Wriggle coastalmanagement

Haldane Estuary

Fine Scale Monitoring 2008/09

Prepared for **Environment Southland**

June 2009

Cover Photo: Haldane Estuary monitoring (Greg Larkin, ES and Barry Robertson, Wriggle).


Jointed wire rush saltmarsh, Haldane Estuary.

Haldane Estuary

Fine Scale Monitoring 2008/09

Prepared for
Environment Southland

By

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All photos by Wriggle except where noted otherwise.

HALDANE ESTUARY - EXECUTIVE SUMMARY

HALDANE ESTUARY

Vulnerability Assessment
Identifies issues and recommends monitoring and management. Completed in 2008 (Robertson and Stevens 2008)

Haldane Estuary Issues
Low eutrophication
Moderate sedimentation
Habitat Loss (saltmarsh, dune and terrestrial margin)

Monitoring

Broad Scale Mapping
Sediment type
Saltmarsh
Seagrass
Macroalgae
Land margin

5 -10 yearly
First undertaken in 2005.
Macroalgae not yet undertaken.

Fine Scale Monitoring
Grain size, RPD, Organic Content Nutrients, Metals, Invertebrates, Macroalgae, Sedimentation,

4yr Baseline then 5 yearly
Baseline yet to complete.
Next survey 2010.

Condition Ratings
Area soft mud, Area saltmarsh, Area seagrass, Area terrestrial margin, RPD depth, Benthic Community, Organic content, N and P, Toxicity, Sedimentation rate.

Other Information
Previous reports, Observations, Expert opinion

ESTUARY CONDITION
Eutrophication
Sedimentation
Toxicity
Habitat (saltmarsh, terrestrial margin)

Recommended Management
- Limit intensive landuse.
- Set nutrient, sediment guidelines.
- Margin vegetation enhancement.
- Manage for sea level rise.
- Enhance saltmarsh.
- Manage weeds and pests.

This report summarises the results of the first two years of fine scale monitoring of one intertidal site (2006 and 2009) within Haldane Estuary, a 206ha, tidal lagoon estuary with a small 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 5cm deep indicating good 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 but mud contents were relatively high.
- Heavy metals were well below the ANZECC (2000) ISQG-Low trigger values (i.e. low toxicity).
- No nuisance macroalgal cover was observed.

Condition Ratings

Indicator	2006	2009
RPD Depth	Good	Good
Macrofauna	Good	Good
Organic Matter (TOC)	Very Good	Very Good
Nutrients (TN and TP)	Very Good	Very Good
Sedimentation Rate		Plates Deployed
Grain Size	Elevated Mud	Elevated Mud
Metals	Very Good	Very Good
Macroalgal % Cover		Very Good

Estuary Condition

Overall, the two years of monitoring show that the dominant intertidal habitat (i.e. unvegetated tidal-flat) in the Haldane Estuary was generally in good condition. However, the presence of elevated mud contents and a benthic invertebrate community dominated by high numbers of a few opportunistic species, suggests that the estuary is currently experiencing problems - possibly related to the increased mud component.

Recommended Monitoring and Management

Fine Scale Monitoring (including sedimentation rate and macroalgal mapping) - at 5 yearly intervals (following completion of baseline monitoring in 2010 and 2011).
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, are therefore seen as priorities 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 Haldane Estuary began in February 2006 and now has two 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 (Robertson and Stevens 2008).

The Haldane 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 2) and appropriate monitoring design. This component has been undertaken for Haldane 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 2005 (Stevens and Asher 2005).
3. **Fine Scale Monitoring** (EMP approach). Monitoring of physical, chemical and biological indicators including sedimentation plate monitoring. This component, which provides detailed information on estuary condition, is the subject of the current report. The first year of monitoring is summarised in Robertson and Asher (2006). This report presents the findings of the February 2009 monitoring plus a summary of the 2006 results. It also presents condition ratings for the estuary.

Haldane Estuary is a medium-sized "tidal lagoon" type estuary (area 206ha), that discharges to the beach at the western end of Haldane Bay. Situated at the confluence of several streams, it drains a primarily native bush catchment. The estuary is relatively shallow (mean depth approximately 1-2m) and bordered primarily by grazed pasture. The estuary has extensive tidal flats (>80% of estuary exposed at low tide), but much of its saltmarsh habitat (>30ha) was cutoff from the estuary when a road was established within it.

As a consequence of the much lower saltmarsh area, the estuary is expected to be more vulnerable to such issues as eutrophication and sedimentation (given that saltmarsh acts to reduce nutrient and sediment impacts), despite the fact that the estuary is well flushed (i.e. low residence time), and tidally-dominated.

A recent vulnerability assessment (Robertson and Stevens 2008) identified habitat loss (i.e. saltmarsh and terrestrial margin development) as the most significant issue in the estuary. It also indicated that sea level rise is likely to expand the estuary and improve habitat diversity, if estuary margins are allowed to naturally migrate inland.

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 2006, one fine scale sampling site (Site A, Figure 1), was selected in mid-low water mudflats, which is the dominant intertidal habitat in Haldane Estuary. A 60m x 30m area in the lower intertidal was marked out and divided into 12 equal sized plots. In 2009, the site was shifted slightly to get further away from the freshwater influence of the main input stream (renamed Site A1). Within the sampling 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 3):
    - 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 3).

2. Methods (Continued)

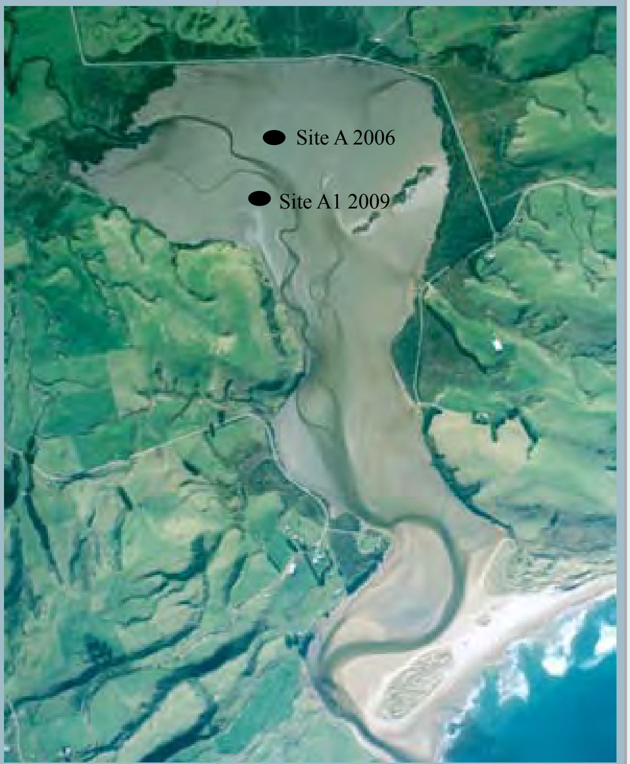


Figure 1. Haldane Estuary - location of fine scale monitoring sites (photo, Environment Southland 2004)

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 Haldane Estuary on 16 February 2009 (Figure 1). The site was located at Site A1 in muddy sand habitat in an area of the 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 A1. The GPS positions of each plate were logged, and the depth from the mud surface to the top of the sediment plate recorded (Appendix 4). In the future, these depths will be measured every 1-5 years and, over the long term, will provide a measure of rate of sedimentation in the estuary.

CONDITION RATINGS

A series of interim fine scale estuary "condition ratings" (presented below) have been proposed for Haldane 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 Haldane, 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 Haldane 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 16 February 2009 fine scale monitoring of Haldane Estuary is presented in Table 3, with detailed results presented in Appendices 4 and 5. 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) for Haldane Estuary.

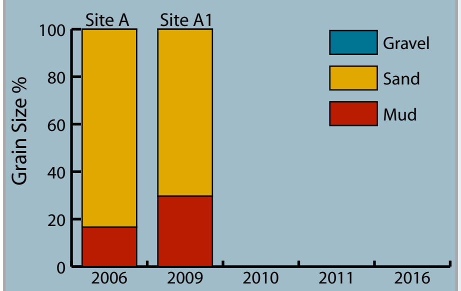
Site	Reps	RPD	Salinity	TOC	Mud	Sands	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP	Abundance	Species
		cm	ppt	%				mg/kg								No./m2	No./core
A1 2009	3	5	30	0.27	29.7	70.3	0.1	0.027	9.9	5.5	7.5	2.6	27.7	590	356	54,270	4.5
A 2006	10	5	NA	0.85	16.6	83.3	0.1	0.100	10.1	4.1	7.0	2.2	23.9	313	393	32,595	4.3

SEDIMENTATION

Soil erosion is a major issue for tidal lagoon estuaries in New Zealand as they form a sink for fine suspended sediments. Haldane Estuary, is particularly at risk because the main basin is already showing signs of mud build-up in the upper basin (8% of the estuary is soft mud - Robertson and Stevens 2006).

In order to assess this potential problem, sedimentation plates were deployed at Site A1 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.

Figure 2. Grain size, Haldane Estuary.

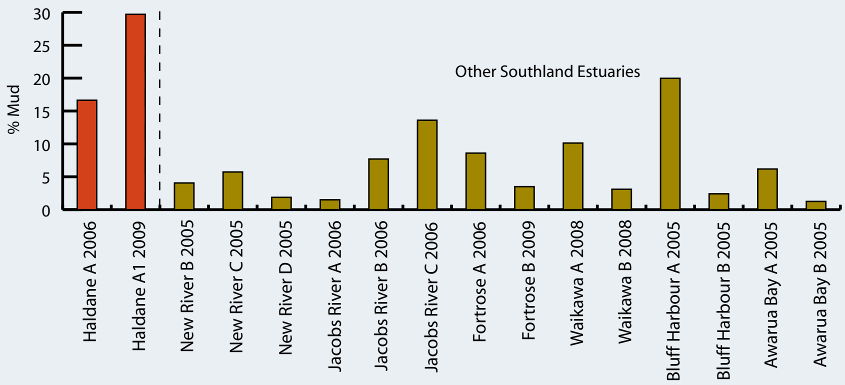


Grain Size

Grain size (% mud, sand, gravel) measurements provide a good indication of the muddiness of a particular site. The monitoring results (Figure 2) show that although the site was dominated by sandy sediments (70% sand in 2009), the mud content was high (30% mud).

The mud content was also high compared with fine scale sites in other Southland estuaries (Figure 3). The source of these muds was almost certainly from the surrounding catchment but it is uncertain as to how long ago they entered the estuary. To address the potential for ongoing sedimentation within the estuary and to measure its magnitude, sediment plates were deployed at the fine scale monitoring site in February 2009.

Figure 3. Percent mud content at fine scale monitoring sites, Southland estuaries.



3. Results and Discussion (Continued)

EUTROPHICATION

2009
RPD RATING

GOOD

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.

Redox Potential Discontinuity (RPD)

Figure 4 shows the sediment profile and RPD depths for the Haldane 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 Haldane Estuary was at a moderate-high depth (5cm) and therefore likely to be well oxygenated (which was further supported by the presence of infauna feeding voids and burrows below the RPD). 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.

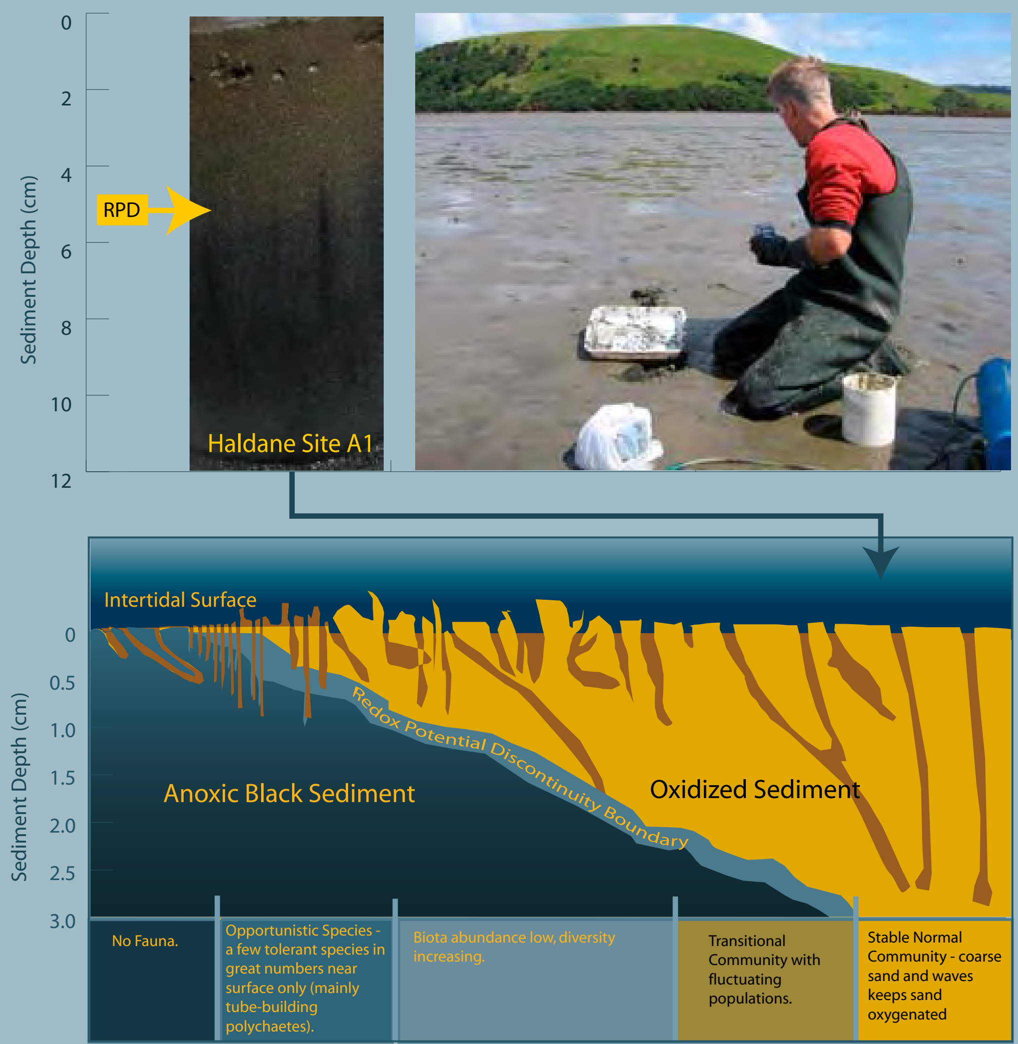
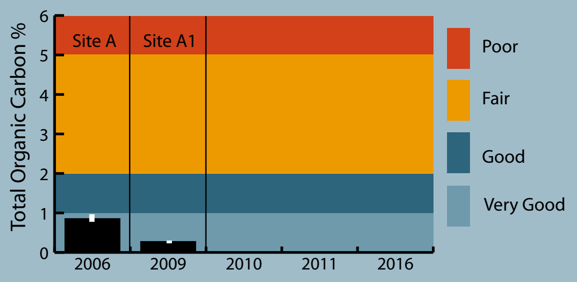


Figure 4. Sediment profiles, depths of RPD and predicted benthic community type, Haldane Estuary, 16 February 2009. Arrow below core relates to the type of community likely to be found in the core.

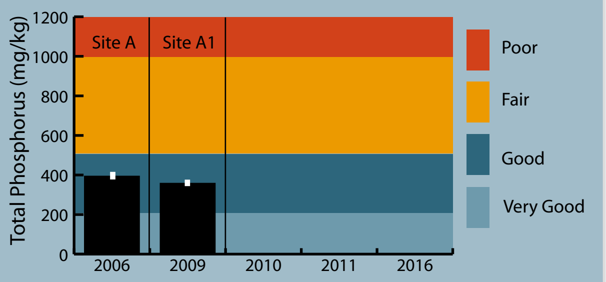
3. Results and Discussion (Continued)

Figure 5. Total organic carbon, (mean and range) Haldane Estuary.



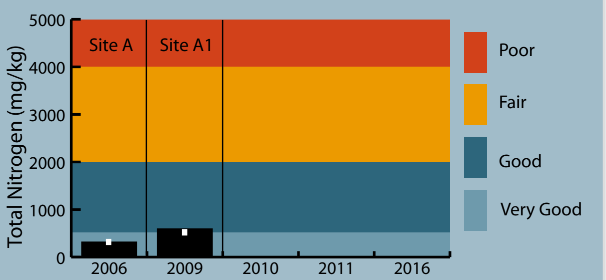
2009 TOC RATING	Very Good

Figure 6. Total phosphorus, (mean and range) Haldane Estuary.



2009 TP RATING	Good

Figure 7. Total nitrogen, (mean and range) Haldane Estuary.



2009 TN RATING	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 numbers of suspension-feeders (e.g. bivalves and certain polychaetes) decline, and deposit-feeders (e.g. opportunistic polychaetes) increase, as organic input to the sediment increases (Pearson and Rosenburg 1978).

The indicator of organic enrichment (TOC) was at very low concentrations (mean 0.27% for 2009) and for both 2006 and 2009 met the “very good” condition rating (Figure 5). Lower TOC concentrations were measured in 2009 compared with 2006, 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, a key nutrient in the eutrophication process, was present at low-moderate concentrations for both years (mean 357mg/kg for 2009), and met the “good” condition rating (Figure 6).

This means that the Haldane 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.

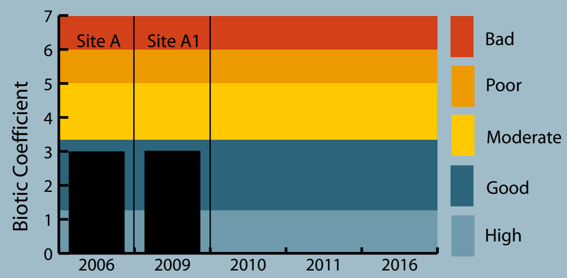
TOTAL NITROGEN (TN)

Total nitrogen (the other key nutrient in the eutrophication process) was present at low concentrations for both years (mean 590mg/kg for 2009) and met the “good” condition rating (Figure 7).

This means that the Haldane 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 8. Benthic community rating, Haldane Estuary.



2009 Benthic Community RATING	Good

SEDIMENT BIOTA

The benthic invertebrate community condition (a key indicator of response to both man-made and natural stressors) in the Haldane Estuary was in the upper range of the "good" category, indicating slight to moderate pollution, for both 2006 and 2009 (Figure 8). Such a rating likely reflects the increasing sediment nutrient concentrations and, in particular, the elevated mud content of this estuary (Figure 11).

As in previous years, the 2009 conditions resulted in a community dominated by species tolerant of a moderate mud content and RPD, and excess organic enrichment levels (Borja et al. 2000). The community was comprised primarily of small surface and subsurface deposit-feeders (Appendix 3).

Compared with the intertidal mudflats in other NZ estuaries, the community diversity was very low in both years (mean 4-5 species per core - Figure 9) and the mean abundance was high at 32,000-54,000m^{-2} (Figure 10).

Figure 9. Mean number of infauna species, Haldane Estuary compared with other NZ estuaries (Source Robertson et al. 2002, Robertson and Stevens 2006).

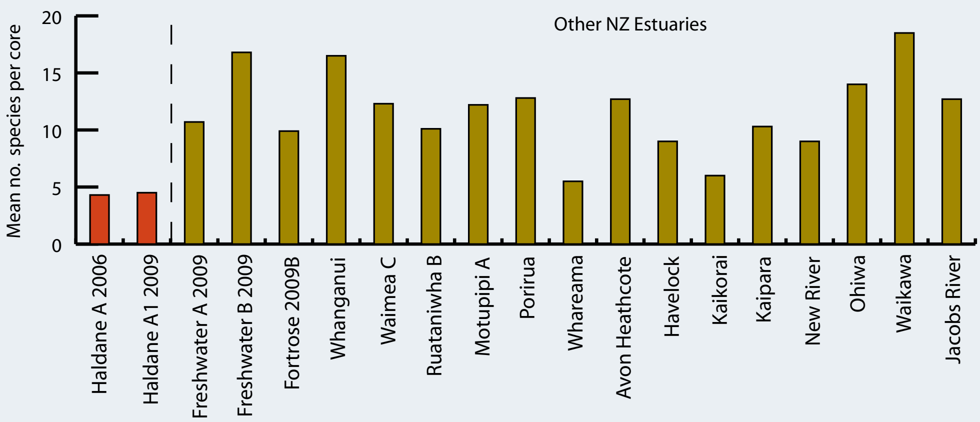
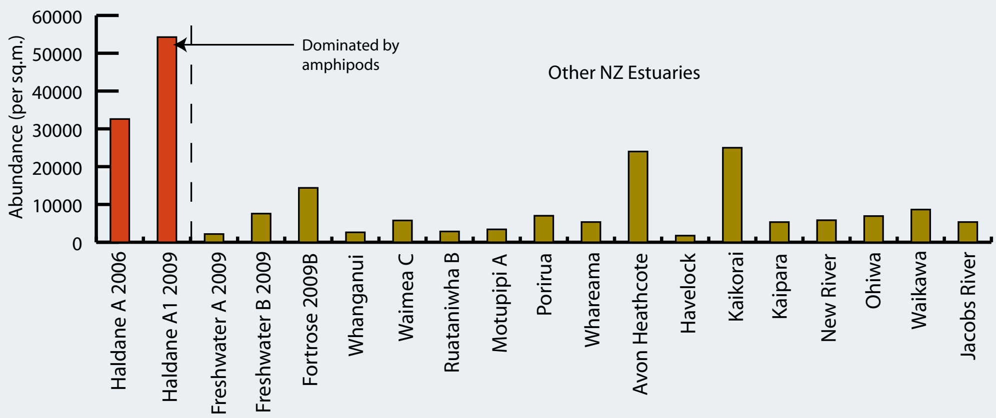
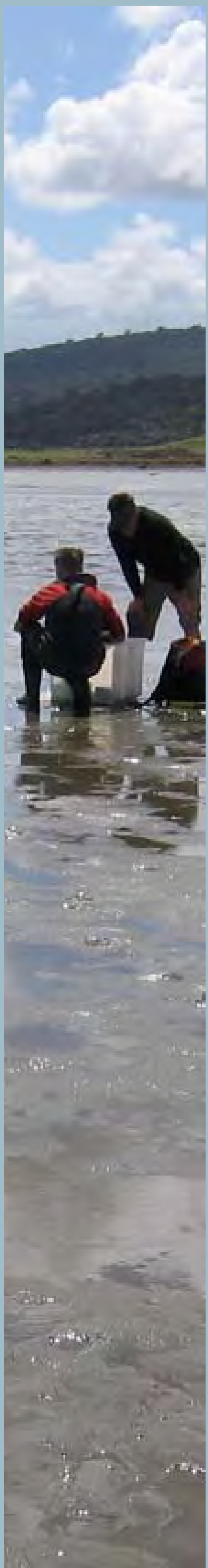


Figure 10. Mean total abundance of macrofauna, Haldane Estuary compared with other NZ estuaries.

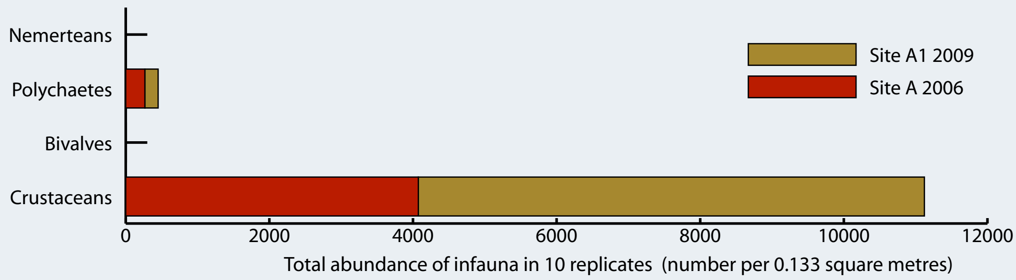


3. Results and Discussion (Continued)



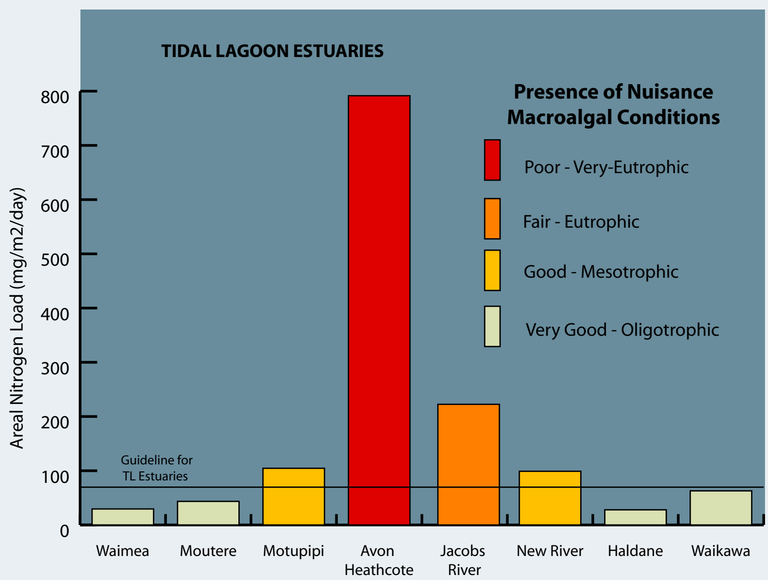
Unlike many other NZ estuaries the intertidal community was relatively depauperate - dominated by two organisms only (both of which have a strong preference for muddy sediments. The first was a crustacean (the opportunistic tube-dwelling amphipod *Paracorophium excavatum*), and the second was the enrichment tolerant and ubiquitous spionid polychaete *Scolecolepides benhami* (Figure 11). However, low numbers of a few other polychaetes, nemerteans, crustaceans and bivalves were also present. The reason for this unusual community (i.e. high abundance of a few opportunistic species tolerant of enriched conditions) is difficult to identify, given the good ratings for the various condition indices (i.e. TOC, nutrients, metals, RPD, and benthic community index). To help remedy this, future monitoring will include additional observations and measurements to identify the cause.

Figure 11. Major macrofauna groups, Haldane Estuary.



In terms of eutrophication, the results suggest that the estuary has a low to moderate level of enrichment. Currently the nitrogen input (as estuary areal load) is estimated to be 30 $mg.m^{-2}.d^{-1}$ which is in the range that is not expected to cause nuisance macroalgal conditions in tidal lagoon estuaries (Figure12). Also it is low compared with the 50 $mg.m^{-2}.d^{-1}$ upper limit suggested by Heggie (2006) for ensuring no eutrophication of temperate tidal lagoon estuaries.

Figure 12. Areal N loads and presence of nuisance macroalgal conditions, NZ estuaries.



3. Results and Discussion (Continued)

TOXICITY

METALS

Heavy metals (Cd, Cr, Cu, Ni, Pb, Zn), used as an indicator of potential toxicants, were at low to very low concentrations in both 2006 and 2009, with all values well below the ANZECC (2000) ISQG-Low trigger values (Figure 13). Metals met the "very good" condition rating for cadmium, chromium, copper, lead, and zinc at all sites, and the "good" condition rating for nickel. These results indicate that there is no widespread toxicity in Haldane Estuary.

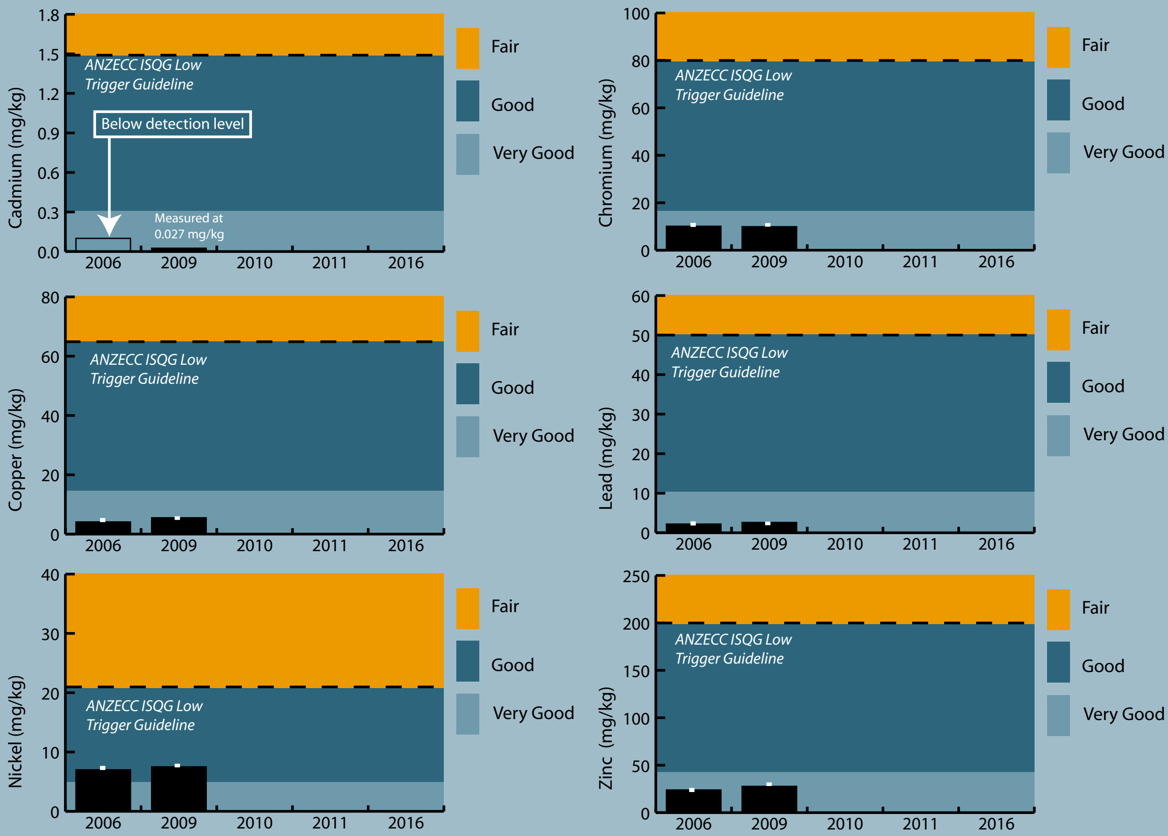


Figure 13. Sediment metal concentrations, (mean and range, Site A 2006 and Site A! 2009) Haldane Estuary.

4. SUMMARY AND CONCLUSIONS

The second year of fine scale monitoring results for estuary condition showed that Haldane Estuary was generally in good condition. Conditions were similar to those measured in 2006, with the key findings as follows;

- The sediments were dominated by sands but mud concentrations were elevated compared with other Southland estuary monitoring sites.
- Sediment levels of organic carbon, nitrogen and phosphorus were low.
- The benthic invertebrate community condition index was in the upper range of the "good" category, indicating slight to moderate pollution. However, the community was unusual for such a "good" condition estuary in that its was dominated by high abundances of a few opportunistic species that are tolerant of enriched situations.

4. Summary and Conclusions (Continued)

- 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, which has not yet been quantitatively monitored, was observed to be present but at very low concentrations (i.e. likely to meet the "very good" rating).
- In terms of eutrophication, the results suggest that the estuary has a low to moderate level of enrichment.

5. MONITORING

Haldane 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 2006 and 2009 monitoring results and condition ratings, it is recommended that monitoring continue as outlined below:

Fine Scale Monitoring (including sedimentation rate).

- Complete two more years of baseline monitoring (2010 and 2011) and subsequently undertake monitoring at five yearly intervals or as deemed necessary based on the condition ratings. The next fine scale monitoring is scheduled for February 2010.

Sedimentation Rate Monitoring.

- Monitor the depths of the existing four sediment plates 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 and field assistance 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

Haldane Site A new 2009	1	2	3	4	5	6	7	8	9	10
NZMGEAST	2206010	2206009	2206015	2206020	2206024	2206015	2206010	2206005	2205996	2205987
NZMGNORTH	5388778	5388778	5388763	5388749	5388735	5388732	5388747	5388757	5388778	5388774

Physical and Chemical Results for Haldane Estuary (Site A new), 16 February 2009.

Site	Reps*	RPD	Salinity	TOC	Mud	Sands	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP
		cm	ppt	%				mg/kg							
Haldane A	1-4	5	30	0.28	34.4	65.6	0.1	0.024	10	5.6	7.7	2.7	28	510	370
Haldane A	5-8	5	30	0.28	29.9	70.1	0.1	0.027	10	5.8	7.7	2.6	28	610	370
Haldane A	9-10	5	30	0.26	24.9	75.1	0.1	0.024	9.6	5.2	7.1	2.5	27	650	330

* composite samples

Fortrose Estuary Sediment Plate Baseline (depths in mm).

Site	No	Date	NZMG East	NZMG North	Plate depth
Haldane A	1	16/2/09	2206006	5388783	235
	2	16/2/09	2205997	5388784	223
	3	16/2/09	2205991	5388782	218
	4	16/2/09	2205986	5388781	274

APPENDIX 2. 2008 DETAILED RESULTS (CONTINUED)

Epifauna (numbers per 0.25m² quadrat)

Haldane Estuary Site A 16 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
Amphibola crenata						2				
No. species/quadrat						1				
No. individuals/quadrat						2				

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

Haldane Estuary Site A 16 February 2009												
Group	**Species**	AMBI	Hal A-01	Hal A-02	Hal A-03	Hal A-04	Hal A-05	Hal A-06	Hal A-07	Hal A-08	Hal A-09	Hal A-10
POLYCHAETA	*Boccardia (Paraboccardia) syrtis*	II	1		1							
	Macroclymenella stewartensis	II								1		
	Paraonidae sp.#1	III	1		4	6	2	3			1	
	Perinereis vallata	III										1
	Scolecolepides benhami	III	15	16	20	16	10	15	15	15	18	23
BIVALVIA	*Austrovenus stutchburyi*	NA			1			1				
	Macomona liliana	NA					1					
	Perrierina turneri	NA	1	1								
CRUSTACEA	*Amphipoda sp.#1*	NA	4	1	2	6	2	1	1		1	5
	Paracorophium excavatum	NA	850	762	768	722	666	689	598	612	684	672
	Phoxocephalidae sp.#1	I			1							
Total species in sample			6	4	7	4	5	5	3	3	4	4
Total specimens in sample			872	780	797	750	681	709	614	628	704	701

APPENDIX 3. INFAUNA CHARACTERISTICS

Group and Species		AMBI Group	Details
Nemertea	Nemertea	III	Ribbon or Proboscis Worms, mostly solitary, predatory, free-living animals. Intolerant of anoxic conditions.
Polychates	*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.
	Macroclymenella stewartensis	II	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. This worm 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.
	Paraonidae sp.#1	III	Slender burrowing worms that are probably selective feeders on grain-sized organisms such as diatoms and protozoans. *Aricidea* sp., a common estuarine paraonid, is a small sub-surface, deposit-feeding worm found in muddy-sands. These occur throughout the sediment down to a depth of 15cm and appear to be sensitive to changes in the mud content of the sediment. Some species of Aricidea are associated with sediments with high organic content.
	Per in ere is vallata	III	An intertidal soft shore nereid (which are common and very active, omnivorous worms). Prefers sandy 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.
	Arthritica sp.#1	III	A small sedentary deposit feeding bivalve, preferring a moderate mud content. Lives greater than 2cm deep in the muds.
Bivalves	*Austrovenus stutchburyi*	NA	The cockle is a suspension feeding bivalve with a short siphon - lives a few cm from sediment surface at mid-low water situations. Can live in both mud and sand but is sensitive to increasing mud - prefers low mud content. Rarely found below the RPD layer.
	Macomona liliana	NA	A deposit feeding wedge shell. This species lives at depths of 5–10cm in the sediment and uses a long inhalant siphon to feed on surface deposits and/or particles in the water column. Rarely found beneath the RPD layer.
	Perrierina turneri	NA	A small bivalve - relatively uncommon.
Crustacea	Amphipoda sp.	NA	An unidentified amphipod.
	Paracorophium excavatum.	III	A species of amphipod in the Family Corophiidae - small opportunistic tube dwelling crustaceans. Can be present in high numbers - very mobile. Often initial colonisers of new habitat. Strong mud preference.
	Phoxocephalidae sp.	I	A family of amphipods.

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 Coefficient from 0-7, divided into a Biotic Index with five levels.