian Cocker (Invercargill City Council) whose help is greatly appreciated.

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# APPENDIX 1. DETAILS ON ANALYTICAL METHODS

| Indicator | Laboratory | Method | Detection Limit |
|---|---|---|---|
| Infauna Sorting and ID | CMES | Coastal Marine Ecology Consultants (Gary Stephenson) * | N/A |
| Grain Size | R.J Hill | Wet sieving, gravimetric (calculation by difference). | 0.1 g/100g dry wgt |
| Total Organic Carbon | R.J Hill | Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser). | 0.05g/100g dry wgt |
| Total recoverable cadmium | R.J Hill | Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2. | 0.01 mg/kg dry wgt |
| Total recoverable chromium | R.J Hill | Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2. | 0.2 mg/kg dry wgt |
| Total recoverable copper | R.J Hill | Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2. | 0.2 mg/kg dry wgt |
| Total recoverable nickel | R.J Hill | Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2. | 0.2 mg/kg dry wgt |
| Total recoverable lead | R.J Hill | Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2. | 0.04 mg/kg dry wgt |
| Total recoverable zinc | R.J Hill | Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2. | 0.4 mg/kg dry wgt |
| Total nitrogen | Cawthron | APHA 21st Edition 4500N C. | 50 mg/kg dry wgt |
| Semivolatile Organic Compounds | R.J. Hill | Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270 | |
| Haloethers | R.J. Hill | Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270 | |
| Nitrogen containing compounds | R.J. Hill | Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270 | |
| Organochlorine Pesticides | R.J. Hill | Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270 | |
| Polycyclic Aromatic Hydrocarbons | R.J. Hill | Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270 | |
| Phenols | R.J. Hill | Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270 | |
| Plasticisers | R.J. Hill | Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270 | |
| Other Halogenated compounds | R.J. Hill | Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270 | |
| Other SVOCs | R.J. Hill | Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270 | |
| SMC Compounds | R.J. Hill | Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270 | |
| Total Petroleum Hydrocarbons | R.J. Hill | Sonication extraction, Silica cleanup, GC-FID analysis. US EPA 8015B/MfE Petroleum Industry Guidelines | |
| Total Recoverable digestion | R.J. Hill | Nitric / hydrochloric acid digestion. US EPA 200.2. | |
| Dry Matter (Env) | R.J. Hill | Dried at 103°C (removes 3-5% more water than air dry) | |

* 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. 2013 DETAILED RESULTS

## Station Locations 2013

| Station | 1A1 | 1A2 | 1A3 | 2A1 | 2A2 | 2A3 | 3A1 | 3A2 | 3A3 |
|---|---|---|---|---|---|---|---|---|---|
| NZTM N | 4845472 | 4845538 | 4845587 | 4845507 | 4845693 | 4845742 | 4845366 | 4845678 | 4845791 |
| NZTM E | 1242753 | 1242739 | 1242725 | 1242490 | 1242471 | 1242487 | 1242289 | 1242301 | 1242297 |

## Epifauna (numbers per 0.25m$^2$ quadrat) - 23 February 2013

| *Scientific name* | Common name | Replicate Number | 1A1 | 1A2 | 1A3 | 2A1 | 2A2 | 2A3 | 3A1 | 3A2 | 3A3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Amphibola crenata* | Estuarine mud snail | 1 | 1 | 0 | 0 | 1 | 0 | 5 | 9 | 2 | 0 |
| *Amphibola crenata* | Estuarine mud snail | 2 | 2 | 0 | 1 | 12 | 0 | 6 | 8 | 0 | 0 |
| *Amphibola crenata* | Estuarine mud snail | 3 | 2 | 0 | 4 | 8 | 0 | 0 | 8 | 0 | 0 |
| *Potamopyrgus estuarinus* | Estuarine mud snail | 1 | 2 | 52 | 450 | 250 | 150 | 480 | 180 | 250 | 120 |
| *Potamopyrgus estuarinus* | Estuarine mud snail | 2 | 35 | 28 | 350 | 420 | 120 | 500 | 200 | 120 | 80 |
| *Potamopyrgus estuarinus* | Estuarine mud snail | 3 | 10 | 57 | 380 | 180 | 180 | 600 | 160 | 250 | 150 |

**Infauna (numbers per 0.01327m$^2$ core)** **(Note NA = Not Assigned)** **see next page.**

# APPENDIX 2. 2013 DETAILED RESULTS (CONTINUED) ICC SITES 2013 - INFAUNA

| Taxa | AMBI | AMBI | MUD | 1A1 | 1A1 | 1A1 | 1A2 | 1A2 | 1A2 | 1A3 | 1A3 | 1A3 | 2A1 | 2A1 | 2A1 | 2A2 | 2A2 | 2A2 | 2A3 | 2A3 | 2A3 | 3A1 | 3A1 | 3A1 | 3A2 | 3A2 | 3A2 | 3A3 | 3A3 | 3A3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Platyhelminthes | Turbellaria | NA | NA | | | | | | | | | | | 1 | 1 | | | | | | | | | | | | | | | |
| Nemertea | Nemertea | III | 3 | | | | | | | | | | | | 1 | | | | | | | | 1 | | | | | | | |
| Nematoda | Nematoda | III | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sipuncula | Sipuncula | I | NA | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Oligochaeta | Oligichaeta | V | 5 | | | | | | | | | | | | | 1 | | | | 1 | | | | | | | | | 1 | |
| Polychaeta | *Capitella capitata* | V | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Heteromastus filiformis* | IV | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Lumbrineridae | II | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Aglaophamus* sp. | II | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 |
| | *Nicon aestuariensis* | III | 4 | 1 | 2 | 4 | 7 | 5 | 2 | 2 | 6 | 5 | 5 | 9 | 1 | 3 | 4 | 1 | 2 | 1 | 3 | 3 | 4 | 4 | 2 | 6 | 6 | | | |
| | *Boccardia* sp. | I | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Polydora* sp.#1 | IV | NA | | | | | | | | | | | | | 2 | | | | | 1 | | 1 | | | | 1 | | | |
| | *Scolecolepides* sp. | III | 5 | 2 | | 7 | 1 | 3 | 1 | 15 | 10 | 6 | 32 | 4 | 14 | 3 | | | 4 | 14 | 5 | 7 | 7 | 5 | 2 | 1 | 1 | | 1 | 1 |
| | *Microspio maori* | III | 4 | | | | | | | | | | | | | | | | | | | | | | | | | 196 | 5 | 17 |
| | Nereidae (unidentified juveniles) | III | 4 | 1 | 1 | | 4 | 1 | | 2 | 6 | 6 | 3 | 3 | 3 | | 1 | | 5 | 2 | 6 | | | | 1 | | 1 | | | |
| Gastropoda | *Amphibola crenata* | NA | 4 | 1 | | 1 | 5 | 3 | 1 | 2 | | 3 | | 4 | 3 | | 2 | 3 | 2 | 1 | | | 1 | | | | | | | 2 |
| | *Potamopyrgus antipodarum* | III | 4 | 55 | 37 | 26 | 13 | 20 | 8 | 63 | 72 | 50 | 26 | 55 | 54 | 58 | 50 | 51 | 80 | 70 | 51 | 49 | 51 | 58 | 68 | 57 | 48 | 47 | 39 | 30 |
| | *Potamopyrgus estuarinus* | III | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bivalvia | *Arthritica bifurca* | I | 3 | | | 3 | | | | 1 | 9 | 4 | 13 | 3 | | 6 | 19 | 5 | 8 | 4 | 8 | 11 | 48 | 22 | 6 | 17 | 20 | 2 | 1 | |
| | *Austrovenus stutchburyi* | I | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Cyclomactra ovata* | I | 2 | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | |
| | *Paphies australis* | II | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Crustacea | *Tenagomysis* sp.#1 | II | NA | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | |
| | Cumacea | NA | NA | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Paracorophium excavatum* | III | 5 | 117 | 41 | 126 | 270 | 222 | 135 | 247 | 271 | 164 | 148 | 137 | 187 | 367 | 423 | 286 | 350 | 257 | 170 | 57 | 60 | 57 | 204 | 250 | 133 | 40 | 10 | 8 |
| | Amphipoda sp.#1 | NA | NA | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| | *Halicarcinus whitei* | NA | NA | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Helice crassa* | NA | 5 | | 1 | 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Colurostylis lemurum* | II | 2 | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| | *Exosphaeroma planulum* | III | NA | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | |
| | *Hemigrapsus crenulatus* | NA | NA | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Macrophthalmus hirtipes* | NA | 3 | | | | | | | 1 | | | | | | | | | 1 | | | | | | | | | | | |
| | *Natantia* unid. | III | NA | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Copepoda | NA | NA | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Ostracoda | NA | NA | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diptera | *Chironomus* sp. | III | NA | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Diptera sp.#1 | IV | NA | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Diptera sp.#2 | IV | NA | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pisces | *Rhombosolea plebeia* | NA | NA | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Total abundance in sample** | | | | **177** | **82** | **169** | **300** | **254** | **147** | **333** | **374** | **238** | **227** | **216** | **266** | **440** | **499** | **346** | **452** | **350** | **244** | **127** | **173** | **147** | **283** | **331** | **210** | **287** | **59** | **60** |
| **Total number of species in sample** | | | | **6** | **5** | **7** | **6** | **6** | **5** | **8** | **6** | **7** | **6** | **8** | **10** | **7** | **6** | **5** | **8** | **8** | **7** | **5** | **8** | **6** | **6** | **5** | **7** | **6** | **8** | **7** |

# APPENDIX 2. 2013 DETAILED RESULTS (CONTINUED)

| Semi-volatile Organic Compounds (mg/kg dry wgt) | | |
|---|---|---|
| Haloethers Trace in SVOC Soil Samples by GC-MS | Bis(2-chloroethoxy) methane | < 0.17 |
| | Bis(2-chloroethyl)ether | < 0.17 |
| | Bis(2-chloroisopropyl)ether | < 0.17 |
| | 4-Bromophenyl phenyl ether | < 0.17 |
| | 4-Chlorophenyl phenyl ether | < 0.17 |
| Nitrogen containing compounds Trace in SVOC Soil Samples, GC-MS | 3,3'-Dichlorobenzidine | < 0.9 |
| | 2,4-Dinitrotoluene | < 0.4 |
| | 2,6-Dinitrotoluene | < 0.4 |
| | Nitrobenzene | < 0.17 |
| | N-Nitrosodi-n-propylamine | < 0.4 |
| | N-Nitrosodiphenylamine | < 0.4 |
| Organochlorine Pesticides Trace in SVOC Soil Samples by GC-MS | Aldrin | < 0.17 |
| | alpha-BHC | < 0.17 |
| | beta-BHC | < 0.17 |
| | delta-BHC | < 0.17 |
| | gamma-BHC (Lindane) | < 0.17 |
| | 4,4'-DDD | < 0.17 |
| | 4,4'-DDE | < 0.17 |
| | 4,4'-DDT | < 0.4 |
| | Dieldrin | < 0.17 |
| | Endosulfan I | < 0.4 |
| | Endosulfan II | < 0.5 |
| | Endosulfan sulphate | < 0.4 |
| | Endrin | < 0.4 |
| | Endrin ketone | < 0.4 |
| | Heptachlor | < 0.17 |
| | Heptachlor epoxide | < 0.17 |
| | Hexachlorobenzene | < 0.17 |
| Polycyclic Aromatic Hydrocarbons Trace in SVOC Soil Samples | Acenaphthene | < 0.10 |
| | Acenaphthylene | < 0.10 |
| | Anthracene | < 0.10 |
| | Benzo[a]anthracene | < 0.10 |
| | Benzo[a]pyrene (BAP) | < 0.17 |
| | Benzo[b]fluoranthene | < 0.17 |
| | Benzo[g,h,i]perylene | < 0.17 |
| | Benzo[k]fluoranthene | < 0.17 |
| | 2-Chloronaphthalene | < 0.10 |
| | Chrysene | < 0.10 |
| | Dibenzo[a,h]anthracene | < 0.17 |
| | Fluoranthene | < 0.10 |
| | Fluorene | < 0.10 |
| | Indeno(1,2,3-c,d)pyrene | < 0.17 |
| | 2-Methylnaphthalene | < 0.10 |
| | Naphthalene | < 0.10 |
| | Phenanthrene | < 0.10 |
| | Pyrene | < 0.10 |

| Semi-volatile Organic Compounds (mg/kg dry wgt) | | |
|---|---|---|
| Phenols Trace in SVOC Soil Samples by GC-MS | 4-Chloro-3-methylphenol | < 0.5 |
| | 2-Chlorophenol | < 0.2 |
| | 2,4-Dichlorophenol | < 0.2 |
| | 2,4-Dimethylphenol | < 0.4 |
| | 3 & 4-Methylphenol (m- + p-cresol) | < 0.4 |
| | 2-Methylphenol (o-Cresol) | < 0.2 |
| | 2-Nitrophenol | < 0.4 |
| | Pentachlorophenol (PCP) | < 6 |
| | Phenol | < 0.4 |
| | 2,4,5-Trichlorophenol | < 0.4 |
| | 2,4,6-Trichlorophenol | < 0.4 |
| Plasticisers Trace in SVOC Soil Samples by GC-MS | Bis(2-ethylhexyl)phthalate | < 0.7 |
| | Butylbenzylphthalate | < 0.4 |
| | Di(2-ethylhexyl)adipate | < 0.2 |
| | Diethylphthalate | < 0.4 |
| | Dimethylphthalate | < 0.4 |
| | Di-n-butylphthalate | < 0.4 |
| | Di-n-octylphthalate | < 0.4 |
| Other Halogenated compounds Trace in SVOC Soil Samples by GC-MS | 1,2-Dichlorobenzene | < 0.4 |
| | 1,3-Dichlorobenzene | < 0.4 |
| | 1,4-Dichlorobenzene | < 0.4 |
| | Hexachlorobutadiene | < 0.4 |
| | Hexachlorocyclopentadiene | < 0.9 |
| | Hexachloroethane | < 0.4 |
| | 1,2,4-Trichlorobenzene | < 0.17 |
| Other SVOC Trace in SVOC Soil Samples by GC-MS | Benzyl alcohol | < 1.7 |
| | Carbazole | < 0.17 |
| | Dibenzofuran | < 0.17 |
| | Isophorone | < 0.17 |
| **Total Petroleum Hydrocarbons (mg/kg dry wgt)** | | |
| Total Petroleum Hydro-carbons in Soil | C7 - C9 | < 19 |
| | C10 - C14 | < 40 |
| | C15 - C36 | < 80 |
| | Total hydrocarbons (C7 - C36) | < 140 |

# APPENDIX 3. INFAUNA CHARACTERISTICS

| Group and Species | | Organic Enrichment Tolerance-AMBI Group ***** | Mud Tolerance **** | Details |
|---|---|---|---|---|
| Platyhelminthes | Turbellaria | II | NA | Are a phylum of relatively simple bilaterian, unsegmented, soft-bodied invertebrate animals. Unlike other bilaterians, they have no body cavity, and no specialized circulatory and respiratory organs, which restricts them to flattened shapes that allow oxygen and nutrients to pass through their bodies by diffusion. |
| Nemertea | Nemertea sp. | III | I<br>Optimum range 55-60% mud,* distribution range 0-95%* | Ribbon or Proboscis Worms, mostly solitary, predatory, free-living animals. Intolerant of anoxic conditions. |
| Nematoda | Nematoda sp | III | M<br>Mud tolerant. | Small unsegmented roundworms. Very common. Feed on a range of materials. Common inhabitant of muddy sands. Many are so small that they are not collected in the 0.5mm mesh sieve. Generally reside in the upper 2.5cm of sediment. Intolerant of anoxic conditions. |
| Sipuncula | Sipuncula | NA | NA | Peanut worms, or sipunculids, are a phylum containing 144-320 species (estimates vary) of bilaterally symmetrical, unsegmented marine worms. Relatively uncommon in NZ estuaries. |
| Polychaeta | *Aglaophamous macroura* | II | S | A large, long-lived (5yrs or more) intertidal and subtidal nephtyid that prefers a sandier, rather than muddier substrate. Feeding type is carnivorous. Significant avoidance behaviour by other species. |
| | *Boccardia (Paraboccardia) syrtis and acus* | III | S<br>Optimum range 10-15% mud,* distribution range 0-50%* | Small surface suspension-feeding spionids (also capable of detrital feeding). Prefers sand with low-mod mud content but found in a wide range of sand/mud. 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 | I<br>Optimum range 10-15%* or 20-40% mud**, distribution range 0-95%** based on *Heteromastus f.* | A blood red capitellid polychaete which is very pollution tolerant. Common in suphide rich anoxic sediments. |
| | *Heteromastus filiformis* | IV | I<br>Optimum range 10-15% mud,* distribution range 0-95%* | Small sized capitellid polychaete. A sub-surface, deposit-feeder that lives throughout the sediment to depths of 15cm, and prefers a muddy-sand substrate. Shows a preference for areas of moderate to high organic enrichment as other members of this polychaete group do. Mitochondrial sulfide oxidation, which is sensitive to high concentrations of sulfide and cyanide, has been demonstrated in this species. |
| | Lumbrineridae | II | I<br>Optimum range 30-35% mud,* distribution range 0-65%*. | Muscular, elongate, cylindrical worms with reduced parapodia, and belonging to the Lumrineriidae Family of polychaetes. Mud tolerance: Optimum range 30-35% mud,* distribution range 0-65%*. |
| | *Microspio maori* | III | S<br>Expect optimum range in 0-20% mud. | A small, common, intertidal spionid. Can handle moderately enriched situations. Tolerant of high and moderate mud contents. Found in low numbers in Waiwhetu Estuary (black sulphide rich muds), Fortrose Estuary very abundant (5% mud, moderate organic enrichment). Prey items for fish and birds. |

# APPENDIX 3. INFAUNA CHARACTERISTICS (CONTINUED)

| Group and Species | | Organic Enrichment Tolerance-AMBI Group ***** | Mud Tolerance **** | Details |
|---|---|---|---|---|
| Polychaeta | Nereidae (unidentified juvs.) | III | M<br>Optimum range 55-60%* or 35-55% mud**, distribution range 0-100%** | Active, omnivorous worms, usually green or brown in colour. There are a large number of New Zealand nereids. Rarely dominant in numbers compared to other polychaetes, but they are conspicuous due to their large size and vigorous movement. Nereids are found in many habitats. Sensitive to large increases in sedimentation. |
| | *Nicon aestuariensis* | III | M<br>Optimum range 55-60%* or 35-55% mud**, distribution range 0-100%**. | A nereid (ragworm) that is tolerant of freshwater and is a surface deposit feeding omnivore. Prefers to live in moderate mud content sediments. |
| | *Polydora* sp | IV | NA | A spionid, relatively uncommon. |
| | *Scolecolepides benhami* | III | MM<br>Optimum range 25-30% mud,* distribution range 0-100%* | A Spionid, surface deposit feeder. Is rarely absent in sandy/mud estuaries, often occurring in a dense zone high on the shore, although large adults tend to occur further down towards low water mark. Strong Mud Preference but prefers moderate mud content (25-30% mud) but also found in 0-100% mud environments. Rare in Freshwater Estuary (<1% mud) and Porirua Estuary (5-10% mud). Common in Whareama (35-65% mud), Fortrose Estuary (5% mud), Waikanae Estuary 15-40% mud. Moderate numbers in Jacobs River Estuary (5-10% muds) and New River Estuary (5% mud).<br>A close relative, the larger *Scolecolepides freemani* occurs upstream in some rivers, usually in sticky mud in near freshwater conditions. e.g. Waihopai Rrm, New River Estuary. |
| Gastropoda | *Amphibola crenata* | NA | M | A pulmonate gastropod endemic to NZ. Common on a variety of intertidal muddy and sandy sediments. A detritus or deposit feeder, it extracts bacteria, diatoms and decomposing matter from the surface sand. It egests the sand and a slimy secretion that is a rich source of food for bacteria. |
| | *Potamopyrgus antipodarum* | II | M<br>Tolerant of muds. | Endemic to NZ. Small snail that can live in freshwater as well as brackish conditions. In estuaries *P. antipodarum* can tolerate up to 17-24% salinity. Shell varies in color (gray, light to dark brown). Feeds on decomposing animal and plant matter, bacteria, and algae. Intolerant of anoxic surface muds but can tolerate organically enriched conditions. Tolerant of muds. Populations in saline conditions produce fewer offspring, grow more slowly, and undergo longer gestation periods. |
| | *Potamopyrgus estuarinus* | II | M<br>Tolerant of muds. | Endemic to NZ. Small estuarine snail, requiring brackish conditions for survival. Feeds on decomposing animal and plant matter, bacteria, and algae. Intolerant of anoxic surface muds. Tolerant of muds and organic enrichment. |
| Bivalvia | *Arthritica bifurca* | III | I | A small sedentary deposit feeding bivalve, preferring a moderate mud content. Lives greater than 2cm deep in the muds. Prefers 55-60% mud (range 5-70% mud). |
| | *Austrovenus stutchburyi* | II | S<br>Prefers sand with some mud (optimum range 5-10% mud* or 0-10% mud**, distribution range 0-85% mud**). | Family Veneridae. 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 (5-10% but can be found in 0-60% mud). Rarely found below the RPD layer. Tolerant of low salinity for short periods (McLeod and Wing 2008). Small cockles are an important part of the diet of some wading bird species. Removing or killing small cockles reduces the amount of food available to wading birds, including South Island and variable oystercatchers, bar-tailed godwits, and Caspian and white-fronted terns. |

## APPENDIX 3. INFAUNA CHARACTERISTICS (CONTINUED)

| Group | Species | Organic Enrichment Tolerance-AMBI Group ***** | Mud Tolerance **** | Details |
|---|---|---|---|---|
| Bivalvia | *Mactra Ovata (Cyclomactra ovata)* | II | S<br>Optimum range 0-10% mud,*<br>distribution range 0-80%* | Trough shell of the family Mactridae, endemic to New Zealand. It is found intertidally and in shallow water, deeply buried in soft mud in estuaries and tidal flats. The shell is large, thin, roundly ovate and inflated, without a posterior ridge. The surface is almost smooth. It makes contact with the surface through its breathing tubes which are long and fused. It feeds on minute organisms and detritus floating in the water when the tide covers the shell's site. Often present in upper estuaries so tolerates brackish water. Mud Tolerance; prefers 0-10% mud (range 0-80%). |
| Bivalvia | *Paphies australis* | II | SS (adults)<br>S or M (Juveniles)<br>Optimum range 0-5% mud*,<br>distribution range 0-5% mud**). | The pipi is endemic to New Zealand. Pipi are tolerant of moderate wave action, and commonly inhabit coarse shell sand substrata in bays and at the mouths of estuaries where silt has been removed by waves and currents. They have a broad tidal range, occurring intertidally and subtidally in high-current harbour channels to water depths of at least 7m. Optimum mud range 0-5% mud and very restricted to this range. Tolerant of low salinity for short periods (McLeod and Wing 2008). Common at mouth of Motupipi Estuary, Freshwater Estuary (<1% mud). |
| Oligichaeta | Oligochaete sp. | V | MM | Segmented worms - deposit feeders. Classified as very pollution tolerant (e.g. Tubificid worms) although there are some less tolerant species. Optimum range 95-100% mud*, distribution range 0-100%**. |
| Crustacea | *Amphipoda* sp. | NA | NA | An unidentified amphipod. |
| Crustacea | *Colurostylis lemurum* | II | S | A cumacean that prefers sandy environments. Prefers 0-5% mud with range 0-60% mud**. Cumacea is an order of small marine crustaceans, occasionally called hooded shrimp. Their unique appearance and uniform body plan makes them easy to distinguish from other crustaceans. |
| Crustacea | Copepoda | NA | NA | Copepods are a group of small crustaceans found in the sea and nearly every freshwater habitat and they constitute the biggest source of protein in the oceans. Usually having six pairs of limbs on the thorax. The benthic group of copepods (Harpactacoida) have worm-shaped bodies. |
| Crustacea | Cumacea | NA | NA | Cumacea is an order of small marine crustaceans, occasionally called hooded shrimps. Some species can survive in water with a lower salinity rate, like in brackish water (e.g. estuaries). Most species live only one year or less, and reproduce twice in their lifetime. Cumaceans feed mainly on microorganisms and organic material from the sediment. Species that live in the mud filter their food, while species that live in sand browse individual grains of sand. |
| Crustacea | *Exosphaeroma planulum* | III | NA | Small seaweed dwelling isopod. Isopods are an order of peracarid crustaceans, including familiar animals such as woodlice and pill bugs. The name Isopoda derives from the Greek iso meaning "same" and pod meaning "foot". |
| Crustacea | *Halicarcinus whitei* | III | NA | Another species of pillbox crab. Lives in intertidal and subtidal sheltered sandy environments. |
| Crustacea | *Helice crassa* | III | MM | Endemic, burrowing mud crab. Helice crassa concentrated in well-drained, compacted sediments above mid-tide level. Highly tolerant of high silt/mud content. Optimum Range 95-100% mud (found in 5-100% mud)*. |
| Crustacea | *Hemigraspus crenulatus* | NA | NA | 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. |

# APPENDIX 3. INFAUNA CHARACTERISTICS (CONTINUED)

| Group | Species | Organic Enrichment Tolerance-AMBI Group ***** | Mud Tolerance **** | Details |
|---|---|---|---|---|
| Crustacea | *Macrophthalmus hirtipes* | III | I Optimum range 45-50% mud, distribution range 0-95%*. | The stalk-eyed mud crab is endemic to NZ and prefers waterlogged areas at the mid to low water level. Makes extensive burrows in the mud. Tolerates moderate mud levels. This crab does not tolerate brackish or fresh water (<4ppt). Like the tunnelling mud crab, it feeds from the nutritious mud. |
| | *Natantia sp* | NA | NA | True shrimps are small, swimming, decapod crustaceans usually classified in the suborder Natantia, found widely around the world in both fresh and salt water. |
| | Ostracoda | NA | NA | Ostracoda is a class of the Crustacea, sometimes known as the seed shrimp because of their appearance. They are typically around 1 millimetre. he body of an ostracod is encased by two valves, superficially resembling the shell of a clam. |
| | *Paracorophium* excavatum | V | MM Optimum Range 95-100% mud (found in 40-100% mud)*. | A tube-dwelling corophioid amphipod. Two species in NZ, *Paracorophium excavatum* and *Paracorophium lucasi* and both are endemic to NZ. *P. lucasi* occurs on both sides of the North Island, but also in the Nelson area of the South Island. *P. excavatum* has been found mainly in east coast habitats of both the South and North Islands. Sensitive to metals. Also very strong mud preference. Optimum Range 95-100% mud (found in 40-100% mud) in upper Nth. Is. estuaries. In Sth. Is. and lower Nth. Is. common in Waikanae Estuary (15-40% mud), Haldane Estuary (25-35% mud) and in Fortrose Estuary (4% mud).<br>Often present in estuaries with regular low salinity conditions. In muddy, high salinity sites like Whareama A and B (30-70% mud) we get very few. |
| | *Tenagomysis* sp. | NA | NA | *Tenagomysis* is a genus of mysid shrimps in the family Mysidae. At least nine of the fifteen species known are from New Zealand |
| Insecta | *Chironomus* sp. | NA | NA | Non-biting midges. Larvae are important as food items for fish and other aquatic organisms. They are also important as indicator organisms, generally they are pollution tolerant. |
| | Diptera sp. | NA | NA | Fly or midge larvae - species unknown. |
| Osteichthyes | *Rhombosolea plebeia* | NA | NA | New Zealand sand flounder, *Rhombosolea plebeia*, is a righteye flounder of the genus Rhombosolea, found around New Zealand in shallow waters down to depths of 100 m. |

NA=Not Allocated

* Preferred and distribution ranges based on findings from the Whitford Embayment in the Auckland Region (Norkko et al., 2001).
** Preferred and distribution ranges based on findings from 19 North Island estuaries (Gibbs and Hewitt, 2004).
*** Preferred and distribution ranges based on findings from Thrush et al. (2003)
**** Tolerance to Mud Codes are as follows (from Gibbs and Hewitt, 2004, Norkko et al. 2001) :

1 = SS, strong sand preference. 2 =S, sand preference. 3 = I, prefers some mud but not high percentages. 4 =M, mud preference. 5 = MM, strong mud preference.

***** Organic Enrichment Groupings (from either Borja et al. 2000 or Modified Sensitivity Grouping based on a review of local species data for 20 plus NZ estuaries (150 plus sites) using species abundance versus TN, TP, TOC, % mud, RPD as eutrophication indicators. All sites had low concentrations of toxicants).

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

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

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

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

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

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