Wriggle coastalmanagement

New River Estuary 2012

Broad Scale Habitat Mapping

Prepared for **Environment Southland**
November 2012

Cover Photo: Waihopai Arm looking towards Invercargill. Inside cover: Saltmarsh in Mokomoko Inlet.

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By

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All photos by Wriggle except where noted otherwise.

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NEW RIVER ESTUARY - EXECUTIVE SUMMARY

This report summarises the results of the 2012 broad scale habitat mapping of New River Estuary, a large (4,600ha) tidal lagoon estuary near Invercargill. It is one of the key estuaries in Environment Southland's long-term coastal monitoring programme. The following sections summarise broad scale monitoring results, condition ratings, overall estuary condition, and monitoring and management recommendations.

BROAD SCALE RESULTS

- Sand substrate dominated the estuary (75%, 2,199ha), mostly in the central estuary basin and towards the estuary mouth.
- Soft and very soft mud cover was extensive (24%, 669ha), and increasing, mostly in the upper northern reaches and the Waihopai Arm.
- Dense nuisance macroalgae (>50%) covered 11% (313ha) of the estuary. High densities were in the east, west and north arms, and near the Oreti River mouth with a dramatic increase (68%) evident since 2007. Most of the intertidal area (68%) had a low or very low percentage cover.
- Gross eutrophic conditions increased from <1% (23ha) of the estuary in 2001, to 2% (49ha) in 2007, to 8% (240ha) in 2012 - a 943% increase.
- Seagrass had declined by 44% (41ha) from 2001 to 2012, losses predominantly in the Waihopai Arm due to excessive sediment and macroalgae.
- Saltmarsh covered 10% of the estuary (463ha) of which 48% was rushland, 26% grassland (predominantly tall fescue among rushland), and 12% herbfield. Reclamation and artificial seawalls have historically replaced large areas of this habitat. A 10% decline in rushland was attributed to erosion in the eastern arm, displacement by grassland in the eastern and Waihopai arms, and changes in classification of features since 2001.
- There was no change in the cover of densely vegetated margin areas (31%) from 2007-2012. Margins remained dominated by grassland (56%), then a combination of scrub and forest (28%) and residential and industrial development (13%).

RATINGS		CONDITION RATINGS			CHANGE RATINGS
Major Estuary Issue	Indicator	2001	2007	2012	2001-2012 Change
Sediment	Soft mud area	POOR	POOR	POOR	LARGE INCREASE
Eutrophication	Macroalgal Coefficient	GOOD	GOOD	GOOD	TRENDING UP = WARNING
	Dense (>50%) macroalgal cover	VERY LOW	MODERATE	HIGH	VERY LARGE INCREASE
	Gross eutrophic condition area	FAIR	POOR	VERY POOR	VERY LARGE INCREASE
Habitat Modification	Seagrass Coefficient/area	POOR	POOR	POOR	VERY LARGE DECREASE
	Saltmarsh area	MOD-HIGH	MODERATE	MODERATE	SMALL DECREASE
	Densely vegetated margin area	not measured	GOOD	GOOD	NO CHANGE

ESTUARY CONDITION AND ISSUES

In relation to the key issues addressed by the broad scale monitoring (i.e. sediment, eutrophication, and habitat modification), the 2012 results indicate that although large sections of the estuary remain in good condition, there has been a significant decline in estuary quality since 2001 (and particularly over the past five years) for all measured parameters except the extent of densely vegetated margin which showed no change.

In particular, the poorly flushed Waihopai and Daffodil Bay arms were excessively muddy, have high nuisance macroalgal growths, and contain poorly oxygenated sediments with toxic sulphides. This has caused a significant loss (44%) of seagrass from the estuary, while the macroinvertebrate community in these areas is severely degraded (little animal life is able to establish in the anoxic sediments, and surface feeding species are few in number and limited to those tolerant of poor conditions). Such conditions limit food availability for fish and birdlife, and show the ability of the estuary to assimilate nutrient and sediment loads from the catchment is currently exceeded.

Issues identified in other monitoring studies of New River Estuary include; disease risk associated with shellfish consumption and bathing, toxicity near urban stormwater drains, and excessive nutrient inputs.

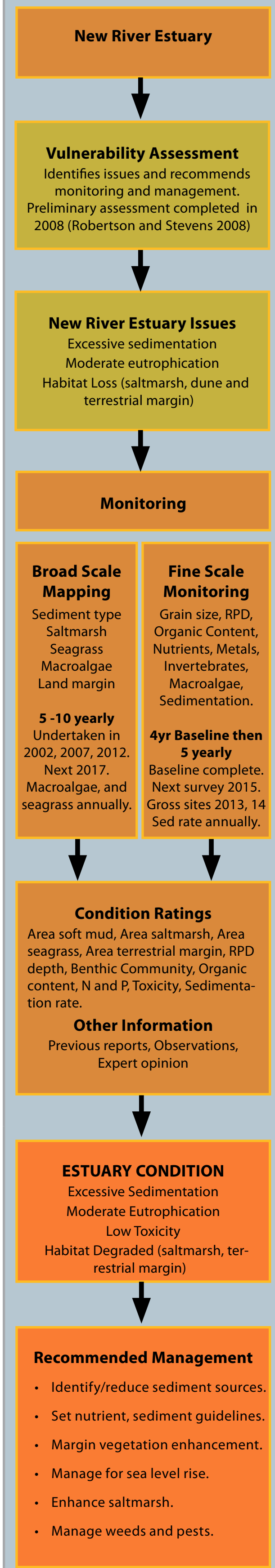
RECOMMENDED MONITORING AND MANAGEMENT

Eutrophication and sedimentation have been identified as issues in New River Estuary since at least 1973 (Blakely 1973), with worsening conditions reported since 2007-2008 (Robertson & Stevens 2007, 2008).

To address these issues it is recommended that monitoring of sedimentation rates, and seagrass and macroalgal cover continue annually, with broad scale habitat mapping every 5 years (next due in 2017). Fine scale monitoring of eutrophic sites should be repeated in Feb. 2013, 2014, and again in 2015 when the 5 yearly fine scale trend monitoring at the existing central basin sites falls due.

Previous recommendations (e.g Robertson and Stevens 2011, 2012) are reiterated for the prioritised development of catchment nutrient and sediment guideline criteria for each estuary type in Southland to derive thresholds protecting against adverse sediment and nutrient impacts. Assessment of the extent to which catchment loads meet guideline criteria will enable ES to sustainably manage the estuary and its surroundings. If catchment inputs can be assimilated by the estuary, it will flourish and provide sustainable human use and ecological values in the long term. If catchment loads exceed the estuary's assimilative capacity, it will continue to degrade. New River Estuary is recommended as the first priority for this work because of its current condition and rate of degradation.

1. INTRODUCTION



Environment Southland (ES) have an established long-term coastal monitoring programme that contributes to the information necessary to make effective management decisions. An outline of the monitoring and management process used for New River Estuary is summarised in the margin flow diagram, and below. It consists of three components developed from the National Estuary Monitoring Protocol (NEMP) (Robertson et al. 2002):

1. **Ecological Vulnerability Assessment** (EVA) of the estuary to major issues (Table 1) and appropriate monitoring design. A preliminary EVA has been completed for New River Estuary and is reported on in Robertson and Stevens (2008).
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 2002 (Robertson et al. 2002), and repeated in 2007 (Robertson and Stevens 2007). The third survey is the focus of the current report. Annual monitoring of macroalgal growth is also undertaken (e.g. Stevens and Robertson 2011).
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 the New River Estuary, has been undertaken in 2001, 2003, 2004, 2005 (Robertson and Stevens 2006) and 2010 (Robertson and Stevens 2010).

In addition, a series of condition ratings, described in Section 2, have been developed to help evaluate overall estuary condition and decide on appropriate monitoring and management actions. These ratings currently trigger annual monitoring of sedimentation rate and macroalgal growth in the estuary.

Further, extensive and increasing eutrophication and sedimentation problems (gross sites with very low sediment oxygenation and sulphide-rich sediments, smothering macroalgae, and rapid soft mud accumulation) have developed in natural settling areas within Waihopai arm and Daffodil Bay arm, particularly since 2007. Fine scale assessments have recently been undertaken in these areas to better characterise the problems evident (see Robertson and Stevens 2011, 2012).

The current report describes the following work undertaken in January 2012:

- 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.

New River Estuary is a large "tidal lagoon" type estuary (area 4,600ha), discharging to the eastern end of Oreti Beach. Situated at the confluence of the Oreti and Waihopai Rivers, it drains a primarily agricultural catchment.

This shallow estuary (mean depth ~2m) is bordered by a mix of vegetation and land uses (urban, bush and grazed pasture). It has a wide range of habitats (extensive mudflats, seagrass and saltmarsh areas) but has also lost large areas through drainage and reclamation. The Waihopai Arm has been most affected with around 1,200ha (75%) of the Arm reclaimed, greatly reducing its ability to filter, dilute, and assimilate nutrient and sediment inputs.

Invercargill City is also located adjacent to the Waihopai Arm and discharges its treated wastewater to the estuary. Nuisance blooms of macroalgae (*Ulva* and *Gracilaria*), exceedance of bathing and shellfish faecal bacterial guidelines, and sedimentation problems are common within the estuary.

As a consequence of the much reduced saltmarsh area, the estuary is expected to be more vulnerable to issues of eutrophication and sedimentation (given that saltmarsh acts to reduce nutrient and sediment impacts).

Despite the presence of these issues, human use and ecological values of large parts of the estuary are high. However, it has been recommended that management actions be taken to improve the situation in areas where the condition is poor.

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 is the mass blooms of green and red macroalgae, mainly of the genera *Cladophora, Ulva (Enteromorpha),* 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 gastro-enteritis, 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 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.

Table 2. Summary of the broad and fine scale EMP indicators (shading signifies indicators used in the fine scale monitoring assessments).

Issue	Indicator	Method
Sedimentation	Soft Mud Area	Broad scale mapping - estimates the area and change in soft mud habitat over time.
Sedimentation	Sedimentation Rate	Fine scale measurement of sediment deposition.
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. New River Estuary, showing location of fine scale and sediment monitoring sites (Photo LINZ).

2. METHODS

BROAD SCALE HABITAT MAPPING

Broad scale mapping in the Oreti Arm.

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).

For the 2012 study, ES supplied rectified ~10cm/pixel resolution colour aerial photos flown by Invercargill City Council in Jan.-March 2011. Photos covering the estuary at a scale of 1:10,000 were laminated, and two scientists ground-truthed the spatial extent of dominant habitat and substrate types by walking the area over several days, and recording features directly on the laminated aerial photos. Field notes and photographs were subsequently used to produce GIS-based habitat maps showing:

- Dominant substrate.
- Percent cover of dominant macroalgae (e.g. *Ulva, Gracilaria*).
- Percent cover of dominant seagrass (*Zostera*).
- Dominant saltmarsh vegetation.
- 200m wide terrestrial margin vegetation/landuse.

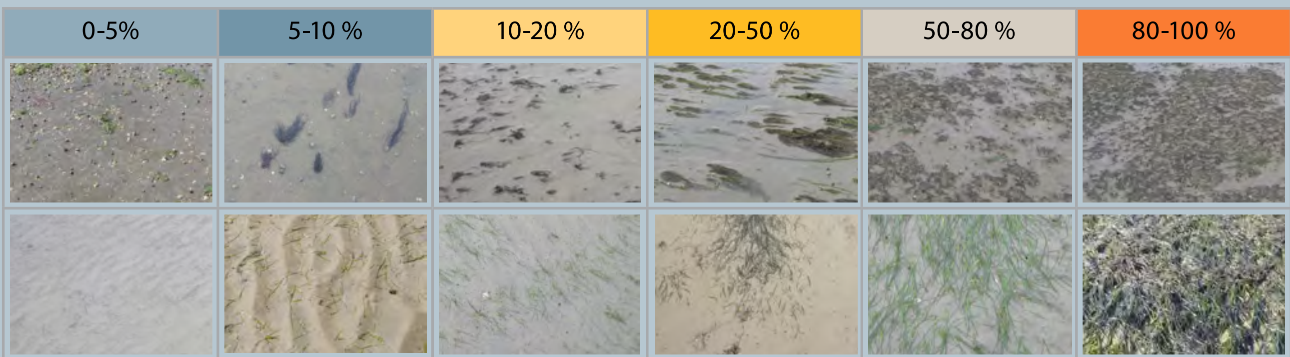
Appendix 1 lists the definitions used to classify substrate and vegetation. The composition of vegetation was classified using an interpretation of the Atkinson (1985) system, where the dominant plant species were coded by using the two first letters of their Latin genus and species names e.g. marram 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 spatially using a 7 category percent cover rating scale (see examples below) to describe density.

Broad scale habitat features were subsequently digitised from aerial photos into ArcMap 9.3 shapefiles using a Wacom Intuos3 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 changes from previous surveys undertaken in 2002 and 2007 to be compared to the 2012 results. However, because of the relatively poor quality of the 2007 aerial photos (which limited the accuracy of seagrass mapping in 2007), seagrass changes are compared with 2002 results only.

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 New River Estuary based on the ratings developed for Southland's estuaries - e.g. Robertson & Stevens 2006, 2007, 2008, and a recent review of monitoring data (Robertson and Stevens, in prep). As more NZ data become available, and the understanding of estuary condition improves, conditions ratings will continue to be revised and updated. The ratings, based on available estuary monitoring data, guideline criteria, and expert opinion, are designed to be used in combination with each other (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management. Some condition ratings include an "early warning trigger". This trigger instigates timely monitoring and management actions based on the presence of conditions that indicate the estuary is likely to be experiencing problems. In most cases initial management is to further assess an issue and consider what specific response actions are appropriate (i.e. 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
Very Small 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	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

MACROALGAL INDEX

A two part macroalgae condition rating has been developed: 1. for the whole estuary, and 2. a warning indicator for hotspots of dense cover within the estuary (see following rating). Whole estuary macroalgal condition is rated using a continuous index (the macroalgae coefficient - MC) based on the percentage cover of macroalgae in defined categories throughout the estuary. The equation used is: ***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.***

MACROALGAL COEFFICIENT CONDITION RATING

CONDITION RATING	DEFINITION	MC	RECOMMENDED RESPONSE
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)

2. METHODS (CONTINUED)

DENSE (>50%) MACROALGAL COVER

This macroalgal warning indicator targets areas of dense growth and is applied to the percentage of the estuary where the cover of intertidal macroalgal 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 (see following indicator). In addition, a trend of an increasing Macroalgal Coefficient is an "early warning trigger" is included as trigger for initiating management action.

MACROALGAE 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	>10% of estuary	Monitor yearly. Initiate Evaluation & Response Plan

DENSE (>50%) 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.

MACROALGAE 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)

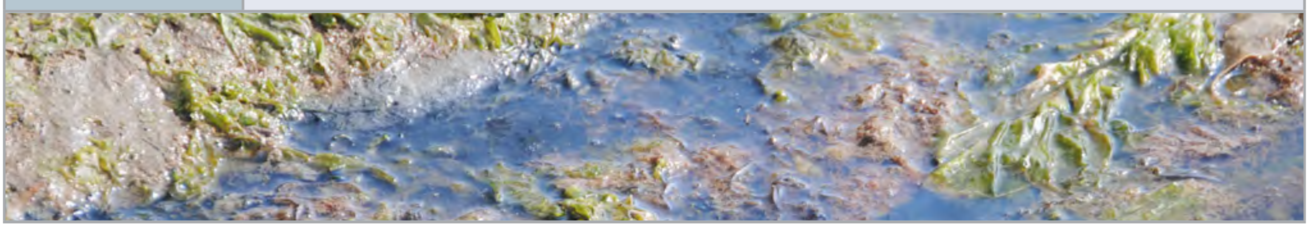
Gross eutrophic conditions occur when sediments exhibit combined symptoms of: a high mud content, a shallow RPD, elevated nutrient and TOC concentrations, displacement of invertebrates sensitive to organic enrichment, and high macroalgal growth (>50% cover).

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. Natural deposition and settlement areas, often in the upper estuary where flocculation at the freshwater/saltwater interface occurs, are commonly the first areas affected.

A condition rating developed based on the area affected by the combined presence of poorly oxygenated and muddy sediments and a high macroalgal cover (>50%) follows. The "early warning trigger" for initiating management action is >0.5ha of gross nuisance conditions in the estuary.

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



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 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%)+(0.5 x %cover 1-5%)+(2 x %cover 5-10%)+(3.5 x %cover 10-20%)+(6 x %cover 20-50%)+(9 x %cover 50-80%)+(12 x %cover >80%))/100.***

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

SEAGRASS CONDITION RATING

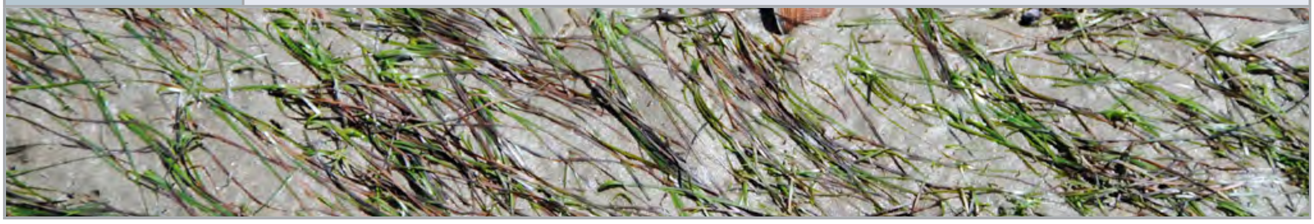
CONDITION RATING	DEFINITION (+Seagrass Coefficient)	RECOMMENDED RESPONSE
Poor	Very Low (0.0 - 0.2)	Post baseline, monitor 5 yearly. Initiate ERP
Fair	Low (0.2 - 0.8)	Post baseline, monitor 5 yearly. Initiate ERP
	Low Low-Moderate (0.8 - 1.5)	Post baseline, monitor 5 yearly. Initiate ERP
Good	Low-Moderate (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)

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. Decreases 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 5 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. Decreases 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 5 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	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 (CHANGE IN AREA)

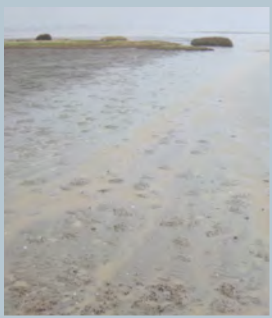
Estuaries are sensitive to a wide range of pressures including land reclamation, margin development, flow regulation, sea level rise, grazing, wastewater contaminants, and weed invasion. Reduction in the vegetated buffer around the estuary is likely to result in a decline in estuary quality.

TERRESTRIAL VEGETATED BUFFER AREA CHANGE RATING

CHANGE RATING	DEFINITION	RECOMMENDED RESPONSE
No Decrease	Terrestrial buffer is 100% dense vegetation	Monitor at 5 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



Fresh mud deposits in the Waihopai Arm (top) the Eastern Flats (middle), and Bushy Point (bottom), Jan. 2012.

Broad scale habitat mapping uses measures of the area of soft mud, macroalgal cover, seagrass, saltmarsh, and densely vegetated 200m terrestrial margin to apply condition ratings to assess key estuary issues of sedimentation, eutrophication, and habitat modification. The results of the broad scale assessment undertaken in 2012 are presented below, along with a comparison of 2001, 2007 and 2012 results for key indicators. In 2012, a total area of 4,636ha of estuary was mapped - 1,220ha covered by water at low tide, 2,952ha unvegetated intertidal flats, and 464ha tidal saltmarsh.

SUBSTRATE MAPPING

Where soil erosion from catchment development exceeds the assimilative capacity of an estuary, impacts such as increased muddiness and turbidity, shallowing, increased nutrients, changes in saltmarsh and seagrass habitats, reduced sediment oxygenation, increased organic matter degradation by anoxic processes (e.g. sulphide production) and alterations to fish and invertebrate communities can result. Also, because contaminants are most commonly associated with finer sediment particles, extensive areas of fine soft muds provide a sink which concentrate catchment contaminants.

Results (summarised in Table 3 and Figure 3) show that although sand was by far the most dominant substrate (75% of the unvegetated intertidal area), extensive parts of the estuary are covered by soft and very soft mud (24%). The soft mud condition rating places the estuary in the "poor" category. Most of the mud is located in or near natural settlement areas in the Waihopai arm and Daffodil Bay, as well as along the banks of the upper Oreti and Waihopai Rivers, and among rushland in the east of the estuary. In Jan. 2012, fresh surface deposits of mud were evident in the Waihopai arm, Daffodil Bay, on mobile sand in the eastern flats, and among previously sandy macroalgal beds near Bushy Point (see inset photos). Sedimentation rate measures, along with historic coring in the central Waihopai arm (see Robertson and Stevens 2012 and 2007 respectively), show sediment deposition has averaged >10mm/year since the 1960's, and >40mm/year for the past 5 years. These inputs are well in excess of the assimilative capacity of this part of the estuary.

Outside of the muddy areas, firm sands dominant throughout the central basin and near the mouth of the estuary, with rock, cobble, and gravel fields located near Omaui. These habitats were in good condition.

Table 3. Summary of dominant intertidal substrate, New River Estuary, Jan. 2012.

Dominant Substrate	Area Ha	Percentage	Comments
Artificial structure	3.5	0.1%	Predominantly rock and boulder margins of reclaimed land to the north and east.
Rock field	36.5	1.2%	Near Omaui and around Mokomoko Inlet.
Cobble field	0.9	0.0%	Common next to reclaimed shorelines on the east side of the Waihopai Arm.
Gravel field	7.6	0.3%	Located on the banks of the Oreti River and near the estuary entrance.
Shell bank	11.8	0.4%	Narrow high tide banks mostly in the east and southeast of the estuary.
Mobile sand	555.5	18.8%	Predominantly located in the central part of the estuary and around the estuary mouth.
Mobile mud/sand	483.1	16.4%	Predominantly on the eastern shoreline between Invercargill and Woodend.
Firm sand	321.0	10.9%	Most common near the estuary mouth and along the southeast of the estuary.
Firm mud/sand	839.6	28.4%	Predominantly in the upper tidal zone of the estuary - most near the Oreti River mouth.
Firm Mud	23.2	0.8%	Concentrated in the east - mostly old Spartina beds or areas of eroding rushland.
Soft mud	296.6	10.0%	Present throughout the estuary - mainly among rushland in the upper tidal reaches.
Very soft mud/sand	372.4	12.6%	Concentrated in Waihopai Arm and Daffodil Bay, and in localised settling areas.
TOTAL	**2952**	**100**	

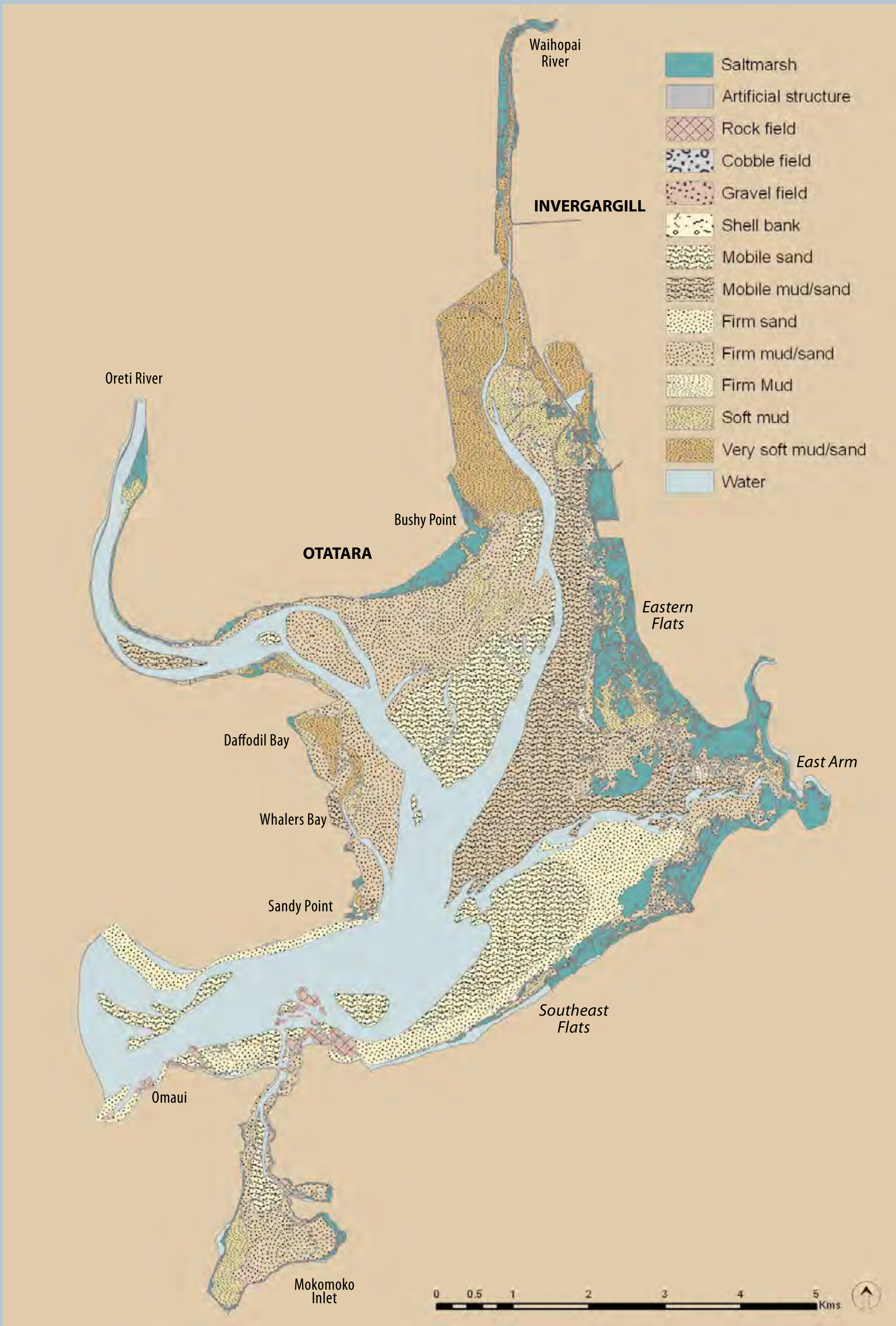


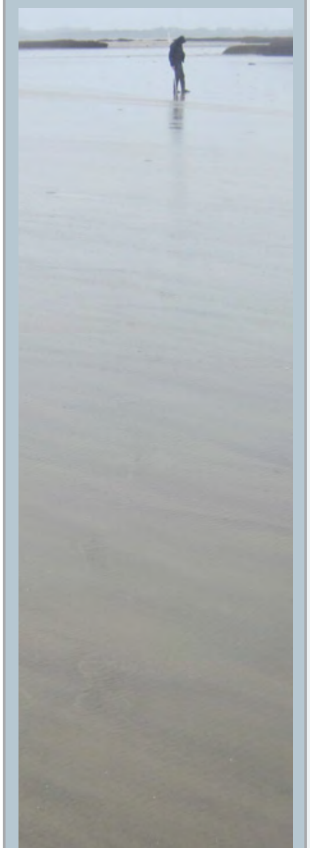
Figure 3. Map of Substrate Types - New River Estuary, Jan. 2012.

3. RESULTS AND DISCUSSION (CONTINUED)

BROAD SCALE MAPPING (CONT.)

SOFT MUD % COVER CONDITION RATING
2001 POOR
2007 POOR
2012 POOR

SOFT MUD AREA CHANGE RATING
2001-2007 SMALL INCREASE
2001-2012 LARGE INCREASE



A thin deposit of mud on firm sands in the eastern estuary.

CHANGES IN ESTUARY SOFT MUD 2001-2012

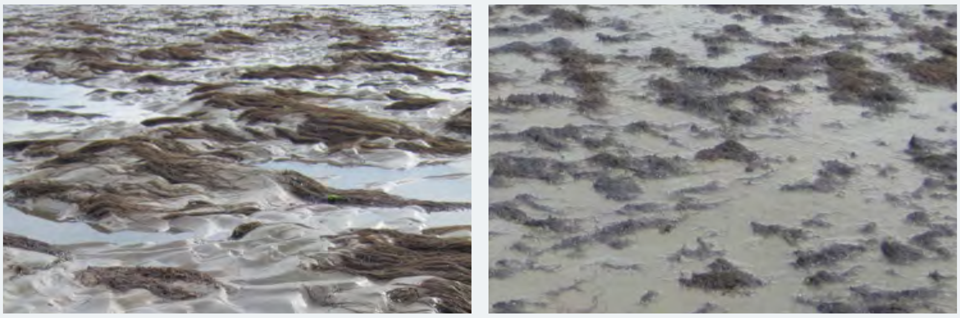
The primary indicator of sediment impacts is the area of the estuary dominated by soft muds. The area of soft mud recorded from broad scale mapping in the estuary is summarised in Table 4. The soft mud percent cover condition rating has not changed from the "poor" category (>15%) that was first recorded in 2001.

Table 4. Broad substrate categories, New River Estuary, 2001, 2007 and 2012.

Substrate Class	2001		2007		2012	
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Sand	2,035	77.8	2,063	76.5	2199	74.5
Soft Mud	548	20.9	569	21.1	669	22.7
Other	34	1.3	64	2.4	84	2.8
TOTAL	2,617	100	2,696	100	2,952	100

Using the 2001 data as a baseline, there was a 4% increase in the area of soft mud from 2001 to 2007, and an 18% increase from 2001 to 2012. This is consistent with field observations, with only small increases evident in soft mud in deposition areas from 2001-2007, but significant increases from 2007-2012. Most mud increases have been associated with macroalgal (*Gracilaria*) beds in the Waihopai arm and Daffodil Bay over the previous five years (see Robertson and Stevens, 2012), and at Bushy Point during this survey. The soft mud change condition rating has consequently gone from "very good" over the period of 2001-2007, to "poor" over 2001-2012.

The increased mud at Bushy Point is particularly concerning as it is settling among dense *Gracilaria* beds where it is likely to lead to an increase in gross nuisance conditions if inputs continue and sediment oxygenation declines (see photos below).



Examples of the rapid change in sediment among macroalgal beds at Bushy Point: clean mobile sand (above left) in 2011, and soft mud in 2012 (above right).

In addition, it is also concerning to note the increased presence of mud on the previously sandy sediments on the eastern side of the estuary (see sidebar photo). This part of the estuary remains dominated by sands, but fine muds are now settling on the surface which are contributing to reduced sediment oxygenation by filling interstitial pore spaces in the coarser sand, and reduced water clarity (the fine muds are readily resuspended by wind waves). While resuspension will help facilitate the removal of some mud by flushing on the outgoing tide, due to the prevailing southwest winds, muds are also highly likely to be pushed into the saltmarsh where they will readily accumulate.

The only other notable change to sediment was in the lower estuary by Omaui where there has been a large movement of sand, primarily through the shifting of channels and associated sand bars. This reflects the dynamic nature of the coast near the entrance to the estuary.

3. RESULTS AND DISCUSSION (CONTINUED)

BROAD SCALE MAPPING (CONT.)

Extensive macroalgal cover along the western side of the Waihopai Arm.

MACROALGAL COEFFICIENT CONDITION RATING
2012 GOOD

MACROALGAL COVER CHANGE RATING
2012 TRIGGER WARNING (TREND OF INCREASE)

MACROALGAL COVER

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

- The majority of the intertidal area (68%) was rated as having a low/very low percentage cover.
- There was a significant percentage of high - very high nuisance macroalgal cover (10.6%, 313ha).
- The dominant macroalgae were the red alga *Gracilaria chilensis* and the green alga *Ulva intestinalis*.
- The most extensive growths were present in the Waihopai arm, at Bushy Point and in Daffodil Bay.

The Macroalgal Coefficient (MC) for the overall estuary is rated as "good" although gross nuisance conditions of rotting macroalgae and poorly oxygenated and sulphide rich sediments are causing significant and worsening problems in the northwestern Waihopai arm, and in sheltered areas in the western flats near Daffodil Bay. This triggers the warning rating (based on the area of estuary with >50% macroalgal cover).

Table 5. Summary of macroalgal cover, New River Estuary, Jan. 2012

Percentage Cover	Area (ha)	Percentage	Dominant Species
<1%	795	26.9	-
1-5%	1,203	40.7	*G. chilensis, U. intestinalis*
5-10%	394	13.3	*U. intestinalis, G. chilensis*
10-20%	129	4.4	*G. chilensis, U. intestinalis, U. lactuca*
20-50%	118	4.0	*G. chilensis, U. intestinalis, U. lactuca*
50-80%	92	3.1	*G. chilensis, U. intestinalis*
>80%	221	7.5	*G. chilensis, U. intestinalis, U. lactuca*
	2,952	100	

CHANGES IN MACROALGAL RATINGS 2001-2012

The Condition Rating (revised in 2011 following a review of data compiled for Southland since 2007), and Macroalgal Coefficient results for the 2001-2012 period, are presented in Table 6. The MC rating has increased since 2007 (indicating worsening conditions), while the warning indicator rating has increased from "very low" in 2001, to "moderate" in 2007, to "high" since 2008. The deteriorating ratings primarily reflect the dramatic expansion of macroalgae in soft sediment areas on the western side of the Waihopai arm and in Daffodil Bay.

Table 6. Summary of macroalgal condition rating and results, New River Estuary, 2001-2012.

Year	MC Rating	Warning Indicator	Result
2001	-	VERY LOW	High cover (>50% cover) over <1% of the estuary (based on both personal observation and limited broad scale mapping (e.g. Robertson et al. 2002).
2007	0.9	MOD	Low cover across most of estuary. Rating driven by patches of high cover near the Oreti River mouth and west of the Waihopai channel by Bushy Point.
2008	1.2	HIGH	A large increase in cover and nuisance conditions on the west side of the northern arm from 2007. Low cover across most of the central and lower estuary.
2009	1.4	HIGH	A large increase in cover and nuisance conditions on the west side of the northern arm and Bushy Point since 2008. Low cover across central and lower estuary.
2010	1.4	HIGH	Rapid deterioration of sediment quality on the northwest flats. Extensive growths at Bushy Point and Daffodil Bay. Low cover across central and lower estuary.
2011	1.2	HIGH	Extensive areas of poor sediment quality on the northwest flats. Heavy growths at Bushy Point and Daffodil Bay. Low cover across central and lower estuary.
2012	1.4	HIGH	Extensive areas of poor sediment quality on the northwest (Waihopai) flats. Heavy growths at Bushy Point and Daffodil Bay. Low cover across central and lower estuary.

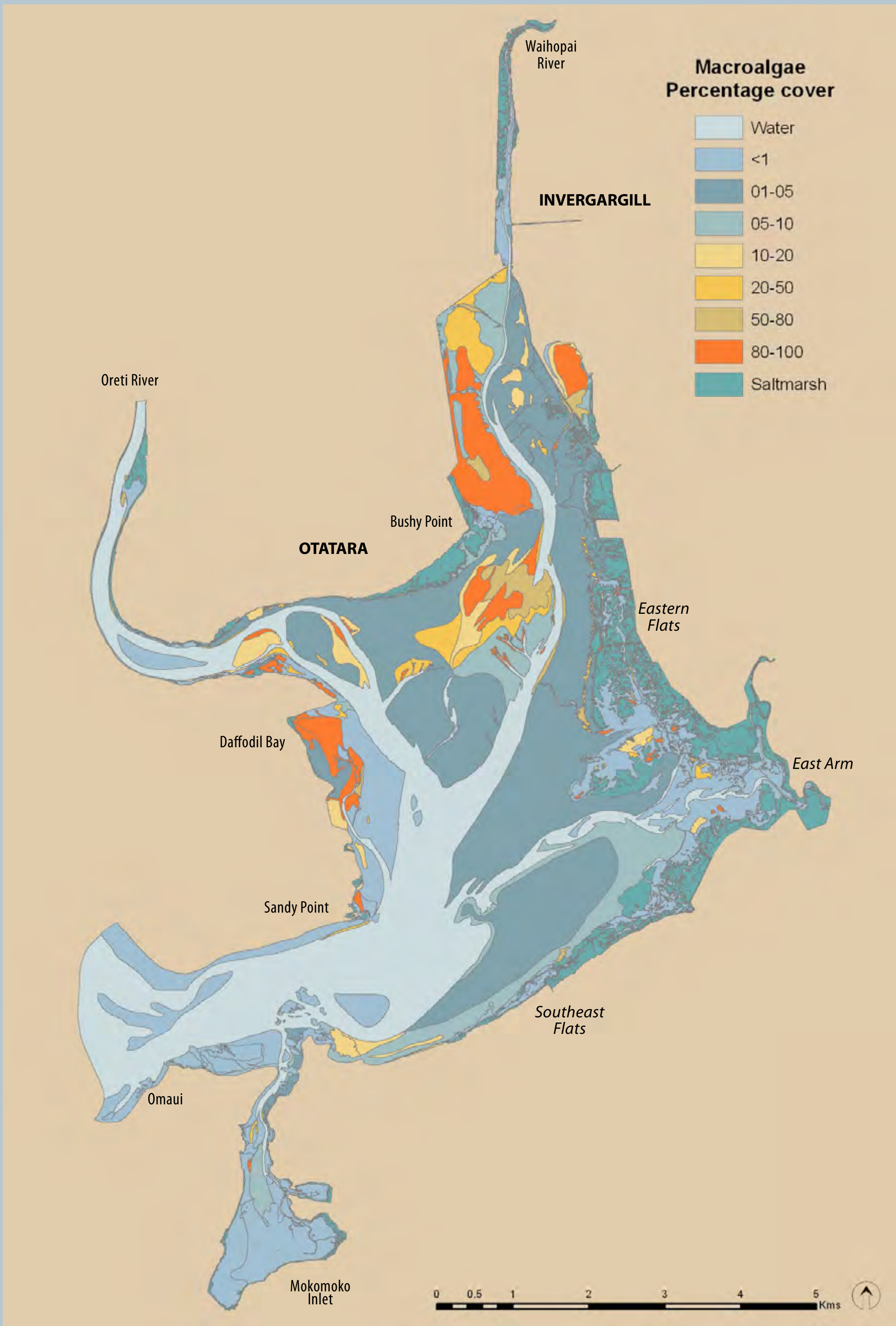
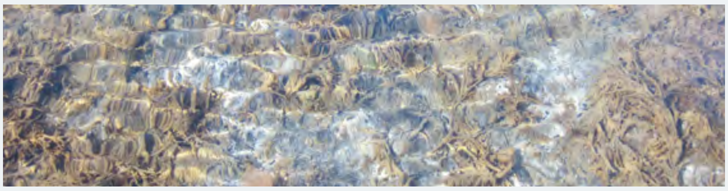


Figure 4. Map of Macroalgal Cover - New River Estuary, Jan. 2012.

3. RESULTS AND DISCUSSION (CONTINUED)

The sidebar photos illustrate the increase in the cover of nuisance macroalgae in Daffodil Bay since 2001. Areas with thick macroalgal cover (i.e. the dark areas in the photos) are generally in very poor condition, with smothering macroalgal growths trapping fine muds at a rapid rate. At the same time the growths are limiting the natural removal of mud from the exposed flats by reducing the re-suspension of sediment by wind-generated waves. As a consequence, the sediments are becoming deeper, softer, and muddier. Further, when the macroalgae dies, it rots and releases organic matter and nutrients into the sediments, reducing oxygenation and fuelling ongoing growths. Where sediment oxygen is depleted, sulphide bacteria grow at the surface (see photo below) reflecting toxic conditions in which few animals can survive.



Surface sulphides in Daffodil Bay, Jan. 2012.

The Waihopai Arm is the worst impacted, with sediment conditions so degraded that nuisance macroalgae are now dying off due to the over-enriched sediment conditions present. The photos in Figure 6 indicate the very rapid changes from 2006-2011 in the Waihopai Arm, and the increase of macroalgal cover in this part of the estuary. Figure 7 illustrates conditions in 2012.

Bushy Point also has extensive macroalgal beds of mostly 50-80% cover. However, in contrast to the northwestern Waihopai arm and Daffodil Bay, underlying sediments are still mostly sandy and relatively well oxygenated. However, in 2012 there was increased deposition of muds over ~27ha, providing a clear early warning of deteriorating conditions in this previously healthy part of the estuary (see photos, page 11).

Overall, the red alga *Gracilaria* was the dominant species in the estuary, followed by the green alga *Ulva (Enteromorpha) intestinalis*. *U. intestinalis* is most common along channel margins and on the root systems of sprayed *Spartina* beds (which remain largely intact), while *Ulva lactuca* (sea lettuce) was most common on sandy flats near Bushy Point and Omaui.

Extensive parts (77%) of the estuary also had a low (<5%) macroalgal cover with no nuisance conditions. These areas were located predominantly in the well-flushed lower estuary and central basin, and the northeastern and eastern flats (Figure 4). Localised pockets of degraded sediment conditions were apparent just east of the entrance to Mokomoko Inlet on the lower south side of the estuary. This is attributed to macroalgae that grows rapidly throughout the estuary in channel areas wherever substrate allows. This macroalgae regularly breaks off and gets moved by wind, wave and currents. It commonly accumulates on the shoreline in the lower reaches of the estuary where it rots.

Figure 5. Aerial photos showing changes in macroalgal cover in Daffodil Bay, 2000, 2006 and 2011.

Figure 6. Aerial photos showing changes in macroalgal cover in the Waihopai Arm, 2006 and 2011. General coverage of nuisance macroalgae indicated by the yellow line.

Figure 7. Examples of the extensive macroalgal cover in the Waihopai Arm in 2012.

BROAD SCALE MAPPING (CONT.)

GROSS EUTROPHIC AREA CONDITION RATING
2001 FAIR
2007 POOR
2012 VERY POOR

GROSS EUTROPHIC AREA CHANGE RATING
2001-2012 VERY LARGE INCREASE

GROSS EUTROPHIC CONDITIONS

When sediments exhibit combined symptoms of a high mud content, a shallow RPD, elevated nutrient and organic concentrations, displacement of invertebrates sensitive to organic enrichment, and high macroalgal growth (>50% cover), they represent gross eutrophic conditions. These conditions will kill or displace most estuarine animals and shellfish, and also release nutrients previously bound in the sediments. As these nutrients will predominantly be released in the form of ammonia, which is much more readily available to fuel macroalgal growth, a cycle of increasing habitat deterioration will establish that is likely to be difficult to reverse. These conditions are most likely to be present in the relatively rare sheltered tidal flats of an estuary which are also those most favourable for the growth of high value seagrass habitat.

CHANGES IN GROSS EUTROPHIC CONDITIONS 2001-2012

A condition rating has been developed that recognises that gross eutrophic conditions should not be present in short residence time estuaries (like New River), with their presence providing a clear signal that the assimilative capacity of the estuary is being exceeded. The rating for 2012 places the estuary in the "very poor" category with 240ha (8%) of the estuary in a severely degraded state. A trend of worsening conditions evident since 2001 (Table 7, Figure 8) provides a clear illustration of the worsening condition of the New River Estuary over the last 10 years.

Table 7. Gross eutrophic intertidal zones, New River Estuary, 2001, 2007 and 2012.

	2001		2007		2012	
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Gross eutrophic area	23	1%	49	2%	240	8%

The most degraded sites are concentrated in natural deposition zones within the estuary (Figure 8) where the combined influence of flocculation at the saltwater/freshwater interface, widening of river channels entering the estuary (reducing flow velocities), and limited tidal flushing all serve to concentrate catchment inputs of sediments and nutrients, and provide good conditions for the growth of macroalgae.

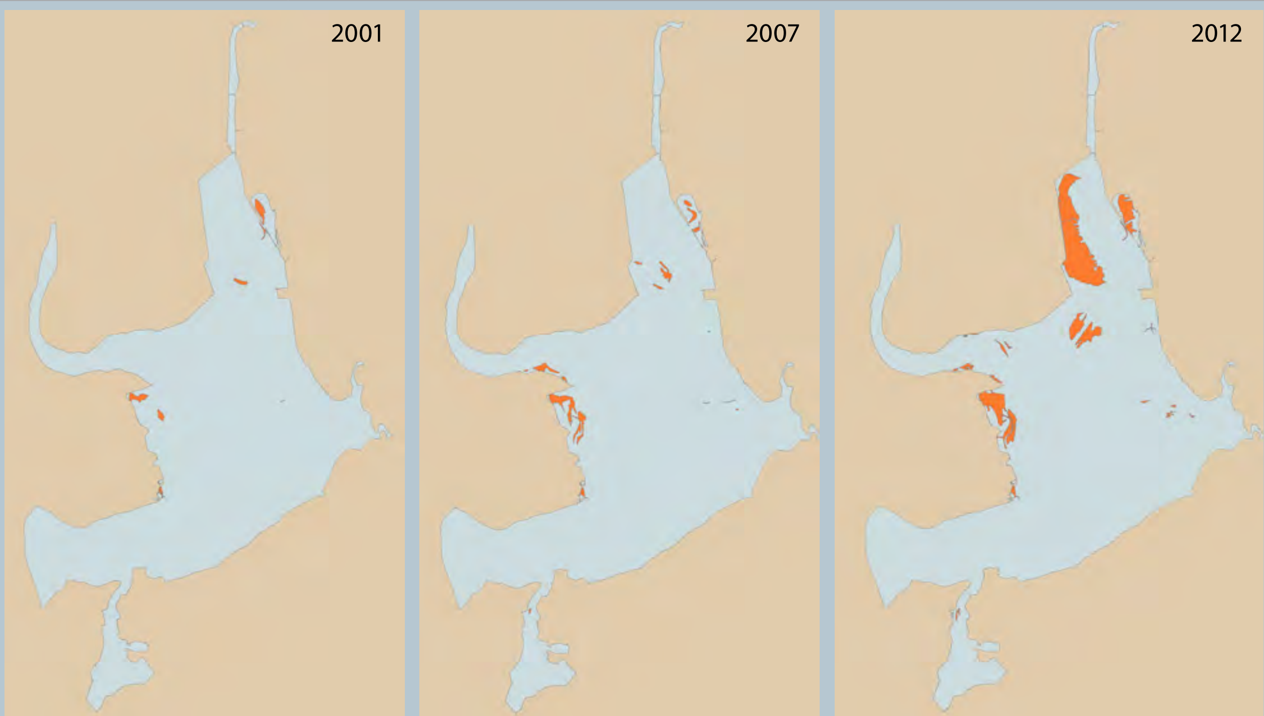
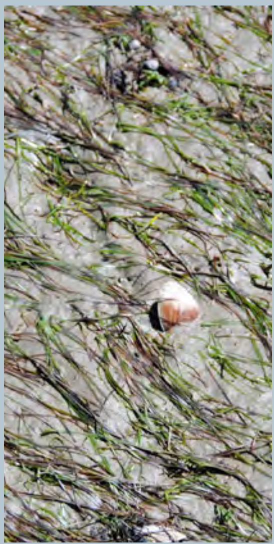


Figure 8. Location and extent of gross eutrophic zones in New River Estuary in 2001, 2007 and 2012.

3. RESULTS AND DISCUSSION (CONTINUED)

BROAD SCALE MAPPING (CONT.)



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. Though tolerant of a wide range of conditions, seagrass is vulnerable to excessive nutrients, fine sediments in the water column, and sediment quality (particularly if there is a lack of oxygen and production of sulphide).

The results of the 2012 intertidal seagrass survey (Table 8 and Figure 10) showed:

- Most of the intertidal area (97%) was rated as having a "low" or "very low" percentage cover.
- Highest densities were in the Waihopai and Eastern arms, near Omaui, and in the Oreti River.
- Because of the size of New River Estuary, areas rated as "low -moderate" to "moderate" (0.6%) and "high" to "very high" (1.8%) represent relatively large areas (16ha and 53ha respectively).

Table 8. Summary of seagrass *(Z. muelleri)* cover, New River Estuary, Jan. 2012.

Percentage Cover	Area (ha)	Percentage
<1%	2,871	97.2
1-5%	0	0.0
5-10%	12	0.4
10-20%	5	0.2
20-50%	11	0.4
50-80%	2	0.1
>80%	51	1.7
	2,952	**100**

SEAGRASS COEFFICIENT CONDITION RATING
2001 POOR
2007 POOR
2012 POOR

The Seagrass Coefficient (SC) was "very low" (0.2), a condition rating of "poor". Dense seagrass beds in the lower estuary near Omaui, in the Eastern arm, and near the Oreti River mouth all appeared in relatively good condition with luscious growths, little fine mud, and no obvious macroalgal smothering (Figure 9). To the east, seagrass was primarily in sandier sediments and beds tended to be less dense than in the north. *Zostera* shoots with a <1% cover were observed throughout the eastern side of the estuary. Subtidal beds (not mapped) were present in the lower Oreti River.

The most extensive areas of seagrass were in the Waihopai arm. However, these beds were very clearly in a state of stress with extensive seagrass beds on the western side of the arm being covered in fine muds, often in combination with smothering by macroalgae. Rotting macroalgae was also creating degraded sediment conditions with black, sulphide rich and anoxic muds dominating the surface sediments (Figure 9).

Figure 9. Contrasting condition of *Zostera* in New River Estuary - healthy beds near Omaui (above left), and severely impacted beds in the Waihopai Arm (above right) which have suffered large areas of die off due to burial in soft muds, smothering by dense macroalgal growths, and toxic (high sulphide/low oxygen) sediment conditions caused by rotting macroalgae.

Figure 10. Map of Seagrass Cover - New River Estuary, Jan. 2012.

BROAD SCALE MAPPING (CONT.)

SEAGRASS AREA CHANGE RATING
2001-2012 VERY LARGE DECREASE

CHANGES IN SEAGRASS COVER 2001-2012

A comparison of seagrass area with >50% cover in 2001 and 2012 (Table 9) shows a 41ha (44%) reduction in the estuary, a condition rating of "high". The losses have occurred almost exclusively in the Waihopai Arm (Figure 11) where there has been a 68% reduction in seagrass overall, most occurring on the western intertidal flats (85% loss). This is attributed to reduced oxygen levels, and smothering by fine sediments and nuisance macroalgal growths that have established since 2007 (Figure 12).

Table 9. Summary of seagrass cover, New River Estuary, 2001 and 2012.

	2001		2012	
	Area (ha)	Percent	Area (ha)	Percent
Seagrass Area (>50% cover)	94	3.1%	53	1.7%

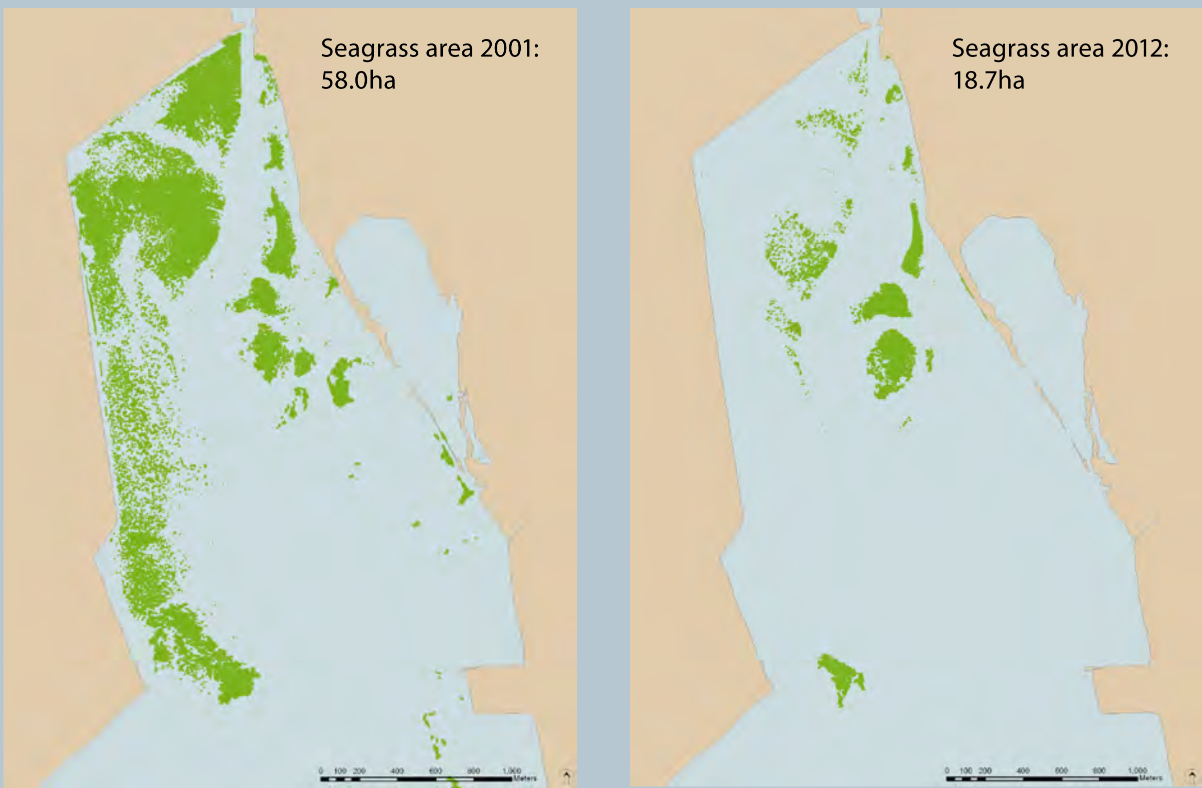


Figure 11. Map of seagrass cover in the Waihopai Arm, 2001 and 2012.

Figure 12. Representative examples of seagrass in good condition in the western Waihopai Arm in 2007 (left) and impacted by sediment and macroalgal smothering in 2012 (centre and right).

BROAD SCALE MAPPING (CONT.)

SALTMARSH % COVER CONDITION RATING
2001 MOD-HIGH
2007 MODERATE
2012 MODERATE

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 an important habitat for a variety of species including fish and birds.

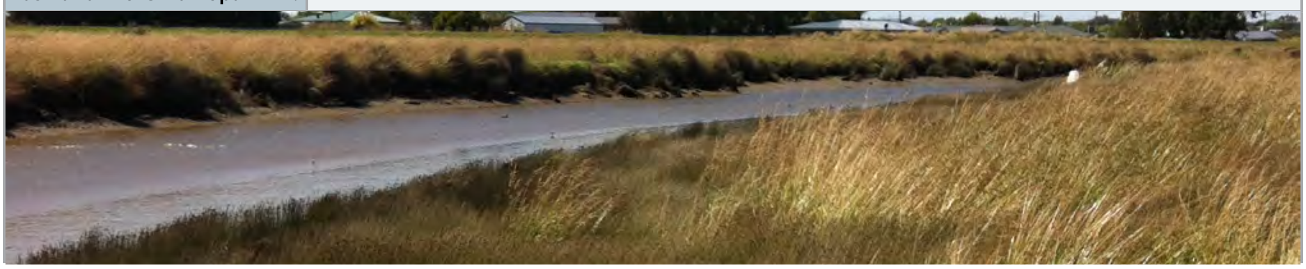
Table 10 and Figure 13 summarise the results of the 2012 saltmarsh mapping. Key findings were:

- 10% (463ha) of the estuary comprised saltmarsh, a condition rating of "moderate".
- The most extensive remaining saltmarsh areas were located along the east of the estuary, and adjacent to Bushy Point in the northwest.
- The dominant saltmarsh was rushland (48%), followed by grassland (27%), and herbfield (12%).
- Recent loss of saltmarsh was evident on farmland areas being drained adjacent to Mokomoko Inlet, and from wave erosion in the east of the estuary and on the northern banks of the Oreti.
- There was a noticeable increase in the presence of tall fescue grassland among rushland, particularly in the upper Waihopai Arm and in the east of the estuary (see photo below).

Table 10. Summary of saltmarsh cover, New River Estuary, Jan. 2012.

Class	Dominant Vegetation	Area (ha)	Percentage
Estuarine shrubs		42.5	9.2%
	Plagianthus divaricatus (Saltmarsh ribbonwood)	42.5	9.2%
Tussockland		8.9	1.9%
	Puccinella stricta (Salt grass)	8.9	1.9%
Sedgeland		9.5	2.1%
	Schoenoplectus pungens (Three square)	6.6	1.4%
	Isolepis cernea (Slender clubrush)	3.0	0.6%
Grassland		123.1	26.6%
	Festuca arundinacea (Tall fescue)	123.1	26.6%
Duneland		2.6	0.6%
	Ammophila arenaria (Marram grass)	2.6	0.6%
Rushland		221.0	47.7%
	Apodasima similis (Jointed wirerush)	211.1	45.5%
	Juncus gerardii (Saltmarsh rush)	9.8	2.1%
	Juncus gregiflorus	0.1	0.0%
Herbfield		55.7	12.0%
	Samolus repens (Primrose)	34.7	7.5%
	Leptinella dioica	20.6	4.4%
	Cotula coronopifolia (Bachelor's button)	0.2	0.0%
	Sarcocornia quinqueflora (Glasswort)	0.2	0.0%
	Crassula helmsii	0.1	0.0%
	Selliera radicans (Remuremu)	0.0	0.0%
TOTAL		**463.4**	**100%**

Tall fescue growing through rushland in the Waihopai Arm.



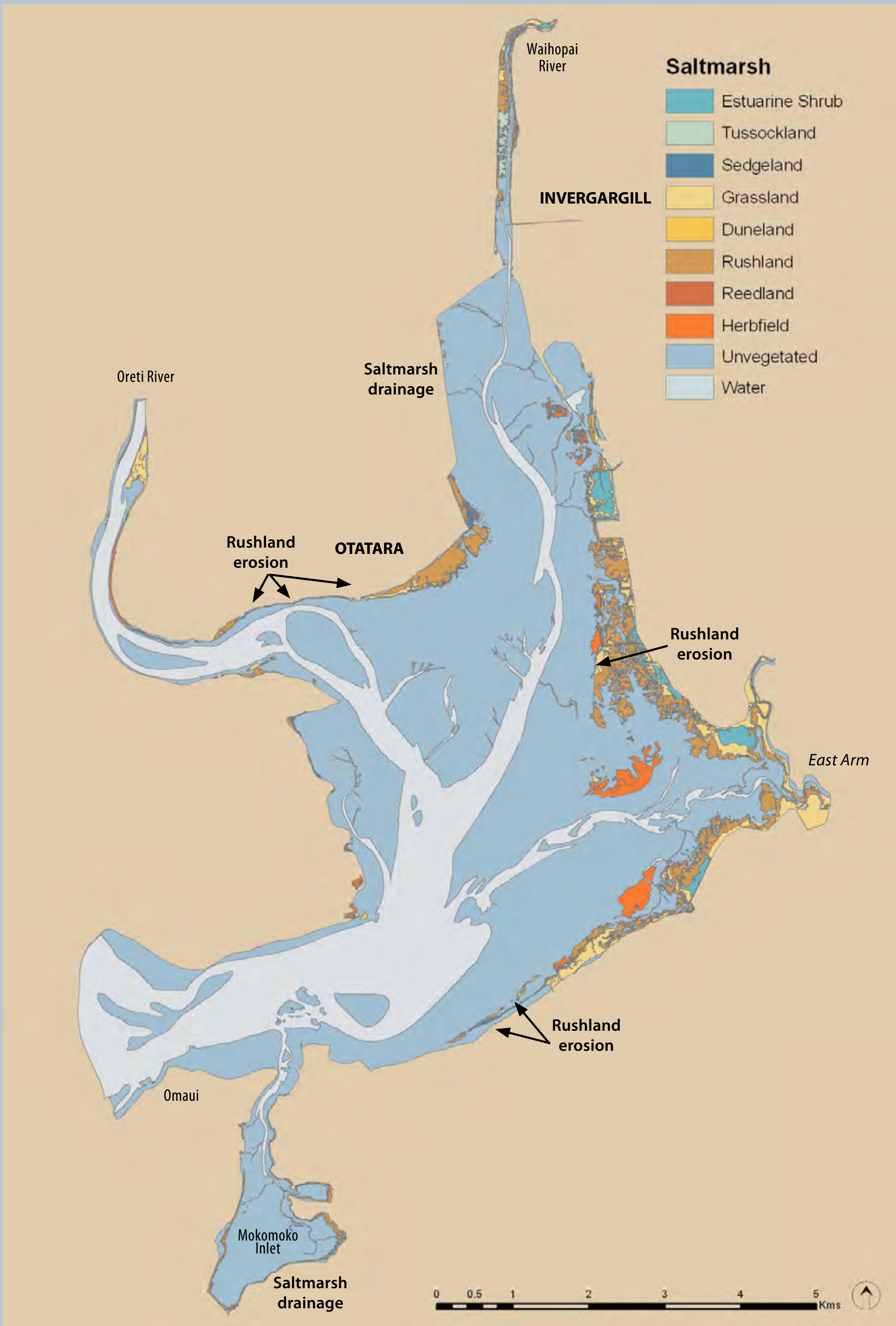
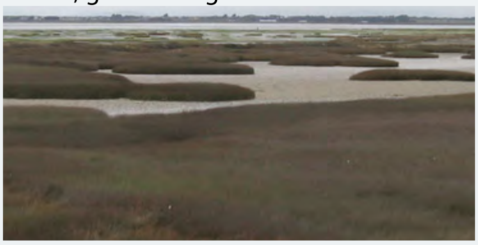


Figure 13. Map of Saltmarsh Vegetation - New River Estuary, Jan. 2012.

3. RESULTS AND DISCUSSION (CONTINUED)

BROAD SCALE MAPPING (CONT.)

The extensive saltmarsh in the east of the estuary was dominated by extensive stands of rushland in the upper intertidal reaches, with a mix of saltmarsh ribbonwood, gorse and grassland inland.




Barriers to the migration of saltmarsh in response to sea level rise (SLR) are apparent around most of the estuary due to the widespread historical reclamation of estuary margins (see photos below). Saltmarsh is likely to be inundated and displaced over time where inland migration is not possible. Bushy Point was one of the few remaining areas where there was a natural transition from rushland to terrestrial forest.




Residual root systems of the invasive cord grass *Spartina* in the east of the estuary (photo right) were predominantly unvegetated and continuing to slowly erode. Relatively extensive herbfields were often growing in sheltered areas adjacent to the root beds (photo below).

Stabilised duneland remained a notable feature near Omaui where steep marram grass dunes flank the estuary (see photo below), as well as at the back of Oreti Beach, and on the east bank of the Oreti River.

The increasing presence of grassland among areas previously dominated by rushland (photo left) suggests a shift to more terrestrial conditions, possibly because the input of sediment is elevating areas so that there is reduced saline influence. If so, there is likely to be a continued increase or terrestrial weeds and grasses establishing in saltmarsh areas.

BROAD SCALE MAPPING (CONT.)

SALTMARSH AREA CHANGE RATING

2001-2007 SMALL DECREASE

Ten metre wide band of rushland eroded by wind driven waves in the eastern arm.

CHANGES IN SALTMARSH COVER 2001-2012

The condition rating for saltmarsh measures a percentage change from an established baseline. Based on the summary information in Table 11, the saltmarsh condition rating is rated as a "small decrease" with a <5% decrease in the area of saltmarsh since 2001.

The key broad scale saltmarsh changes from 2001, 2007 and 2012 were as follows:

- **Reedland:** The absence of reedland in 2007 is directly attributable to the successful eradication of *Spartina* between 2001 and 2007. A small area had re-established in 2012 near Bushy Point, with isolated plants present in the east (subsequently removed by DOC).
- **Herbfield:** The increase of herbfield is due to colonisation of the dead *Spartina* root systems and adjacent sheltered areas with a variety of herbfield species (as well as the macroalgae *U. intestinalis*).
- **Rushland:** The decrease from 2001 to 2007 is primarily due to rushland being more accurately separated in 2007 into rushland, grassland, estuarine shrubs and scrub categories. Localised areas of rushland erosion were evident on the north bank of the Oreti River and in the eastern arm (see sidebar photo) in 2012, and there was an increase in grassland as the dominant cover in many areas of rushland in the upper tidal reaches in 2012 (see below).
- **Grassland:** The apparent increase from 2001 is due to some areas of rushland being more accurately classified in 2007 as grassland, and the increased dominance of grassland within rushland in 2012, predominantly in the upper Waihopai River and eastern side of the estuary.
- **Tussockland, Scrub and Estuarine Shrubs:** Most changes are due to more accurate classification in 2012 due to the high quality aerial photos supplied by ES, but also to the increased presence of grassland within areas previously dominated by saltmarsh ribbonwood.

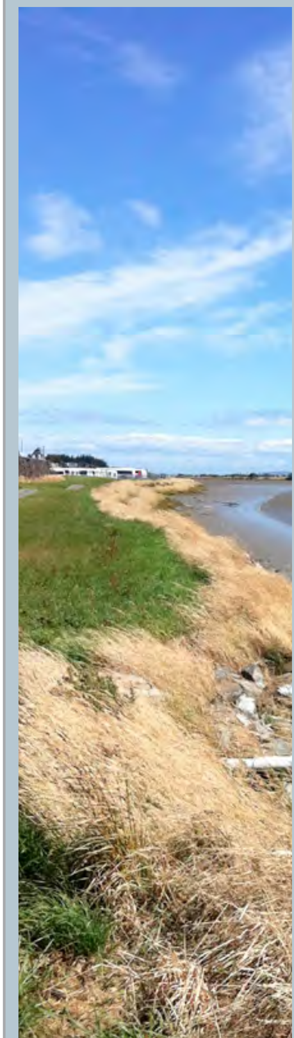
Table 11. Summary of saltmarsh cover, New River Estuary, 2001, 2007 and 2012.

Vegetation Class	2001		2007		2012	
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Estuarine shrubs	-	-	48.2	11%	42.5	9%
Tussockland	14.9	3%	12.6	3%	8.9	2%
Sedgeland	4.3	1%	6.1	1%	9.5	2%
Grassland	14.4	3%	113.8	25%	123.1	27%
Duneland	2.6	1%	5.3	1%	2.6	1%
Rushland	318.9	68%	232.3	51%	221.0	48%
Reedland	112.3	24%	0	0%	0.1	0%
Herbfield	3.1	1%	37.8	8%	55.7	12%
TOTAL	470.5	100%	456.1	100%	463.6	100%
% of estuary in saltmarsh	11.1		10.7		10.0	

The trend of a reducing percentage cover of saltmarsh invokes the Early Warning Trigger. Although the changes evident are relatively small, because saltmarsh around the estuary has already been greatly reduced, further reductions of this important habitat are highly undesirable. It is also obvious that ongoing margin development is continuing on private land adjacent to the estuary which is both further diminishing saltmarsh and, through drainage and reclamation, is removing many of the low lying margins favoured by saltmarsh and flanking wetlands e.g. western Waihopai arm, eastern arm, Mokomoko Inlet. Such areas buffer the estuary from sediment and nutrients, provide high value wildlife habitat, and will be very important in the future if predicted sea level rise forces saltmarsh inland.

BROAD SCALE MAPPING (CONT.)

VEGETATED MARGIN % COVER CONDITION RATING
2007 GOOD
2012 GOOD



VEGETATED MARGIN CHANGE RATING
2007-2012 NO 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 helping to moderate stream temperature fluctuations, and improves estuary biodiversity. The results of the 200m terrestrial margin survey (Table 12 and Figure 14) showed:

- The mapped 200m wide terrestrial vegetation buffer was dominated by grassland (56%), the eastern estuary margin almost exclusively channelled and drained grazed pasture.
- Scrub and forest (28%) was also prominent, most present on the western side of the estuary.
- Duneland was most concentrated near Omaui, Awarua, Oreti Beach and the Oreti River.

Terrestrial grassland generally extended to artificial seawalls along the estuary edge, or to floodbanks bordering industrial and residential developments. In these areas, there was a relatively abrupt change from terrestrial cover to the estuary and very limited natural buffering capacity remained. To the west, forest and scrub were the dominant cover, often mixed with grassland particularly around the Oreti River.

Table 12. Summary of 200m terrestrial margin, New River Estuary, Jan 2012.

Class	Dominant Cover	Percentage
Forest		2.5%
	Native forest	1.0%
	Exotic forest	1.0%
	Mixed native and exotic forest	0.6%
Scrub/Forest		15.2%
	Mixed native and exotic scrub/forest	5.4%
	Native scrub/forest	3.8%
	Pinus radiata (Pine tree)	5.8%
	Cupressus macrocarpa	0.2%
Scrub		10.1%
	Mixed native and exotic scrub	5.8%
	Native scrub	2.8%
	Ulex europaeus (Gorse)	1.2%
	Lupinus arboreus (Tree lupin)	0.2%
	Cytisus scoparius (Broom)	0.1%
	Exotic Scrub	0.0%
Estuarine shrubs	*Plagianthus divaricatus (Saltmarsh ribbonwood)*	1.5%
Tussockland	*Phormium tenax* (New Zealand flax)	0.1%
Grassland	Pasture	56.2%
Duneland	*Ammophila arenaria* (Marram grass)	1.4%
Rushland	*Isolepis nodosa* (Knobby clubrush)	0.1%
Industrial		8.8%
Residential		4.1%
Total		**100%**

CHANGES IN TERRESTRIAL MARGIN COVER 2007-2012

No significant changes to the overall mix of terrestrial margin cover were identified (Table 13), although the ongoing development and drainage of wetland and saltmarsh areas on private land (removing the vegetative buffering capacity) are of concern.

Table 13. Densely vegetated terrestrial margin (%), 2007 and 2012.

TERRESTRIAL MARGIN	2007	2012
Percentage densely vegetated	31%	31%

Figure 14. Map of 200m Terrestrial Margin Vegetation - New River Estuary, Jan. 2012.

4. SUMMARY AND CONCLUSIONS

Table 14 summarises condition ratings in relation to the key issues addressed by the broad scale monitoring (i.e. sediment, eutrophication and habitat modification).

Table 14. Summary of broad scale condition ratings for New River Estuary, 2001, 2007 and 2012.

Major Estuary Issue	Indicator	2001	2007	2012	2001-2012 Change
Sediment	Soft mud area	POOR	POOR	POOR	LARGE INCREASE
Eutrophication	Macroalgal Coefficient	GOOD	GOOD	GOOD	TRENDING UP = WARNING
	Dense (>50%) macroalgal cover	VERY LOW	MODERATE	HIGH	VERY LARGE INCREASE
	Gross eutrophic condition area	FAIR	POOR	VERY POOR	VERY LARGE INCREASE
Habitat Modification	Seagrass area	POOR	POOR	POOR	VERY LARGE DECREASE
	Saltmarsh area	MOD-HIGH	MODERATE	MODERATE	SMALL DECREASE
	Densely vegetated margin area	not measured	GOOD	GOOD	NO CHANGE

The 2012 broad scale mapping results show that while large sections of the estuary remain in good condition, there has been a significant decline in estuary quality since 2001 (most particularly over the past five years), for all measured parameters except the extent of densely vegetated margin.

While the estuary remains predominantly sandy (75% firm mud/sand and mobile mud/sand), soft and very soft mud now cover 24% of the surface sediments in the estuary. There has been a significant (22%) increase in the area of soft mud (121ha) since 2001, much of which (100ha) has deposited since 2007. Most is located in the upper northern reaches including the Waihopai arm, and in sheltered arms to the east and west of the estuary - largely due to their propensity to act as natural settling areas for fine sediment and macroalgae.

Macroalgal growth remained relatively low throughout most of the lower estuary, although dense subtidal beds of both *Gracilaria* and *U. intestinalis* were observed in the central basin and near the Oreti and Waihopai River mouths. Nuisance levels of intertidal macroalgae were present in certain locations. In particular, high density *Gracilaria* beds were located in the centre, west and north of the estuary, the heaviest growths in the poorly flushed parts of the Waihopai and Daffodil Bay arms. These beds are now commonly associated with soft, muddy, anaerobic, and sulphide and organic rich sediments, creating gross eutrophic conditions that are adversely impacting the estuary.

The area of the estuary with gross eutrophic conditions had expanded significantly from 23ha in 2001, to 240ha in 2012. This has caused a very significant loss (44% of seagrass with >50% cover) from the estuary, while the macroinvertebrate community in these areas is severely degraded (little animal life is able to establish in the anoxic sediments, and surface feeding species are few in number and limited to those tolerant of poor conditions). Such conditions limit the food availability for fish and birdlife, and show the capacity of the estuary to assimilate nutrient and sediment loads from the catchment is currently exceeded in these locations. These symptoms serve a clear warning that if management action is not taken, problems are likely to continue to worsen and begin to impact on the wider estuary.

The most extensive seagrass (*Zostera*) beds are still located in the Waihopai arm, but they are clearly under stress from impacts related to excessive sediment and nutrient inputs, and as mentioned above, have decreased in area dramatically. Elsewhere, seagrass with a <1% cover was observed throughout the eastern side of the estuary, with dense healthy beds growing in sandy sediments along the edge of rushland in the east arm, near Mokomoko Inlet, and along the margins and subtidal fringes of the Oreti River.

Around the estuary edges, saltmarsh vegetation was still prominent (463ha, 10% of the estuary) of which 48% was rushland, 27% grassland, and 12% herbfield. From 2001 to 2012, there has been a small reduction in saltmarsh cover (470ha to 463ha), partly due to erosion, but also from a noticeable increase in the dominance of grass among rushland in parts of the upper tidal reaches of the estuary. Changes to classification since 2001 also contribute to the reduction. Saltmarsh remained most extensive in the eastern arm of the estuary where wide beds of rushland extended out over large intertidal flats. Reclamation has historically replaced large areas of this type of habitat elsewhere in the estuary. Artificial structures (e.g. rockwalls, floodbanks) that protect reclaimed shorelines were a dominant feature in the north and east and limit the area available for saltmarsh growth.

4. SUMMARY AND CONCLUSIONS (CONTINUED)

The terrestrial margin surrounding the estuary was dominated by grassland (56%), a combination of scrub and forest (28%), and residential and industrial development (13%). Grassland generally extended to artificial seawalls along the estuary edge, or to floodbanks bordering industrial and residential developments. In these areas, limited natural buffering capacity remained and saltmarsh vegetation was either absent or restricted to narrow bands. There was no significant change in the percentage of the margin that was densely vegetated from 2007 to 2012, although ongoing drainage of saltmarsh on private land was apparent in several locations.

5. MONITORING

New River Estuary has been identified by Environment Southland as a high priority for monitoring, and is a key part of their coastal monitoring programme being undertaken in a staged manner throughout the Southland region. Monitoring recommendations for the estuary are as follows:

Broad Scale Habitat Mapping.
Continue with the programme of 5 yearly broad scale habitat mapping. Next monitoring due in February/March 2017.

Macroalgal and Seagrass Monitoring.
Continue with the programme of annual broad scale mapping of macroalgae. Next monitoring due in February 2013. In addition, in order to assess changes in seagrass cover (particularly in the Waihopai Arm), it is recommended that seagrass cover be monitored annually in priority areas in tandem with the macroalgal monitoring.

Fine Scale Monitoring.
Monitor Daffodil Bay and Waihopai arm gross eutrophic sites E and F in February 2013, 2014 and again in February 2015 when the 5 yearly fine scale trend monitoring falls due and is undertaken.

Sedimentation Rate Monitoring.
Because sedimentation is a priority issue in the estuary it is recommended that sediment plate depths be measured annually and the number of plates deployed in the estuary expanded.

Terrestrial Margin Saltmarsh.
Because of ongoing margin development around the estuary it is recommended that saltmarsh areas located on private land be identified and landowners be encouraged to protect these remaining, but vulnerable, stands. Where LIDAR data are available they should be used to identify the areas most likely to be influenced by sea level rise to assist in planning for the managed retreat of saltmarsh.

6. MANAGEMENT

Eutrophication and sedimentation have been identified as major issues in New River Estuary since at least 1973 (Blakely 1973), with worsening conditions reported since 2007-2008 (Robertson and Stevens 2007, 2008), as has been the case for several other Southland estuaries (e.g. Jacobs River, Waimatuku and Waituna Lagoon).

Previous recommendations (e.g Robertson and Stevens 2011, 2012, Stevens and Robertson 2011) are reiterated for the prioritised development of catchment nutrient and sediment guideline criteria for each estuary type in Southland to derive thresholds protecting against adverse sediment and nutrient impacts. New River Estuary was identified as the first priority for this work because of its current extent and rate of degradation. The 2012 broad scale mapping results emphasise the importance and priority of this work in New River Estuary.

Assessment of the extent to which catchment loads meet guideline criteria will enable ES to sustainably manage the estuary and its surroundings. If catchment inputs can be assimilated by the estuary, it will flourish and provide sustainable human use and ecological values in the long term. If catchment loads exceed the estuary's assimilative capacity, it will continue to degrade.

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.