MOUTERE INLET
FINE-SCALE MONITORING
2013

State of the Environment Report

Moutere Inlet Fine Scale Monitoring 2013

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A technical report presenting results of the Tasman District Council's 'State of the Environment' Estuary Monitoring Programme for the 2012-13 year which included broad-scale and fine scale monitoring of Moutere Inlet, near Motueka. Indicators used in this fine-scale assessment include: percent mud content, invertebrates (mud and enrichment response), sediment oxygenation (RPD), total organic carbon, total nitrogen, total phosphorus, metals. The report compares the current condition to that assessed in 2006. Recommended monitoring and management tasks are also identified.

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Moutere Inlet

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Prepared for
Tasman District Council

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MOUTERE INLET - EXECUTIVE SUMMARY

Moutere Inlet is a 769ha, tidal lagoon estuary located near the Motueka township in the Tasman District. It is part of Tasman District Council's (TDC's) coastal SOE monitoring programme. This report summarises the results of two years of the fine scale monitoring (2006, 2013) at two sites within Moutere Inlet. The monitoring results, condition ratings, overall estuary condition, and monitoring and management recommendations are presented below.

FINE SCALE MONITORING RESULTS

- Sediment mud content was relatively high, averaging 18%, and had increased by 63% from 2006.
- Sediment oxygenation (RPD depth) in 2013 was "poor" (1cm) and had declined from the "fair" rating in 2006 (2-3cm).
- Total organic carbon (TOC) was in the "good" category in 2013, but had increased between 2006 and 2013 (37% and 60% increases for Sites A and B respectively). Concentrations of total phosphorus (TP), and total nitrogen (TN) were similar between these years.
- Macro-invertebrates consisted of an assemblage of species both sensitive and insensitive to mud and organic enrichment in both years at both sites. The communities had similar overall tolerance ratings for mud and organic enrichment, but there was an average 46% decline in mean species richness and a 71% decrease in mean abundance in 2013 compared with 2006. In addition, there were major reductions in the mean number of species per core in each of the five mud and organic enrichment tolerance groupings between 2006 and 2013.
- Heavy metals (used as an indicator of toxicity) were well below the ANZECC (2000) ISQG-Low trigger values.

CONDITION SUMMARY		2006		2013		2006-2013
		Site A	Site B	Site A	Site B	Key Trends
Sediment (muddiness)	Percent mud content	Fair	Fair	High	High	Increased muddiness
	Invertebrates (mud response)	Baseline	Baseline	Diversity Decline	Diversity Decline	Reduced abundance
Eutrophication	RPD Profile (sediment oxygenation)	Fair	Fair	Poor	Poor	Reduced oxygenation
	TOC (Total Organic Carbon)	Very Good	Very Good	Very Good	Very Good	Likely increase
	Total Phosphorus (TP)	Fair	Fair	Fair	Fair	No significant change
	Total Nitrogen (TN)	Very Good	Very Good	Very Good	Very Good	No significant change
	Invertebrates (enrichment response)	Baseline	Baseline	Diversity Decline	Diversity Decline	Reduced abundance
Toxicity	Metals (Cd, Cu, Cr, Pb, Zn,Ni)	Good/V. Good	Good/V. Good	Good/V. Good	Good/V. Good	No significant change

ESTUARY CONDITION AND ISSUES

Moutere Inlet was found to be muddy (overall 'fair' rating), moderately enriched, but with low toxicity. Increasing muddiness and organic enrichment were identified, and are the most likely explanations for the measured decline in macro-invertebrate abundance and species richness between 2006 and 2013. However, clear trends are difficult to distinguish from seasonal variation because only a single year of baseline data (2006) has been collected. Given the magnitude of the changes between the 2006 and 2013, it is recommended that annual monitoring be undertaken for the next two years to establish whether the deteriorating results observed in 2013 are truly representative of current conditions. This recommendation is supported by the findings of the broad scale mapping of soft muddy sediments, nuisance macroalgae and seagrass beds in the estuary in 2013 (Stevens and Robertson 2013) which reported a 277% increase in the area of soft mud, and a 160% increase in gross eutrophic conditions since 2006. In order to assess contamination from current pesticide use in this potentially high risk catchment, it is also recommended that analyses for pesticides be included in the next round of fine scale monitoring.

RECOMMENDED MONITORING AND MANAGEMENT

Sedimentation and nutrient enrichment have been identified as major issues in Moutere Inlet. In order to assess their extent and ongoing trends, it is recommended that fine scale monitoring be continued (including pesticides). Ideally, this should be undertaken annually for three years (2013-15) to establish a clear baseline, and then resume the 5-yearly planned cycle. Sedimentation rate monitoring should continue annually but with additional sites deployed in eutrophic/high sediment locations. In addition, it is recommended that broad scale habitat mapping be repeated every 5 years (next due in 2018) to assess trends and condition of major habitat types. It is further recommended that a rapid visual assessment of macroalgal growth be undertaken annually (Jan/Feb), with annual broad scale macroalgal mapping initiated if conditions appear to be worsening.

In order to improve our understanding of what are acceptable levels of sediment and nutrients entering the estuary, it is recommended that catchment nutrient and sediment guideline criteria be developed, with input load assessments then undertaken to assess the extent to which loads meet guideline criteria. Where loads exceed the estuary's guidelines, it is recommended that sources of elevated loads in the catchment be identified and management undertaken (e.g. rules on existing sediment discharges) to minimise their adverse effects on estuary uses and values.

1. INTRODUCTION

OVERVIEW

Developing an understanding of the condition and risks to coastal and estuarine habitats is critical to the management of biological resources. These objectives, along with understanding change in condition/trends, are the key objectives of Tasman District Council's State of the Environment Estuary monitoring programme that is largely carried out by Wriggle Coastal Management. Recently, Tasman District Council (TDC) undertook a vulnerability assessment of the region's coastlines to establish priorities for a long-term monitoring programme (Robertson and Stevens 2012). The assessment identified the Waimea, Moutere, Motueka Delta, Motupipi, Ruataniwha and Whanganui estuaries as priorities for monitoring.

For Moutere Inlet, the monitoring and management process consists of three components developed from the National Estuary Monitoring Protocol (NEMP) (Robertson et al. 2002) as follows:

1. **Ecological Vulnerability Assessment** (EVA) of the estuary to major issues (see Table 1) and appropriate monitoring design. A region-wide EVA has been undertaken (Robertson and Stevens 2012) including specific recommendations for Moutere Inlet.
2. **Broad Scale Habitat Mapping** (NEMP approach). This component (see Table 2) documents the key habitats within the estuary, and changes to these habitats over time. Broad scale mapping of Moutere Inlet was undertaken in 2006 (Clark et al. 2006), and historical vegetation cover assessed from 1947 and 1988 aerial photographs (Clark and Gillespie 2007). Broad scale habitat mapping was repeated in the summer of 2012/13 (Robertson and Stevens 2013).
3. **Fine Scale Monitoring** (NEMP approach). Monitoring of physical, chemical and biological indicators (see Table 2). This component, which provides detailed information on the condition of Moutere Inlet, was undertaken in 2006, (Gillespie and Clark 2006). Additionally, sedimentation rates in the estuary have been monitored annually by TDC at four sites since 2008.

In 2012, TDC commissioned Wriggle Coastal Management to undertake a repeat of the fine scale monitoring of Moutere Inlet undertaken in 2006 (Gillespie and Clark 2006). The current report describes the 2013 fine scale results and compares them to the previous findings.

Moutere Inlet is a moderate-sized (769ha), shallow (mean depth ~2m), well-flushed, seawater-dominated, tidal lagoon type estuary. It has two tidal openings, one main basin, several tidal arms separated by causeways, and an extensive coastal tidal flat delta (243ha) located inshore of the Motueka sandspit. The catchment is fully developed and dominated by high producing pasture, cropping/horticulture and exotic forestry (Clark et al. 2006), while much of the margin (~70%)is directly bordered by roads, causeways and seawalls.

The estuary, despite having a relatively simple shape, contains a wide variety of habitats. While dominated by intertidal sand and mudflats perched high in the tidal range, the well flushed and often steeply incised estuary channels are deep and, particularly near the entrances, support a variety of cobble, gravel, sand, and biogenic (oysters, mussels, tubeworms) habitats. Small, but resilient seagrass beds remain in the lower well flushed estuary, but are significantly reduced from their historical coverage.

Reclamation and development has significantly displaced high value saltmarsh habitat around the estuary margins, with shoreline modification (e.g. seawalls, bunds, roads) now greatly limiting natural saltmarsh expansion and restricting its capacity to migrate inland in response to predicted sea level rise. Consequently, future saltmarsh loss is highly likely.

The estuary has high use and is valued for its aesthetic appeal, rich biodiversity, shellfish collection, bathing, waste assimilation, whitebaiting, fishing, boating, walking, and scientific appeal. The inlet is recognised as a valuable nursery area for marine and freshwater fish, an extensive shellfish resource, and is important for birdlife. In 2012, a $40k saltmarsh and terrestrial margin restoration project was undertaken, and a section of causeway removed following road realignment. This project continues in 2013. A small commercial port and marina is located at the north western entrance.

A recent vulnerability assessment (Robertson and Stevens 2012) identified habitat loss, excessive muddiness, moderate disease risk, and changes in biota as a result of climate change, as the most significant issues in the estuary. Excessive muds and increasing eutrophication and sedimentation are most evident in the presence of gross eutrophic sites with low sediment oxygenation and sulphide-rich sediments, smothering macroalgae, and rapid soft mud accumulation that are developing in natural settling areas both within the estuary, and in the sheltered delta basin outside the northern entrance.

The Moutere Inlet is currently being monitored every five years and 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.

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 are 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 gastroenteritis, salmonellosis, hepatitis A, and noroviruses.
Toxic Contamination	In the last 60 years, New Zealand has seen a huge range of synthetic chemicals introduced to estuaries through urban and agricultural stormwater runoff, industrial discharges and air pollution. Many of them are toxic in minute concentrations. Of particular concern are polycyclic aromatic hydrocarbons (PAH's), heavy metals, polychlorinated biphenyls (PCB's), 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 commonplace 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 fine scale monitoring assessments).

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

2. METHODS

FINE SCALE MONITORING

Fine scale monitoring is based on the methods described in the NEMP (Robertson et al. 2002) and provides detailed information on indicators of chemical and biological condition of the dominant habitat type in the estuary. This is most commonly unvegetated intertidal mudflats at low-mid water. Using the outputs of the broad scale habitat mapping, representative sampling sites (usually two per estuary) are selected and samples collected and analysed for the following variables.

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

For the Moutere Inlet, two fine scale sampling sites (Figure 3) were selected in unvegetated, mid-low water mudflats (avoiding areas of significant vegetation and channels). At both sites, 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 (precise locations are in Appendix 1), 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 Redox Potential Discontinuity (RPD) depth recorded.
- At each site, three samples (two a composite from four plots and one a composite from two plots) of the top 20mm of sediment (each approx. 250gms) were collected adjacent to each core. All samples were kept in a chillybin in the field.
- Chilled samples were sent to R.J. Hill Laboratories for analysis of the following (details of lab methods and detection limits in Appendix 1):
  - Grain size/Particle size distribution (% mud, sand, gravel).
  - Nutrients - total nitrogen (TN), total phosphorus (TP), and total organic carbon (TOC).
  - Trace metal contaminants (Cd, Cr, Cu, Ni, Pb, Zn). Analyses were based on whole sample fractions which are not normalised to allow direct comparison with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000).
- Samples were tracked using standard Chain of Custody forms and results were checked and transferred electronically to avoid transcription errors.
- Photographs were taken to record the general site appearance.
- Salinity of the overlying water was measured at low tide.

Epifauna (surface-dwelling animals).

Conspicuous epifauna visible on the sediment surface within the 60m x 30m sampling area were semi-quantitatively assessed based on the UK MarClim approach (MNCR 1990, Hiscock 1996, 1998). Epifauna species are identified and allocated a SACFOR abundance category based on percentage cover (Appendix 1, Table A), or by counting individual organisms >5mm in size within quadrats placed in representative areas (Appendix 1, Table B). Species size determines both the quadrat size and SACFOR density rating applied, while photographs are taken and archived for future reference. This method is ideally suited to characterise often patchy intertidal epifauna, and macroalgal and microalgal cover.

Infauna (animals within sediments).

- One randomly placed sediment core was taken from each of ten plots using a 130mm diameter (area = $0.0133m^2$) PVC tube.
- The core tube was manually driven 150mm into the sediments, removed with the core intact and inverted into a labelled plastic bag.
- Once all replicates had been collected at a site, the plastic bags were transported to a nearby source of seawater and the contents of the core 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)

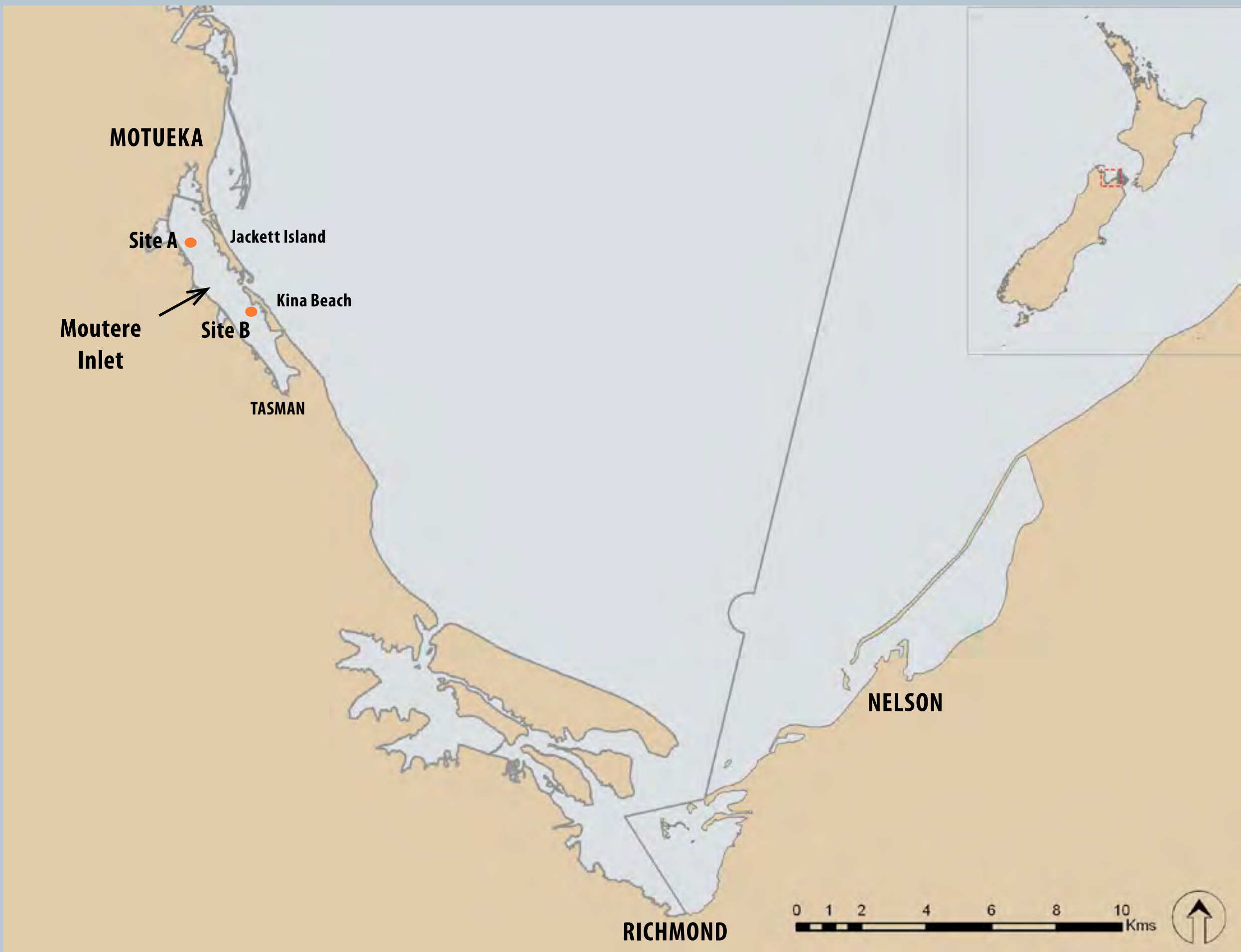

Figure 1. Moutere Inlet - location of fine scale monitoring sites.

2. Methods (Continued)

CONDITION RATINGS

A series of interim fine scale estuary "condition ratings" (presented below) have been proposed for Moutere Inlet (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, and other important condition indices, (and 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).

Sediment Mud Content

In their natural state, most NZ estuaries would have been dominated by sandy or shelly substrates. Fine sediment is likely to cause detrimental and difficult to reverse changes in community composition (including invasive species), turbidity (from re-suspension), and amenity values. Increasing mud content can indicate where changes in land use management may be needed.

SEDIMENTATION MUD CONTENT

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<2%	Monitor at 5 year intervals after baseline established
Good	2-5%	Monitor at 5 year intervals after baseline established
Fair	5-15%	Monitor at 5 year intervals after baseline established
Poor	>15%	Monitor at 5 year intervals. Initiate ERP
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. This rating provides an indication of the overall tolerance for mud of the macro-invertebrate community. However, it does not account for changes in species numbers directly, therefore an assessment of differences in both species numbers and abundance between each of the mud tolerance groups is required.

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:

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

The tendency for sediments to become anoxic is much greater if the sediments are muddy. In sandy porous sediments, the RPD layer is usually relatively deep (>3cm) and is maintained primarily by current or wave action that pumps oxygenated water into the sediments. In finer silt/clay sediments, physical diffusion limits oxygen penetration to <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 Moutere, 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 Moutere, 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.

Note that this rating provides an indication of the combined tolerance for organic enrichment of the macro-invertebrate community, and also includes influences from mud and toxins. However, it does not account for changes in species numbers directly, therefore a species diversity index is also required to assess differences in both species numbers and abundance between each of the enrichment tolerance groups.

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

3. RESULTS AND DISCUSSION

OUTLINE

A summary of the results of the 2006 and 2013 fine scale monitoring of Moutere Inlet is presented in Table 3, with detailed results in Appendices 2 and 3. The results and discussion section is divided into three subsections based on the key estuary problems that the fine scale monitoring is addressing: eutrophication, sedimentation, 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 two sites is presented in the accompanying figures.

Table 3. Physical, chemical and macrofauna results (means), Moutere Inlet.

Site	RPD	Salinity	TOC	Mud	Sand	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP	Abundance	No. Species
	cm	ppt	%				mg/kg								No./m^2	No./core
2006 A*	3	30	0.75	12.9	86.6	0.5	<0.01	29.6	6.1	58.4	4.6	25.0	368	513	5,534	15.7
2006 B*	2	30	0.62	10.3	88.8	1.0	<0.01	33.8	6.0	76.1	3.7	26.8	309	546	6,970	17.2
2013 A	1	30	1.03	18.2	80.4	1.3	0.022	36.7	7.5	87.0	4.6	34.0	<500	520	1,887	9.0
2013 B	1	30	0.99	18.2	81.6	0.2	0.022	30.7	6.8	66.3	5.0	31.7	<500	497	1,729	7.5

*results from Gillespie and Clark 2006.

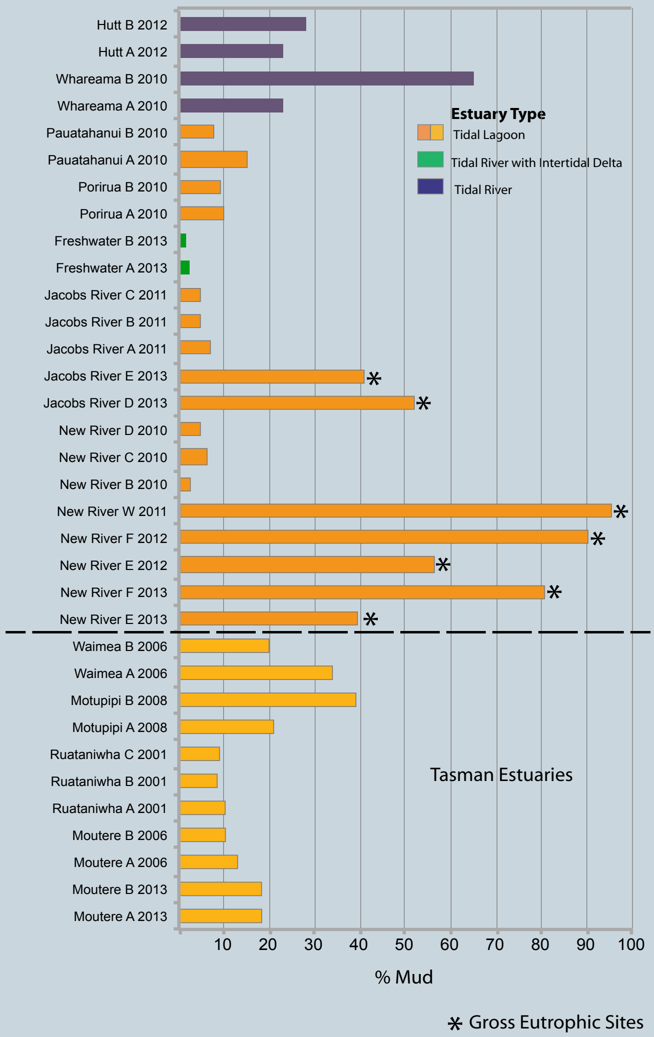

Figure 2. Percentage of mud at fine scale sites in NZ estuaries.

SEDIMENTATION

Soil erosion is a major issue in New Zealand and the resulting suspended sediment impacts are of particular concern in estuaries because they act as a sink for fine sediments or muds. Sediments containing high mud content (i.e. around 30% with a grain size <63µm) are now typical in NZ estuaries that drain developed catchments (Figure 2). In such mud-impacted estuaries, the muds generally occur in the areas that experience low energy tidal currents and waves [i.e. the intertidal margins of the upper reaches of estuaries (e.g. Waihopai Arm, New River Estuary), and in the deeper subtidal areas at the mouth of estuaries (e.g. Hutt Estuary)]. In contrast, the main intertidal flats of developed estuaries (e.g. New River Estuary) are usually characterised by sandy sediments reflecting their exposure to wind-wave disturbance and are hence low in mud content (2-10% mud). In estuaries where there are no large intertidal flats, then the presence of mud along the narrow channel banks in the lower estuary can also be elevated (e.g. Hutt Estuary and Whareama Estuary, Wairarapa Coast). In estuaries with undeveloped catchments the mud content is extremely low (e.g. Freshwater Estuary, Stewart Island where the mud content is <1%), unless the catchment is naturally erosion-prone, with a low predominance of wetland filters.

The Moutere Inlet has an estimated suspended solids loading of 23.7 kt/yr (CLUES Model outputs) and is a developed catchment with primarily exotic forestry, intensive horticulture and agriculture and lifestyle blocks. As a consequence, ongoing sedimentation is likely to be a major issue in this estuary from activities such as drain clearance, forest harvesting/clearance, cultivation, road construction and property development.

3. Results and Discussion (Continued)

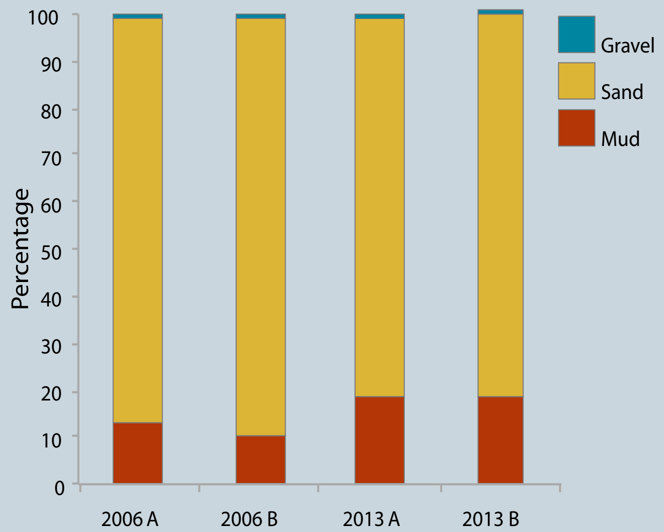

Figure 3. Grain size, Moutere Inlet, 2006 and 2013.

SEDIMENT MUD CONTENT CONDITION RATING
2006 FAIR
2013 HIGH

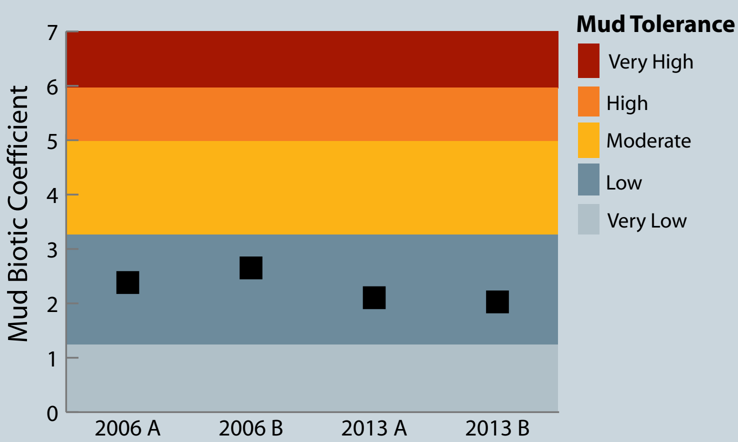

Figure 4. Mud tolerance macro-invertebrate rating, Moutere Inlet, 2006 and 2013 (Sites A and B).

In order to assess sedimentation in Moutere Inlet, two indicators have been used: grain size and the macro-invertebrate community.

Grain Size

Grain size (% mud, sand, gravel) measurements provide a good indication of the muddiness of a particular site. Monitoring results (Figure 3) showed that fine scale sites were dominated by sand (>80%) in both 2006 and 2013. However, since 2006 the mud content of sediments had increased from 12.9% and 10.3% at Sites A and B respectively to 18.2% at both sites (a 41% increase for Site A, and a 77% increase for Site B).

This corresponds to a chance in the condition rating from 'fair' to 'high'. Although the mud content is similar to fine scale tidal lagoon sites elsewhere in NZ (Figure 2), the change to increased mud indicates a clear decline in sediment condition.

Macro-invertebrate Community in Relation to Sedimentation

Sediment mud content is a major determinant of the structure of the benthic invertebrate community. This section examines this relationship in Moutere Inlet using various approaches.

Table 3 shows that the macro-invertebrate mean abundance and species richness at both sites were much lower in 2013 than in 2006 (mean abundance 2006: 6,252m^{-2}, 2013: 1,808m^{-2}, mean species richness 2006: 16.5 per core; 2013: 8.3 per core).

These results indicate a major change in the invertebrate community structure, with a 50% decline in mean species richness and 71% decrease in mean abundance since 2006. Figures 4, 5, 6 and 7, plus Table 4, explore these changes in more detail.

Figure 4 shows that the overall rating for mud tolerant invertebrates was in the "low" category at both sites in 2006 and 2013 (Figure 4), reflecting the dominance of sand in the sediments and a mixed community of sand and mud tolerant species. However, the large decline in species richness and abundance of individuals over time, strongly indicates a shift towards a more unstable community in 2013.

3. Results and Discussion (Continued)

This instability is further explored in Figures 5 and 6. Figure 5 shows major reductions in abundance between 2006 and 2013 in all the major infauna groups. Figure 6 separates the species into their mud tolerance groupings and shows major reductions in the abundance of species in all the 5 major groupings (i.e. "strong sand preference" group through to "strong mud preference" group) between 2006 and 2013. Table 4 summarises the extent of these reductions in the mean number of species per core in each of the mud tolerance groupings. The large decrease in the very sensitive species (i.e. Groups 1 and 2) are considered particularly important and indicate a shift towards a more mud tolerant, unstable community.

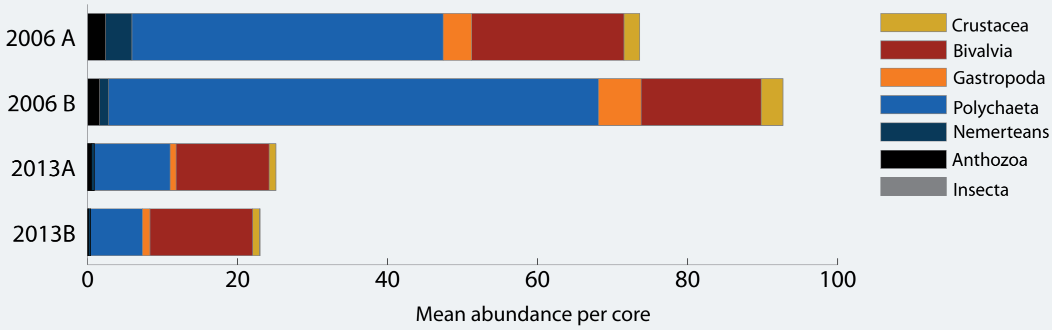

Figure 5. Mean abundance of major infauna groups, Moutere Inlet, 2006 and 2013 (Sites A and B).

Table 4. Percent change in number of species in each mud tolerance group (means), Moutere Inlet (2006-2013).

Mud Tolerance Group	% Change in Number of Species/Core
1. Strong sand preference	50% reduction
2. Sand preference	37% reduction
3. Prefers some mud but not high %'s	46% reduction
4. Mud preference	29% reduction
5. Strong mud preference	0% reduction

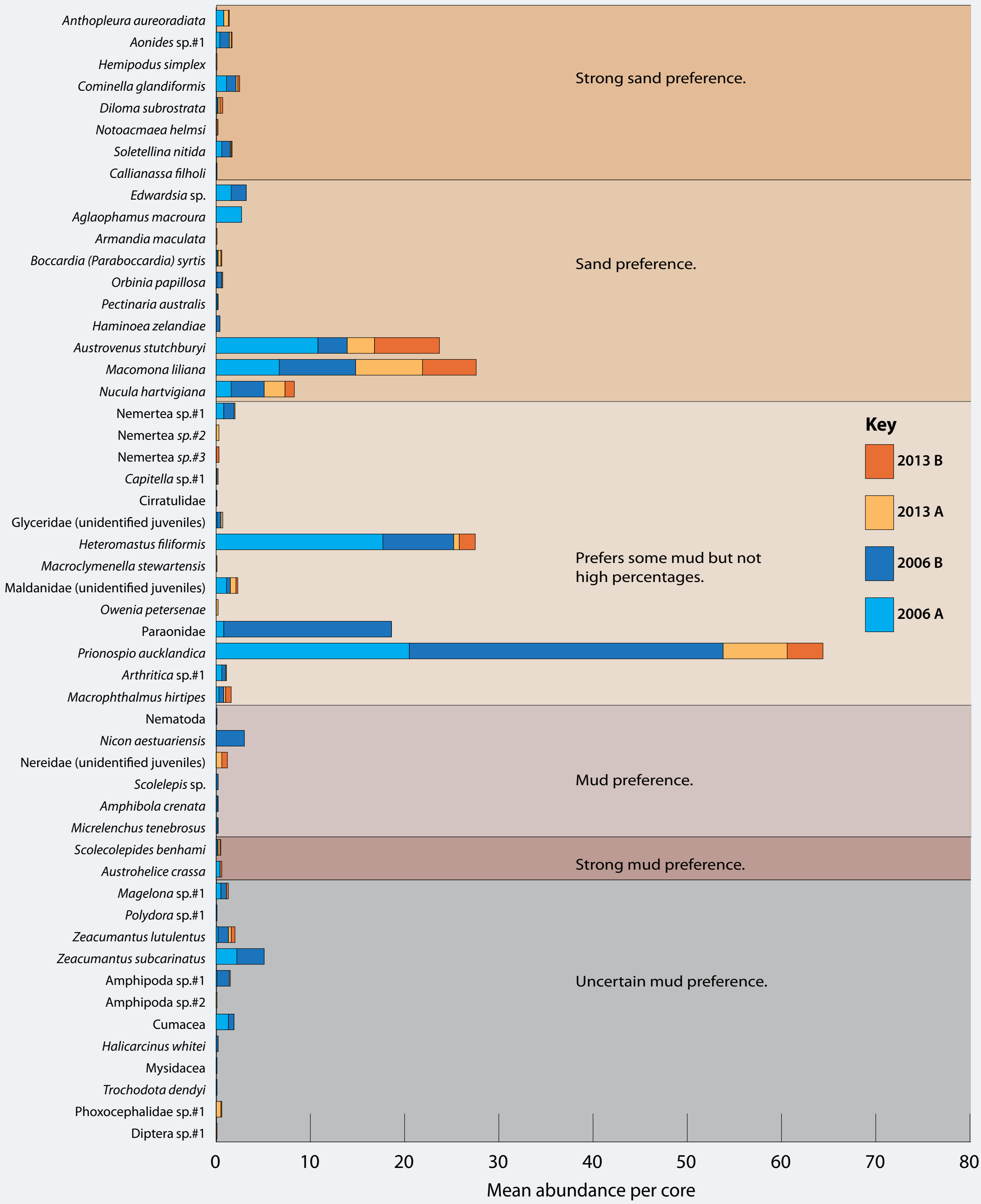

Figure 6. Benthic invertebrate mud sensitivity (see Appendix 3 for sensitivity details).

3. Results and Discussion (Continued)

Differences in the benthic invertebrate communities over time are clearly evident in the results of the multivariate analysis (NMDS Plot, Figure 7) showing that sites are split between years, with the wider spread of points within the 2013 data reflecting the less stable community present.

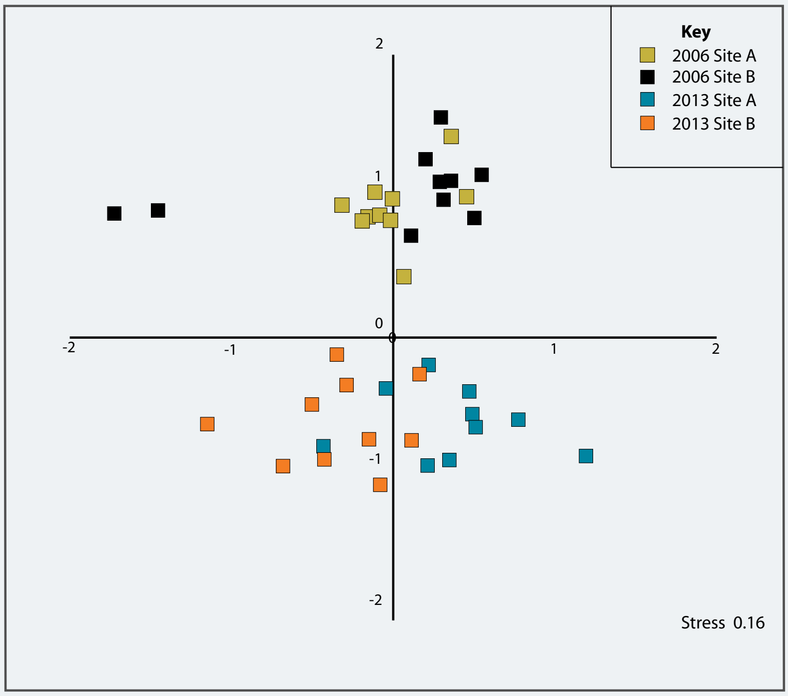

Figure 7. NMDS plot for Moutere Inlet macro-invertebrates, 2006 and 2013. Shows the relationship among samples in terms of similarity in macro-invertebrate community composition at Sites A and B for the two years of sampling. The plot shows each of the 10 replicate samples for each year and is based on Bray Curtis dissimilarity and square root transformed data.

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

Overall, the results show that a significant decline in the invertebrate community condition, with the increased mud content likely to be a major factor in the observed changes.

EUTROPHICATION

In order to assess eutrophication five fine scale indicators are used:

- grain size,
- RPD depth,
- sediment organic matter,
- nitrogen and phosphorus concentrations, and
- the macro-invertebrate community.

In addition, the broad scale indicators i.e. the percentage of the estuary covered by macroalgae and soft muds (see Stevens and Robertson 2013), are relevant and are discussed in the conclusions.

3. Results and Discussion (Continued)

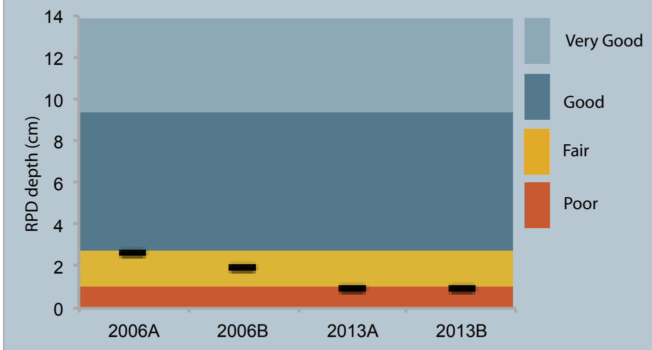

Figure 8. Redox potential discontinuity (RPD) depth, 2006 and 2013, Moutere Inlet.

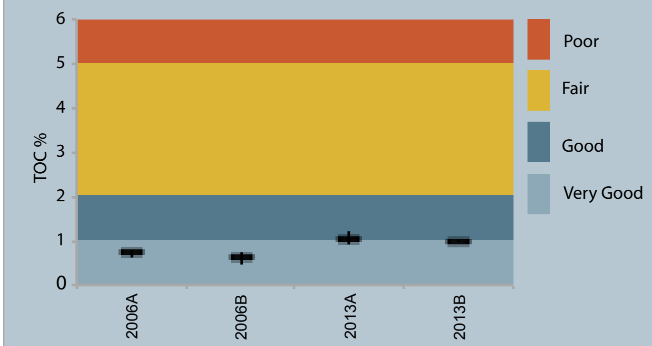

Figure 9. Total organic carbon (mean and range), 2006 and 2013, Moutere Inlet.

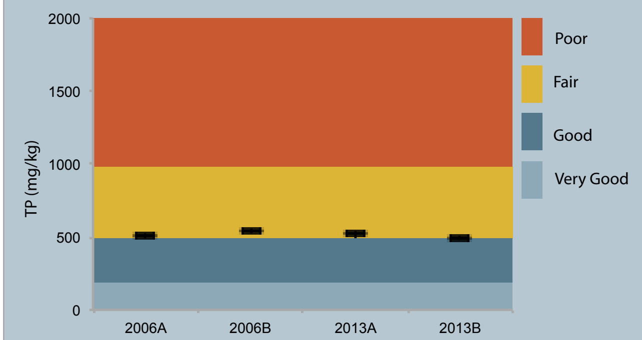

Figure 10. Total phosphorus (mean and range), 2006 and 2013, Moutere Inlet.

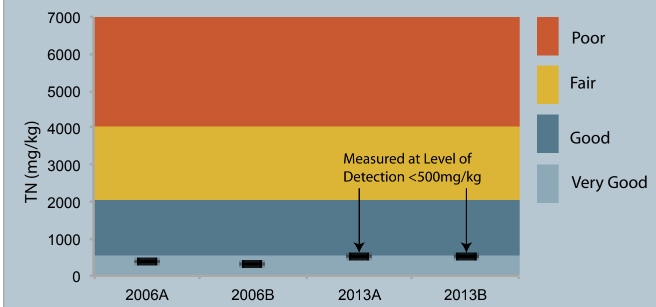

Figure 11. Total nitrogen (mean and range), 2006 and 2013, Moutere Inlet.

Grain Size

This indicator has been discussed in the sedimentation section and is not repeated here. However, in relation to eutrophication, the large increase in mud content at both sites in 2013 (Figure 3) will result in reduced sediment porosity, and is therefore expected to cause a decline in sediment oxygenation (RPD).

Redox Potential Discontinuity (RPD) depth

Figure 8 shows the RPD depths for the two Moutere sampling sites. The 2013 results show that the RPD depth was shallow (1cm) compared with those in 2006 (2-3cm). Such shallow RPD values in 2013 fit the "poor" condition rating and indicate that the benthic invertebrate community was likely to be in a "transitional" state. The decline in RPD in 2013 was likely attributable to the increased mud and macroalgae cover in the estuary (Stevens and Robertson 2013).

Total Organic Carbon and Nutrients

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

The 2013 results showed relatively low TOC (~1%) and TN concentrations (<500mg/kg), but elevated ("fair") concentrations of TP (Figures 9, 10, and 11). The low TOC levels reflect the well-flushed nature of much of the estuary, and a likely moderate load of organic matter, sourced primarily from the catchment and benthic macro-algae. Although the results showed TOC concentrations had increased between 2006 and 2013 (37% and 60% for Sites A and B respectively), this may be the result of a method change. In 2006 ash free dry weight and a standard conversion factor were used to estimate TOC, while in 2013 TOC was measured directly.

TP concentrations showed no appreciable change between 2006 and 2013. TN changes are not possible to accurately assess due to a forced change in the analysis method, and the 2013 results being below the new method detection limit.

3. Results and Discussion (Continued)

Macro-invertebrate Community in Relation to Organic Enrichment

Organic matter is a major determinant of the structure of the benthic invertebrate community. The sedimentation section has already established that there were large declines in species abundance and richness between 2006 and 2013 and this coincided with an increase in mud content. However, the previous section also indicates an associated decline in RPD and TOC, which implies that the community shift may be influenced by organic enrichment, as well as increasing mud. If organic enrichment contributed to the changes, then one or both of the following must be present:

- an increase in the overall organic enrichment tolerance rating, and/or
- major reductions in the abundance of species in the 5 major enrichment tolerance groupings (i.e. "very sensitive to organic enrichment" group through to "1st-order opportunistic species" group).

These two aspects of the invertebrate community are assessed as follows:

1. **Overall organic enrichment tolerance rating.** Figure 12 shows the overall enrichment tolerance rating of the Moutere Inlet macro-invertebrate community using monitoring results from 2006 and 2013 at Sites A and B. The results showed that, in 2013, the rating was in the "low" category, and in 2006 in the "low-moderate" category. These indicate that the overall community had a mix of enrichment tolerant and less tolerant species. Clearly, this condition rating alone does not indicate that the 2013 community was dominated by more enrichment tolerant organisms than were present in 2006.

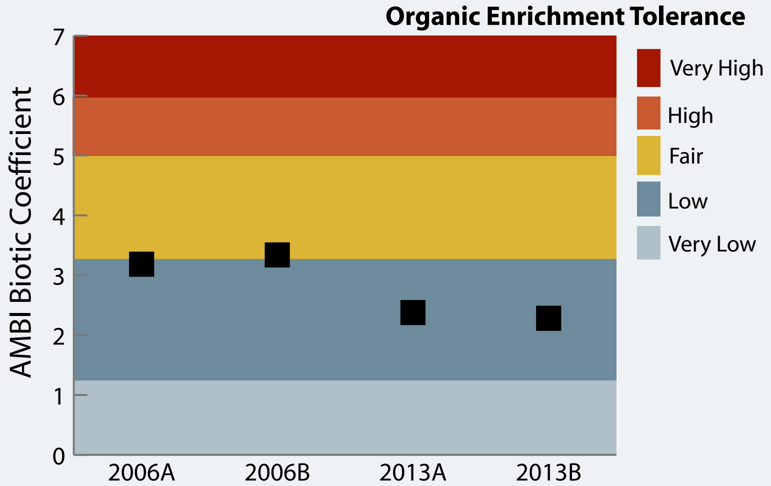

Figure 12. Benthic invertebrate organic enrichment tolerance rating, Moutere Inlet.

2. **Reductions in the abundance of species in the 5 major enrichment tolerance groupings.** Although Figure 12 provides little support for organic enrichment as a causative agent, Figure 13 and Table 5 do. They show major reductions in the abundance of certain species in all the 5 major enrichment tolerance groupings between 2006 and 2013, particularly Group V organisms (highly insensitive species).

It can therefore be concluded that overall, both mud and organic enrichment were likely to be contributing factors in the observed changes to the macro-invertebrate community. However, because there has only been one year of baseline results, establishing trends with any precision is difficult. This community is likely to be in an unstable, transitional state and further monitoring will establish changes in the future.

Table 5. Percent change in mean species numbers in each enrichment tolerance group, Moutere Inlet.

Organic Enrichment (AMBI) Tolerance Group	% Change in Number of Species/Core
I. Very sensitive to organic enrichment.	19% reduction
II. Indifferent to organic enichment (slightly unbalanced).	54% reduction
III. Tolerant to excess organic enrichment (unbalanced situations).	44% reduction
IV. 2nd-order opportunistic species (slight to pronounced unbalanced).	31% reduction
V. 1st-order opportunistic species (pronounced unbalanced situations).	80% reduction

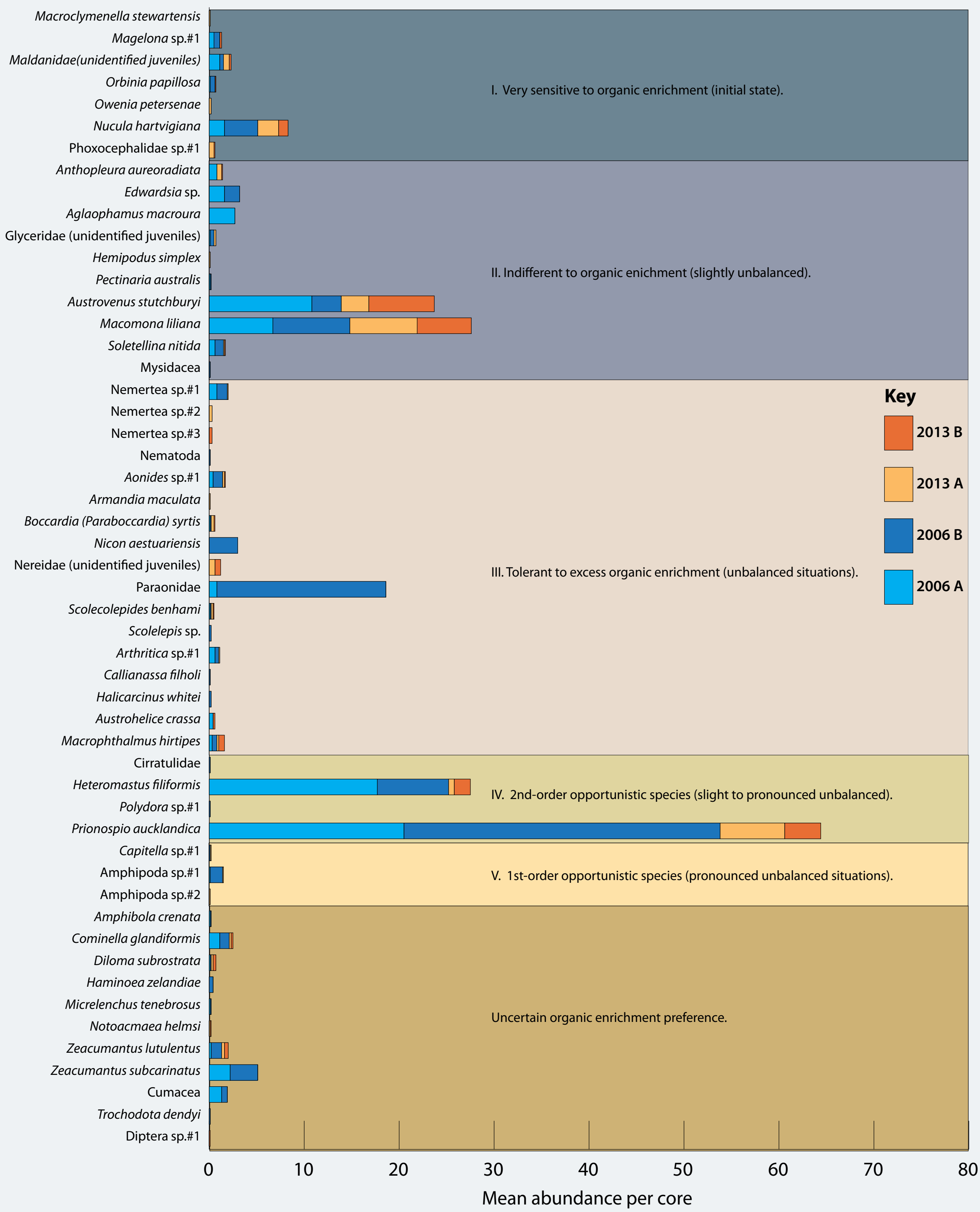

Figure 13. Organic enrichment sensitivity of macro-invertebrates, Moutere Inlet, 2006 and 2013 (see Appendix 3 for sensitivity details).

3. Results and Discussion (Continued)

TOXICITY CONDITION RATING

2013 GOOD-VERY GOOD

TOXICITY

Heavy metals (Cd, Cr, Cu, Ni, Pb, Zn), used as an indicator of potential toxicants, were at low to very low concentrations in 2006 and 2013, with all values well below the ANZECC (2000) ISQG-Low trigger values (Figure 14). Metals met the "very good" condition rating for cadmium, copper, lead and zinc. Nickel met the "good" condition rating in 2013 at Site A, and the "very good" condition rating at Site A in 2006 and Site B in both years. Chromium met the "good" condition rating in 2006 and 2013 at both sites. These results indicate that there is no widespread metal toxicity in Moutere Inlet. However, because organochlorine pesticides have been recorded previously from the estuary at low levels (MFE 1998), and there is potential for ongoing pesticide contamination from this high risk horticultural catchment, it is recommended that analysis of pesticides be included in the next round of fine scale monitoring.

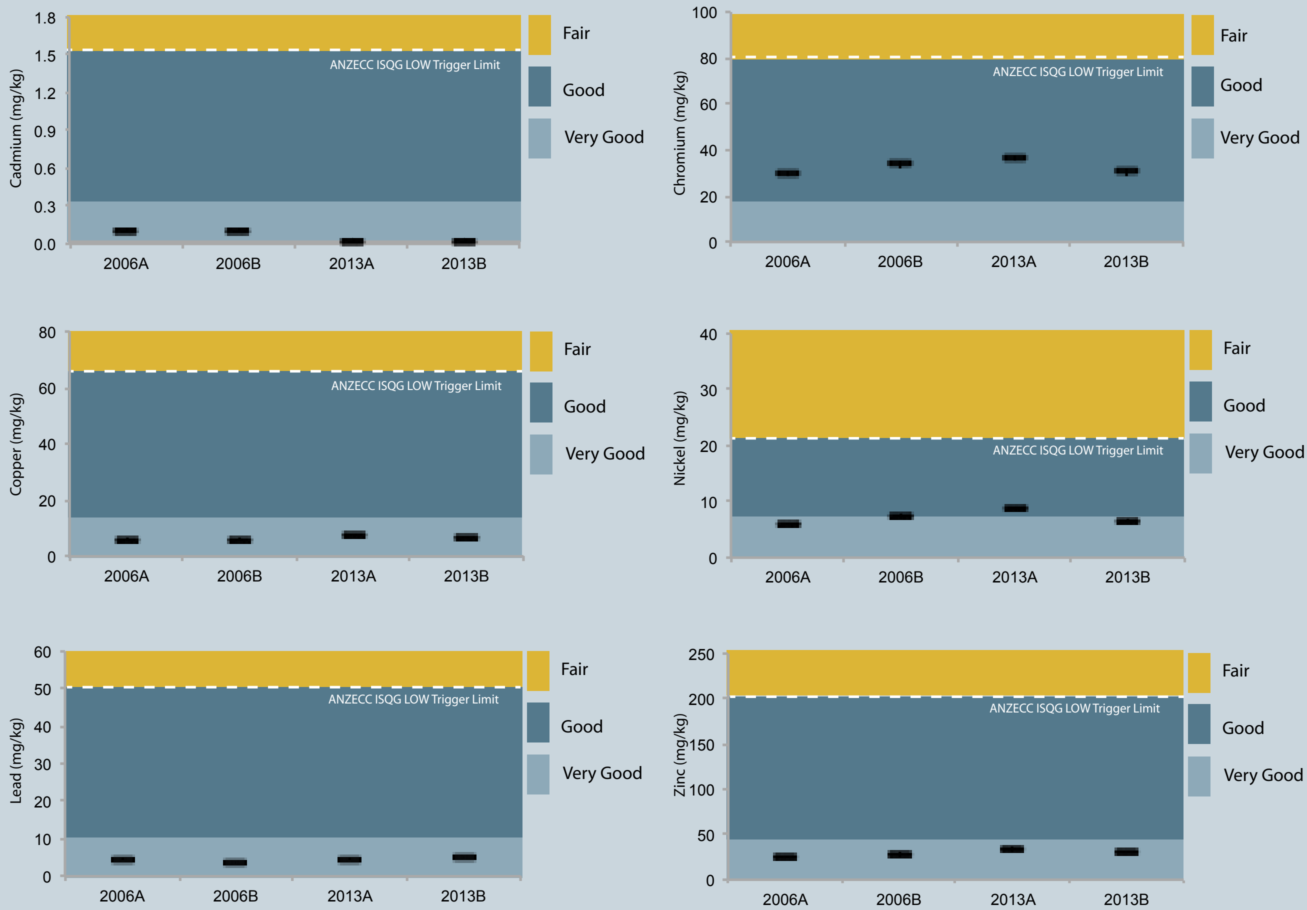

Figure 14. Sediment metal concentrations (mean and range), 2006 and 2013, Moutere Inlet.

4. SUMMARY AND CONCLUSIONS

Fine scale monitoring results of estuary condition within Moutere Inlet in 2006 and 2013 showed the following key findings:

- The sediment mud content in 2013 was relatively high at 18% mud and had increased by 63% from 2006.
- Sediment oxygenation in 2013 was "fair-poor" as indicated by RPD depth (1cm) and had declined from the "fair" rating in 2006 (2-3cm).
- Although TOC was in the "good" category in 2013, it had increased between 2006 and 2013 (37% and 60% increase for Sites A and B respectively). However, concentrations of TP, and possibly, TN (taking TN level of detection change in 2013 into account) were similar between these years.
- Macro-invertebrates consisted of an assemblage of species both sensitive and insensitive to mud and organic enrichment. However, although the communities in both years had similar overall tolerance ratings for mud and organic enrichment, there was a 46% decline in mean species richness and 71% decrease in mean abundance in 2013 compared with 2006. In addition, there were major reductions in the mean number of species per core in each of the five mud and organic enrichment tolerance groupings between 2006 and 2013. These findings demonstrated a significant decline in the community condition at both sites between 2006 and 2013. The cause of this change was likely atributable to the combined effect of the increase in mud and organic carbon content of the sediments.
- Heavy metals (Cd, Cr, Cu, Ni, Pb, Zn), used as an indicator of potential toxicants, were at low-very low concentrations at both sites.

Overall, it can therefore be concluded that the estuary is relatively muddy, getting muddier, at least moderately enriched, and that both mud and organic enrichment are likely to be contributing factors to the measured decline in macro-invertebrate abundance and species richness between 2006 and 2013.

However, clear trends are difficult to distinguish from seasonal variation because only a single year of baseline data (2006) has been collected. Given the magnitude of the changes between the years, it is recommended that annual monitoring be undertaken for the next two years to establish whether the deteriorating results observed in 2013 are truly representative of current conditions.

These findings of increased mud and organic enrichment are supported by the results of the broad scale mapping results of soft muddy sediments, nuisance macroalgae and seagrass beds in the estuary in 2013 (Stevens and Robertson 2013) which reported a 277% increase in the area of soft mud, and a 160% increase in gross eutrophic conditions since 2006.

5. MONITORING

Moutere Inlet has been identified by TDC as a priority for monitoring, and is a key part of TDC's coastal monitoring programme being undertaken in a staged manner throughout the Tasman district. Based on the 2013 monitoring results and condition ratings, it is recommended that monitoring continue as follows:

Fine Scale Monitoring
Two years of fine scale monitoring at Sites A and B have now been completed (2006 and 2013). It is recommended that TDC monitor annually for the next two years to establish a baseline, and thereafter at 5 yearly intervals. In order to assess the extent of contamination from pesticide use in this potentially high risk catchment, it is also recommended that analyses for pesticides be included in the next round of fine scale monitoring.

Broad Scale Habitat Mapping, Including Macroalgae.
Continue with the programme of 5 yearly broad scale habitat mapping. Next monitoring due in February/March 2018. Undertake a rapid visual assessment of macroalgal growth annually, and initiate broad scale macroalgal mapping if conditions appear to be worsening over the 5 years before broad scale mapping is repeated.

Sedimentation Rate Monitoring.
Because sedimentation is a priority issue in the estuary it is recommended that sediment plate depths be measured annually, and new plates be deployed in the highly eutrophic locations where sediment is rapidly accumulating.

6. MANAGEMENT

The combined results from the 2013 fine scale and broad scale reports (Stevens and Robertson 2013) identify sedimentation and nutrient enrichment as major issues in Moutere Inlet. To address these issues, it is recommended that catchment nutrient and sediment input load guideline criteria be developed for the estuary, with input load assessments then undertaken to assess the extent to which current catchment loads are likely to meet guideline criteria. If catchment loads exceed the estuary's guidelines then it is recommended that sources of elevated loads in the catchment be identified and management undertaken to minimise their adverse effects on estuary uses and values.

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	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 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.

Epifauna (surface-dwelling animals).

SACFOR Percentage Cover and Density Scales (after Marine Nature Conservation Review - MNCR).

A. PERCENTAGE COVER	Growth Form	
	i. Crust/Meadow	ii. Massive/Turf
>80	S	-
40-79	A	S
20-39	C	A
10-19	F	C
5-9	O	F
1-4	R	O
<1	-	R

SACFOR Category
S = Super Abundant
A = Abundant
C = Common
F = Frequent
O = Occasional
R = Rare

- Whenever percentage cover can be estimated for an attached species, it should be used in preference to the density scale.
- The massive/turf percentage cover scale should be used for all species except those classified under crust/meadow.
- Where two or more layers exist, for instance foliose algae overgrowing crustose algae, total percentage cover can be over 100%.

B. DENSITY SCALES

SACFOR size class				Density				
i	ii	iii	iv	$0.25m^2$	$1.0m^2$	$10m^2$	$100m^2$	$1,000m^2$
<1cm	1-3cm	3-15cm	>15cm	(50x50cm)	(100x100cm)	(3.16x3.16m)	(10x10m)	(31.6x31.6m)
S	-	-	-	>2500	>10,000			
A	S	-	-	250-2500	1000-9999	>10,000		
C	A	S	-	25-249	100-999	1000-9999	>10,000	
F	C	A	S	1-9	10-99	100-999	1000-9999	>10,000
O	F	C	A		1-9	10-99	100-999	1000-9999
R	O	F	C			1-9	10-99	100-999
-	R	O	F				1-9	10-99
-	-	R	O					1-9
-	-	-	R					<1

APPENDIX 1. DETAILS ON ANALYTICAL METHODS (CONTINUED)

Station Locations

Moutere Site A	1	2	3	4	5	6	7	8	9	10
NZTM EAST	1601472	1601483	1601496	1601507	1601504	1601494	1601481	1601466	1601462	1601468
NZTM NORTH	5444745	5444734	5444724	5444717	5444707	5444713	5444723	5444735	5444727	5444721
Moutere Site B	1	2	3	4	5	6	7	8	9	10
NZTM EAST	1603632	1603622	1603610	1603602	1603593	1603604	1603612	1603622	1603616	1603606
NZTM NORTH	5442419	5442407	5442395	5442384	5442391	5442399	5442412	5442421	5442433	5442424

APPENDIX 2. 2013 DETAILED RESULTS

Physical and Chemical Results for Moutere Inlet (Sites A and B), 30 March 2006 and 21 March 2013.

Site**	Reps*	RPD	Salinity	TOC***	Mud	Sands	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP
		cm	ppt	%				mg/kg							
2006A-01	1-4	3	30	0.65	13.9	85.7	0.4	<0.1	30	5.9	59	4.5	26	390	524
2006A-02	5-8	3	30	0.78	13.0	86.6	0.5	<0.1	29	6.3	58	4.8	25	355	521
2006A-03	9-10	3	30	0.81	12.2	87.3	0.5	<0.1	30	6.2	58	4.6	24	361	500
2006B-01	1-4	2	30	0.46	9.5	89.8	0.7	<0.1	33	5.8	79	3.5	26	310	557
2006B-02	5-8	2	30	0.67	9.0	89.7	1.2	<0.1	36	6.0	77	3.8	26	305	525
2006B-03	9-10	2	30	0.72	14.2	84.8	1.2	<0.1	33	6.5	70	3.9	30	315	565
2013A-01	1-4	1	30	1.23	21.9	76.3	1.8	0.022	38	8.0	84	4.9	36	500	520
2013A-02	5-8	1	30	0.92	17.1	81.7	1.2	0.022	35	7.4	87	4.5	34	500	540
2013A-03	9-10	1	30	0.93	15.7	83.3	1.0	0.021	37	7.0	90	4.3	32	500	500
2013B-01	1-4	1	30	0.96	17.0	82.9	0.1	0.021	31	6.5	66	4.9	31	500	480
2013B-02	5-8	1	30	1.05	17.8	82.1	0.2	0.022	29	6.9	66	4.9	32	500	510
2013B-03	9-10	1	30	0.95	19.8	79.8	0.4	0.023	32	7.1	67	5.1	32	500	500

* composite samples
**results from Gillespie and Clark 2006.
*** AFDW results converted to TOC using equation Nagao N, Toda T, Takahashi K, Hamasaki K, Kikuchi T, Taguchi S (2001) High ash content in net-plankton samples from shallow coastal water: Possible source of error in dry weight measurement of zooplankton biomass. J Oceanogr 57: 105–107. Equation TOC% = ((AFDW%.0.37)+0.87)/10.

Epifauna Results for Moutere Inlet, 21 March 2013.

Group	Family	Species	Common name	Scale	Class	A	B
Bivalves	*Mytilidae*	*Mytilus galloprovincialis*	Blue mussel	#	iii	-	R
Topshells	*Buccinidae*	*Cominella glandiformis*	Mudflat whelk	#	ii	R	R
	Trochidae	*Diloma subrostrata*	Grooved topshell	#	ii	C	F
	Buccinidae	*Zeacumantus lutulentus*	Spire shell	#	ii	C	C
Limpets	*Lottiidae*	*Notoacmaea helmsi*	Estuarine limpet	#	i	F	F
Red algae	*Gracilariaceae*	*Gracilaria sp. ?secundata*	Gracilaria weed	%	ii	R	O
Green algae	*Ulvaceae*	*Ulva lactuca*	Sea lettuce	%	i	R	R

APPENDIX 2. 2013 DETAILED RESULTS (CONTINUED)

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

Moutere Inlet Sites A and B, 21 March 2013

Group	Species	AMBI	MUD	A-01	A-02	A-03	A-04	A-05	A-06	A-07	A-08	A-09	A-10	B-01	B-02	B-03	B-04	B-05	B-06	B-07	B-08	B-09	B-10
ANTHOZOA	*Anthopleura aureoradiata*	II	1			1		1			3					1							
NEMERTEA	Nemertea sp.#1	III	3		1																		
	Nemertea sp.#2	III	3							1		1	1										
	Nemertea sp.#3	III	3											1	1	1							
POLYCHAETA	*Aonides* sp.#1	III	1							1			1			1							
	Armandia maculata	III	2					1															
	Boccardia (Paraboccardia) syrtis	III	2				1		1			1					1						
	Capitella sp.#1	V	3									1											
	Glyceridae	II	3	1							1												
	Hemipodus simplex	II	1									1											
	Heteromastus filiformis	IV	3		1			2					3	2	3		4		3		1	1	3
	Macroclymenella stewartensis	I	3			1																	
	Magelona sp.#1	I	NA														1				1		
	Maldanidae	I	3	1			1			1	1		2						1		1		
	Nereidae	III	4	1		1		2	1				1			1		2		1	1	1	
	Orbinia papillosa	I	2													1							
	Owenia petersenae	I	3	1	1																		
	Prionospio aucklandica	IV	3	3	1	15	13	2	3	7	7	10	7	3	1	14	7	1	7	4	1		
	Scolecolepides benhami	III	5	1			1																1
GASTROPODA	*Cominella glandiformis*	NA	1	2										1		1							
	Diloma subrostrata	NA	1		1	1									1	1		1					
	Notoacmaea helmsi	NA	1					1							1								
	Zeacumantus lutulentus	NA	NA			2					1			1			1	2					
BIVALVIA	*Arthritica* sp.#1	III	3						1														
	Austrovenus stutchburyi	II	2	6		6	4	1	2	4	2	2	2	4	2	6	5	11	9	5	12	10	5
	Macomona liliana	II	2	7	10	7	6	6	7	10	6	5	7	5	4	5	6	4	6	8	10	3	6
	Nucula hartvigiana	I	2	1	1	3	2	5	4	3	1	1	1		2	1		2		3	1	1	
	Soletellina nitida	II	1										1								1		
CRUSTACEA	Amphipoda sp.#1	V	NA				1																
	Amphipoda sp.#2	V	NA										1										
	Austrohelice crassa	III	5																				2
	Macrophthalmus hirtipes	III	3					1					1			2	2					1	1
	Phoxocephalidae sp.#1	I	NA	2			1			1	1					1							
INSECTA	Diptera sp.#1	NA	NA																		1		
Total individuals in sample				**26**	**16**	**37**	**30**	**22**	**19**	**28**	**23**	**22**	**28**	**17**	**15**	**36**	**27**	**23**	**26**	**21**	**30**	**17**	**18**
Total species in sample				**11**	**7**	**9**	**9**	**10**	**7**	**8**	**9**	**8**	**12**	**7**	**8**	**13**	**8**	**7**	**5**	**5**	**10**	**6**	**6**

APPENDIX 3. INFAUNA CHARACTERISTICS

Group	Species	Tolerance to Organic Enrichment *****	Tolerance to Mud****	Details
Anthozoa	*Anthopleura aureo-radiata*	II	SS Optimum range 5-10% mud*, distribution range 0-10%**	Mud flat anemone, attaches to cockle shells and helps to reduce the rate at which cockles accumulate parasites. It can also grow in small vertical shafts of its own an inch or more deep, fastened to small stones. Grows up to 10mm, intolerant of low salinity, high-turbidity and increasing silt/clay sediment content (Norkko et al., 2001). It has green plant cells in its tissues that convert solar energy to food.
Nemertea	Nemertea sp.	III	I Optimum range 10-15%* or 20-40% mud**, distribution range 0-95%**	Ribbon or Proboscis Worms, mostly solitary, predatory, free-living animals. Intolerant of anoxic conditions.
Polychaeta	*Aonides* sp.	III	SS Optimum range 0-5% mud*, distribution range 0-80%**	A small surface deposit-feeding spionid polychaete that lives throughout the sediment to a depth of 10 cm. 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. **But is generally tolerant of organically enriched situations.** In general, polychaetes are important prey items for fish and birds.
	Armandia maculata	III	S Optimum range 5-10% mud,* distribution range 0-40%*	Common subsurface deposit-feeding/herbivore. Belongs to Family Opheliidae. Found intertidally as well as subtidal in bays and sheltered beaches. Prefers fine sand to sandy mud at low water. Does not live in a tube. Depth range: 0-1000m. A good coloniser and explorer. Pollution and mud intolerant. Prefers 0-10% mud.
	Boccardia (Paraboccardia) syrtis	III modified from AMBI	S Optimum range 10-15% mud,* distribution range 0-50%*	A small surface deposit-feeding spionid. Prefers low-mod mud content but found in a wide range of sand/mud. It lives in flexible tubes constructed of fine sediment grains, and can form dense mats on the sediment surface. Very sensitive to organic enrichment and usually present under unenriched conditions.
	Capitellidae	V or IV	I Optimum range 10-15%* or 20-40% mud**, distribution range 0-95%**	Subsurface deposit feeder, occurs down to about 10 cm sediment depth. Common indicator of organic enrichment. Bio-turbator. Prey for fish and birds.
	Glyceridae	II	I Optimum range 10-15% mud,* distribution range 0-95%*	Glyceridae (blood worms) are predators and scavengers. They are typically large, and are highly mobile throughout the sediment down to depths of 15 cm. They are distinguished by having 4 jaws on a long eversible pharynx. **Intolerant of anoxic conditions. Prefer 10-15% mud but found in wide range. Intolerant of low salinity.**
	Hemipodus simplex	II	SS Optimum range 5-10% mud*, distribution range 0-10%**	A glycerid, or bloodworm, found in clean sand sites in estuaries and on clean sandy beaches. The glycerids in general are cylindrical, very muscular and active large predators and detritivores living in sands and sandy muds. Mud Tolerance; strong sand preference******.
	Heteromastus filiformis	IV	I Optimum range 10-15%* or 20-40% 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. Mud Tolerance; Optimum range 10-15% mud,* distribution range 0-95%*.

APPENDIX 3. INFAUNA CHARACTERISTICS

Group	Species	Tolerance to Organic Enrichment *****	Tolerance to Mud****	Details
Polychaeta	*Macroclymenella stewartensis*	I	I Optimum range 55-60%* or 35-55% mud**, distribution range 0-100%**. Sensitive to large increases in sedimentation	Bamboo worms. A sub-surface, deposit-feeder that is usually found in tubes of fine sand or mud. This species is found throughout the sediment to depths of 15cm and potentially has a key role in the re-working and turn-over of sediment and may modify the sediment conditions, making it more suitable for other species (Thrush et al. 1988). Common at low water in estuaries. Prefers sand. Intolerant of anoxic conditions.
	Magelona sp.	I	NA	Small thin spionid worms which selectively deposit-feed on the surface. Responds negatively to an increase in silt/clay. Highly intolerant of reducing conditions. Found throughout New Zealand. Mid-intertidal and subtidal to continental slope. Magelonids build wandering burrows in medium to fine sands. The worms are visible to the naked eye as pinkish threads when sediment clumps are broken apart by hand. Found at Waimea, Waikawa and Ohiwa estuaries. Mud Tolerance; Optimum range 10-15% mud,* distribution range 0-95%*.
	Maldanidae	I	I Optimum range 55-60%* or 35-55% mud**, distribution range 0-100%**	Bamboo worms are large, blunt-ended, cylindrical worms and feed as bulk consumers of sediment using a balloon-like proboscis. Most bamboo worms live below the surface in flimsy sediment tubes. They process copious amounts of sediment and deposit it in earthworm-like surface casts.
	Nereidae	III	M Optimum range 55-60%* or 35-55% mud**, distribution range 0-100%**. Sensitive to large increases in sedimentation	Active, omnivorous worms, usually green or brown in colour. Rarely dominant in numbers compared to other polychaetes, but are conspicuous due to their large size and vigorous movement. Nereids are found in many habitats. The tube-dwelling nereid polychaete *Nereis diversicolor* is usually found in the innermost parts of estuaries and fjords in different types of sediment, but it prefers silty sediments with a high content of organic matter.
	Orbinia papillosa	I	S Optimum range 5-10% mud,* distribution range 0-40%*	Endemic orbiniid. 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.
	Owenia petersenae	II	I Optimum range 10-15%* or 20-40% mud**, distribution range 0-95%**	Members of the Oweniidae have characteristic tubes which are longer than the animal and are composed of shell fragments and sand grains which are stacked on top of each other. Oweniids often remain intact within their tubes and must be carefully removed for proper examination. Normally a suspension feeder, but is capable of detrital feeding and is a cosmopolitan species frequently abundant on sandflats. **Are classified as intermediate type species along organic enrichment gradients (Pearson and Rosenberg 1978).**
	Prionospio aucklandica	IV	I Optimum range 65-70% mud,* distribution range 0-95%*	Prionospio-group have many New Zealand species and are difficult to identify unless complete and in good condition. Common is *Prionospio aucklandica* which was renamed to *Aquilaspio aucklandica*. Common at low water mark in harbours and estuaries. A surface deposit-feeding spionid that prefers living in muddy sands but is very sensitive to changes in the level of silt/clay in the sediment (Norkko et al. 2001).

APPENDIX 3. INFAUNA CHARACTERISTICS

Group	Species	Tolerance to Organic Enrichment *****	Tolerance to Mud****	Details
Polychaeta	*Scolecolepides benhami*	III	MM Optimum range 25-30% mud,* distribution range 0-100%*	A Spionid, surface deposit feeder. Is rarely absent in sandy/mud estuaries, often occurring in a dense zone high on the shore, although large adults tend to occur further down towards low water mark. **Strong Mud Preference.** Prey items for fish and birds.
Gastropoda	*Cominella glandiformis*	NA	SS Optimum range 5-10% mud*, distribution range 0-10%**	Endemic to NZ. A very common 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. Strong Sand Preference. Optimum mud range 5-10% mud.
	Diloma subrostrata	NA	SS Optimum range 5-10% mud*, distribution range 0-15%**	The mudflat top shell, lives on mudflats, but prefers a more solid substrate such as shells, stones etc. Endemic to NZ. Feeds on the film of microscopic algae on top of the sand. **Strong Sand Preference . Optimum mud range 5-10% mud.**
	Notoacmaea helmsi	NA	SS Optimum range 0-5% mud*, distribution range 0-10%**	Endemic to NZ. Small grazing limpet attached to stones and shells in intertidal zone. **Intolerant of anoxic surface muds and sensitive to pollution. Strong sand preference 0-5% mud (range 0-10% mud).** Present in Porirua Harbour 4-5% mud, Freshwater Estuary <1% mud. A few in Fortrose (5% mud).
	Zeacumantus lutulentus	NA	NA	Belongs to the Family Muricidae, or murex snails, which are a large and varied taxonomic family of small to large predatory sea snails.
Bivalvia	*Arthritica* sp. #1	III modified from AMBI	I Optimum range 10-15%* or 20-40% mud**, distribution range 0-95%**	A small sedentary deposit feeding bivalve. Lives greater than 2cm deep in the muds. Sensitive to changes in sediment composition. Mud Tolerance; Optimum range 55-60% mud*, or 20-40%***, distribution range 5-70%**.
	Austrovenus stutchburyi	III modified from AMBI	S Prefers sand with some mud (optimum range 0-5% mud* distribution range 0-40% mud**).	The cockle is a suspension feeding bivalve with a short siphon - lives a few cm from sediment surface at mid-low water situations. Responds positively to relatively high levels of suspended sediment concentrations for short period; long term exposure has adverse effects. 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.
	Mocomona liliana	II modified from AMBI	S Prefers sand with some mud (optimum range 0-5% mud* distribution range 0-40% mud**)	**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. Adversely affected at elevated suspended sediment concentrations. Thrush et al. (2006) shows that this large deposit feeding bivalve is important in that it enhances nutrient and oxygen fluxes and its presence influences the types of other macroinvertebrate species present. These bivalves draw organic material and microphytes from the sediment surface with their inhalant siphon and defecate directly into the sediment around their shell, enhancing the concentration of organic matter at 5–10 cm below the sediment surface. Sand Preference: **Prefers 0-5% mud (range 0-40% mud).**

APPENDIX 3. INFAUNA CHARACTERISTICS

Group	Species	Tolerance to Organic Enrichment *****	Tolerance to Mud****	Details
Bivalvia	*Nucula hartvigiana*	I	S Prefers sand with some mud (optimum range 0-5% mud* distribution range 0-60% mud**)	Small deposit feeder. Nut clam of the family Nuculidae (<5mm), is endemic to New Zealand. Often abundant in top few cm. It is found intertidally and in shallow water, especially in Zostera sea grass flats. Has a plug-like foot, which it uses for motion in mud deposits. Intolerant of organic enrichment. Prefers 0-5% mud (range 0-60%)**.
Bivalvia	*Soletellina nitida*	II	SS Optimum range 5-10% mud*, distribution range 0-10%**	Soletellina is a genus of bivalve molluscs in the family Psammobiidae, known as sunset shells. Intolerant of eutrophic or muddy conditions.
Crustacea	Amphipoda sp. #1	V Preliminary modified rating to reflect NZ estuary data.	NA	An unidentified amphipod species.
Crustacea	Amphipoda sp. #2	V Preliminary modified rating to reflect NZ estuary data.	NA	An unidentified amphipod species.
Crustacea	*Austrohelice crassa*	III	MM Optimum Range 95-100% mud (found in 40-100% mud)*	A cumacean that prefers sandy environments. Prefers 0-5% mud with range 0-60% mud**. Small marine crustaceans, occasionally called hooded shrimp. Their unique appearance and uniform body plan makes them easy to distinguish from other crustaceans.
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.
Crustacea	Phoxocephalidae sp.	I	NA	A family of gammarid amphipods. Common example is *Waitangi* sp. which is a strong sand preference organism.
Insecta	Diptera sp. #1	NA	NA	An unknown dipteran or fly larvae.

* 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.