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Fortrose (Toetoes) Estuary

Fine Scale Monitoring 2008/09

Prepared for **Environment Southland**

June 2009

Cover Photo: Fortrose Estuary. Inside Photo: Green nuisance macroalgal growth (*Enteromorpha*) lower Fortrose Estuary.

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Prepared for
Environment Southland

By

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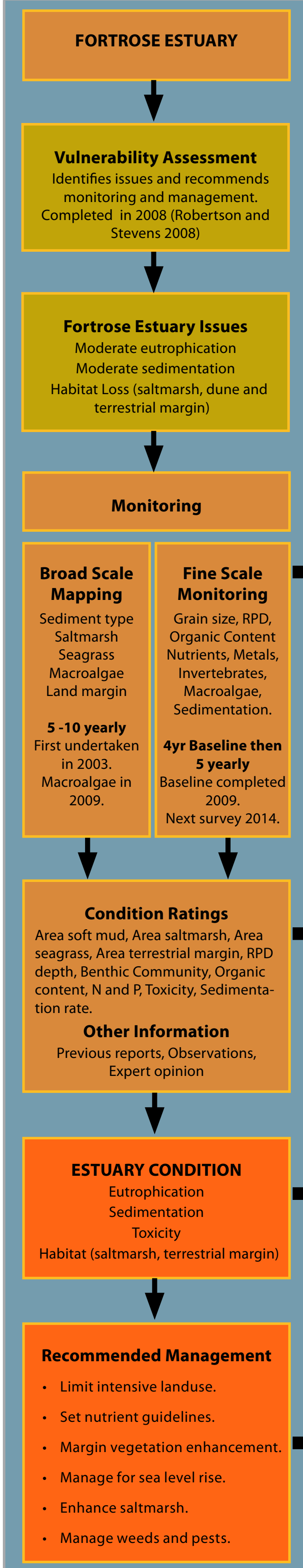
FORTROSE ESTUARY - EXECUTIVE SUMMARY



This report summarises the results of the first four years of fine scale monitoring of two intertidal sites (2004, 2005, 2006 and 2009) within Fortrose Estuary, a 500ha, tidal lagoon estuary with a large freshwater influence, on the Eastern Southland coast. It is one of the key estuaries in Environment Southland's (ES's) long-term coastal monitoring programme. An outline of the process used for estuary monitoring and management in Southland is outlined in the margin flow diagram, and the following table summarises fine scale monitoring results, condition ratings, overall estuary condition, and monitoring and management recommendations.

Fine Scale Monitoring Results

- Sediment Oxygenation: Redox Potential Discontinuity was 3cm deep indicating moderate oxygenation.
- The benthic invertebrate community condition rating indicated a slightly polluted or "good" condition.
- The indicator of organic enrichment (Total Organic Carbon) was at low concentrations in all years.
- Nutrient enrichment indicators (total nitrogen and phosphorus) were at low concentrations in all years.
- Sediment plates were deployed; allowing sedimentation to be measured in the future.
- Sand dominated the sediments and mud contents were low.
- Heavy metals were well below the ANZECC (2000) ISQG-Low trigger values (i.e. low toxicity).
- Moderate nuisance macroalgal cover was measured as part of fine scale monitoring - result was "fair".

Condition Ratings

Indicator	2004	2005	2006	2009
RPD Depth	Good	Good	Good	Good
Macrofauna	Good	Good	Good	Good
Organic Matter (TOC)	Very Good	Very Good	Very Good	Very Good
Nutrients (TN and TP)	Very Good	Very Good	Very Good	Very Good
Sedimentation Rate	Not measured			Plates Deployed
Grain Size	Low Mud	Low Mud	Low Mud	Low Mud
Metals	Very Good	Very Good	Very Good	Very Good
Macroalgal % Cover	Not measured			Fair

Estuary Condition

Overall, the four years of monitoring show that the dominant intertidal habitat in the Fortrose Estuary was in good condition. However, the presence of nuisance macroalgal blooms, moderate sediment oxygenation, and a benthic community indicating slightly polluted conditions, suggests that the estuary is in a mesotrophic or moderately enriched state.

Recommended Monitoring and Management

Fine Scale Monitoring (including sedimentation rate and macroalgal mapping) - at 5 yearly intervals (next monitoring programmed for February 2014). The fine scale monitoring results reinforce the need for management of nutrient and fine sediment sources entering the estuary. Setting nutrient limits on inputs and identification and management of nutrient sources is therefore seen as a priority for this estuary.

1. INTRODUCTION

OVERVIEW

Developing an understanding of the condition and risks to coastal and estuarine habitats is critical to the management of biological resources. In 2000, Environment Southland (ES) identified a number of estuaries in it's region as immediate priorities for long term monitoring and in 2002 began the monitoring programme in a staged manner. The estuaries currently included in the programme are New River, Jacobs River, Fortrose, Waikawa, Haldane, Waiau, Waituna and Freshwater. Risk assessments have been undertaken for a number of other estuaries in order to establish priorities for their management.

Monitoring of Fortrose Estuary began in February 2004 and now has four years of fine scale baseline monitoring data for key estuary indicators. Wriggle Coastal Management and ES currently undertake the work using the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002) plus recent extensions.

The Fortrose Estuary monitoring programme consists of three components:

1. **Ecological Vulnerability Assessment** (UNESCO 2000 modified approach)**.** Assessment of the vulnerability of the estuary to major issues (Table 1) and appropriate monitoring design. This component has been undertaken for Fortrose Estuary and is reported in Robertson and Stevens (2008).
2. **Broad Scale Habitat Mapping** (EMP approach). This component, which documents the key habitats within the estuary, and changes to these habitats over time, was undertaken in 2003, and is reported separately in Robertson et al. (2003).
3. **Fine Scale Monitoring** (EMP approach). Monitoring of physical, chemical and biological indicators including sedimentation plate monitoring (Table 2). This component, which provides detailed information on estuary condition, is the subject of the current report. The first 3 years of monitoring are summarised in Robertson and Stevens (2006). This report presents the findings of the February 2009 monitoring plus summaries of the previous years. It also presents condition ratings for the estuary.

Fortrose or Toetoes Estuary is a medium-sized "tidal lagoon" type estuary (area 500ha) that discharges to Toetoes Beach at Fortrose. Situated at the mouth of the Mataura and Titiroa Rivers, it drains a large and primarily high productivity agricultural catchment, and the estuary is small in relation to the freshwater input (i.e. it has a large freshwater influence). The estuary is bordered by grazed pasture and duneland and has extensive mudflats (50% of estuary exposed at low tide) and saltmarsh areas.

The estuary has several issues:

- Water quality is moderately degraded (reduced clarity, elevated faecal coliforms, elevated nutrients), particularly in high river flows.
- Localised macroalgal blooms are common (Figure 1) and are driven by elevated nutrient inputs.
- Sediment type is mixed with areas of firm muddy sands and gravels plus soft and very soft muds - with some areas poor in oxygen with elevated sulphide concentrations.

A recent vulnerability assessment (Robertson and Stevens 2008) identified eutrophication, sedimentation and habitat loss as moderate vulnerabilities within the estuary and recommended ongoing monitoring and management to address these issues.

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 *Enteromorpha, Cladophora, Ulva,* and *Gracilaria* which are now widespread on intertidal flats and shallow subtidal areas of nutrient-enriched New Zealand estuaries. They present a significant nuisance problem, especially when loose mats accumulate on shorelines and decompose. Blooms also have major ecological impacts on water and sediment quality (e.g. reduced clarity, physical smothering, lack of oxygen), affecting or displacing the animals that live there.
Disease Risk	Runoff from farmland and human wastewater often carries a variety of disease-causing organisms or pathogens (including viruses, bacteria and protozoans) that, once discharged into the estuarine environment, can survive for some time. Every time humans come into contact with seawater that has been contaminated with human and animal faeces, we expose ourselves to these organisms and risk getting sick. Aside from serious health risks posed to humans through recreational contact and shellfish consumption, pathogen contamination can also cause economic losses due to closed commercial shellfish beds. Diseases linked to pathogens include gastroenteritis, salmonellosis, hepatitis A, and noroviruses.
Toxic Contamination	In the last 60 years, New Zealand has seen a huge range of synthetic chemicals introduced to estuaries through urban and agricultural stormwater runoff, industrial discharges and air pollution. Many of them are toxic in minute concentrations. Of particular concern are polycyclic aromatic hydrocarbons (PAHs), heavy metals, polychlorinated biphenyls (PCBs), and pesticides. These chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to people and marine life.
Habitat Loss	Estuaries have many different types of habitats including shellfish beds, seagrass meadows, saltmarshes (rushlands, herbfields, reedlands etc.), forested wetlands, beaches, river deltas, and rocky shores. The continued health and biodiversity of estuarine systems depends on the maintenance of high-quality habitat. Loss of habitat negatively affects fisheries, animal populations, filtering of water pollutants, and the ability of shorelines to resist storm-related erosion. Within New Zealand, habitat degradation or loss is 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.

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 EMP (Robertson et al. 2002) and provides detailed information on the condition of the estuary. Using the outputs of the broad scale habitat mapping, representative sampling sites (usually two per estuary) are selected and samples collected and analysed for physical, chemical and biological variables.

In 2003, two fine scale sampling sites (Sites A and B, Figure 1), were selected in mid-low water mudflats, which is the dominant intertidal habitat in Fortrose Estuary. At each site, a 60m x 30m area in the lower intertidal was marked out and divided into 12 equal sized plots. In 2009, only site B was selected for sampling, due to ongoing access difficulties to Site A. Within each site, ten plots were selected, a random position defined within each, and the following sampling undertaken.

Physical and chemical analyses

- Within each plot, one random core was collected to a depth of at least 100mm and photographed alongside a ruler and a corresponding label. Colour and texture were described and average redox potential discontinuity (RPD) depth recorded.
- At each site, three samples (each a composite from four plots) of the top 20mm of sediment (each approx. 250gms) were collected adjacent to 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 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 are 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)

Epifauna were assessed from one random 0.25m^2 quadrat within each of ten plots. All animals observed on the sediment surface were identified and counted, and any visible microalgal mat development noted. The species, abundance and related descriptive information were recorded on specifically designed waterproof field sheets containing a checklist of expected species. Photographs of quadrats were taken and archived for future reference.

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).

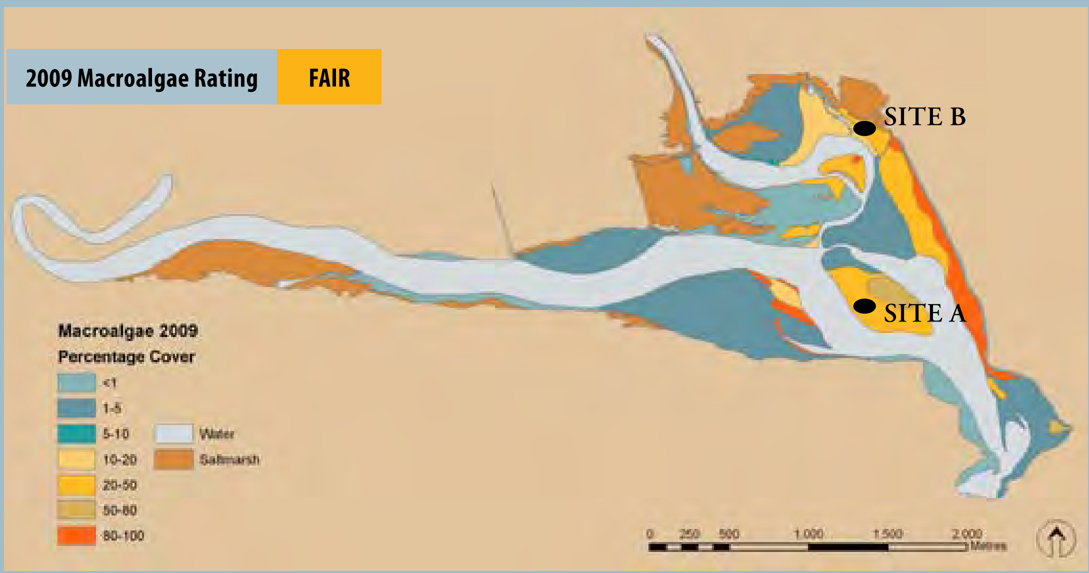
2. Methods (Continued)

Sedimentation Plate Deployment

Determining the future sedimentation rate involves a simple method of measuring how much sediment builds up over a buried plate over time. Once a plate has been buried and levelled, probes are pushed into the sediment until they hit the plate and the penetration depth is measured. A number of measurements on each plate are averaged to account for irregular sediment surfaces, and a number of plates are buried to account for small scale variance.

One site (with four plates) was established in Fortrose Estuary on 17 February 2009 (Figure 1). The site was located at Site B in muddy sand habitat in an area of the lower estuary where sedimentation rates are likely to be elevated. Four plates (20cm wide square concrete blocks) were buried at 5m, 10m, 20m, and 25m from the south eastern corner peg of Site B. The GPS positions of each plate were logged, and the depth from the undisturbed mud surface to the top of the sediment plate recorded (Appendix 4). In the future, these depths will be measured annually and, over the long term, will provide a measure of the rate of sedimentation in the estuary.

Figure 1. Fortrose Estuary - location of monitoring sites, and % cover of macroalgae (from Stevens and Robertson 2009).



CONDITION RATINGS

A series of interim fine scale estuary "condition ratings" (presented below) have been proposed for Fortrose 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).

Total Nitrogen

In shallow estuaries like Fortrose, 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)

Total Phosphorus

In shallow estuaries like Fortrose 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 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

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

2. Methods (Continued)

Metals

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

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

Sedimentation Rate

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

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

Benthic Community Index

Soft sediment macrofauna can be used to represent benthic community health and provide an estuary condition classification (if representative sites are surveyed). The AZTI (AZTI-Tecnalia Marine Research Division, Spain) Marine Benthic Index (AMBI) (Borja et al. 2000) has been verified successfully in relation to a large set of environmental impact sources (Borja, 2005) and geographical areas (in both northern and southern hemispheres) and so is used here. However, although the AMBI is particularly useful in detecting temporal and spatial impact gradients care must be taken in its interpretation in some situations. In particular, its robustness can be reduced when only a very low number of taxa (1–3) and/or individuals (<3 per replicate) are found in a sample. The same can occur when studying low-salinity locations (e.g. the inner parts of estuaries), some naturally-stressed locations (e.g. naturally organic matter enriched bottoms; *Zostera* beds producing dead leaves; etc.), or some particular impacts (e.g. sand extraction, for some locations under dredged sediment dumping, or some physical impacts, such as fish trawling).
The equation to calculate the AMBI Biotic Coefficient (BC) is a s follows;

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

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

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

3. RESULTS AND DISCUSSION

OUTLINE

A summary of the results of the 17 February 2009 fine scale monitoring of Fortrose Estuary is presented in Tables 3 and 4, with detailed results presented in Appendices 2 and 3. In order to facilitate understanding, this 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 (e.g. total nitrogen is presented under the issue of eutrophication). A summary of the condition ratings for each of the two sites is presented in the accompanying figures.

Table 3. Physical and chemical results (means) for Fortrose Estuary.

Estuary	Reps	RPD	Salinity	TOC	Mud	Sands	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP
		cm	ppt	%				mg/kg							
Fortose B 2009	3	3	30	0.15	3.50	94.9	1.6	0.014	4.2	1.9	2.9	1.6	11.7	500	167
Fortrose B 2004	10	-	-	0.41	2.28	94.54	3.19	<1.100	3.9	1.7	1.6	2.6	36.5	223	203
Fortrose A 2004	10	-	-	0.37	2.20	79.03	18.79	<1.000	4.6	2.0	2.0	3.1	43.0	172	156
Fortrose A 2005	10	-	-	0.19	0.94	85.59	13.47	<0.050	4.9	2.0	3.0	2.1	15.6	119	166
Fortrose A 2006	10	-	-	0.51	8.60	71.67	19.73	<0.100	6.9	2.7	6.3	2.8	16.3	350	231

Table 4. Macrofauna results (means) for Fortrose Estuary.

Fortrose Estuary Site and Year	Mean Total Abundance/m^2	Mean Number of Species/Core
2009 B	14,385	9.9
2004 B	6,960	10.5
2004 A	9,195	11.6
2005 A	2,842	6.1
2006 A	33,435	9.9

EUTROPHICATION

The primary fine scale indicators of eutrophication are grain size, RPD boundary, sediment organic matter, nitrogen and phosphorus concentrations and the community structure of certain sediment-dwelling animals. The broad scale indicators (reported in Robertson et al. 2003 and Robertson and Stevens 2009) are the percentages of the estuary covered by macroalgae and soft muds.

3. Results and Discussion (Continued)

2009 RPD RATING

GOOD

The Redox Potential Discontinuity (RPD)

Figure 2 shows the sediment profile and RPD depths for the Fortrose Estuary and the likely benthic community that is supported at each site based on the measured RPD depth (adapted from Pearson and Rosenberg 1978). The results showed that the RPD depth in Fortrose Estuary was at a moderate depth (3cm) and therefore likely to be moderately oxygenated (which was further supported by the presence of infauna feeding voids and burrows below the RPD and by the fact that sediments were dominated by sands).

Such moderately deep RPD values fit the “good” condition rating and indicate that the benthic invertebrate community was likely to be in a “normal to transitional” state. In addition, because the sediments were dominated by sands it is inferred that sediment aeration was relatively good.

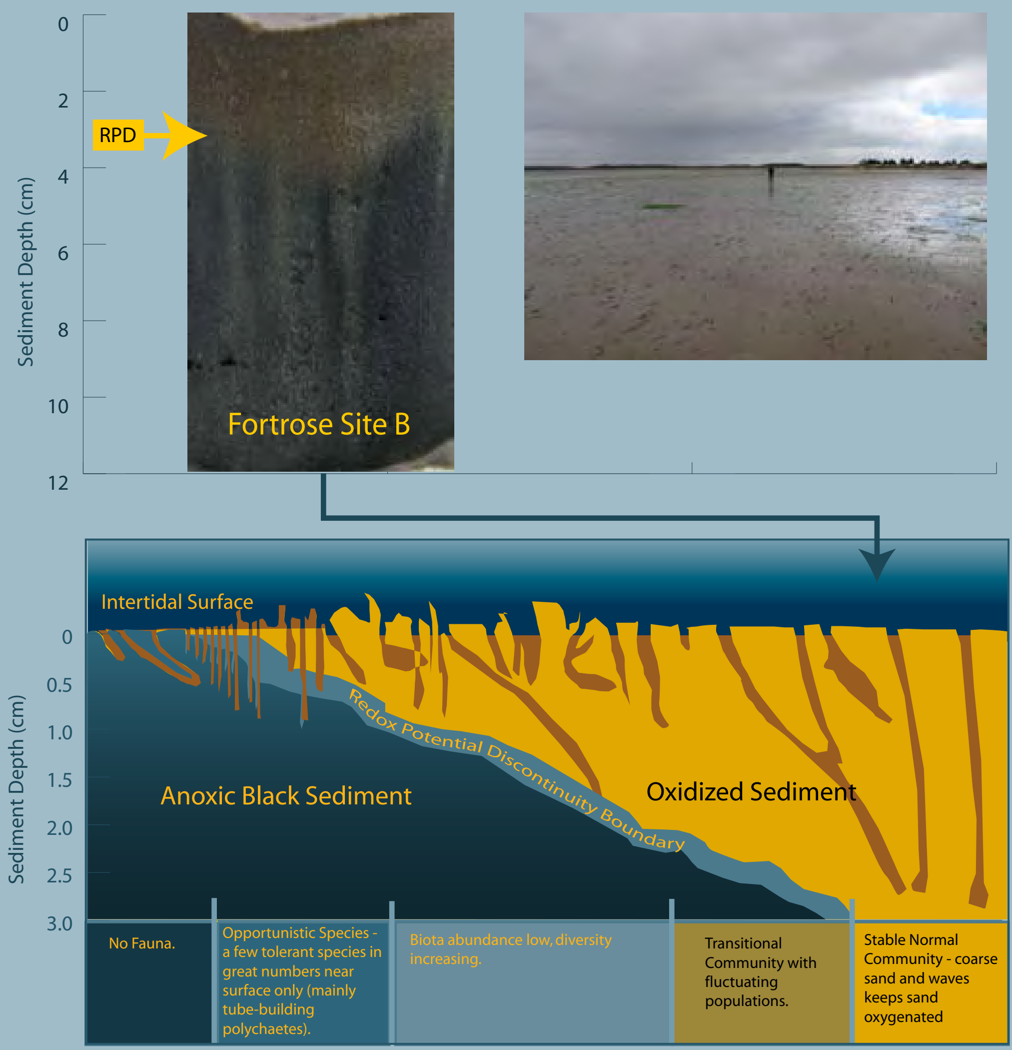
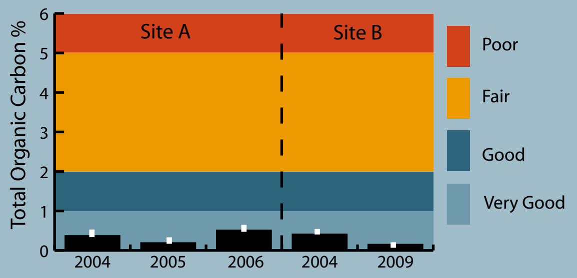


Figure 2. Sediment profiles, depths of RPD and predicted benthic community type, Fortrose Estuary, 17 February 2009. Arrows below cores relate to the type of community likely to be found in each core.

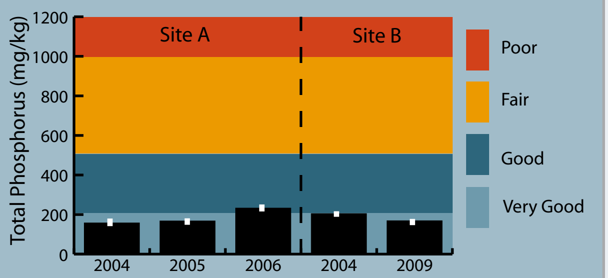
3. Results and Discussion (Continued)

Figure 3. Total organic carbon, (mean and range) Fortrose Estuary.



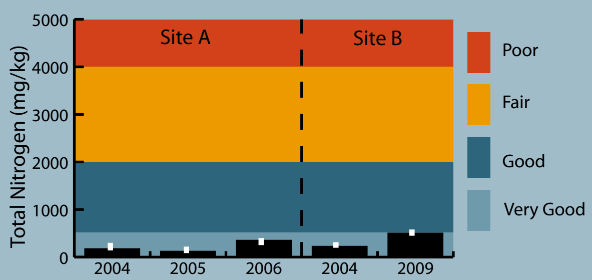
2009 TOC RATING	Very Good

Figure 4. Total phosphorus, (mean and range) Fortrose Estuary.



2009 TP RATING	Very Good

Figure 5. Total nitrogen, (mean and range) Fortrose Estuary.



2009 TN RATING	Very Good

ORGANIC MATTER (TOC)

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

The indicator of organic enrichment (TOC) at both sites and for all four years was at very low concentrations (mean 0.15% for 2009) and met the "very good" condition rating (Figure 3). Lower TOC concentrations were measured in 2009 compared with previous years, which is likely to be the result of a method change. Ash free dry weight and a standard conversion factor were previously used to estimate TOC, which in 2009 was measured directly.

The low TOC levels reflect the generally well-flushed nature of much of the estuary area and a likely moderate load of organic matter sourced primarily from phytoplankton and macroalgae depositing on the sediments.

TOTAL PHOSPHORUS (TP)

Total phosphorus was present at both sites and for all four years at very low concentrations (mean 167mg/kg for 2009), and met the "very good" condition rating (Figure 4).

This means that the Fortrose Estuary sediments have a low store of P in the sediments (sourced from both recent and historical catchment inputs). In addition, this store of P is primarily unavailable for fertilising nuisance algal growth, given the absence of anoxic conditions under which P release is favoured.

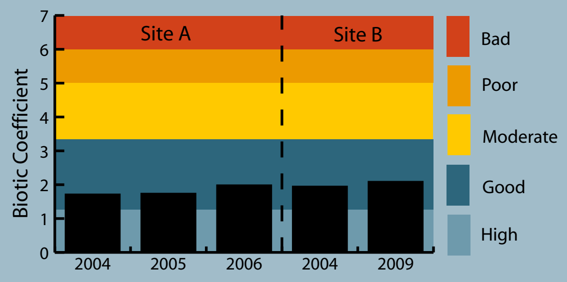
TOTAL NITROGEN (TN)

Like TP, TN was present at very low concentrations (mean 500mg/kg for 2009) for all four years and met the "very good" condition rating (Figure 5).

This means that the Fortrose sediments have a low store of N in the sediments (sourced from both recent and historical catchment inputs).

As with phosphorus, this store of N is also primarily unavailable for fertilising nuisance algal growth, because of the absence of anoxic conditions which favours release of bioavailable nitrogen sources to the water column.

Figure 6. Macroinvertebrate rating, sites A and B, Fortrose Estuary.



2009 Benthic Community RATING	Good

SEDIMENT BIOTA

The benthic invertebrate community in the Fortrose Estuary was in the "good" condition category, indicating only slight pollution (Figure 6).

As in previous years, the 2009 conditions resulted in a community dominated by organisms tolerant of low moderate mud, shallow RPD, strong salinity fluctuations during floods, and moderate organic enrichment levels. The community was comprised primarily of small surface and subsurface deposit-feeders (i.e. the bivalve *Arthritica bifurca*, the estuarine mud snails *Potamopyrgus estuarinus* and *P. antipodarum*, the ubiquitous spionid polychaete *Scolecolepides benhami*), and another spionid that prefers sandy sediments *Microspio maori* (Borja et al. 2000) (Appendix 3).

Compared with the intertidal mudflats in other NZ estuaries, the community diversity was moderate in all years (mean 6-12 species per core - Figure 7). Mean abundance at each site was variable between sites and years at 2,000-33,000m^{-2} (Figure 8). The very elevated abundance in 2006 at site A was attributed to large numbers of amphipods at the site.

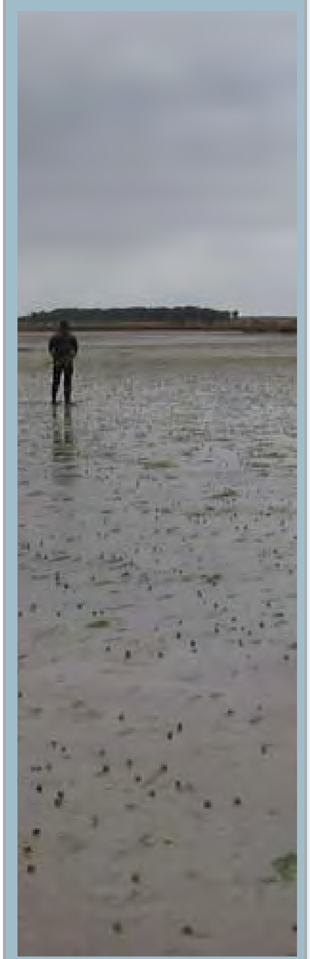


Figure 7. Mean number of infauna species, Fortrose Estuary compared with other NZ estuaries (Source Robertson et al. 2002, Robertson and Stevens 2006).

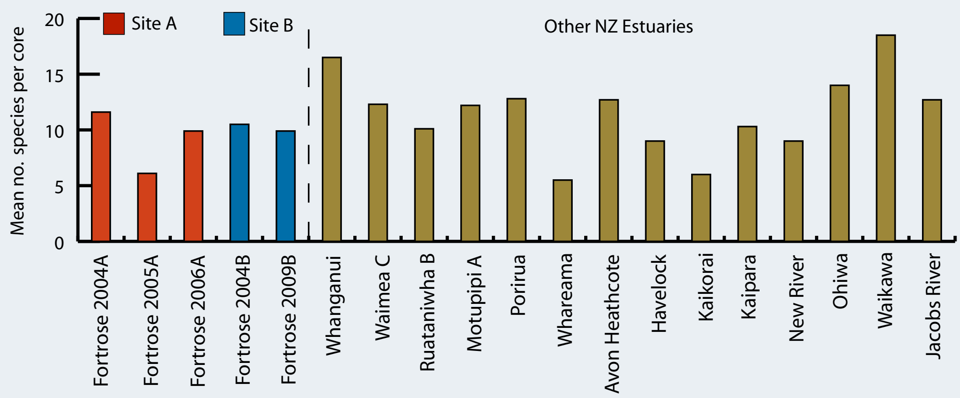
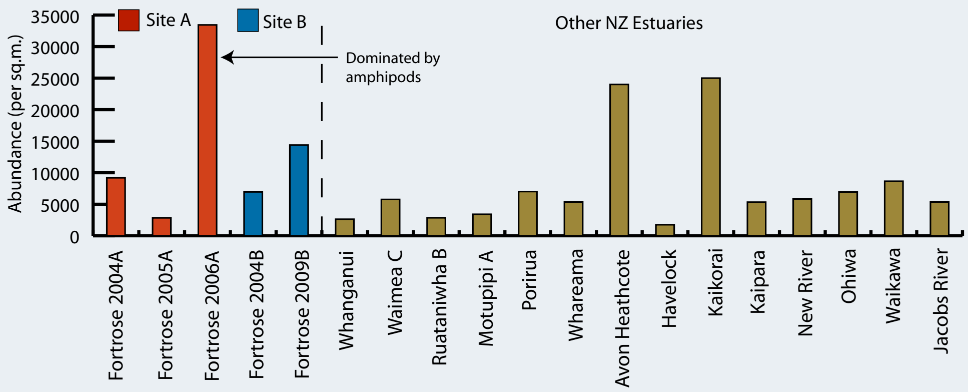


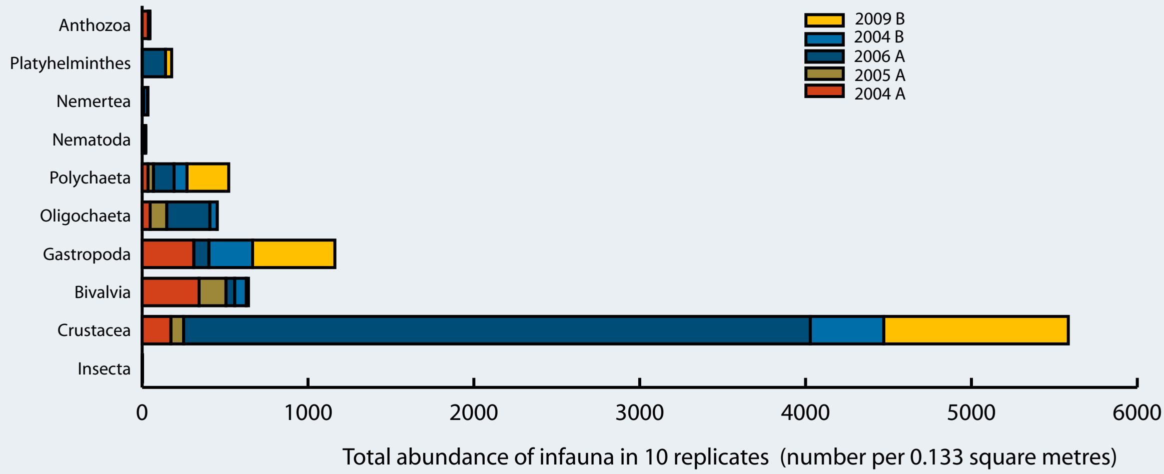
Figure 8. Mean total abundance of macrofauna, Fortrose Estuary compared with other NZ estuaries.



3. Results and Discussion (Continued)

Like other NZ estuaries the intertidal community was dominated by crustacea, gastropods and polychaetes (Figure 9).

Figure 9. Major macrofauna groups, Fortrose Estuary.



METALS

Heavy metals (Cd, Cr, Cu, Ni, Pb, Zn), used as an indicator of potential toxicants, were at low to very low concentrations at both intertidal sites in all four years of monitoring, with all values well below the ANZECC (2000) ISQG-Low trigger values (Figure 10). Metals met the “very good” condition rating for cadmium, chromium, copper, lead, nickel and zinc at all sites. The one exception was nickel at site A in 2006, which met the “good” condition rating. These results indicate that there is no widespread toxicity in Fortrose Estuary.

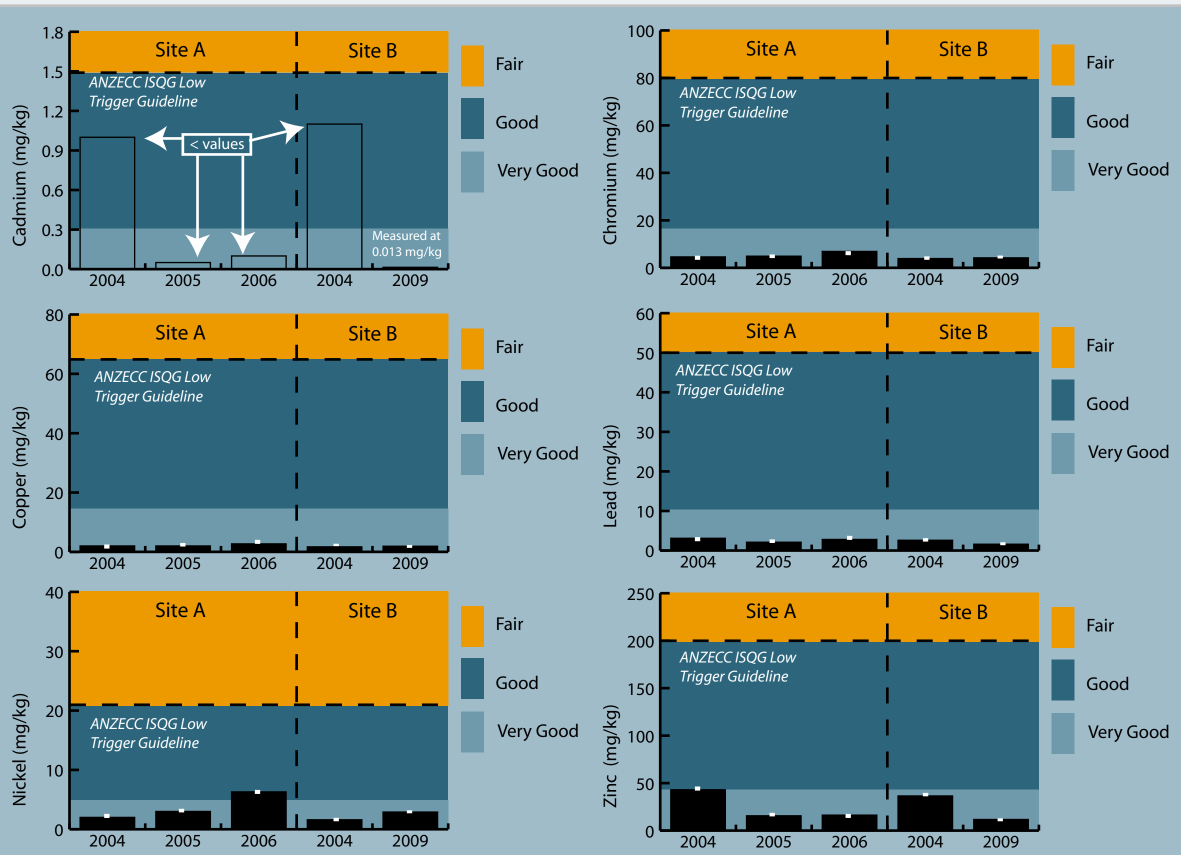
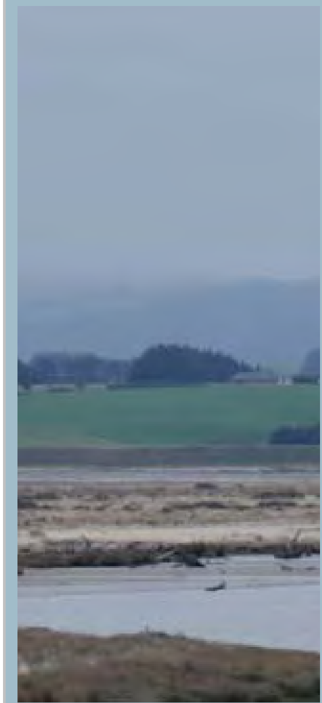


Figure 10. Sediment metal concentrations, (mean and range) Fortrose Estuary.

3. Results and Discussion (Continued)

SEDIMENTATION OF FINE SEDIMENT

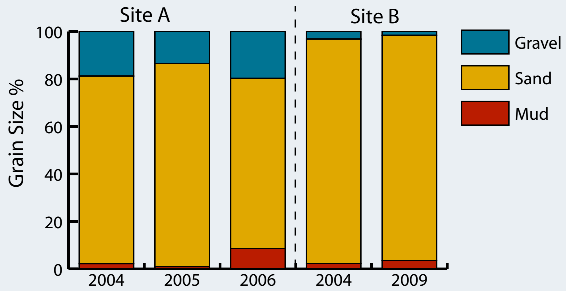


Soil erosion is a major issue in New Zealand and the resulting suspended sediment impacts are of particular concern in "tidal lagoon" estuaries because they have a central basin which forms a sink for fine sediments. However in well-flushed tidal lagoon estuaries like Fortrose (which is narrower and smaller than normal tidal lagoon estuaries), there are fewer sheltered areas for mud to accumulate. High river flows tend to wash a lot of the suspended solid load out to sea and consequently much of the estuary bed is sandy. However, there are areas in the northeastern flats away from the main channel where muds may accumulate (i.e. near Site B). In order to assess this potential problem, sedimentation plates were deployed at Site B in February 2009, and in future years the depth of overlying sediment will be measured and used to estimate sedimentation rates in the estuary. In addition, grains size is measured as one of the primary fine scale indicators of fine sediment deposition.

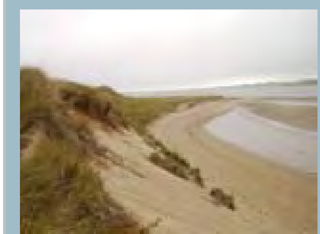
Grain Size

Grain size (% mud, sand, gravel) measurements provide a good indication of the muddiness of a particular site. The monitoring results show that both sites were dominated by sandy sediments (80-95% sand), with little mud content (1-8% mud) (Figure 11).

Figure 11. Grain size, Fortrose Estuary.



4. SUMMARY



The fourth year of fine scale monitoring results for a range of physical, chemical and biological indicators of estuary condition show that the dominant intertidal habitat (i.e. unvegetated tidal-flat) in the Fortrose Estuary was generally in good condition. Conditions were similar to those measured in previous years, with the key findings as follows:

- Both sites were dominated by sandy sediments with a low mud content.
- Sediment levels of organic carbon, nitrogen and phosphorus were low.
- The benthic invertebrate life showed a typical estuarine sand community dominated by crustacea, polychaetes, gastropods and bivalves. The invertebrate community condition rating was "good", indicating only slight pollution.
- Heavy metals (Cd, Cr, Cu, Ni, Pb, Zn), used as an indicator of potential toxicants, were at low to very low concentrations.
- Nuisance macroalgal growth in the estuary (reported separately in Stevens and Robertson 2009) was rated as "fair" (Figure 1).

In terms of eutrophication, the results suggest that the estuary is moderately enriched or mesotrophic. The cause of this enrichment is expected to be driven by the high estimated nitrogen inflow concentration (mean 1mg/l; ES monitoring data) which, because of the well-flushed nature of the estuary, results in elevated water column (but not sediment) nutrient concentrations within the estuary. As a consequence, nuisance macroalgal growth is common in areas of the estuary exposed to these high concentrations (i.e. near the channels), or in natural settling areas.

In terms of sedimentation, Fortrose Estuary is moderately vulnerable to excessive inputs of fine sediments and sediment plates have been deployed to measure this.

5. MONITORING

Fortrose Estuary has been identified by ES as a priority for monitoring, and is a key part of ES's coastal monitoring programme being undertaken in a staged manner throughout the Southland region. Based on the 2004 to 2009 monitoring results and condition ratings, it is recommended that monitoring continue as outlined below:

Fine Scale Monitoring (including sedimentation rate). Undertake monitoring (at Site B only, as access to Site A is difficult) at five yearly intervals or as deemed necessary based on the condition ratings. The next fine scale monitoring is scheduled for February 2014.

Sedimentation Rate Monitoring. Monitor the depths of the existing four sediment plates during the broad scale mapping exercise scheduled for 2010. Following the 2010 monitoring, it is recommended that the depth of all plates be measured whenever fine scale monitoring is undertaken.

Macroalgal Mapping. Macroalgal cover was not observed to be causing conditions unsuitable for estuarine animals (e.g. low levels of sediment dissolved oxygen from rotting algae) nor were nuisance effects from smells evident. Consequently it is recommended that macroalgae be monitored at the same time that sediment plates are measured, or five yearly in the absence of obvious changes in the estuary.

6. MANAGEMENT

The fine scale monitoring results reinforced the need for management of nutrient and fine sediment sources entering the estuary. It is recommended that sources of elevated loads in the catchment be identified and management undertaken to minimise their adverse effects on estuary uses and values.

7. ACKNOWLEDGEMENTS

This survey and report has been undertaken with organizing help from Greg Larkin (Coastal Scientist, Environment Southland), and Maz Robertson (Wriggle) for editing.

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APPENDIX 1. DETAILS ON ANALYTICAL METHODS

Indicator	Laboratory	Method	Detection Limit
Infauna Sorting and ID	CMES	Coastal Marine Ecology Consultants (Gary Stephenson) *	N/A
Grain Size	R.J Hill	Air dry (35 degC, sieved to pass 2mm and 63um sieves, gravimetric - (% sand, gravel, silt)	N/A
Total Organic Carbon	R.J Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	0.05g/100g dry wgt
Total recoverable cadmium	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.01 mg/kg dry wgt
Total recoverable chromium	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable copper	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable nickel	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable lead	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.04 mg/kg dry wgt
Total recoverable zinc	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.4 mg/kg dry wgt
Total recoverable phosphorus	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	40 mg/kg dry wgt
Total nitrogen	R.J Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	500 mg/kg dry wgt

* Coastal Marine Ecology Consultants (established in 1990) specialises in coastal soft-shore and inner continental shelf soft-bottom benthic ecology. Principal, Gary Stephenson (BSc Zoology) has worked as a marine biologist for more than 25 years, including 13 years with the former New Zealand Oceanographic Institute, DSIR. Coastal Marine Ecology Consultants holds an extensive reference collection of macroinvertebrates from estuaries and soft-shores throughout New Zealand. New material is compared with these to maintain consistency in identifications, and where necessary specimens are referred to taxonomists in organisations such as NIWA and Te Papa Tongarewa Museum of New Zealand for identification or cross-checking.

APPENDIX 2. 2009 DETAILED RESULTS

Station Locations

Fortrose Site B 2009	1	2	3	4	5	6	7	8	9	10
NZMGEAST	2186885	2186870	2186855	2186846	2186841	2186854	2186867	2186877	2186869	2186859
NZMGNORTH	5396714	5396725	5396730	5396742	5396736	5396726	5396715	5396705	5396696	5396709

Physical and Chemical Results for Fortrose Estuary (Site B), 17 February 2009.

Site	Reps*	RPD	Salinity	TOC	Mud	Sands	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP
		cm	ppt	%				mg/kg							
Fortrose B	1-4	1	30	0.16	3.7	93.9	2.4	0.013	3.8	1.8	2.7	1.4	11	<510	160
Fortrose B	5-8	1	30	0.15	3.8	94.6	1.6	0.011	4.4	2.0	2.9	1.6	12	690	160
Fortrose B	9-10	1	30	0.15	3.0	96.3	0.7	0.017	4.4	2.0	3.1	1.7	12	<500	180

* composite samples

Fortrose Estuary Sediment Plate Baseline (depths in mm).

Site	No	Date	NZMG East	NZMG North	Plate depth
Fortrose B	1	17/2/09	2186888	5396709	220
	2	17/2/09	2186884	5396705	183
	3	17/2/09	2186878	5396697	191
	4	17/2/09	2186875	5396693	212

APPENDIX 2. 2008 DETAILED RESULTS (CONTINUED)

Epifauna (numbers per 0.25m² quadrat)

Fortrose Estuary Site B 17 February 2009

Station	For B-01	For B-02	For B-03	For B-04	For B-05	For B-06	For B-07	For B-08	For B-09	For B-10
Austrovenus stutchburyi cockle	3	3	3	3	4	6	2	1	1	3
Potamopyrgus sp.		2	9			2	11	1	4	1
No. species/quadrat	1	2	2	1	1	2	2	2	2	2
No. individuals/quadrat	3	5	12	3	4	8	13	2	5	4

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

Fortrose Estuary Site B 17 February 2009

Group	**Species**	AMBI Group	For B-01	For B-02	For B-03	For B-04	For B-05	For B-06	For B-07	For B-08	For B-09	For B-10
Anthozoa	*Edwardsia sp.*	II	0	0	0	0	2	0	0	0	0	0
Platyhelminthes	Turbellaria	II	1	1	6	4	0	9	1	3	6	6
Nemertea	Nemertea	III	1	0	0	1	0	0	0	0	1	0
Nematoda	Nematoda	III	0	0	0	0	0	0	0	0	0	0
Polychaeta	*Aglaophamus macroura*	II	0	0	0	0	0	0	0	0	0	0
	Aonides sp.	III	0	0	0	0	0	0	0	0	0	0
	Boccardia sp.	I	1	0	0	0	0	0	0	0	0	0
	Capitella sp.	IV	7	3	1	1	1	6	0	6	15	8
	Dorvilleidae	NA	0	0	0	0	0	0	0	0	0	0
	Microspio maori	III	9	8	0	0	24	26	6	32	3	3
	Nicon aestuariensis	III	2	4	2	2	7	5	5	4	7	2
	Scolecolepides benhami	III	6	5	2	1	10	8	5	7	3	5
	Scoloplos cylindrifer	I	0	0	0	0	0	0	0	0	0	0
Oligochaeta	Oligochaeta	NA	0	0	0	0	0	0	0	0	0	1
Gastropoda	*Amphibola crenata*	NA	2	1	0	2	2	0	1	4	3	1
	Notoacmea helmsi	NA	0	0	0	0	0	0	0	0	0	0
	Potamopyrgus antipodarum	II	15	20	5	13	6	13	19	13	6	10
	Potamopyrgus estuarinus	II	52	38	44	58	15	33	31	32	34	23
Bivalvia	*Arthritica bifurca*	III	0	0	1	1	0	0	5	0	2	1
	Austrovenus stutchburyi	II	0	0	0	0	0	0	0	0	0	0
	Mactra ovata ovata	I	0	0	0	0	0	0	0	0	0	0
	Paphies australis	II	0	0	2	0	0	0	0	0	0	2
Crustacea	Amphipoda	NA	6	3	2	1	3	2	6	0	1	0
	Copepoda	NA	0	0	0	0	0	1	0	0	0	0
	Cumacea	NA	0	0	0	0	0	0	0	0	0	0
	Exosphaeroma planulum	NA	1	0	2	0	0	0	4	0	0	0
	Flabellifera	NA	0	0	0	0	0	0	0	0	0	0
	Macrophthalmus hirtipes	NA	0	0	0	0	0	0	0	0	0	0
	Mysidacea	II	0	0	0	0	0	0	0	0	0	0
	Paracorophium sp.	NA	141	110	145	136	3	124	242	99	32	49
Insecta	Elmidae larvae	NA	0	0	0	0	0	0	0	0	0	0
Total individuals in sample			244	193	212	220	73	227	325	200	113	111
Total number of species in sample			13	10	11	11	10	10	11	9	12	12

APPENDIX 3. INFAUNA CHARACTERISTICS

Group and Species		AMBI Group	Details
Anthozoa	Anthozoa sp.1	II	Unidentified anemone.
Platyhelminthes	Turbellaria sp	II	A free living flatworm. Flatworms have simple, flattened, leaf-like bodies and glide along on a bed of fine hairs or by ripples of contracting muscles. A flexible tubular proboscis traps prey such as small crustaceans and molluscs. The digestive canal ends blindly without any anus.
Nemertea	Nemertea	III	Ribbon or Proboscis Worms, mostly solitary, predatory, free-living animals. Intolerant of anoxic conditions.
Nematoda	Nematoda sp	III	Small unsegmented roundworms. Very common. Feed on a range of materials. Common inhabitant of muddy sands. Many are so small that they are not collected in the 0.5mm mesh sieve. Generally reside in the upper 2.5cm of sediment. Intolerant of anoxic conditions.
Polychaeta	*Aglaophamous spp.*	II	A carnivorous, intertidal and subtidal nephtyid that prefers a sandier, rather than muddier substrate.
	Aonides spp.	III	Small surface deposit-feeding spionid polychaete that lives throughout the sediment to a depth of 10cm. *Aonides* is free-living, not very mobile and prefers to live in fine sands; also very sensitive to changes in the silt/clay content of the sediment. In general, polychaetes are important prey items for fish and birds.
	Boccardia (Paraboccardia) syrtis and acus	I	Small surface deposit-feeding spionids. Prefers low-mod mud content but found in a wide range of sand/mud. Lives in flexible tubes of fine sediment grains, and can form dense mats on the sediment surface. Very sensitive to organic enrichment and usually present under unenriched conditions. When in dense beds, the community tends to encourage build-up of muds.
	Capitella capitata	V	A blood red capitellid polychaete which is very pollution tolerant. Common in sulphide rich anoxic sediments.
	Dorvilleidae sp.	NA	Active surface-dwelling omnivores with chitinous jaw elements consisting of four longitudinal rows of minute, toothed, black plates, and with two pairs of appendages on the rounded prostomium. Not generally common.
	Microspio maori	III	A small endemic spionid. Often misidentified as *Scolelepis* (earlier Fortrose monitoring reports made this mistake). Common inhabitants of intertidal sandy sediments in estuaries throughout New Zealand. Depth range: 0-1 (m). Present near sediment surface but no tube and has a vertical burrow. Surface and subsurface deposit-feeding/herbivore. Can reach very high densities on some sand flats.
	Nicon aestuariensis	III	A nereid (ragworm) that is tolerant of freshwater and is a surface deposit feeding omnivore. Prefers to live in moderate to high mud content sediments.
	Scolecolepides benhami	III	A surface deposit feeder. Is rarely absent in sandy/mud estuaries, often occurring in a dense zone high on the shore, although large adults tend to occur further down towards low water mark. Prefers low-moderate mud content (<50% mud). A close relative, the larger *Scolecolepides freemani* occurs upstream in some rivers, usually in sticky mud in near freshwater conditions.
	Scoloplos (Scoloplos) cylindrifer	I	Belongs to Family Orbiniidae which are thread-like burrowers without head appendages. Common in intertidal sands of estuaries. Long, slender, sand-dwelling unselective deposit feeders.
Oligochaeta	Oligochaete sp.	NA	Segmented worms - deposit feeders. Classified as very pollution tolerant by AMBI (Borja et al. 2000) but a review of literature suggests that there are some less tolerant species.
Gastropoda	*Amphibola crenata*	NA	A pulmonate gastropod endemic to New Zealand. Common on a variety of intertidal muddy and sandy sediments. A detritus or deposit feeder, it extracts bacteria, diatoms and decomposing matter from the surface sand. It egests the sand and a slimy secretion that is a rich source of food for bacteria.
	Notoacmaea helmsi	NA	Endemic to NZ. Small limpet attached to stones and shells in intertidal zone. Intolerant of anoxic surface muds.
	Potamopyrgus estuarinus	II	Endemic to NZ. Small estuarine snail, requiring brackish conditions for survival. Feed on decomposing animal and plant matter, bacteria, and algae. Intolerant of anoxic surface muds. Tolerant of muds.

APPENDIX 3. INFAUNA CHARACTERISTICS (CONTINUED)

Group and Species		AMBI Group	Details
	Potamopyrgus antipodarum	II	Endemic to NZ. This small snail tolerates siltation, thrives in disturbed watersheds, and benefits from high nutrient flows allowing for filamentous green algae growth. It occurs amongst macrophytes and prefers littoral zones in lakes or slow streams with silt and organic matter substrates, but tolerates high flow environments where it can burrow into the sediment. Can reach very high densities. This species is euryhaline, establishing populations in fresh and brackish water. Optimal salinity is near or below 5 ppt, but is capable of feeding, growing, and reproducing at salinities of 0–15 ppt and can tolerate 30–35 ppt for short periods of time.It tolerates temperatures of 0–34°C. Is a nocturnal grazer, feeding on plant and animal detritus, epiphytic and periphytic algae, sediments and diatoms
Bivalvia	*Arthritica sp.#1*	III	A small sedentary deposit feeding bivalve, preferring a moderate mud content. Lives greater than 2cm deep in the muds.
Bivalvia	*Austrovenus stutchburyi*	II	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 sand with low mud content. Rarely found below the RPD layer.
Bivalvia	*Mactra ovata*	I	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.
Bivalvia	*Paphies australis*	II	Pipi (endemic) are tolerant of moderate wave action, 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. Have a strong sand preference.
Crustacea	Amphipoda sp.	NA	An unidentified amphipod.
Crustacea	Copepoda	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	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 sp.*	NA	Small isopod.
Crustacea	Flabellifera	NA	Flabellifera is the second largest isopod suborder.
Crustacea	*Macrophthalmus hirtipes*	NA	The stalk-eyed mud crab is endemic to New Zealand and prefers water-logged areas at the mid to low water level. Makes extensive burrows in the mud. Tolerates moderate mud levels. This crab does not tolerate brackish or fresh water (<4ppt). Like the tunneling mud crab, it feeds from the nutritious mud.
Crustacea	*Mysidacea sp.#1*	II	Mysidacea is a group of small, shrimp-like creatures (opossum shrimps). Wherever mysids occur, whether in salt or fresh water, they are often very abundant and form an important part of the normal diet of many fishes.
Crustacea	*Paracorophium sp.*	NA	A species of amphipod in the Family Corophiidae.
Insecta	Elmidae larvae	NA	Riffle beetles. Elmids are small beetles, usually less than 3 mm long and most are aquatic in both adult and larval stages. Adults and larvae feed on diatoms, encrusting algae detritus or submerged decaying wood; they are intolerant of enriched conditions or muddy sediments.

AMBI Sensitivity to Stress Groupings (from Borja et. al 2000)

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

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

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

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

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

The distribution of these ecological groups, according to their sensitivity to pollution stress, provides a Biotic Index with seven levels, from 0 to 7.