Wriggle

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Freshwater Estuary

Broad Scale Habitat Mapping 2007/08

Prepared for

Environment Southland

December 2008

Cover Photo: Extensive seagrass flats, Freshwater Estuary

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By

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All photos by Wriggle except where noted otherwise.

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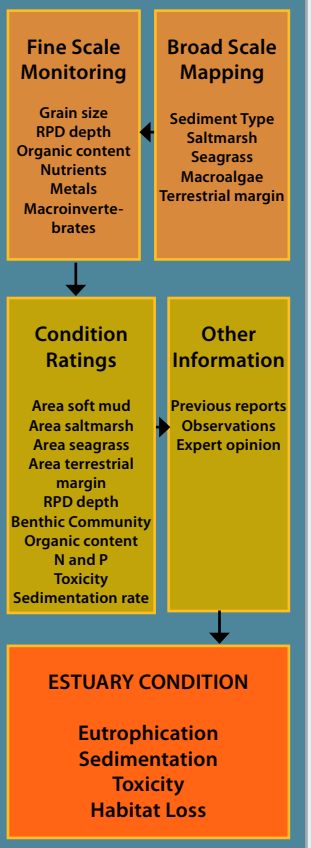
EXECUTIVE SUMMARY



In the 1990's, Environment Southland (ES) established a long-term monitoring programme to assess the condition of key estuaries in its region. Estuaries monitored to date include New River, Jacobs River, Bluff Harbour and Awarua Bay, Toetoes (Fortrose) Harbour, and Haldane, Waikawa, and Waiau Estuaries. In 2008, ES contracted Wriggle Coastal Management to undertake broad scale mapping of Freshwater Estuary, located at the head of Paterson Inlet on Stewart Island.

The current report describes the broad scale habitat mapping undertaken in February 2008. Broad scale habitat mapping is a tool used to assess the condition of estuaries. It includes mapping and condition ratings for key habitat elements including: estuary sediment types, macroalgal beds (i.e. *Ulva* (sea lettuce), *Gracilaria, Enteromorpha*), macrophytes (e.g. *Zostera* - seagrass), saltmarsh vegetation, and the 200m terrestrial margin surrounding the estuary. The methods used were based on the tools included in the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002), and a number of extensions (Table 1).

The outcome is a series of GIS-based habitat maps (often complex), that provide measures of the extent of different types of habitat cover. Taken in combination with fine scale physical, chemical and biological monitoring results, these measures are applied into different rating scales which are used alongside other relevant information to assess the condition of the estuary in relation to the key issues of sedimentation, eutrophication and habitat loss. Toxicity is addressed as part of fine scale monitoring, while disease risk is monitored and reported separately, principally through recreational water quality monitoring programmes. A summary of the approach is outlined in the figure in the sidebar.

A broad scale summary map is presented on the next page (much reduced but included as a reminder of the more user-friendly GIS-based maps that accompany this report).

OVERVIEW

Freshwater Estuary (812ha) is a relatively large "tidal river mouth" type estuary with an extensive sandy intertidal delta that has established within the sheltered confines of Paterson Inlet. The estuary is dominated by vast and healthy seagrass (*Zostera*) beds (58% of the intertidal area) that are thriving in the sandy sediments and clear water conditions in the estuary. Sediments appeared to be well oxygenated and in good condition, with the Redox Potential Discontinuity (RPD) depth 3-5cm across most of the estuary.

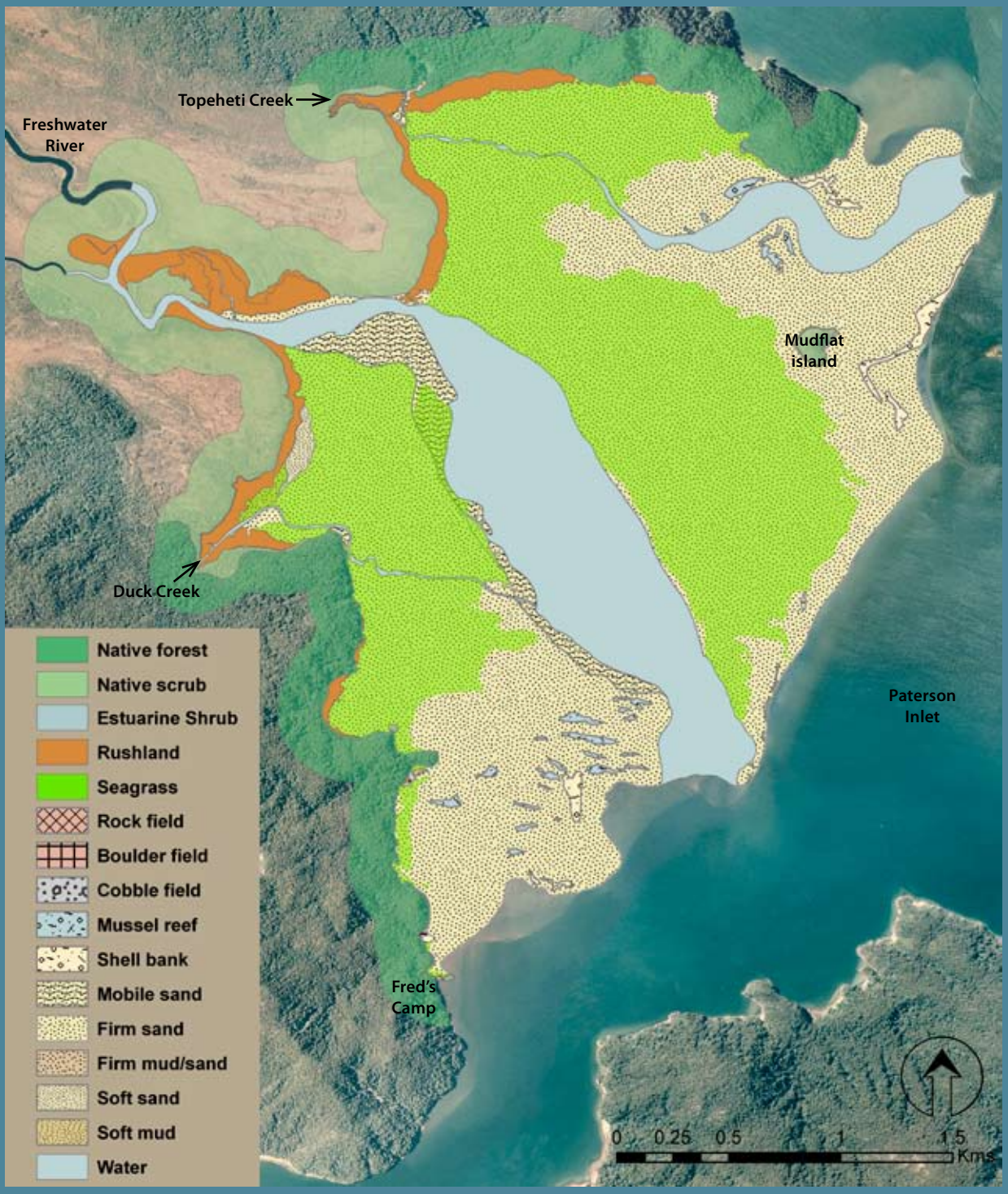
Saltmarsh (predominantly jointed wire rush) was limited in its extent due to the topography surrounding the estuary, present mostly in firm mud/sand as a narrow band on the east of the estuary. All of the 200m terrestrial margin was covered in dense native forest and scrub. Macroalgal growth (predominantly *Gracilaria* and, to a lesser extent, *Enteromorpha* and *Ulva*) was widespread, (>5% cover across 85% of the intertidal area) but was generally not associated with nuisance conditions.

The intertidal broad scale mapping data were used to determine condition ratings for key broad scale indicators. The results were as follows:

BROAD SCALE CONDITION RATINGS

BROAD SCALE RATING 2008	% COVER SOFT MUD	% COVER MACROALGAE	% COVER SEAGRASS	% COVER SALTMARSH	RPD DEPTH	TERRESTRIAL VEGETATED BUFFER
FRESHWATER ESTUARY	VERY GOOD	FAIR	VERY GOOD	MODERATE	FAIR/GOOD	VERY GOOD

Summary of the broad scale features of Freshwater Estuary, February 2008.



EXECUTIVE SUMMARY (CONTINUED)

ESTUARY ISSUES

The broad scale intertidal monitoring results, in combination with other available information, provide an overview of likely estuary condition in relation to the key issues examined in this broad scale assessment, namely sedimentation, eutrophication and habitat loss:

SEDIMENTATION: Freshwater Estuary is dominated by firm sand with very little soft mud present, giving the estuary a 'very good' condition rating for sedimentation. The dominance of firm sand reflects that fine sediment inputs are limited by the intact sequence of dense saltmarsh and native forest surrounding the estuary, while high wind fetch across the delta is likely to promote wave generated resuspension and removal of fine sediment from the estuary. The firm sands and clear water provide ideal habitat for the large seagrass beds that are a dominant feature of the intertidal flats.

EUTROPHICATION: Macroalgae is present throughout Freshwater Estuary, particularly on the lower estuary delta, giving it a rating of 'fair', although nuisance conditions were not observed. Nuisance intertidal macroalgal growth is a key broad scale indicator of eutrophication, along with the depth of the RPD layer. Current uncertainty over the nutrient source supporting the macroalgal growth will be addressed as part of the fine scale monitoring.

HABITAT LOSS: Freshwater Estuary lies within Rakiura National Park and the waters of Te Whaka a Te Wera Mataitai Reserve. As such, there is little potential for direct human modification of the estuary saltmarsh or vegetated terrestrial margin, and past habitat loss has been minimal. The vast intertidal seagrass beds have high ecological value but may be susceptible to key stressors such as climate change or sea level rise. Habitat loss condition ratings will be applied when the broad scale mapping is repeated.

RECOMMENDED MONITORING

Freshwater Estuary has been identified by ES as a priority for monitoring, and is a key part of ES's existing estuary monitoring programme being undertaken in a staged manner throughout Southland. The excellent condition of the estuary means it is a very important reference for assessing the health of other estuaries in the region, while key features, in particular the highly valued seagrass beds, need to be maintained. To provide the information needed to maintain the estuary, a combination of broad and fine scale monitoring of the estuary is recommended as follows:

Fine Scale Monitoring	Establish a 3 year fine scale baseline (scheduled for 2009-11) then monitor thereafter on a 5 yearly cycle or as deemed necessary based on the condition ratings.
Broad Scale Macroalgal Mapping	Map macroalgal cover in January-March as the fine scale baseline is established over 3 years, and then as deemed necessary based on the condition ratings.
Broad Scale Sedimentation Rate Mapping	Install sediment plates in representative parts of the estuary (e.g. one new site on the north side of the estuary delta) in January-March 2009. Monitor annually thereafter or as deemed necessary based on the condition ratings.
Broad Scale Habitat Mapping	Repeat broad scale habitat mapping at 5 yearly intervals (next scheduled for 2013), and then as deemed necessary based on the condition ratings.

The recommended monitoring will provide a baseline record of a near pristine estuary against which to compare other estuaries in the region, as well as identifying any changes in estuary condition. This will provide a robust framework for identifying, evaluating and providing management options for any significant issues that arise within Freshwater Estuary in the future. Because Freshwater Estuary is relatively unmodified and the surrounding land is protected within Rakiura National Park, direct management action by ES is currently considered unnecessary.

1. INTRODUCTION

OVERVIEW

Developing an understanding of the condition and risks to estuarine habitats is critical to the management of biological resources. In the 1990's, Environment Southland (ES) established a long-term monitoring programme to assess the condition of key estuaries in its region. Those monitored to date include Jacobs River, New River, Haldane, Waikawa, and Waiau Estuaries, and Toetoes (Fortrose) Harbour, Bluff Harbour and Awarua Bay (see references). Results for the estuaries in the ES monitoring programme have been presented in a series of separate reports (e.g. Robertson et al. 2002, 2003, 2004, Stevens & Asher 2005, Robertson & Asher 2003, 2006, Robertson & Stevens, 2006). In 2008, Wriggle Coastal Management was contracted to undertake broad scale habitat mapping of Freshwater Estuary, located at the head of Paterson Inlet on Stewart Island, using the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002) plus recent extensions (see Table 1 and Table 3).

The estuary monitoring programme consists of three components:

1. **Ecological Vulnerability Assessment** of the estuary to major issues (see Table 2), and appropriate monitoring design. This has yet to be undertaken for Stewart Island, although a high level overview of Freshwater Estuary based on existing information is included in this report.
2. **Broad scale habitat mapping,** (EMP approach). This component, which documents the key habitats within the estuary, and changes to these habitats over time, is the subject of the current report.
3. **Fine scale physical, chemical and biological monitoring**, (EMP approach) including sedimentation plate deployment. This component provides detailed information on estuary condition, and is scheduled for February 2009.

This report documents the results of the broad scale monitoring undertaken in February 2008 of Freshwater Estuary. It includes:

- Broad scale mapping of intertidal sediment types.
- Broad scale mapping of macroalgal beds (i.e. *Ulva* (sea lettuce), *Gracilaria, Enteromorpha*).
- Broad scale mapping of seagrass beds (i.e. *Zostera capricorni*).
- Broad scale mapping of saltmarsh vegetation.
- Broad scale mapping of the 200m terrestrial margin surrounding the estuary.
- Broad scale mapping of the Redox Potential Discontinuity (RPD) depth.
- Condition ratings for the Freshwater Estuary (based on Robertson & Stevens, 2006, 2007, 2008). A suggested monitoring or management response is linked to each condition rating.

REPORT STRUCTURE

The report is structured as follows:

Section 1 Introduction to the scope and structure of the study.
Section 2 Methods - broad scale mapping and estuary condition ratings.
Section 3 Results and Discussion.
Section 4 Conclusions.
Section 5 Recommended Monitoring.
Section 6 References.
Section 7 Acknowledgements.

Appendix 1 Substrate and vegetation classification.

This report characterises the baseline conditions of the estuary, providing detailed information on key broad scale indicators of sedimentation, eutrophication and habitat loss (Table 3). The results will help determine the extent to which the estuary is affected by major estuary issues (Table 2), both in the short and long term.

1. INTRODUCTION (CONTINUED)

Table 1. Coastal Monitoring Tools (Wriggle Coastal Management).

Resource	Tools for Monitoring and Management
Estuaries	Estuary vulnerability matrix. Broad scale estuary and 200m terrestrial margin habitat mapping. Fine scale estuary monitoring. Sedimentation rate measures (using plates buried in sediment). Historical sedimentation rates (using radio-isotope ageing of sediment cores). Macroalgae and seagrass mapping (reported as separate GIS layers). Condition ratings for key indicators. Georeferenced digital photos (as a GIS layer). Upper estuary monitoring and assessment.
Beaches, Dunes	Beach and dune vulnerability matrix. Broad scale beach, dune and terrestrial margin mapping. Fine scale beach monitoring. Condition ratings for key indicators. Georeferenced digital photos (as a GIS layer).
Rocky Shores	Rocky shore vulnerability matrix. Broad scale rocky shore and terrestrial margin mapping. Fine scale rocky shore monitoring. Georeferenced digital photos (as a GIS layer).

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

Key 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), toxic heavy metals, polychlorinated biphenyls (PCBs), and pesticides. These chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to people and marine life.
Habitat Loss	Estuaries have many different types of habitats including shellfish beds, seagrass meadows, saltmarshes (rushlands, herbfields, reedlands etc.), forested wetlands, beaches, river deltas, and rocky shores. The continued health and biodiversity of estuarine systems depends on the maintenance of high-quality habitat. Loss of habitat negatively affects fisheries, animal populations, filtering of water pollutants, and the ability of shorelines to resist storm-related erosion. Within New Zealand, habitat degradation or loss is common-place with the major causes cited as sea level rise, population pressures on margins, dredging, drainage, reclamation, pest and weed invasion, reduced flows (damming and irrigation), over-fishing, polluted runoff and wastewater discharges.

1. INTRODUCTION (CONTINUED)

Table 3. Summary of the broad and fine scale EMP indicators.

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

1. INTRODUCTION (CONTINUED)

BACKGROUND TO FRESHWATER ESTUARY

Estuary Type/Area	Tidal River Estuary with Delta
Catchment	320 km^2
Mean annual rainfall	1612.4 mm
Dairy cows	0
Mean annual flow	Freshwater River: 7.9m^3/sec
Sediment loading	Low: 1.9 t/km^2/yr
Nitrogen loading	Catchment: Low-Mod: 6 kg/ha/yr (WRENZ) Freshwater River: High: 0.779 g/m^3 * *based on estimated flow and WRENZ nitrogen load.
Catchment geology	Granite
Catchment landuse	Native forest (Rakirua National Park)
Salinity	>30ppt, well mixed, sea water dominated
Mean depth (m)	1-2 m
Saltmarsh area	40 ha (4.9%) primarily *Apodasima similis*
Intertidal area	621.6 ha (76.5%)
Subtidal area	151 ha (18.6%)
Point discharges	None
Uses/Values	Walking, shellfish collection, birds, scenic, fishing.

FRESHWATER ESTUARY, STEWART ISLAND

Human Use		Moderate
Ecological Value		Very High
Existing Condition		Very Good
Susceptibility		Moderate
Stressors		Low

Freshwater Estuary, fed by the largest river on Stewart Island, is a relatively large "tidal river mouth" type estuary and intertidal delta (area 812 ha) that has established within the sheltered confines of Paterson Inlet. It drains the native forest catchment of the Mount Anglem highlands and Ruggedy Mountain area, with its lower reaches meandering across Freshwater Valley, the largest area of flat land on Stewart Island. The estuary itself is relatively shallow (mean depth approximately 2m), has an extensive intertidal area (77% of estuary exposed at low tide), and supports very large areas of seagrass growing in the firm sands and bathed in the clear seawater of Paterson Inlet. Muddy sediments are a very minor component (<1%) and restricted to the immediate vicinity of freshwater inputs and in sheltered arms. The combination of wave resuspension and good flushing means that the majority of the delta sediments tend to be sandy and homogeneous, and biodiversity is generally high.

Uses and Values. Human use of the estuary is moderate, mainly for walking, bird study, scenic values, fishing, shellfish collection.

Ecological Values. Ecologically, habitat diversity is high, given benefits of extensive sandy tidal flats and seagrass beds, clear seawater, saltmarsh, and a native forest catchment. Such conditions provide ideal habitat for native fish, birdlife (including the endangered NZ dotterel), and tidal flat organisms.

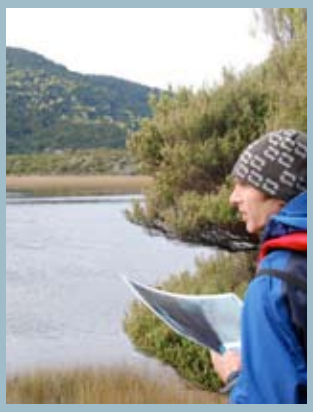
Existing Condition. Water quality is high (high clarity, low faecal coliforms, low catchment sediment and nutrient inputs). Macroalgae (mostly *Gracilaria* and *Ulva*) is common and widespread on the intertidal estuary delta. Sediment type is predominantly firm sand with very little soft muds present. Sediment quality is expected to be good with metal concentrations expected to be low, and good oxygenation. Estimated catchment nitrogen loadings (the major driver of eutrophication) are low.

Presence of Stressors. The presence of stressors is expected to be "low". The estuary is surrounded by native forest protected within the Rakiura National Park, while the waters of Paterson Inlet are managed under a mataitai (Te Whaka a Te Wera Mātaitai Reserve). The main threats to the estuary are weed and pest invasions and, in the long term, climate change and sea level rise.

Susceptibility to Stressors. Susceptibility to stressors is expected to be moderate given that the estuary is well flushed (low residence time), but largely unmodified.

2. METHODS

BROAD SCALE HABITAT MAPPING



Unvegetated
1-5%
5-10 %
10-20 %
20-50 %
50-80 %
80-100 %

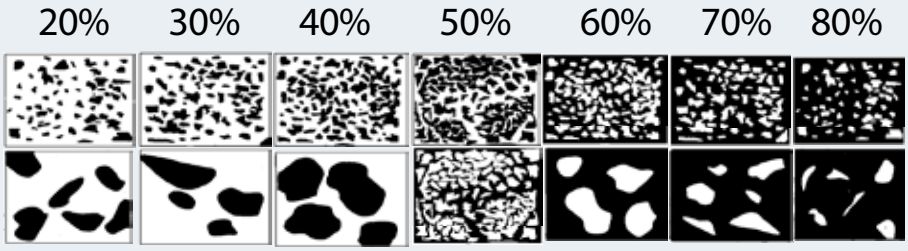
Broad-scale mapping is a method for describing habitat types based on the dominant surface features present (e.g. substrate: mud, sand, cobble, rock; or vegetation: macrophyte, macroalgae, rushland, etc). It follows the EMP approach originally described for use in NZ estuaries by Robertson et al. (2002) with a combination of aerial photography, detailed ground-truthing, and GIS-based digital mapping used to record the primary habitat features present. Very simply, the method involves three key steps:

- Obtaining laminated aerial photos for recording dominant habitat features.
- Carrying out field identification and mapping (i.e. ground-truthing).
- Digitising the field data into GIS layers (ArcMap 9.2).

For the 2008 study, ES supplied rectified ~0.75m/pixel resolution colour aerial photos. Photos covering the estuary at a scale of 1:5,000 were laminated, and two scientists ground-truthed the spatial extent of dominant habitat and substrate types by walking the extent of the estuary recording features directly on the laminated aerial photos over two days in February 2008.

Classification of macroalgae and macrophyte percentage cover within the estuary was assessed using a seven category visual rating scale (see examples below and left). The results are used to describe macroalgae and macrophyte density and distribution within the estuary.

Visual rating scale for percentage cover estimates



Sampling positions and photographs were georeferenced and the information collected was used to produce GIS-based habitat maps showing the following:

- Dominant substrate.
- Percent cover of dominant intertidal macroalgae (e.g. *Gracilaria, Enteromorpha, Ulva*).
- Percent cover of intertidal macrophytes (*Zostera*).
- Depth of the Redox Potential Discontinuity (RPD).
- Dominant saltmarsh vegetation.
- 200m wide terrestrial margin vegetation/landuse.

Appendix 1 lists the class definitions used to classify substrate and vegetation. Vegetation was further classified using an interpretation of the Atkinson (1985) system, whereby dominant plant species were coded by using the two first letters of their Latin genus and species names e.g. marram grass, *Ammophila arenaria*, was coded as Amar. An indication of dominance is provided by the use of ( ) to distinguish subdominant species e.g. Amar(Caed) indicates that marram grass was dominant over ice plant (*Carpobrotus edulis*). The use of ( ) is not always based on percentage cover, but the subjective observation of which vegetation is the dominant or subdominant species within the patch. A measure of vegetation height can be derived from its structural class (e.g. rushland, scrub, forest).

2. METHODS (CONTINUED)

BROAD SCALE HABITAT MAPPING (CONTINUED)

Digital mapping results were entered by digitising features directly off aerial photos in the GIS using a Wacom Intuos3 electronic drawing tablet within ArcMap 9.2. The spatial location, size, and type of broad scale habitat features in the estuary are provided as ArcMap 9.2 GIS shapefiles on a separate CD. Georeferenced digital field photos (GPS-Photolink) are also supplied as a GIS layer. The broad scale results are summarised in the current report in Section 3, with the supporting GIS files providing much more detail in a data set designed for easy interrogation to address specific monitoring and management questions.

CONDITION RATINGS

A series of interim broad scale estuary "condition ratings" (presented below) have been proposed for Freshwater Estuary (based on the ratings developed for New Zealand estuaries - Robertson & Stevens 2006, 2007, 2008a). The condition ratings have been developed through a review of monitoring data, use of existing 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 responses. The condition ratings include an "early warning trigger" so that ES is alerted where rapid or unexpected change occurs, and each rating has a recommended monitoring frequency management response. In most cases the management recommendation is to further assess an issue and consider what response actions may be appropriate (e.g. develop an Evaluation and Response Plan - ERP).

Redox Potential Discontinuity (RPD)

The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. The RPD marks the transition between oxygenated and reduced conditions and is an effective ecological barrier for most, but not all, sediment-dwelling species. A rising RPD will force most macrofauna towards the sediment surface to where oxygen is available. In addition, nutrient availability in estuaries is generally much greater where sediments are anoxic, with consequent exacerbation of the eutrophication process. The majority of the other eutrophication indicators (e.g. macroalgal blooms, soft muds, sediment organic C, TP, and TN) are less critical, in that they can be elevated, but not necessarily causing sediment anoxia and adverse impacts to aquatic life. The tendency for sediments to become anoxic is much greater if the sediments are muddy. In sandy porous sediments, the RPD layer is usually relatively deep (>3cm) and is maintained primarily by current or wave action that pumps oxygenated water into the sediments. In finer silt/clay sediments, physical diffusion limits oxygen penetration to <1cm (Jørgensen and Revsbech 1985) unless bioturbation by infauna oxygenates the sediments.

RPD CONDITION RATING

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

Soft Mud Percent Cover

Soft mud in estuaries decreases water clarity, lowers biodiversity and affects aesthetics and access. Increases in the area of soft mud indicate where changes in catchment land use management may be needed.

SOFT MUD PERCENT COVER CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Low	<2% of estuary substrate is soft mud	Monitor at 5 year intervals after baseline established
Good	2%-5% of estuary substrate is soft mud	Monitor at 5 year intervals after baseline established
Fair	5%-15% of estuary substrate is soft mud	Post baseline, monitor 5 yearly. Initiate ERP
Poor	>15% of estuary substrate is soft mud	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	>5% of estuary substrate is soft mud	Initiate ERP (Evaluation and Response Plan)

2. METHODS (CONTINUED)

Soft Mud Area

Soft mud in estuaries decreases water clarity, lowers biodiversity and affects aesthetics and access. Increases in the area of soft mud indicate where changes in catchment land use management may be needed.

SOFT MUD AREA CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	Area of cover (ha) not increasing	Monitor at 5 year intervals after baseline established
Good	Increase in area of cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Fair	Increase in area of cover (ha) 5-15% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Poor	Increase in area of cover (ha) >15% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	Trend of increase in area of cover (ha)	Initiate ERP (Evaluation and Response Plan)

Macroalgae Index

Certain types of macroalgae can grow to nuisance levels in nutrient-enriched estuaries causing sediment deterioration, oxygen depletion, bad odours and adverse impacts to biota. A continuous index (the macroalgae coefficient - MC) has been developed to rate macroalgal condition based on the percentage cover of macroalgae in defined categories using the following equation: ***MC=((0 x %macroalgal cover <1%)+(0.5 x %cover 1-5%)+(1 x %cover 5-10%)+(3 x %cover 10-20%)+(4.5 x %cover 20-50%)+(6 x %cover 50-80%)+(7.5 x %cover >80%))/100.*** Overriding the MC is the presence of either nuisance conditions within the estuary, or where >5% of the intertidal area has macroalgal cover >50%. In these situations the estuary is given a minimum rating of FAIR and should be monitored annually with an Evaluation & Response Plan initiated.

MACROALGAE CONDITION RATING

RATING	DEFINITION (+Macroalgae Coefficient)	RECOMMENDED RESPONSE
Over-riding rating: Fair	Nuisance conditions exist, or >50% cover over >5% of estuary	Monitor yearly. Initiate Evaluation & Response Plan
Very Good	Very Low (0.0 - 0.2)	Monitor at 5 year intervals after baseline established
Good	Low (0.2 - 0.8)	Monitor at 5 year intervals after baseline established
	Low Low-Moderate (0.8 - 1.5)	Monitor at 5 year intervals after baseline established
Fair	Low-Moderate (1.5 - 2.2)	Monitor yearly. Initiate ERP
	Moderate (2.2 - 4.5)	Monitor yearly. Initiate ERP
Poor	High (4.5 - 7.0)	Monitor yearly. Initiate ERP
	Very High (>7.0)	Monitor yearly. Initiate ERP
Early Warning Trigger	Trend of increasing Macroalgae Coefficient	Initiate ERP (Evaluation and Response Plan)

Seagrass Index

Seagrass (*Zostera capricorni*) grows in soft sediments in NZ estuaries where its presence enhances estuary biodiversity. Though tolerant of a wide range of conditions, it is vulnerable to fine sediments in the water column and sediment quality (particularly if there is a lack of oxygen and production of sulphide). A continuous index (the seagrass coefficient - SC) has been developed to rate seagrass condition based on the percentage cover of seagrass in defined categories using the following equation: ***SC=((0 x %seagrass cover <1%)+(1 x %cover 1-5%)+(3 x %cover 5-10%)+(6 x %cover 10-20%)+(9 x %cover 20-50%)+(12x %cover 50-80%)+(15 x %cover >80%))/100.***

SEAGRASS CONDITION RATING

RATING	DEFINITION (+Seagrass Coefficient)	RECOMMENDED RESPONSE
Poor	Very Low (0.0 - 0.2)	Post baseline, monitor 5 yearly. Initiate ERP
Fair	Low (0.2 - 0.8)	Post baseline, monitor 5 yearly. Initiate ERP
	Low Low-Moderate (0.8 - 1.5)	Post baseline, monitor 5 yearly. Initiate ERP
Good	Low-Moderate (1.5 - 2.2)	Monitor at 5 year intervals after baseline established
	Moderate (2.2 - 4.5)	Monitor at 5 year intervals after baseline established
Very Good	High (4.5 - 7.0)	Monitor at 5 year intervals after baseline established
	Very High (>7.0)	Monitor at 5 year intervals after baseline established
Early Warning Trigger	Trend of decreasing Seagrass Coefficient	Initiate ERP (Evaluation and Response Plan)

2. METHODS (CONTINUED)

Saltmarsh Percent Cover

A variety of saltmarsh species (commonly dominated by rushland but including scrub, sedge, tussock, grass, reed, and herb fields) grow in the upper margins of most NZ estuaries where vegetation stabilises fine sediment transported by tidal flows. Saltmarshes have high biodiversity, are amongst the most productive habitats on earth and have strong aesthetic appeal. Where saltmarsh cover is limited, these values are decreased.

SALTMARSH PERCENT COVER CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very High	>20% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
High	10%-20% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
Moderate	5%-10% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
Low	2%-5% of estuary area is saltmarsh	Post baseline, monitor 5 yearly. Initiate ERP
Very Low	<2% of estuary area is saltmarsh	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	<5% of estuary area is saltmarsh	Initiate ERP (Evaluation and Response Plan)

Saltmarsh Area

Saltmarshes are sensitive to a wide range of pressures including land reclamation, margin development, flow regulation, sea level rise, grazing, wastewater contaminants, and weed invasion. Decreases in saltmarsh extent is likely to indicate an increase in these types of pressures.

SALTMARSH AREA CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	Area of cover (ha) not decreasing	Monitor at 5 year intervals after baseline established
Good	Decline in area of cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Fair	Decline in area of cover (ha) 5-20% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Poor	Decline in area of cover (ha) >20% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	Trend of decrease in area of cover (ha)	Initiate ERP (Evaluation and Response Plan)

Terrestrial Vegetated Buffer Percent Cover

The presence of a terrestrial margin dominated by a dense assemblage of scrub/shrub and forest vegetation acts as an important buffer between developed areas and the saltmarsh and estuary. This buffer protects against introduced weeds and grasses, naturally filters sediments and nutrients, and provides valuable ecological habitat.

TERRESTRIAL VEGETATED BUFFER PERCENT COVER CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very High	80%-100% cover of terrestrial vegetated buffer	Monitor at 5 year intervals after baseline established
High	50%-80% cover of terrestrial vegetated buffer	Monitor at 5 year intervals after baseline established
Fair	25%-50% cover of terrestrial vegetated buffer	Post baseline, monitor 5 yearly. Initiate ERP
Poor	5%-25% cover of terrestrial vegetated buffer	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	<50% cover of terrestrial vegetated buffer	Initiate ERP (Evaluation and Response Plan)

Terrestrial Vegetated Buffer Area

Estuaries are sensitive to a wide range of pressures including land reclamation, margin development, flow regulation, sea level rise, grazing, wastewater contaminants, and weed invasion. Reduction in the vegetated buffer around the estuary is likely to result in a decline in estuary quality.

TERRESTRIAL VEGETATED BUFFER AREA CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	Terrestrial buffer is 100% dense vegetation	Monitor at 5 year intervals after baseline established
Good	Decline in vegetated buffer (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Fair	Decline in vegetated buffer (ha) 5-10% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Poor	Decline in vegetated buffer (ha) >10% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	Trend of decrease in area of vegetated buffer (ha)	Initiate ERP (Evaluation and Response Plan)

3. RESULTS AND DISCUSSION

OVERVIEW

This section summarises the dominant features of the estuary (Tables 4 and 5), and presents the results and a discussion of each broad scale GIS layer that has been mapped. For each layer (substrate, macroalgae, seagrass, saltmarsh, RPD, and the 200m terrestrial margin), condition ratings are used to assess each indicator, which are then evaluated along with other relevant expert information to assess the condition of the estuary in relation to the key issues of sedimentation, eutrophication and habitat loss.

The most striking feature of Freshwater Estuary is the very large and healthy seagrass beds that dominated the intertidal area (58% cover). This alone makes the estuary special, but the surrounding native forest, firm sand substrate, clear waters, and large numbers of plants and animals growing in it, all combine to make the estuary a remarkable place that is in very good condition. As such, it is very important to maintain its current healthy state, particularly as it represents one of the few remaining examples of what many of NZ's estuaries would once have been like.

The flourishing seagrass and extensive growths of macroalgae (85% cover) indicate that there is a ready supply of nutrients in Freshwater Estuary. The nutrient source is unclear (native forest is not usually associated with high nutrient inputs), but may come from a combination of catchment geology and internal cycling of nutrients within the seagrass beds - questions fine scale monitoring of the estuary will address.

Another feature of the estuary was the small extent of saltmarsh. This is a natural phenomena which reflects that the majority of the estuary delta is open to the sea, while much of the terrestrial margin of estuary is bordered by low cliffs or steep bush-clad hillsides, both features limiting available saltmarsh habitat.

Susceptibility to key stressors such as sedimentation, eutrophication, and toxins is considered low because the estuary catchment is undeveloped (and protected), therefore sediment, nutrient and contaminant inputs are expected to be low. Furthermore, the upper reaches of the river estuary have relatively high freshwater inputs in relation to its area and, as a result, most deposition will occur outside the river estuary on the delta. Because the generally shallow delta (average depth~2m) receives good tidal flushing (most of the estuary drains at low tide), and because high wind fetch across the delta is likely to promote wave generated resuspension and removal of fine sediment from the estuary, the delta is also considered to have low susceptibility to key stressors. The main threats to the estuary are weed and pest invasions and, in the long term, climate change and sea level rise.

Table 4. Summary of dominant estuary features, February 2008.

Dominant Feature	Area (Ha)	Area (%)
Saltmarsh	39.8	4.9
Intertidal flats	621.6	76.5
Water	151.0	18.6
TOTAL	**812.4**	**100**

Table 5. Summary of dominant intertidal vegetation, February 2008.

Dominant Feature	Area (Ha)	Area (%)
Intertidal Seagrass Cover >5%	356.8	57.5
Intertidal Macroalgal Cover >5%	529.5	85.3

SUBSTRATE MAPPING

Mobile sand where the river enters the estuary.

Sand flats showing shellfish bioturbation.

Sand and shell neat Mudflat island.

Shell (cockle) bank.

Mussel beds (Mytilus edulis).

Rockfield and low cliff bordering the southwest shoreline.

Freshwater Estuary, with a native forest catchment, was not expected to exhibit the soil erosion impacts commonly associated with many developed NZ catchments, e.g. suspended sediment impacts such as increased muddiness and turbidity, shallowing, increased nutrients, changes in saltmarsh and seagrass habitats, less oxygen, increased organic matter degradation by anoxic processes (e.g. sulphate reduction), and alterations to fish and invertebrate communities.

The findings of the broad scale mapping confirmed this, in that the estuary was dominated by firm sand (90%, 596ha) and mobile sand (3.5%, 22.9ha) extending across most of the intertidal delta area (Table 6, Figure 1). Soft mud was uncommon, with only one small area present in the northwest where Topeheti Creek enters the estuary. The soft mud condition rating placed the estuary in the "very good" category (<2% of the estuary is soft mud).

The sand flats were generally well oxygenated and in unvegetated areas characterised by a temporary 3-dimensional seascape of holes excavated by burrowing animals that are washed away and rebuilt on each tide.

Within saltmarsh areas (mostly limited to a narrow band on the east of the estuary between Duck and Topeheti Creeks), the underlying substrate was predominantly firm mud/sand. The higher mud component in these areas is expected due to the role saltmarsh plays in flood and erosion control, trapping and stabilising sediment inputs around the estuary margin. In relation to estuaries elsewhere in NZ, the substrate among the saltmarsh in Freshwater Estuary was firm with a low mud content.

Other prominent features of the estuary were the mussel reefs and shell banks. The mussel reefs (the blue mussel, *Mytilus edulis*) have established low in the intertidal reaches in dense clumps slightly elevated above the surrounding sand. They were most common in the southern seaward edge of the delta and near the subtidal channel in the north. The shellbanks (cockle shells - *Austrovenus stutchburyi*) immediately east of Mudflat Island extend in long narrow banks parallel with the shoreline, with smaller banks on the southern seaward edge of the delta.

Other features of the estuary were small areas of rock, boulder and cobble located predominantly on the south western and north eastern shorelines of the estuary.

Table 6. Summary of dominant intertidal substrate, February 2008.

Dominant Substrate	Area (ha)	%	Comments
Rock field	0.8	0.1	Mostly along the estuary terrestrial margin.
Boulder field	0.2	0.03	Mostly along the estuary terrestrial margin.
Cobble field	0.2	0.03	Mostly along the estuary terrestrial margin.
Mussel reef	5.4	0.8	Near the seaward edge of the delta.
Shell bank	6.4	1.0	Cockle banks along the seaward edge of the delta.
Mobile sand	22.9	3.5	Mostly along the subtidal channel on the southern delta.
Firm sand	596.2	90.1	Dominant across most of the intertidal delta.
Firm mud/sand	24.7	3.7	In saltmarsh areas to the west near Freshwater River.
Soft sand	2.6	0.4	In front of saltmarsh between Duck Ck and Freshwater River.
Soft mud	2.0	0.3	Confined to the Topeheti Ck arm in the northwest delta.
TOTAL	**661.4**	**100**	

Figure 1. Map of Dominant Substrate - Freshwater Estuary, February 2008

MACROALGAL MAPPING

***Gracilaria* and *Ulva* (80-100% cover) among *Zostera*.**

***Gracilaria* and *Ulva* (50-80% cover) on the upper southern delta.**

***Gracilaria* and *Enteromorpha* (10-20% cover) on the upper southern delta.**

***Ulva* (80-100% cover) at the seaward edge of the delta.**

Macroalgal blooms are a symptom of estuary eutrophication. These can deprive seagrass areas of light causing their eventual decline, while decaying macroalgae can accumulate on shorelines causing depletion of sediment dissolved oxygen and nuisance odours. Figure 2 and Table 7 summarise the results of macroalgal mapping within Freshwater Estuary. Overall, 530ha (85% of the intertidal area) had a macroalgal cover >5%. Cover was dominated by the red alga *Gracilaria chilensis* and, to a lesser extent, by the green alga *Enteromorpha* which was most common along the edges of the main river channels. Sea lettuce (*Ulva*) was a common subdominant species and was also present in the highest percentage cover along the seaward edge of the estuary.

The Macroalgae Coefficient (MC) for the estuary was "moderate" (4.0), a condition rating of "fair", and although a large portion of the estuary (26%) had a high (>50%) cover, there was little evidence of nuisance conditions of anoxic muds and sulphide odours.

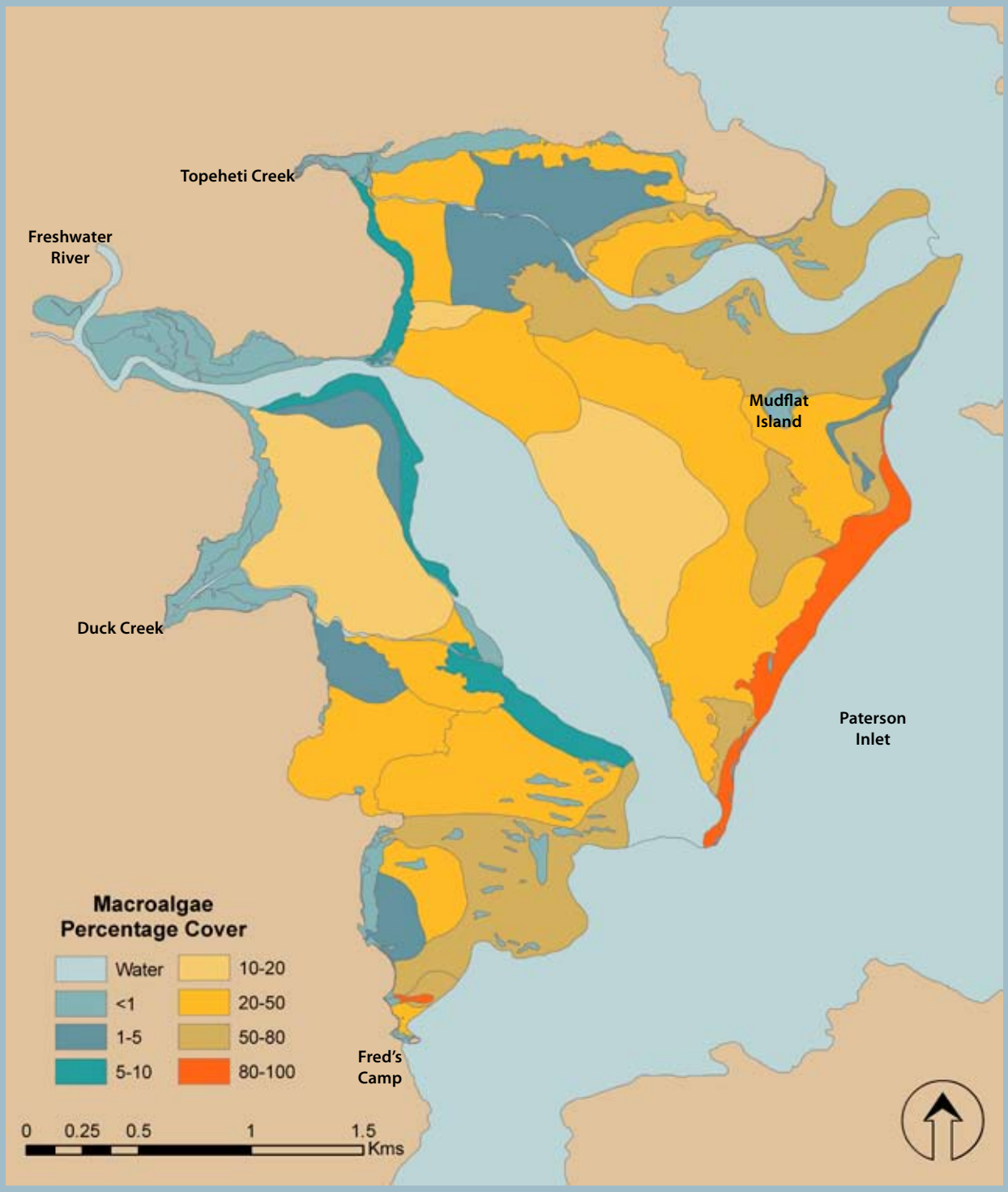
Table 7. Summary of macroalgal cover results, February 2008.

MACROALGAE	Freshwater Estuary		
Percentage Cover	Area (ha)	Percentage	Dominant Species
Unvegetated	27.8	4.5	
1-5%	64.4	10.4	*Enteromorpha*
5-10%	19.4	3.1	*Enteromorpha, Gracilaria, Ulva*
10-20%	109.9	17.7	*Gracilaria, Enteromorpha*
20-50%	235.3	37.8	*Gracilaria, Enteromorpha, Ulva*
50-80%	145.5	23.4	*Gracilaria, Ulva*
>80%	19.4	3.1	*Ulva*

At present it is unclear as to the source of the nutrients supporting the relatively high cover of macroalgae in the estuary. However, ultrabasic rock in the catchment can cause drainage waters to become alkaline and such alkalinisation has the potential to increase nitrogen inputs to the streams draining these catchments through increased organic matter turnover (Biggs and Gerbeaux 1993).

It is also possible that nitrogen fixing bacteria associated with the seagrass beds are supporting macroalgal growth within the estuary. Environment Southland are looking to collect additional data on catchment inputs while fine scale monitoring proposed for 2009 will measure sediment nutrients to better understand the source.

Figure 2. Map of Macroalgae Percentage Cover - Freshwater Estuary, February 2008



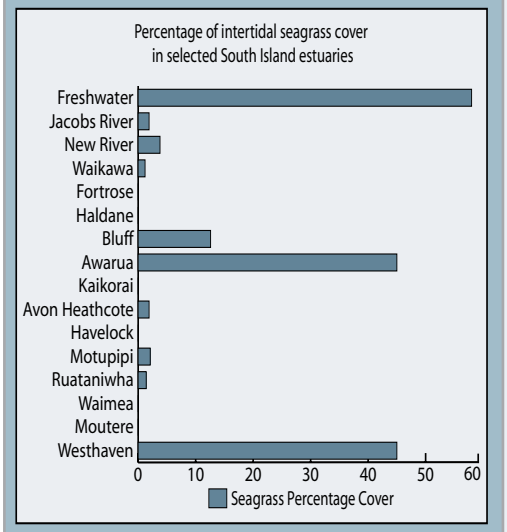
3. RESULTS AND DISCUSSION (CONTINUED)

SEAGRASS MAPPING

Seagrass (*Zostera capricorni*) is highly valued ecologically for its multiple roles in primary production, nutrient cycling, sediment stabilisation, and as a feeding and nursery area for fish and invertebrates. Seagrass meadows are also a major source of detrital material, and the bacteria and fungi that decompose this material contribute significantly to the sediment nitrogen pool and provide a food source for zooplankton, worms, etc., which are the base of the predatory food web. Seagrass is also an important forerunner to the establishment of saltmarsh on tidal flats, and grows subtidally where water clarity allows light to penetrate to it. Table 8 and Figure 3 summarise the results of seagrass mapping in Freshwater Estuary.

Table 8. Summary of seagrass cover results, February 2008.

SEAGRASS	Freshwater Estuary	
Percentage Cover	Area (ha)	Percentage
Unvegetated	262.5	42.2
1-5%	2.2	0.4
5-10%	5.1	0.8
10-20%	6.3	1.0
20-50%	37.2	6.0
50-80%	88.0	14.2
>80%	220.3	35.4

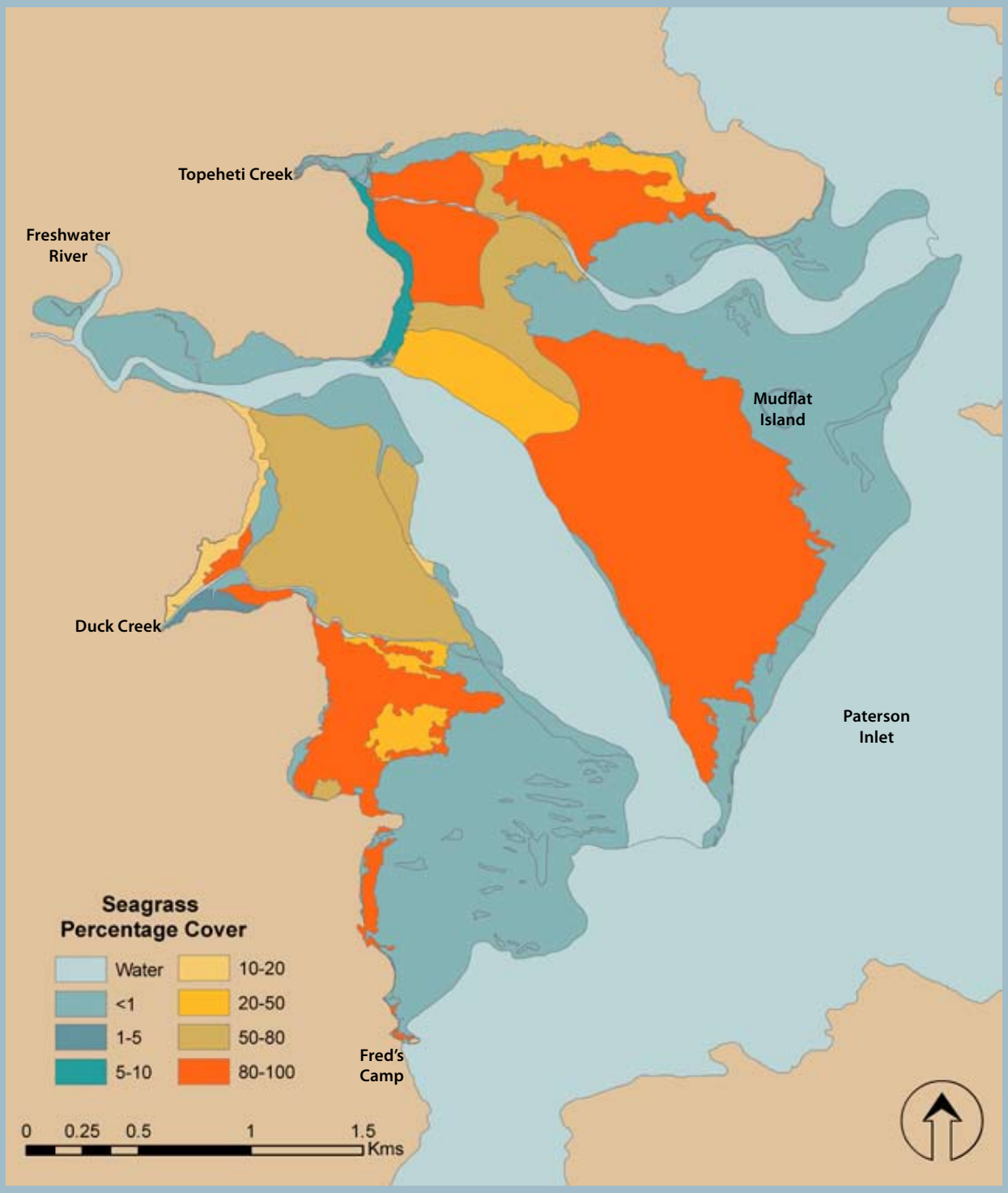


The Seagrass Coefficient (SC) for the estuary was "very high" (7.6), a condition rating of "very good" reflecting that half the estuary had a seagrass cover >50%. Seagrass cover is commonly <5% of the intertidal area in NZ estuaries (see inset Figure for South Island examples), with the exceptions being those estuaries that have relatively intact terrestrial margins and low suspended sediment inputs e.g. Freshwater, Awarua, Westhaven.

Within Freshwater Estuary, seagrass was predominantly located in firm sand in the upper reaches of the delta (Figure 3), with the highest density cover between Mudflat Island and Freshwater River. The beds appeared healthy, often with a clearly distinct edge between seagrass and adjacent sandflats (see the aerial photo in Figure 4 and photo below left). Within the seagrass, macroalgae growths were common, and at times thick.

Like macroalgae, the source of nutrients supporting these dense seagrass beds are likely to originate mainly from catchment inputs and nitrogen fixation in the seagrass root zone.

Figure 3. Map of Seagrass Percentage Cover - Freshwater Estuary, February 2008



SALTMARSH MAPPING

Saltmarsh vegetation (able to tolerate saline conditions and where terrestrial plants are unable to survive) is highly productive, provides important habitat for a variety of species, naturally filters sediments and nutrients, and acts as an important buffer that protects against introduced weeds and grasses. Results are summarised in Figure 4 with the broad vegetation class and species composition shown in Table 9.

Overall, saltmarsh covered 5% of the estuary (condition rating = "moderate"). While this may appear to be low for a largely unmodified estuary, it reflects that Freshwater Estuary has limited suitable habitat available for saltmarsh growth because of the open nature of the delta, the generally steep surrounding hills, and the confined nature of the upper river estuary contained within incised river banks.

The saltmarsh was dominated by rushland (almost exclusively jointed wire rush - 99%) with a subcomponent of flax, saltmarsh ribbonwood and tall fescue usually at the landward edge. The largest area was located at the mouth of Freshwater River in old river channels, now slightly elevated above the estuary and inundated only on spring tides or at high river flows. While much of the lower Freshwater River valley floor is low lying, it is predominantly a terrestrial wetland dominated by heath and bog communities.

An interesting feature was seagrass growing among the rushland in the upper reaches of the estuary between Duck Creek and Freshwater River (lower left photo).

A very narrow strip of saltmarsh ribbonwood and flax was present at the terrestrial margin of the rushland around Duck Creek, with terrestrial native scrub and forest backing directly onto the estuary in most other areas.

Table 9. Summary of saltmarsh vegetation results, February 2008.

Class	Dominant Species	Primary subdominant species	Ha	%
Estuarine Shrubs			0.5	1.3
	Plagianthus divaricatus (Saltmarsh ribbonwood)		*0.2*	*0.5*
		Phormium tenax (New Zealand flax)	*0.3*	*0.8*
Rushland			39.3	98.7
	Apodasima similis (Jointed wirerush)		*32.0*	*80.4*
		Plagianthus divaricatus (Saltmarsh ribbonwood)	*3.5*	*8.8*
		Phormium tenax (New Zealand flax)	*2.6*	*6.6*
		Festuca arundinacea (Tall fescue)	*1.1*	*2.8*
Total			39.8	100

Saltmarsh by Duck Creek

Figure 4. Map of Saltmarsh Vegetation - Freshwater Estuary, February 2008

TERRESTRIAL MARGIN MAPPING

Examples of saltmarsh in front of native bush.

Low cliff along the southern margin.

Native bush on the raised banks of Freshwater River.

Like saltmarsh, a densely vegetated terrestrial margin provides important habitat for a variety of species, naturally filters sediments and nutrients entering the estuary, and acts as an important buffer protecting against introduced weeds and grasses. The results of the 200m terrestrial margin mapping are summarised in Figure 5.

All of the 200m terrestrial margin was covered by a dense assemblage of native scrub/ shrub (50%) and mature native forest (50%), a condition rating of "very good".

Native scrub (particularly manuka - *Leptospermum scoparium* and inaka - *Dracophyllum longifolium*) dominated the valley floor adjacent to Freshwater River, and was perched a couple of metres above the river level. Native podocarp forest (rimu, kamahi, miro and rata all prominent) covered the hillsides to the north and south and either extended directly to the estuary or bordering saltmarsh, or in many instances, ended in a low cliff between 1-4 metres high.

Figure 5. Map of 200m Terrestrial Margin Features - Freshwater Estuary, February 2008

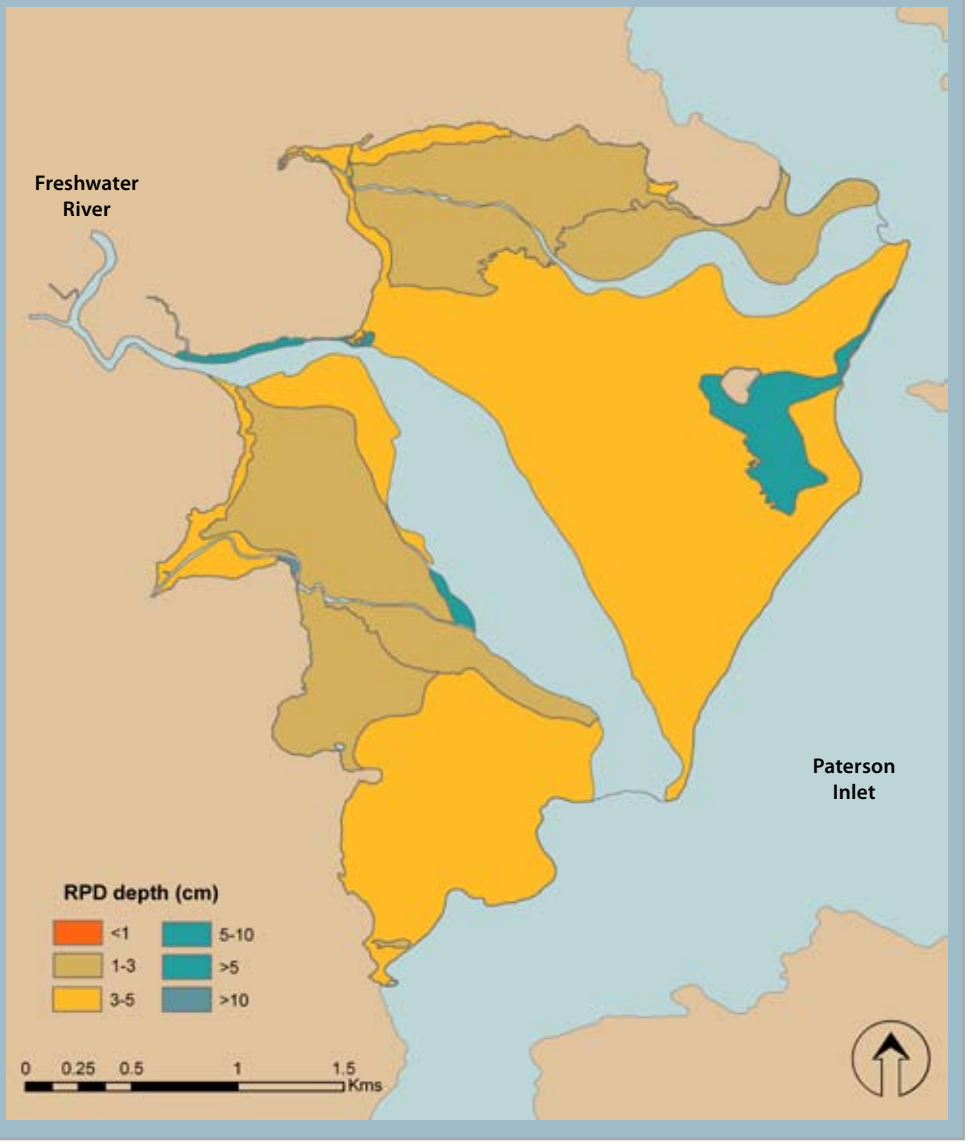
REDOX POTENTIAL DISCONTINUITY (RPD) MAPPING

The Redox Potential Discontinuity (RPD) depth, which marks the transition between oxygenated and reduced conditions, is summarised in Figure 6 (based on approximately 80 data points). Across the majority of the estuary the RPD was between 3-5cm deep, although among seagrass beds in the upper tidal range, it was closer to the surface (1-3cm). Overall the RPD condition rating was "fair to good".

However, the black sediment used to indicate the RPD depth was not particularly sulphide enriched and did not represent eutrophic conditions that commonly creates an ecological barrier to sediment dwelling macrofauna. In contrast, a vibrant and healthy sediment dwelling community was evident, and the sediments appeared to be well oxygenated and in good condition with the enriched layer often limited to a band a few centimetres wide and overlying clean sand (see photos).

Fine scale monitoring proposed for 2008/2009 will provide more detailed measures of the sediment conditions and animals living within them.

Figure 6. Map of RPD depth - Freshwater Estuary, February 2008



3. RESULTS AND DISCUSSION (CONTINUED)

MONITORING SEDIMENTATION RATE

In order to enable the sedimentation rate from now into the future to be measured, four plates (20cm square concrete blocks) were buried approximately 20m apart in a square configuration deep in the sediments where substrate was stable. The site was located in unvegetated firm sand where sediment from Freshwater River was considered most likely to deposit. It is proposed to add a second site on the northern site of the delta in 2009.

The position of each plate was marked with wooden stakes, their GPS positions logged, and the depth from the undisturbed mud surface to the top of the sediment plate was recorded (Table 10). Following establishment of this baseline, ongoing monitoring results can be used to determine the sedimentation rate in the estuary, with a sediment condition rating developed and used to assess any changes.

Table 10. Location and depth of sedimentation plates and height of marker stakes.

Site	No.	DATE	NZMG EAST	NZMG NORTH	Plate Depth (mm)
West (Duck Creek)	1	10/4/08	2127174	5355217	235
West (Duck Creek)	2	10/4/08	2127167	5355236	250
West (Duck Creek)	3	10/4/08	2127181	5355249	286
West (Duck Creek)	4	10/4/08	2127192	5355234	278

CONDITION RATINGS

The 2008 broad scale mapping has enabled condition ratings to be applied for the key issues of sedimentation (extent of soft mud), eutrophication (macroalgal cover), and habitat loss (extent of seagrass, saltmarsh, and terrestrial vegetated buffer). In addition a baseline has been established against which future changes in the estuary can be assessed. A summary of condition ratings is presented in Table 11, with results discussed for each issue in Section 5.

Table 11. Summary of Condition Ratings for indicators of estuary issues.

BROAD SCALE RATING 2008	% COVER SOFT MUD	% COVER MACROALGAE	% COVER SEAGRASS	% COVER SALTMARSH	RPD DEPTH	TERRESTRIAL VEGETATED BUFFER
FRESHWATER ESTUARY	VERY GOOD	FAIR	VERY GOOD	MODERATE	FAIR/GOOD	VERY GOOD

4. CONCLUSIONS

Freshwater Estuary (812ha) is a relatively large "tidal river mouth" type estuary with an extensive sandy intertidal delta. The estuary is dominated by vast and healthy seagrass (*Zostera*) beds (58% of the intertidal area) that are thriving in the sandy sediment and clear water conditions in the estuary. Sediments appeared to be well oxygenated and in good condition, with the RPD depth 3-5cm across most of the estuary. Saltmarsh (predominantly jointed wire rush) was limited in its extent due to the topography surrounding the estuary, present mostly in firm mud/sand as a narrow band on the east of the estuary between Duck and Topeheti Creeks. All of the 200m terrestrial margin was covered in dense native forest and scrub. Macroalgal growth (predominantly *Gracilaria chilensis* and, to a lesser extent, *Enteromorpha* and *Ulva*) was widespread, (>5% cover across 85% of the intertidal area) but was generally not associated with nuisance conditions.

The broad scale intertidal monitoring results, in combination with other available information, are used below to provide an overview of likely estuary condition in relation to the key issues examined in this broad scale assessment, namely sedimentation, eutrophication and habitat loss.

SEDIMENTATION: Freshwater Estuary is dominated by firm sand with very little soft mud present, giving the estuary a very good condition rating for sedimentation. The dominance of firm sand reflects that fine sediment inputs are limited by the intact sequence of dense saltmarsh and native forest surrounding the estuary, while high wind fetch across the delta is likely to promote wave generated resuspension and removal of fine sediment from the estuary. The clear water and firm sands provide ideal habitat for the large areas of seagrass that are a dominant feature of the intertidal flats.

The primary broad scale indicator of sediment deposition is the area of soft mud. Because the dense native forest catchment and catchment geology combine to limit sediment inputs it is recommended that broad scale mapping of the intertidal area be undertaken 5 yearly, then as determined based on the condition ratings. Fine scale indicators of grain size and sedimentation rate are to be collected over three years starting in 2009, then as determined based on the condition ratings.

EUTROPHICATION: Macroalgae is present throughout Freshwater Estuary, particularly on the lower estuary delta, giving it a rating of fair, although nuisance conditions were not observed. Nuisance intertidal macroalgal growth is a key broad scale indicator of eutrophication, along with the depth of the RPD layer. Current uncertainty over the nutrient source supporting the macroalgal growth will be addressed as part of the fine scale monitoring baseline to be collected over three years starting in 2009. Broad scale mapping of macroalgal cover is recommended annually for this period, then as determined based on the condition ratings.

HABITAT LOSS: Freshwater Estuary lies within Rakiura National Park and the waters of Te Whaka a Te Wera Mataitai Reserve. As such, there is little potential for human modification of the estuary saltmarsh or vegetated terrestrial margin, and past habitat loss has been minimal. The vast intertidal seagrass beds have high ecological value but may be susceptible to key stressors such as climate change or sea level rise.

The primary broad scale indicators of habitat loss are the area of saltmarsh, seagrass, and terrestrial vegetated buffer, and condition ratings will be applied when the broad scale mapping is repeated. Repeat broad scale mapping is recommended in 2013, then as determined based on the condition ratings.

5. RECOMMENDED MONITORING

Freshwater Estuary has been identified by ES as a priority for monitoring, and is a key part of ES's existing estuary monitoring programme being undertaken in a staged manner throughout Southland. The excellent condition of the estuary means it is a very important reference for assessing the health of other estuaries in the region and, as such, should be monitored regularly. Other key features, in particular the highly valued seagrass beds and sandy substrate, need to be maintained. Because seagrass health is directly linked to nutrient loadings, sedimentation rates, water clarity, and sediment oxygenation levels, fine scale monitoring of the estuary is recommended to ensure these parameters are maintained at levels supporting a healthy seagrass community. In addition, broad scale mapping of sedimentation rates and macroalgal cover are recommended to indicate changes in sedimentation and eutrophication, along with broad scale habitat mapping to monitor key long-term stressors of climate change and sea level rise. The following specific monitoring is recommended:

Fine Scale Monitoring	Establish a 3 year fine scale baseline (scheduled for 2009-11) then monitor thereafter on a 5 yearly cycle or as deemed necessary based on the condition ratings.
Broad Scale Macroalgal Mapping	Map macroalgal cover in January-March as the fine scale baseline is established over 3 years, and then as deemed necessary based on the condition ratings.
Broad Scale Sedimentation Rate Mapping	Install sediment plates in representative parts of the estuary (e.g. one new site on the north side of the estuary delta) in January-March 2009. Monitor annually thereafter or as deemed necessary based on the condition ratings.
Broad Scale Habitat Mapping	Repeat broad scale habitat mapping at 5 yearly intervals (next scheduled for 2013), and then as deemed necessary based on the condition ratings.

The recommended monitoring will provide a baseline record of a near pristine estuary against which to compare other estuaries in the region, as well as identifying any changes in estuary condition. This will provide a robust framework for identifying, evaluating and providing management options for any significant issues that arise within Freshwater Estuary in the future. Because Freshwater Estuary is relatively unmodified and the surrounding land is protected within Rakiura National Park, direct management action by ES is currently considered unnecessary.

6. REFERENCES

REPORT REFERENCES

Atkinson, I.A.E. 1985. Derivation of vegetation mapping units for an ecological survey of Tongariro National Park Nth Island, NZ. NZ Journal of Botany, 23; 361-378.

Biggs B.J.F., Gerbeaux P., 1993. Periphyton development in relation to macro-scale (geology) and micro-scale (velocity) limiters in two gravel-bed rivers, New Zealand. NZ Journal of Marine and Freshwater Research, 27; 39-53.

Jørgensen, N., Revsbech, N.P. 1985. Diffusive boundary layers and the oxygen uptake of sediments and detritus. Limnology and Oceanography 30:111-122.

Robertson, B.M. Gillespie, P.A. Asher, R.A. Frisk, S. Keeley, N.B. Hopkins, G.A. Thompson, S.J. Tuckey, B.J. 2002. Estuarine Environmental Assessment and Monitoring: A National Protocol. Part A. Development, Part B. Appendices, and Part C. Application. Prepared for supporting Councils and the Ministry for the Environment, Sustainable Management Fund Contract No. 5096. Part A. 93p. Part B. 159p. Part C. 40p plus field sheets.

Robertson B.M., Tuckey B.J., Robertson B. 2003. Broadscale mapping of Jacobs River Estuary intertidal habitats. Prepared for Environment Southland.

Robertson B.M., Asher R. 2003. Environment Southland Estuary Monitoring 2003. Prepared for Environment Southland.

Robertson B.M., Asher R., Sneddon R. 2004. Environment Southland Estuary Monitoring 2004. Prepared for Environment Southland.

Robertson B.M., Asher, R. 2006. Environment Southland Estuary Monitoring 2006. Prepared for Environment Southland.

Robertson, B.M. and Stevens, L. 2006. Southland Estuaries State of Environment Report 2001-2006. Prepared for Environment Southland.

Robertson, B.M. and Stevens, L. 2007. Waikawa Estuary 2007 Fine Scale Monitoring & Historical Sediment Coring. Prepared for Environment Southland. 29p.

Robertson, B.M. and Stevens, L. 2008. Southland Coast, Te Waewae Bay to the Catlins Habitat Mapping, Risk Assessment, and Monitoring. Prepared for Environment Southland.

Stevens, L., Asher, R. 2005. Environment Southland Estuary Monitoring 2005. Prepared for Environment Southland.

6. REFERENCES (CONTINUED)

ENVIRONMENT SOUTHLAND COASTAL MONITORING REPORTS

Robertson, B.M. and Stevens, L. 2008. Southland Coast, Te Waewae Bay to the Catlins Habitat Mapping, Risk Assessment, and Monitoring. Prepared for Environment Southland.

Robertson, B., Stevens, L. 2007. New River Estuary 2007 Broad Scale Habitat Mapping and Sedimentation Rate. Prepared for Env. Southland. 34p.

Robertson, B., Stevens, L. 2007. Waikawa Estuary 2007 Fine Scale Monitoring and Historical Sediment Coring. Prepared for Env. Southland. 29p.

Robertson B.M., Asher, R. 2006. Environment Southland Estuary Monitoring 2006. Prepared for Environment Southland.

Robertson, B., Stevens, L. 2006. Southland Estuaries State of Environment Report 2001-2006. Prepared for Env. Southland.

Robertson B.M., Asher R., Sneddon R. 2004. Environment Southland Estuary Monitoring 2004. Prepared for Env. Southland.

Robertson, B., Stevens, L., Thompson, S., Robertson, B. 2004. Broad scale intertidal habitat mapping of Awarua Bay. Prepared for Env. Southland.

Robertson, B., Stevens, L., Thompson, S., Robertson, B. 2004. Broad scale intertidal habitat mapping of Bluff Harbour. Prepared for Env. Southland.

Robertson, B., Stevens, L., Thompson, S., Robertson, B. 2004. Broad scale intertidal habitat mapping of Waikawa Estuary. Prepared for Env. Southland.

Robertson B.M., Asher R. 2003. Environment Southland Estuary Monitoring 2003. Prepared for Env. Southland.

Robertson B.M., Tuckey B.J., Robertson B. 2003. Broadscale mapping of Jacobs River Estuary intertidal habitats. Prepared for Env. Southland.

Robertson B.M., Tuckey B.J., Robertson B. 2003. Broadscale mapping of Fortrose Estuary intertidal habitats. Prepared for Env. Southland.

Robertson, B.M., Gillespie, P.A., Asher, R.A., Frisk, S., Keeley, N.B., Hopkins, G.A., Thompson, S.J., Tuckey, B.J. 2002. Estuarine Environmental Assessment and Monitoring: A National Protocol. Part A. Development, Part B. Appendices, and Part C. Application. Prepared for supporting Councils and the Ministry for the Environment, Sustainable Management Fund Contract No. 5096. Part A. 93p. Part B. 159p. Part C. 40p plus field sheets.

Robertson, B.M. 1997. Southland Coastal Ecology Programme 1996-7. Report prepared for Southland Regional Council. Barry Robertson, Consultant, Nelson. 50p.

Robertson, B.M. 1995. Southland Estuaries: heavy metal monitoring. Report prepared for the Southland Regional Council. Robertson Ryder & Associates, Dunedin. 35p.

Robertson, B.M. 1992. Aparima Catchment Water Quality Review. Report prepared for the Southland Regional Council. Barry Robertson & Associates, Dunedin. 67p.

Robertson, B.M. 1992. New River Estuary: Review of Existing Water Quality. Report prepared for Southland Regional Council. Barry Robertson & Assoc, Dunedin. 76p.

Stevens, L. Robertson, B., 2008. Waiau Lagoon 2008. Broad scale habitat mapping 2007/08. Report prepared for Environment Southland. 19p.

Stevens, L. Robertson, B., 2008. New River Estuary 2008. Macroalgal monitoring 2007/08. Report prepared for Environment Southland. 5p.

Stevens, L. Robertson, B., 2007. Jacobs River Estuary 2007. Macroalgal monitoring. Report prepared for Environment Southland. 4p.

Stevens, L. Robertson, B., 2007. Waituna Lagoon 2007. Broad Scale Habitat Mapping and Historical Sediment Coring. Report prepared by Wriggle Coastal Management for Environment Southland. 36p.

Stevens, L. Robertson, B., 2007. Waituna Lagoon 2007. Ecological Vulnerability Assessment and Monitoring Recommendations. Report prepared by Wriggle Coastal Management for Environment Southland. 40p.

Stevens, L., Asher, R. 2005. Broad scale intertidal habitat mapping of Haldane Estuary. Prepared for Environment Southland.

Stevens, L., Asher, R. 2005. Environment Southland Estuary Monitoring 2005. Prepared for Environment Southland.

Stevens, L. Clarke, M. 2004. Broad scale mapping of subtidal habitat and ecology of Bluff Harbour, 2004. Prepared for Environment Southland.

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APPENDIX 1. BROAD SCALE HABITAT CLASSIFICATION DEFINITIONS

Forest: Woody vegetation in which the cover of trees and shrubs in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants ≥10 cm diameter at breast height (dbh). Tree ferns ≥10cm dbh are treated as trees. Commonly sub-grouped into native, exotic or mixed forest.

Treeland: Cover of trees in the canopy is 20-80%. Trees are woody plants >10cm dbh. Commonly sub-grouped into native, exotic or mixed treeland.

Scrub: Cover of shrubs and trees in the canopy is >80% and in which shrub cover exceeds that of trees (c.f. FOREST). Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed scrub.

Shrubland: Cover of shrubs in the canopy is 20-80%. Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed shrubland.

Tussockland: Vegetation in which the cover of tussock in the canopy is 20-100% and in which the tussock cover exceeds that of any other growth form or bare ground. Tussock includes all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and >100 cm height. Examples of the growth form occur in all species of Cortaderia, Gahnia, and Phormium, and in some species of Chionochloa, Poa, Festuca, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla, and Celmisia.

Duneland: Vegetated sand dunes in which the cover of vegetation in the canopy (commonly Spinifex, Pingao or Marram grass) is 20-100% and in which the vegetation cover exceeds that of any other growth form or bare ground.

Grassland: Vegetation in which the cover of grass (excluding tussock-grasses) in the canopy is 20-100%, and in which the grass cover exceeds that of any other growth form or bare ground.

Sedgeland: Vegetation in which the cover of sedges (excluding tussock-sedges and reed-forming sedges) in the canopy is 20-100% and in which the sedge cover exceeds that of any other growth form or bare ground. "Sedges have edges." Sedges vary from grass by feeling the stem. If the stem is flat or rounded, it's probably a grass or a reed, if the stem is clearly triangular, it's a sedge. Sedges include many species of Carex, Uncinia, and Scirpus.

Rushland: Vegetation in which the cover of rushes (excluding tussock-rushes) in the canopy is 20-100% and where rush cover exceeds that of any other growth form or bare ground. A tall grasslike, often hollow-stemmed plant, included in rushland are some species of Juncus and all species of Leptocarpus.

Reedland: Vegetation in which the cover of reeds in the canopy is 20-100% and in which the reed cover exceeds that of any other growth form or open water. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either round and hollow – somewhat like a soda straw, or have a very spongy pith. Unlike grasses or sedges, reed flowers will each bear six tiny petal-like structures. Examples include Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata, and Baumea articulata.

Cushionfield: Vegetation in which the cover of cushion plants in the canopy is 20-100% and in which the cushion-plant cover exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions.

Herbfield: Vegetation in which the cover of herbs in the canopy is 20-100% and where herb cover exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens.

Lichenfield: Vegetation in which the cover of lichens in the canopy is 20-100% and where lichen cover exceeds that of any other growth form or bare ground.

Introduced weeds: Vegetation in which the cover of introduced weeds in the canopy is 20-100% and in which the weed cover exceeds that of any other growth form or bare ground.

Seagrass meadows: Seagrasses are the sole marine representatives of the Angiospermae. They all belong to the order Helobiae, in two families: Potamogetonaceae and Hydrocharitaceae. Although they may occasionally be exposed to the air, they are predominantly submerged, and their flowers are usually pollinated underwater. A notable feature of all seagrass plants is the extensive underground root/rhizome system which anchors them to their substrate. Seagrasses are commonly found in shallow coastal marine locations, salt-marshes and estuaries.

Macroalgal bed: Algae are relatively simple plants that live in freshwater or saltwater environments. In the marine environment, they are often called seaweeds. Although they contain cholorophyll, they differ from many other plants by their lack of vascular tissues (roots, stems, and leaves). Many familiar algae fall into three major divisions: Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae). Macroalgae are algae observable without using a microscope.

Cliff: A steep face of land which exceeds the area covered by any one class of plant growth-form. Cliffs are named from the dominant substrate type when unvegetated or the leading plant species when plant cover is ≥1%.

Rock field: Land in which the area of residual rock exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Boulder field: Land in which the area of unconsolidated boulders (>200mm diam.) exceeds the area covered by any one class of plant growth-form. Boulder fields are named from the leading plant species when plant cover is ≥1%.

Cobble field: Land in which the area of unconsolidated cobbles (20-200 mm diam.) exceeds the area covered by any one class of plant growth-form. Cobble fields are named from the leading plant species when plant cover is ≥1%.

Gravel field: Land in which the area of unconsolidated gravel (2-20 mm diameter) exceeds the area covered by any one class of plant growth-form. Gravel fields are named from the leading plant species when plant cover is ≥1%.

Mobile sand: The substrate is clearly recognised by the granular beach sand appearance and the often rippled surface layer. Mobile sand is continually being moved by strong tidal or wind-generated currents and often forms bars and beaches. When walking on the substrate you'll sink <1 cm.

Firm sand: Firm sand flats may be mud-like in appearance but are granular when rubbed between the fingers, and solid enough to support an adult's weight without sinking more than 1-2 cm. Firm sand may have a thin layer of silt on the surface making identification from a distance difficult.

Soft sand: Substrate containing greater than 99% sand. When walking on the substrate you'll sink >2 cm.

Firm mud/sand: A mixture of mud and sand, the surface appears brown, and may have a black anaerobic layer below. When walking you'll sink 0-2 cm.

Soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When you'll sink 2-5 cm.

Very soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking you'll sink >5 cm.

Cockle bed: Area that is dominated by both live and dead cockle shells.

Mussel reef: Area that is dominated by one or more mussel species.

Oyster reef: Area that is dominated by one or more oysters species.

Sabellid field: Area that is dominated by raised beds of sabellid polychaete tubes.

Shell bank: Area that is dominated by dead shells.

Artificial structures: Introduced natural or man-made materials that modify the environment. Includes rip-rap, rock walls, wharf piles, bridge supports, walkways, boat ramps, sand replenishment, groynes, flood control banks, stopgates.