coastalmanagement

Freshwater Estuary

Broad Scale Habitat Mapping 2012/13

Prepared for

Environment Southland

November 2013

Cover Photo: Freshwater Estuary near Fred's Camp, February 2013.

Unmodified terrestrial margin, Freshwater Estuary, February 2013

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By

Leigh Stevens and Barry Robertson

Wriggle Limited, PO Box 1622, Nelson 7040, Ph 021 417 936 or 0275 417 935, www.wriggle.co.nz

All photos by Wriggle except where noted otherwise.

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EXECUTIVE SUMMARY

This report summarises the results of the 2013 broad scale intertidal habitat mapping of Freshwater Estuary, a relatively large (818ha), unmodified "tidal river plus intertidal delta" type estuary that has established within the confines of Paterson Inlet. It drains the native forest catchment of the Mt Anglem highlands and Ruggedy Mountains area. Its lower reaches meander across Freshwater Valley, the largest area of flat land on Stewart Island. It is one of the key estuaries in Environment Southland's long-term coastal monitoring programme. The following sections summarise broad scale monitoring results (from the current report and previous studies), condition ratings, overall estuary condition, and monitoring and management recommendations.

BROAD SCALE RESULTS

- Sandy substrate dominated the estuary (98%, 663ha), with very little soft mud present (<1%, 2ha). There had been no significant change in dominant substrate cover from 2008-2013.
- High density non-nuisance macroalgae (>50%) covered 45% (288ha) of the intertidal area, with highest densities on the seaward edge and channel margins of the estuary. Remaining intertidal areas supported widespread non-nuisance low density growths. There had been a large natural increase in high density non-nuisance macroalgae from 2008-2013 (27% to 45%).
- Gross eutrophic conditions were not present within the estuary.
- Dense seagrass cover (>50%) was very high (315ha, 47%). There had been no significant change from 2008-2013.
- Saltmarsh cover was 40ha (5%), of which 99% was dominated by rushland (jointed wire rush) and 1% by estuarine shrub (saltmarsh ribbonwood). Although saltmarsh extent was naturally constrained by topography, it grew extensively wherever conditions enabled it to establish. There had been no significant change from 2008-2013.
- Densely vegetated 200m terrestrial margin (scrub and forest) cover was high (100%), with an even split between native forest (50%) and native scrub (50%). There had been no significant change from 2008-2013.

RATINGS			CONDITION RATINGS		CHANGE RATINGS
Major Issue	Overall Rating	Indicator	2008	2013	Change from 2008 Baseline
Muddiness	VERY GOOD	Soft mud area	Very Good	Very Good	No increase
Eutrophication	MODERATE	Low density macroalgal cover	High	Moderate	Decrease
		High density macroalgal cover	High	Very High	Very large (natural) increase
		Gross eutrophic condition area	Very Good	Very Good	No increase
Habitat Modification	VERY GOOD	Seagrass Coefficient/area	Very Good	Very Good	No decrease
		Saltmarsh area	Moderate	Moderate	No decrease
		Densely vegetated margin area	Very Good	Very Good	No decrease

ESTUARY CONDITION AND ISSUES

Because Freshwater Estuary lies within Rakiura National Park and the waters of Te Whaka a Te Wera Mataitai Reserve, there is little potential for direct human modification of the estuary, saltmarsh or terrestrial margin, and past habitat disturbance has been minimal. In relation to the key issues addressed by the broad scale monitoring (i.e. sediment, eutrophication, and habitat modification), the 2013 broad scale mapping results show that the estuary was in an unmodified condition with sandy well-oxygenated sediments, high production of both seagrass and macroalgae, clear waters, and an absence of typical eutrophication symptoms. No significant change was observed from 2008 to 2013. Consequently, it provides a key reference for assessing the condition of other estuaries in Southland and New Zealand, with the most likely drivers of future changes in Freshwater Estuary expected to be from global stressors such as climate change or sea level rise.

RECOMMENDED MONITORING AND MANAGEMENT

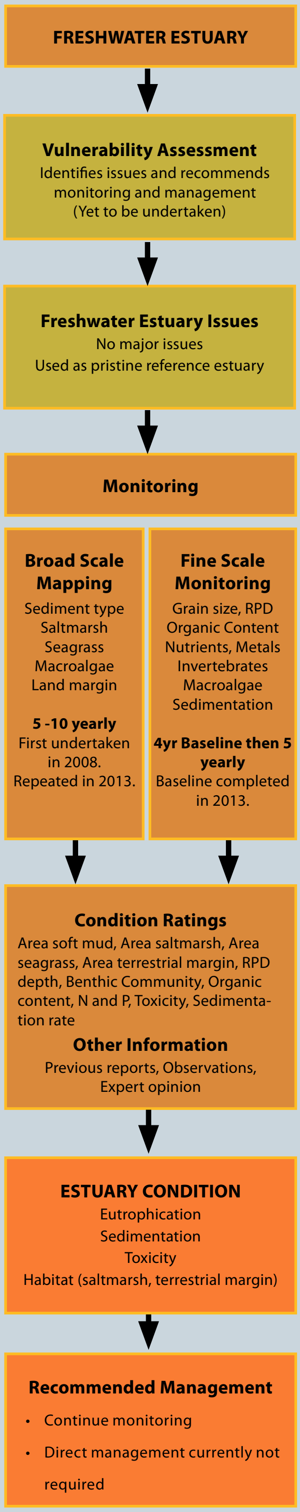
To provide an ongoing reference against which to compare changes in the more developed estuaries of the Southland region, it is recommended that:

- Broad scale habitat mapping be repeated every 5 years (next due in 2018).
- Fine scale intertidal monitoring be repeated on a 5 yearly cycle (next due in 2018).
- Sedimentation rate and macroalgal monitoring be repeated on a 5 yearly cycle (next due in 2018).

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.

However, it is recommended that research work be undertaken to assess the source of the nutrients driving the elevated macroalgal growth in the estuary, to help guide effective management of other estuaries in the region.

1. INTRODUCTION



Developing an understanding of the condition and risks to coastal and estuarine habitats is critical to the management of biological resources. Recently, Environment Southland (ES) undertook vulnerability assessments of its region's coastlines to establish priorities for a long-term monitoring programme for the region (Robertson and Stevens 2008). These assessments identified the following estuaries as immediate priorities for monitoring: Waikawa, Haldane, Fortrose (Toetoes), New River, Waimatuku, Jacobs River, Waituna Lagoon, Waiau Lagoon, and Lake Brunton. In order to provide information on more pristine estuaries in the region, Freshwater Estuary, Stewart Island was included in ES's estuary monitoring priorities and ES began monitoring Freshwater Estuary in April 2008, with the work being undertaken by Wriggle Coastal Management using the National Estuary Monitoring Protocol (NEMP) (Robertson et al. 2002) plus recent extensions. The monitoring consists of three components:

1. **Ecological Vulnerability Assessment** (EVA) of the estuary to major issues (Table 1) and appropriate monitoring design. Because of its low priority for assessment compared with other estuaries in the region, this component has not yet been undertaken for Freshwater Estuary.
2. **Broad Scale Habitat Mapping** (NEMP approach). This component, which documents the key habitats within the estuary (Table 2), and changes to these habitats over time, was undertaken in 2008 (Stevens and Robertson (2008). The second survey is the focus of the current report.
3. **Fine Scale Monitoring** (NEMP approach). Monitoring of physical, chemical and biological indicators (Table 2) including sedimentation rate monitoring. This component, which provides detailed information on the condition of Freshwater Estuary, is reported on in Robertson and Stevens 2009, 2010, 2011 and 2013.

To help evaluate overall estuary condition and decide on appropriate monitoring and management actions, a series of condition ratings has also been developed and is described in Section 2.

The current report describes the following work undertaken in February 2013:

- Broad scale mapping of estuary sediment types.
- Broad scale mapping of macroalgal beds (i.e. *Ulva* (sea lettuce), *Gracilaria*).
- Broad scale mapping of gross eutrophic areas.
- Broad scale mapping of seagrass (*Zostera muelleri*) beds.
- Broad scale mapping of saltmarsh vegetation.
- Broad scale mapping of the 200m terrestrial margin surrounding the estuary.

Freshwater Estuary is a relatively large (818ha), unmodified "tidal river plus intertidal delta" type estuary that has established within the confines of Paterson Inlet. Fed by the largest river on Stewart Island, Freshwater River, it drains the native forest catchment of the Mt Anglem highlands and Ruggedy Mountains area. Its lower reaches meander 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 the estuary is exposed at low tide), and supports very large areas of seagrass. The combination of a hard-rock, native bush catchment and clear waters, good flushing and wave resuspension means that the majority of the delta sediments are sandy and homogeneous, and muddy sediments are a very minor component (<1%). Because of the unmodified nature of the estuary, including its high value seagrass and saltmarsh habitats and natural vegetated margin and catchment, Freshwater Estuary serves as a valuable reference estuary for the rest of New Zealand.

Recreational use of the estuary is moderate, mainly for walking, bird study, scenic values, fishing and shellfish collection. Commercially, the estuary is used for access to the Stewart Island walkway. Ecologically, habitat diversity is high, given the benefits of extensive sandy intertidal flats and seagrass beds, clear seawater, saltmarsh, and a native forest catchment. It provides important habitat for the endangered NZ dotterel.

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

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.
Eutrophication (Nutrients)	Increased nutrient richness of estuarine ecosystems stimulates the production and abundance of fast-growing algae, such as phytoplankton, and short-lived macroalgae (e.g. sea lettuce). Fortunately, because most New Zealand estuaries are well flushed, phytoplankton blooms are generally not a major problem. Of greater concern are the mass blooms of green and red macroalgae, mainly of the genera *Cladophora, Ulva,* and *Gracilaria* which are now widespread on intertidal flats and shallow subtidal areas of nutrient-enriched New Zealand estuaries. They present a significant nuisance problem, especially when loose mats accumulate on shorelines and decompose. Blooms also have major ecological impacts on water and sediment quality (e.g. reduced clarity, physical smothering, lack of oxygen), affecting or displacing the animals that live there.
Disease Risk	Runoff from farmland and human wastewater often carries a variety of disease-causing organisms or pathogens (including viruses, bacteria and protozoans) that, once discharged into the estuarine environment, can survive for some time. Every time humans come into contact with seawater that has been contaminated with human and animal faeces, we expose ourselves to these organisms and risk getting sick. Aside from serious health risks posed to humans through recreational contact and shellfish consumption, pathogen contamination can also cause economic losses due to closed commercial shellfish beds. Diseases linked to pathogens include gastroenteritis, salmonellosis, hepatitis A, and noroviruses.
Toxic Contamination	In the last 60 years, New Zealand has seen a huge range of synthetic chemicals introduced to estuaries through urban and agricultural stormwater runoff, industrial discharges and air pollution. Many of them are toxic in minute concentrations. Of particular concern are polycyclic aromatic hydrocarbons (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 broad and fine scale NEMP indicators (shading signifies indicators used in the broad scale monitoring assessments)**.**

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

Figure 1. Freshwater Estuary - location of fine scale and sedimentation rate monitoring sites.

2. METHODS

BROAD SCALE HABITAT MAPPING

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 NEMP 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 (e.g. ArcMap).

Rectified ~0.75m/pixel resolution colour aerial photos flown by ES in 2008 were supplied by ES. Photos at a scale of 1:5,000 were laminated, and experienced scientists ground-truthed the spatial extent of dominant habitat and substrate types on 16 February 2013 by walking the area and recording features directly on the laminated aerial photos. Previously mapped features were re-checked in the field using an iPad (iGIS app) which showed live position tracking in relation to 2008 shapefiles of estuary features.

Field notes and photographs were subsequently combined to produce GIS-based habitat maps showing dominant cover of: substrate, macroalgae (e.g. *Ulva, Gracilaria*), gross eutrophic conditions, seagrass (*Zostera*), saltmarsh vegetation, and the 200m wide terrestrial margin vegetation/land use.

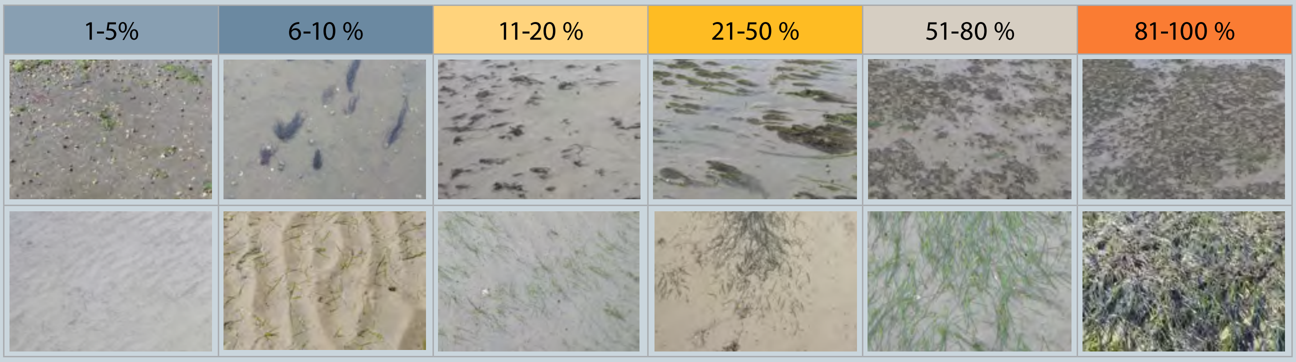
Appendix 1 lists the definitions used to classify substrate and vegetation. The composition of vegetation was classified using an interpretation of the Atkinson (1985) system, where the dominant plant species were coded by using the two first letters of their Latin genus and species names e.g. marram grass, *Ammophila arenaria*, was coded as Amar. Dominance was indicated by the order of codes and the use of ( ) to distinguish subdominant species e.g. Amar(Caed) indicates that marram grass was dominant over ice plant (*Carpobrotus edulis*). A measure of vegetation height can be derived from its structural class (e.g. rushland, scrub, forest).

When present, macroalgae and seagrass were mapped using a 6 category percent cover rating scale (see Figure 2 below) to describe density.

Broad scale habitat features were subsequently digitised from aerial photos into ArcMap 9.3 shapefiles using a Wacom Cintiq21UX drawing tablet. The broad scale results are summarised in Section 3, with the supporting GIS files (supplied on a separate CD) providing a much more detailed data set designed for easy interrogation to address specific monitoring and management questions.

The georeferenced spatial habitat maps allow the 2013 results to be compared to changes from the 2008 survey (Stevens and Robertson 2008).

Figure 2. Visual rating scale for percentage cover estimates of macroalgae (top) and seagrass (bottom).



2. METHODS (CONTINUED)

CONDITION AND CHANGE RATINGS

A series of broad scale estuary "condition and change ratings" (below) have been proposed for Freshwater Estuary based on ratings developed for NZ's estuaries - e.g. Robertson & Stevens 2006, 2007, 2008, 2012 and a recent review of NZ monitoring data (Robertson and Stevens, in prep). As more NZ data become available, and the understanding of estuary condition improves, condition ratings will continue to be revised and updated.

The ratings are designed to be used in combination with each other, along with other important condition indices, and expert input, when evaluating overall estuary condition and deciding on appropriate management. Some 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).

SOFT MUD (PERCENT COVER)

Estuaries are a sink for sediments. Where large areas of soft mud are present, they are likely to lead to major and detrimental ecological changes that could be very difficult to reverse, and indicate where changes in land management may be needed.

SOFT MUD PERCENT COVER CONDITION RATING

CONDITION RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<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	6%-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)

SOFT MUD (CHANGE IN 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 CHANGE RATING

CHANGE RATING	DEFINITION	RECOMMENDED RESPONSE
No Increase	Area of cover (ha) not increasing, or is decreasing	Monitor at 10 year intervals after baseline established
Small Increase	Increase in area of cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Moderate Increase	Increase in area of cover (ha) 5-15% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Large Increase	Increase in area of cover (ha) 16-50% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Very Large Increase	Increase in area of cover (ha) >50% from baseline	Post baseline, monitor 5 yearly. Initiate ERP

LOW DENSITY MACROALGAL COVER

A two part macroalgae condition rating has been developed: 1. for low density (<50%) macroalgal cover throughout the estuary, and 2. a warning indicator for hotspots of high density (>50%) cover (see following rating). Low density macroalgal condition is rated using a continuous index (the macroalgae coefficient - MC) based on the percentage cover of macroalgae in defined categories in the estuary where cover is <50%. The equation used is: *MC=((0 x %macroalgal cover <1%)+(0.5 x %cover 1-5%)+(1.5 x %cover 5-10%)+(4.5 x %cover 10-20%)+(7.5 x %cover 20-50%))/100.*

LOW DENSITY MACROALGAL COVER CONDITION RATING

CONDITION RATING	DEFINITION	MC	RECOMMENDED RESPONSE
Very Low	Very Low	0.0 - 0.2	Monitor at 5 year intervals after baseline established
Low	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
Moderate	Low-Moderate	>1.5 - 2.2	Monitor yearly. Initiate ERP
	Moderate	>2.2 - 4.5	Monitor yearly. Initiate ERP
High	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)

2. METHODS (CONTINUED)

HIGH DENSITY MACROALGAL COVER

The high density macroalgae condition rating targets areas of high density growth and is applied to the percentage of the estuary where the cover of intertidal macroalgae exceeds 50%. While this may not necessarily be combined with the presence of nuisance conditions, dense growths are an early warning of the estuary potentially exceeding its assimilative capacity and developing gross eutrophic conditions. A trend of an increasing dense macroalgal cover, or an increasing Macroalgal Coefficient for low density cover, provides an "early warning trigger" for initiating management action.

HIGH DENSITY MACROALGAL COVER CONDITION RATING		
CONDITION RATING	>50% MACROALGAL COVER OVER:	RECOMMENDED RESPONSE
Very Low	<1% of estuary	Monitor at 5 year intervals after baseline established
Low	1-5% of estuary	Post baseline, monitor 5 yearly. Initiate ERP
Moderate	6-10% of estuary	Monitor yearly. Initiate Evaluation & Response Plan
High	11-30% of estuary	Monitor yearly. Initiate Evaluation & Response Plan
Very High	>30% of estuary	Monitor yearly. Initiate Evaluation & Response Plan

HIGH DENSITY MACROALGAL COVER (CHANGE IN AREA)

Increases in the area of dense macroalgal cover indicate changes in catchment land use management are likely to be needed. Because extensive cover of dense macroalgae is commonly associated with gross eutrophic conditions that can be very difficult to reverse, even relatively small changes from baseline conditions should be evaluated as a priority.

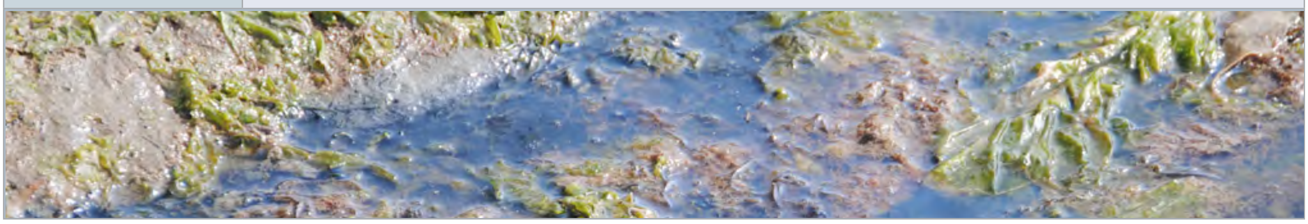
HIGH DENSITY MACROALGAL COVER, AREA CHANGE RATING		
CHANGE RATING	DEFINITION	RECOMMENDED RESPONSE
No increase	Area of cover (ha) not increasing, or is decreasing	Monitor at 5 year intervals after baseline established
Small Increase	Increase in area of cover (ha) <5% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Moderate Increase	Increase in area of cover (ha) 5-15% from baseline	Post baseline, monitor annually. Initiate ERP
Large Increase	Increase in area of cover (ha) 16-50% from baseline	Post baseline, monitor annually. Initiate ERP
Very Large Increase	Increase in area of cover (ha) >50% from baseline	Post baseline, monitor annually. Initiate ERP

GROSS EUTROPHIC CONDITIONS (AREA)

Gross eutrophic conditions occur when sediments exhibit combined symptoms of: a high mud content, a shallow Redox Potential Discontinuity (RPD) depth, elevated nutrient and total organic carbon concentrations, displacement of invertebrates sensitive to organic enrichment, and high macroalgal growth (>50% cover).

Persistent and extensive areas of gross nuisance conditions should not be present in short residence time estuaries, and their presence provides a clear signal that the assimilative capacity of the estuary is being exceeded. Consequently, the actual area exhibiting nuisance conditions, rather than the % of an estuary affected, is the primary condition indicator. Natural deposition and settlement areas, often in the upper estuary where flocculation at the freshwater/saltwater interface occurs, are commonly first affected. The gross eutrophic condition rating is based on the area affected by the combined presence of poorly oxygenated and muddy sediments, and a dense (>50%) macroalgal cover, as follows:

GROSS EUTROPHIC CONDITION RATING		
CONDITION RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	No nuisance conditions	Monitor at 5 year intervals after baseline established
Low	Area of nuisance conditions <0.5ha	Monitor at 5 year intervals after baseline established
Fair	Area of nuisance conditions 0.5-5ha	Post baseline, monitor 5 yearly. Initiate ERP
Poor	Area of nuisance conditions 6-20ha	Post baseline, monitor annually. Initiate ERP
Very Poor	Area of nuisance conditions >20ha	Post baseline, monitor annually. Initiate ERP
Early Warning Trigger	Area of nuisance conditions >0.5ha or increasing	Initiate ERP (Evaluation and Response Plan)



2. METHODS (CONTINUED)

GROSS EUTROPHIC CONDITIONS (CHANGE IN AREA)

Increases in the area of gross eutrophic conditions indicate changes in catchment land use management are likely to be needed. Because of the highly undesirable and often rapidly escalating decline in estuary quality associated with gross eutrophic conditions, even relatively small changes from baseline conditions should be evaluated as a priority.

GROSS EUTROPHIC AREA CHANGE RATING

CHANGE RATING	DEFINITION	RECOMMENDED RESPONSE
No increase	Area of cover (ha) not increasing, or is decreasing	Monitor at 5 year intervals after baseline established
Small Increase	Increase in area of cover (ha) <5% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Moderate Increase	Increase in area of cover (ha) 5-15% from baseline	Post baseline, monitor annually. Initiate ERP
Large Increase	Increase in area of cover (ha) 16-50% from baseline	Post baseline, monitor annually. Initiate ERP
Very Large Increase	Increase in area of cover (ha) >50% from baseline	Post baseline, monitor annually. Initiate ERP

SEAGRASS INDEX

Seagrass (*Zostera muelleri*) 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 and excessive nutrients 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%)+(6x %cover 10-20%)+(9x %cover 20-50%)+(12 x %cover 50-80%)+(15 x %cover >80%))/100.***

The "early warning trigger" for initiating management action is a trend of a decreasing Seagrass Coefficient.

SEAGRASS CONDITION RATING

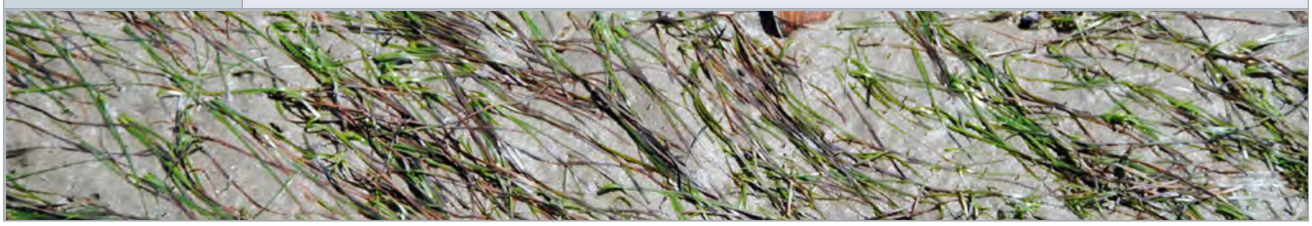
CONDITION RATING	DEFINITION	SC	RECOMMENDED RESPONSE
Poor	Very Low	0.0 - 0.2	Post baseline, monitor 5 yearly. Initiate ERP
Fair	Low	>0.2 - 0.8	Post baseline, monitor 5 yearly. Initiate ERP
	Low Low-Moderate	>0.8 - 1.5	Post baseline, monitor 5 yearly. Initiate ERP
Good	Low-Moderate	>1.5 - 2.2	Monitor at 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)

SEAGRASS (CHANGE IN AREA)

Seagrass is vulnerable to fine sediments in the water column, rapid sediment deposition, poor sediment quality (particularly reduced oxygen or production of sulphide), excessive macroalgal growth, high nutrient concentrations, and reclamation. Decrease in seagrass extent is likely to indicate an increase in these types of pressures.

SEAGRASS AREA CHANGE RATING

CHANGE RATING	DEFINITION	RECOMMENDED RESPONSE
No Decrease	Area of cover (ha) not decreasing, or is increasing	Monitor at 5 year intervals after baseline established
Small Decrease	Decrease in area of cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Moderate Decrease	Decrease in area of cover (ha) 5-15% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Large Decrease	Decrease in area of cover (ha) 16-50% from baseline	Post baseline, monitor annually. Initiate ERP
Very Large Decrease	Decrease in area of cover (ha) >50% from baseline	Post baseline, monitor annually. Initiate ERP



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. The "early warning trigger" for initiating management action is <5% of the estuary as saltmarsh.

SALTMARSH PERCENT COVER CONDITION RATING

CONDITION RATING	DEFINITION	RECOMMENDED RESPONSE
Very High	>20% of estuary area is saltmarsh	Monitor at 10 year intervals after baseline established
High	11%-20% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
Moderate	6%-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 (CHANGE IN 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. Decrease in saltmarsh extent is likely to indicate an increase in these types of pressures.

SALTMARSH AREA CHANGE RATING

CHANGE RATING	DEFINITION	RECOMMENDED RESPONSE
No Decrease	Area of cover (ha) not decreasing, or is increasing	Monitor at 10 year intervals after baseline established
Small Decrease	Decline in area of cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Moderate Decrease	Decline in area of cover (ha) 5-10% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Large Decrease	Decline in area of cover (ha) 11-50% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Very Large Decrease	Decline in area of cover (ha) >50% from baseline	Post baseline, monitor annually. Initiate ERP

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. The "early warning trigger" for initiating management action is <50% of the estuary with a densely vegetated margin.

TERRESTRIAL VEGETATED BUFFER PERCENT COVER CONDITION RATING

CONDITION RATING	DEFINITION	RECOMMENDED RESPONSE
Very High	81%-100% cover of terrestrial vegetated buffer	Monitor at 10 year intervals after baseline established
High	51%-80% cover of terrestrial vegetated buffer	Monitor at 5 year intervals after baseline established
Fair	26%-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 (CHANGE IN 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 CHANGE RATING

CHANGE RATING	DEFINITION	RECOMMENDED RESPONSE
No Decrease	Vegetated buffer not decreasing, or is increasing	Monitor at 10 year intervals after baseline established
Small Decrease	Decline in vegetated buffer (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Moderate Decrease	Decline in vegetated buffer (ha) 5-10% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Large Decrease	Decline in vegetated buffer (ha) 11-50% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Very Large Decrease	Decline in vegetated buffer (ha) >50% from baseline	Post baseline, monitor annually. Initiate ERP

3. RESULTS AND DISCUSSION

BROAD SCALE MAPPING

Shell, rock and boulder habitat in the upper intertidal.

Mussel reef in the mid-low intertidal.

SOFT MUD % COVER CONDITION RATING
2008 VERY GOOD (<1%)
2013 VERY GOOD (<1%)

SOFT MUD AREA CHANGE RATING
2008-2013 NO INCREASE

Broad scale habitat mapping uses measures of the area of soft mud, macroalgal cover, gross eutrophic zones, seagrass, saltmarsh, and the densely vegetated 200m terrestrial margin to apply condition ratings to assess key estuary issues of sedimentation, eutrophication, and habitat modification. The results of the February 2013 broad scale assessment are presented in the following sections.

In 2013, 678ha of estuary was mapped comprising 323ha unvegetated intertidal flats, 40ha tidal saltmarsh, and 315ha seagrass (Table 3). A further 141ha was covered by water at low tide. The mapping extent mirrored as much as possible that presented in Stevens and Robertson (2008) to facilitate the comparison of results for key condition ratings (Table 3), although in 2013 the border of the southeastern seaward edge of the estuary was better defined (contributing to minor changes in Table 3).

Table 3. Summary of broad scale features, Freshwater Estuary, 2008 and 2013.

Dominant Estuary Features	2008		2013	
	Ha	%	Ha	%
Saltmarsh	39.8	4.9%	39.8	4.9%
Seagrass (>50% cover)	308.3	37.9%	314.7	38.4%
Unvegetated intertidal flats	313.3	38.6%	323.3	39.5%
Water	151.0	18.6%	140.6	17.2%
TOTAL	**812**	**100**	**818**	**100**

SUBSTRATE MAPPING

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

Figure 3 and Table 4 summarise the unvegetated intertidal substrate of Freshwater Estuary. The primary indicator of sediment impacts is the area of the estuary dominated by soft and very soft muds, with estuaries with an area >5% mud exceeding the early warning trigger for management action. Freshwater Estuary had very little soft mud (2ha, 0.3% present in the northwest where Topeheti Creek enters the estuary), with the vast majority (99.5%) firm sand or shell, or rock/boulder/cobble (0.2%). Such conditions place the estuary in the "very good" condition rating and all of the habitats appeared to be in good (healthy) ecological condition.

CHANGES IN ESTUARY SOFT MUD 2008-2013

There was no change in the soft mud extent from 2008-2013, indicating estuary sediment composition remained in very good condition.

Table 4. Summary of dominant intertidal substrate, Freshwater Estuary, February 2013.

Dominant Substrate	Area Ha	Percentage	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	0.9	Cockle banks along the seaward edge of the delta.
Mobile sand	26.7	3.9	Mostly along the subtidal channel on the southern side of Freshwater River.
Firm sand	608.6	89.8	Dominant across most of the intertidal delta.
Firm mud/sand	24.7	3.6	In saltmarsh areas to the west near Freshwater River.
Soft sand	2.6	0.4	In front of saltmarsh between Duck Creek and Freshwater River.
Soft mud	2.0	0.3	Confined to the Topeheti Creek arm in the northwest delta.
TOTAL	**678**	**100**	

Figure 3. Map of dominant intertidal substrate types - Freshwater Estuary, February 2013.

BROAD SCALE MAPPING (CONT.)

LOW DENSITY MACROALGAL CONDITION RATING

2013 MODERATE

HIGH DENSITY MACROALGAL CONDITION RATING

2013 VERY HIGH

GROSS EUTROPHIC AREA CONDITION RATING

2013 VERY GOOD

Dense macroalgal growth on firm intertidal sand flats near Freshwater River.

HIGH DENSITY MACROALGAL COVER CHANGE RATING

2008 to 2013 VERY LARGE INCREASE

INTERTIDAL MACROALGAL COVER

Nuisance macroalgal blooms are a symptom of estuary eutrophication. These can deprive seagrass beds of light causing their decline, while decaying macroalgae can accumulate subtidally and on shorelines causing oxygen depletion and nuisance odours. The results of the 2013 intertidal macroalgal survey (Table 5 and Figure 4) showed:

- A large portion of the intertidal area 288ha (45%) had high density (>50%) macroalgal cover, but no gross nuisance conditions were observed.
- The dominant macroalgal species were the green alga *Ulva intestinalis* (concentrated along channel margins) and *Ulva lactuca* (which dominated near the seaward edge of the estuary) and the red alga *Gracilaria chilensis* (widespread on the intertidal flats).
- Neptune's necklace (*Hormosira banksii*), which had washed in from the sea, formed a dense (50-80%) cover over 22ha in the southwest.

Table 5. Summary of intertidal macroalgal cover, Freshwater Estuary, Feb. 2013.

MACROALGAE	Freshwater Estuary		
Percentage Cover	Ha	%	Dominant species
<1%	32	4.9	-
1-5%	63	9.9	*Ulva intestinalis, U. lactuca, Gracilaria chilensis*
5-10%	56	8.8	*Gracilaria chilensis, Ulva lactuca, U. intestinalis*
10-20%	66	10.3	*Ulva intestinalis, Gracilaria chilensis*
20-50%	134	21.1	*Gracilaria chilensis, Ulva lactuca*
50-80%	268.1	42.0	*Ulva intestinalis, U. lactuca, Gracilaria chilensis*
>80%	19.4	3.0	*Ulva intestinalis, Gracilaria chilensis*
TOTAL	**638**	**100**	

Condition ratings have been developed to characterise the distribution of low density macroalgal growths in the estuary (which generally do not cause significant nuisance conditions), and distinguish these from areas of high density macroalgal growths that are commonly associated with nuisance conditions and sediment deterioration, particularly when they combine with excessive soft muds in estuaries.

The Macroalgal Coefficient (MC) for low density cover within the estuary in 2013 was 4.1 (Table 6), a condition rating of "moderate", reflecting widespread low growth across much of the estuary. The high density macroalgal cover was rated as "very high" with 45% of the estuary experiencing dense (>50%) macroalgal growths. However, despite this extensive high density cover, the estuary exhibited no signs of eutrophication and was in a very good condition.

CHANGES IN INTERTIDAL MACROALGAL COVER 2008-2013

Compared to the macroalgal cover in 2008, there had been a decrease in low density cover but a very large increase in high density cover in 2013 (Table 6). This had not caused any nuisance conditions and reflects that pristine estuaries are able to support dense macroalgal growths without exhibiting eutrophication symptoms. Gaining an understanding of the nutrient sources and the processes that maintain Freshwater Estuary in such good condition would provide valuable information for future NZ estuary management, particularly as setting limits on nutrient inputs, and the identification and management of nutrient sources, is a priority for many of Southland's estuaries.

Table 6. Summary of intertidal macroalgal cover, Freshwater Estuary, 2008 and 2013.

Year	Low Density (MC) Rating	High Density (%) Rating	Result
2008	HIGH 5.1	HIGH (27%)	Widespread non-nuisance macroalgal growth present throughout the estuary.
2013	MODERATE 4.1	VERY HIGH (45%)	Widespread non-nuisance growth present throughout the estuary, predominantly near the seaward margins and channel areas. Localised deposits of windblown marine algae.

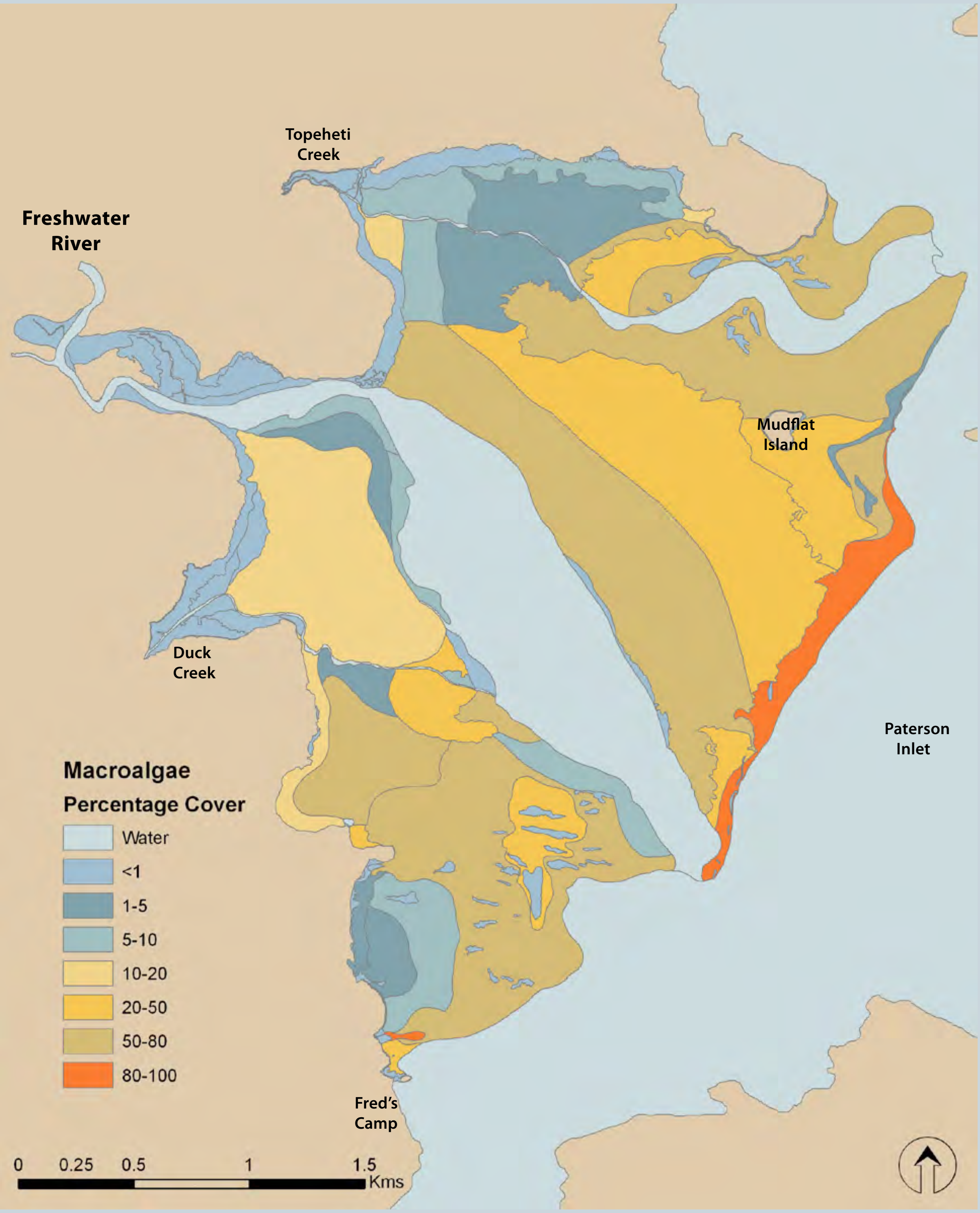


Figure 4. Map of intertidal macroalgal cover - Freshwater Estuary, February 2013.

BROAD SCALE MAPPING (CONT.)

SEAGRASS COEFFICIENT CONDITION RATING
2008 VERY GOOD
2013 VERY GOOD

Dense seagrass bed growing among rushland near Freshwater River.

SEAGRASS AREA CHANGE RATING
2008-2013 NO DECREASE

INTERTIDAL SEAGRASS COVER

Seagrass (*Zostera muelleri*) beds are important ecologically because they enhance primary production and nutrient cycling, stabilise sediments, elevate biodiversity, and provide nursery and feeding grounds for a range of invertebrates and fish. 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 supporting macroalgal growth and provide a food source for zooplankton, worms, etc., which are the base of the predatory food web. Though tolerant of a wide range of conditions, seagrass is vulnerable to stressors of excessive nutrients, fine sediments in the water column, and sediment quality (particularly if there is a lack of oxygen and the production of toxic sulphide). Because Freshwater Estuary is largely unmodified and free of these stressors, it provides one of the few remaining examples of the likely previous extent of important seagrass habitat in NZ estuaries.

The results of the 2013 intertidal seagrass survey (Table 7 and Figure 6) showed:

- Overall, 47% of the estuary had dense (>50%) seagrass cover, and seagrass was present over 55% of the intertidal area.
- The highest density beds were located in firm sand in the mid-high tidal range.
- Seagrass beds generally had a clearly defined edge with an abrupt shift to adjacent sand flats.

Table 7. Summary of seagrass cover, Freshwater Estuary, February 2013.

Percentage Cover	Area (ha)	Percentage
<1%	313	46.2
1-5%	2.2	0.3
5-10%	5.1	0.7
10-20%	5.8	0.9
20-50%	37.2	5.5
50-80%	81.0	11.9
>80%	233.7	34.5
Total	**678**	**100**

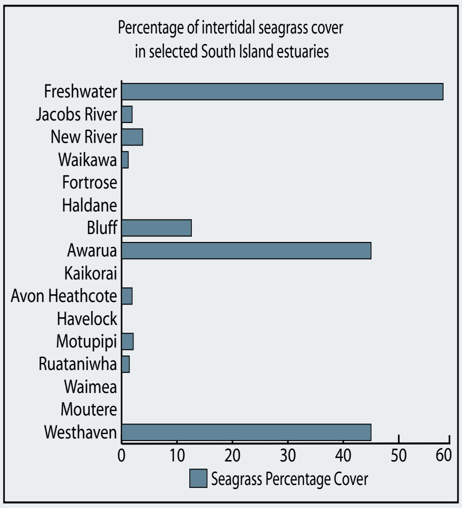


Figure 5. Percentage of seagrass cover in selected South Island estuaries.

The 2013 Seagrass Coefficient (SC) was "very high" (7.3), a condition rating of "very good" (the same rating as in 2008), reflecting the presence of dense seagrass beds over nearly half of the estuary. This high cover (present only in estuaries with relatively intact terrestrial margins and low suspended sediment inputs e.g. Awarua, Westhaven, Bluff), is well above the <5% intertidal cover commonly remaining in most other NZ estuaries (see Figure 5 for South Island examples).

Of particular interest was dense seagrass growing in rushland (see sidebar photo). This is very seldom observed in estuaries with modified catchments, probably because saltmarsh traps and concentrates fine muds lowering water clarity, reducing sediment oxygenation and creating unfavourable growing conditions. Its presence in Freshwater most likely reflects the very low sediment mud content in the estuary.

Although the estuary remains pristine (i.e. low sediment organic matter, RPD, and nutrients), it clearly contains sufficient nutrients to support dense seagrass and non-nuisance macroalgal growths. Identifying the source of nutrients, and the processes that maintain Freshwater Estuary in such good condition, would provide valuable information for NZ estuary management in the future.

CHANGES IN INTERTIDAL SEAGRASS COVER 2008-2013

There was no significant change in seagrass cover from 2008-2013 with the seagrass area change rating rated as "no decrease".

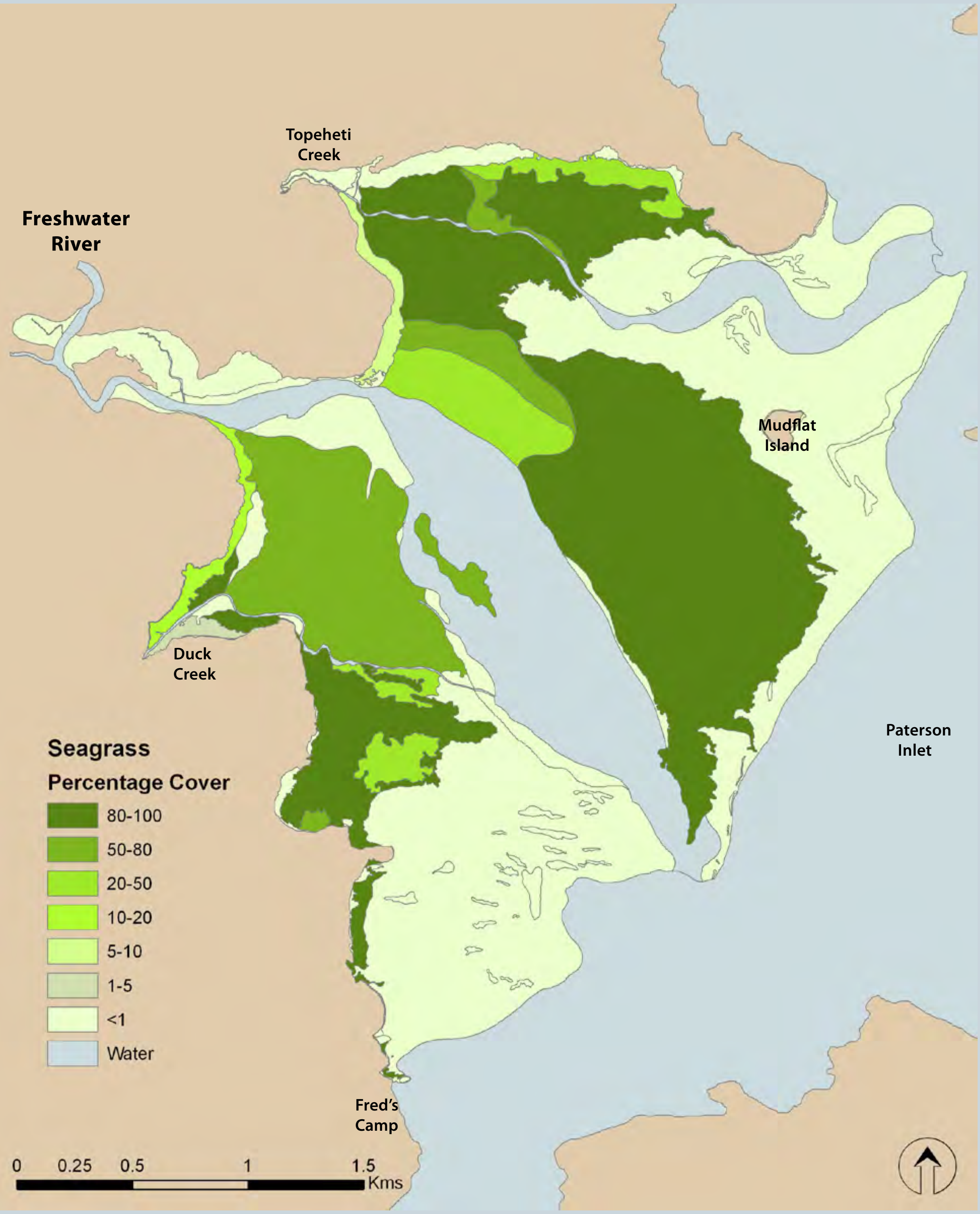


Figure 6. Map of intertidal seagrass cover - Freshwater Estuary, February 2013.

BROAD SCALE MAPPING (CONT.)

SALTMARSH % COVER CONDITION RATING
2003 MODERATE
2013 MODERATE

Rushland (top photos) and forest (lower photo) along the upper estuary margins.

SALTMARSH AREA CHANGE RATING
2008-2013 NO DECREASE

SALTMARSH MAPPING

Saltmarsh (vegetation able to tolerate saline conditions where terrestrial plants are unable to survive) is important as it is highly productive, naturally filters and assimilates sediment and nutrients, acts as a buffer that protects against introduced grasses and weeds, and provides important habitat for a variety of species including fish and birds. Table 8 and Figure 7 summarise the 2013 saltmarsh mapping results. Overall, 5% of the estuary (40ha) is saltmarsh, a condition rating of "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.

Key findings were:

- The dominant saltmarsh cover (99%) was jointed wire rush, predominantly in exclusive stands near the upper intertidal margins, and with a subdominant cover of flax, saltmarsh ribbonwood and the introduced weed species, tall fescue common near the terrestrial fringe.
- The most extensive areas of saltmarsh were located near the mouth of Freshwater River, and in a narrow strip around Duck Creek.
- Native scrub and forest grew directly to the rocky margins of the estuary edge in most other areas (lower sidebar photo).

Table 8. Summary of saltmarsh cover, Freshwater Estuary, February 2013.

Class	Dominant Species		2013	
		Primary subdominant species	Area (ha)	%
Estuarine Shrub			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
	Apodasmia 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**

CHANGES IN SALTMARSH COVER 2008-2013

The condition rating for saltmarsh measures a percentage change from an established baseline. Based on the summary information in Table 9, and using 2008 data as a baseline, the 2013 saltmarsh condition rating is rated as "no decrease". This reflects the pristine and protected nature of the estuary and surrounding catchment.

Figure 7. Map of saltmarsh vegetation - Freshwater Estuary, February 2013.

BROAD SCALE MAPPING (CONT.)

VEGETATED MARGIN % COVER CONDITION RATING
2008 VERY GOOD
2013 VERY GOOD

VEGETATED MARGIN CHANGE RATING
2008-2013 NO SIGNIFICANT CHANGE

TERRESTRIAL MARGIN COVER

Like saltmarsh, a densely vegetated terrestrial margin filters and assimilates sediment and nutrients, acts as an important buffer that protects against introduced grasses and weeds, is an important habitat for a variety of species, provides shade to help moderate stream temperature fluctuations, and improves estuary biodiversity. The results of the 200m terrestrial margin survey (Table 9 and Figure 8) showed:

- 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.

Table 9. Summary of the 200m terrestrial margin, Freshwater Estuary, February 2013.

Class	Dominant Feature	Percentage Cover
Native Forest	Mixed native and exotic scrub/forest	50%
Native Scrub	Mixed native and exotic scrub	50%
TOTAL		**100**

CHANGES IN 200m TERRESTRIAL MARGIN COVER 2008-2013

The 2013 200m terrestrial margin condition rating is rated as "no decrease". This reflects the pristine and protected nature of the estuary and surrounding catchment.

Native forest catchment behind saltmarsh at Duck Creek.

Figure 8. Map of 200m terrestrial margin vegetation - Freshwater Estuary, February 2013.

4. SUMMARY AND CONCLUSIONS

Table 10 summarises condition ratings and overall ratings in relation to the key issues addressed by the broad scale monitoring (i.e. sediment, eutrophication and habitat modification).

Table 10. Summary of broad scale condition ratings for Freshwater Estuary 2008, 2013.

Major Issue	Overall Rating	Indicator	2008	2013	Change from 2008 Baseline
Muddiness	VERY GOOD	Soft mud area	Very Good	Very Good	No increase
Eutrophication	MODERATE	Low density macroalgal cover	High	Moderate	Decrease
		High density macroalgal cover	High	Very High	Very large (natural) increase
		Gross eutrophic condition area	Very Good	Very Good	No increase
Habitat Modification	VERY GOOD	Seagrass area	Very Good	Very Good	No decrease
		Saltmarsh area	Moderate	Moderate	No decrease
		Densely vegetated margin area	Very Good	Very Good	No decrease

Overall, Freshwater Estuary was characterised by having clear waters, a sand dominated substrate, and extensive intertidal beds of dense seagrass (>50% cover over 47% of the estuary). Soft mud was scarce (2ha, 0.3%), and while macroalgal growth was extensive, it was flourishing and not causing any nuisance conditions. Saltmarsh (predominantly jointed wire rush) covered 40ha near Freshwater River, but was naturally constrained elsewhere in the estuary by the topography of the steep surrounding hills, and the intertidal delta. Although the major estuarine saltmarsh weed tall fescue was present, it was relatively scarce (<1% cover) compared with the mainland estuaries (>10% cover). The estuary's terrestrial margin was dominated by native forest and native scrub.

Because Freshwater Estuary lies within Rakiura National Park and the waters of Te Whaka a Te Wera Mataitai Reserve, there is little potential for direct human modification of the estuary, saltmarsh or terrestrial margin, and past habitat disturbance has been minimal. Consequently, it provides a key reference for assessing the condition of other estuaries in Southland and New Zealand, with the most likely drivers of future changes expected to be from global stressors such as climate change or sea level rise.

Based on the key broad scale indicators of sediment, eutrophication and habitat loss issues examined in this assessment, it is clear that Freshwater Estuary is in a near pristine state with little change in key condition indicators over the past 5 years. Estuary substrate was dominated by clean firm sands and there had been no increase in soft mud cover since 2008, which remained confined to a small area near Topeheti Creek. The dominance of sand reflects that fine sediment inputs are limited by the intact sequence of native forest and dense saltmarsh surrounding the estuary, while high wind fetch across the delta is likely to promote wave generated re-suspension and export of fine sediment from the estuary.

Macroalgal growth (dominated by *Gracilaria* and *Ulva* spp.) comprised a "moderate" widespread low-density cover, particularly on the upper estuary flats, and a "very high" high-density macroalgal cover, particularly near the seaward edge low tide channels of the estuary. Elevated nitrogen loads from natural sources (e.g. sediment N fixation, nutrient rich ocean waters and runoff from the catchment) are expected to fuel this growth, but because the sediments were sandy and well-oxygenated, and benthic biodiversity was high, the presence of high macroalgal growth was not causing nuisance conditions.

Extensive seagrass (*Zostera*) beds were a dominant feature of the intertidal flats and appeared to be under no obvious stress from macroalgal smothering, and fine sediment related reductions in sediment oxygenation and water clarity were not observed. The regular presence of the endangered NZ dotterel feeding in the seagrass beds highlights the wider ecological importance of this habitat.

While the high-density macroalgal growth would be of concern in most modified estuaries with developed catchments and elevated mud contents, in Freshwater Estuary the absence of nuisance conditions reflects the capacity for pristine estuaries to support dense natural macroalgal growths without exhibiting symptoms of eutrophication. In fact, it may be that the very extensive seagrass beds, and the associated detrital inputs and related nutrient cycling, are a key source of the nutrients which support the extensive growth of non-nuisance macroalgae in the estuary.

Gaining an understanding of the nutrient sources and the processes that maintain Freshwater Estuary in such good condition would provide valuable information for future NZ estuary management, particularly as setting limits on nutrient inputs, and the identification and management of nutrient sources, is a priority for many of Southland's estuaries.

5. MONITORING

Freshwater 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 region. This arises because the unmodified state of the estuary makes it a key reference for assessing the condition of other estuaries in Southland and New Zealand. Because the estuary is unmodified, it has a high vulnerability to sediment muddiness, eutrophication, disease risk, and habitat modification. However, the vulnerability is greatly mitigated by the protection afforded by the surrounding Rakiura National Park and the waters of Te Whaka a Te Wera Mataitai Reserve.

Based on the 2013 monitoring results and condition ratings, and changes since 2008, it is recommended that monitoring continue as follows:

Broad Scale Habitat Mapping
Repeat broad scale intertidal habitat mapping on a 5 yearly cycle (next scheduled for February 2018).

Fine Scale Monitoring
Repeat fine scale intertidal monitoring at 5 yearly intervals (next scheduled for February 2018).

Sediment Monitoring
Because sedimentation is not an obvious issue in the estuary it is recommended that sediment plate depths be measured 5 yearly in conjunction with fine scale monitoring, or more frequently if there is any indication of change within the catchment.

Macroalgal Monitoring
Although there is a widespread cover of high-density macroalgae, monitoring of macroalgal cover is only recommended 5 yearly due to the absence of nuisance conditions (next scheduled for February 2018).

6. MANAGEMENT

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.

However to better inform the process for setting limits on nutrient and sediment inputs for Southland's estuaries, it is recommended that research work be undertaken to:

Characterise Major Nutrient Sources and Nutrient Processes in Freshwater Estuary

- Freshwater Estuary is unmodified and supports extensive seagrass beds, yet also maintains extensive high-density macroalgal growth without exhibiting symptoms of eutrophication. In contrast, high-density macroalgal growths in many other Southland estuaries are strongly linked to excessive nutrient inputs and significantly degraded estuary condition.
- Assessing reference estuary nutrient loads from both terrestrial catchment and marine sources, and investigating internal nutrient cycling processes within a near pristine estuary, will help guide effective management of other estuaries in the region.

7. ACKNOWLEDGEMENTS

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APPENDIX 1. BROAD SCALE HABITAT CLASSIFICATION DEFINITIONS.

Vegetation was 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).

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 /Mussel reef/ Oyster reef: Area that is dominated by both live and dead cockle shells, or one or more mussel or oyster species respectively.

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.