Wriggle

coastalmanagement

Moutere Inlet 2013

Broad Scale Habitat Mapping

Prepared for

Tasman District Council

September 2013

Cover Photo: Moutere Inlet, 2012.


Perched tidal flats in the southern end of Moutere Inlet.

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by

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All photos by Wriggle except where noted otherwise.

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MOUTERE INLET - EXECUTIVE SUMMARY

This report summarises the results of the 2013 broad scale habitat mapping of Moutere Inlet, a moderate-sized (769ha), shallow, well-flushed, seawater dominated, two opening, tidal lagoon estuary near Motueka. It is one of the key estuaries in Tasman District Council'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

- Sand substrate dominated the estuary (51%, 369ha), mostly in the central estuary towards the estuary entrances.
- Soft and very soft mud cover was extensive (38%, 274ha), mostly in the central basin and sheltered embayments. Cover had increased dramatically since 2006 (from 99ha to 274ha), a likely consequence of catchment land disturbance (e.g. forest clearance/subdivision/road construction).
- Dense nuisance macroalgae (>50%) covered 11% (70ha) of the intertidal area, while most of the intertidal area (80%) had a low or very low percentage cover. Highest densities were in the central basin and Wharf Road embayment, obvious deposition zones for mud and organic matter.
- Gross eutrophic conditions had increased from <1% (~1ha) of the estuary in 1947, to 2% (37ha) in 2006, to 8% (60ha) in 2013 - a 160% increase over the last 7 years. The central basin, Wharf Road embayment, and southeast flats were the worst affected areas.
- Seagrass cover was very low (2ha), and had clearly declined since 1947. Losses are attributed primarily to excessive mud.
- Saltmarsh covered 10.6% of the estuary (82ha) of which 55% was rushland and 36% herbfield. A 53% decline in saltmarsh since 1947 was attributed primarily to reclamation from road construction and margin development, which has historically displaced large areas of saltmarsh habitat.
- The densely vegetated margin (scrub and forest) cover was low (17%). Margins were dominated by horticulture (36%), grassland (21%), and residential and industrial development (21%). No significant change since 1947 was evident as margins were already extensively modified by then.

RATINGS		CONDITION RATINGS *estimated value				CHANGE RATINGS
Major Issue	Indicator	1947	1988	2006	2013	Change from Baseline
Sediment	Soft mud area	unknown	unknown	POOR	POOR	LARGE INCREASE
Eutrophication	Low density macroalgal cover	GOOD*	GOOD*	GOOD	GOOD	TRENDING UP = WARNING
	High density macroalgal cover	VERY LOW*	LOW*	MODERATE	HIGH	VERY LARGE INCREASE
	Gross eutrophic condition area	GOOD	MODERATE*	POOR	VERY POOR	VERY LARGE INCREASE
Habitat Modification	Seagrass area	FAIR*	POOR*	POOR	POOR	VERY LARGE DECREASE
	Saltmarsh area	HIGH	MODERATE	MODERATE	MODERATE	LARGE DECREASE
	Densely vegetated margin area	POOR*	POOR*	POOR	POOR	NO SIGNIFICANT 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 2013 broad scale mapping results show that while large sections of the estuary remain in good condition, there has been a significant decline in most estuary condition indicators since 1947, the exception being the extent of densely vegetated margin which had largely been already lost and has changed very little.

In particular, natural settlement areas in the main estuary and sheltered embayments were excessively muddy (especially those influenced by causeways with relatively high culvert inverts), and large areas of the estuary have high nuisance macroalgal growths and poorly oxygenated sediments. The areas impacted have increased dramatically since 2006. In these areas the macroinvertebrate community will be severely degraded (little animal life can establish in anoxic sediments, and surface feeding species are generally 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 catchment nutrient and sediment loads is currently exceeded in these areas. Localised disturbance of saltmarsh from vehicles and a mud run event is also evident.

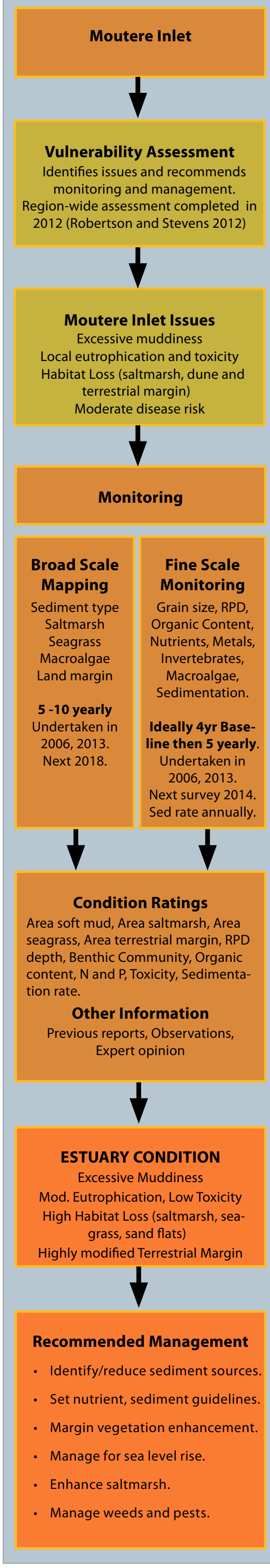
RECOMMENDED MONITORING AND MANAGEMENT

Sedimentation and nutrient enrichment have been identified as major issues in Moutere Inlet. To address these issues it is recommended that broad scale habitat mapping be repeated every 5 years (next due in 2018). Fine scale monitoring is recommended annually for three years (2013-15) to establish a clear baseline, and then resume the 5-yearly planned cycle. Sedimentation rate monitoring should continue annually but with additional sites deployed in eutrophic/high sediment locations. A rapid visual assessment of macroalgal growth should be undertaken annually (Jan/Feb), with annual broad scale macroalgal mapping initiated if conditions appear to be worsening.

It is also recommended that catchment nutrient and sediment guideline criteria be developed for the estuary, with input load assessments then undertaken to assess the extent to which current catchment loads are likely to meet guideline criteria. Where catchment loads exceed the estuary's guidelines, it is recommended that sources of elevated loads in the catchment be identified and management undertaken to minimise their adverse effects on estuary uses and values.

While some small restoration projects are occurring on the margin, opportunities to increase the cover of the naturally vegetated terrestrial margin should be encouraged, and plans developed to facilitate the expansion of estuary margins in response to predicted sea level rise.

1. INTRODUCTION



Developing an understanding of the condition and risks to coastal and estuarine habitats is critical to the management of biological resources. These objectives, along with understanding change in condition/trends, are the key objectives of Tasman District Council's State of the Environment Estuary monitoring programme that is largely carried out by Wriggle Coastal Management. Recently, Tasman District Council (TDC) undertook a vulnerability assessment of the region's coastlines to establish priorities for a long-term monitoring programme (Robertson and Stevens 2012). The assessment identified the Waimea, Moutere, Motueka Delta, Motupipi, Ruataniwha and Whanganui estuaries as priorities for monitoring. The monitoring and management process used for Moutere Inlet is summarised in the margin diagram, and is described 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 (see Table 1) and appropriate monitoring design. A region-wide EVA has been undertaken (Robertson and Stevens 2012) including specific recommendations for Moutere Inlet.
2. **Broad Scale Habitat Mapping** (NEMP approach). This component (see Table 2) documents the key habitats within the estuary, and changes to these habitats over time. Broad scale mapping of Moutere Inlet was undertaken in 2006 (Clark et al. 2006), and historical vegetation cover assessed from 1947 and 1988 aerial photographs (Clark and Gillespie 2007). The current report focuses on detailed broad scale habitat mapping undertaken in the summer of 2012/13 to assess the current state of the estuary.
3. **Fine Scale Monitoring** (NEMP approach). Monitoring of physical, chemical and biological indicators (see Table 2). This component, which provides detailed information on the condition of Moutere Inlet, was undertaken in 2006, (Gillespie and Clark 2006), and repeated in the summer of 2012/13 (Robertson and Stevens 2013). Sedimentation rates in the estuary have been monitored annually by TDC at four sites since 2008 (see Figure 1).

To help evaluate overall estuary condition and decide on appropriate monitoring and management actions, a series of condition ratings have been developed and are described in Section 2. The current report describes the following work undertaken between November 2012 to March 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.

Moutere Inlet is a moderate-sized (769ha), shallow (mean depth ~2m), well-flushed, seawater-dominated, tidal lagoon type estuary. It has two tidal openings, one main basin, several tidal arms separated by causeways, and an extensive coastal tidal flat delta (243ha) located inshore of the Motueka sandspit. The catchment is fully developed and dominated by high producing pasture, cropping/horticulture and exotic forestry (Clark et al. 2006), while much of the margin (~70%)is directly bordered by roads, causeways and seawalls.

The estuary, despite having a relatively simple shape, contains a wide variety of habitats. While dominated by intertidal sand and mudflats perched high in the tidal range, the well flushed and often steeply incised estuary channels are deep and, particularly near the entrances, support a variety of cobble, gravel, sand, and biogenic (oysters, mussels, tubeworms) habitats. Small, but resilient seagrass beds remain in the lower well flushed estuary, but are significantly reduced from their historical coverage.

Reclamation and development have significantly displaced saltmarsh habitat around the estuary margins, with shoreline modification (e.g. seawalls, bunds, roads) now greatly limiting natural saltmarsh expansion and restricting its capacity to migrate inland in response to predicted sea level rise. Consequently, future saltmarsh displacement is highly likely.

The estuary has high use and is valued for its aesthetic appeal, rich biodiversity, shellfish collection, bathing, waste assimilation, whitebaiting, fishing, boating, walking, and scientific appeal. A small commercial port and marina is located at the north western entrance.

The main issues within the estuary are excessive muds and increasing eutrophication and sedimentation. These are most evident in the presence of gross eutrophic sites with low sediment oxygenation and sulphide-rich sediments, smothering macroalgae, and rapid soft mud accumulation that are developing in natural settling areas both within the estuary, and in the sheltered delta basin outside the northern entrance.

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 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 200m margin buffer habitat over time.

Figure 1. Moutere Inlet, showing location of fine scale and sediment monitoring sites (Photo LINZ).

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).

For the current study, TDC supplied rectified ~0.5m/pixel resolution colour aerial photos flown in March 2010. Photos covering the estuary at a scale of 1:3,000 were laminated, and experienced scientists ground-truthed the spatial extent of dominant habitat and substrate types between Dec. 2012 and Jan. 2013, by walking the area and recording features directly on the laminated aerial photos. Field notes and photographs were subsequently used 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/landuse.

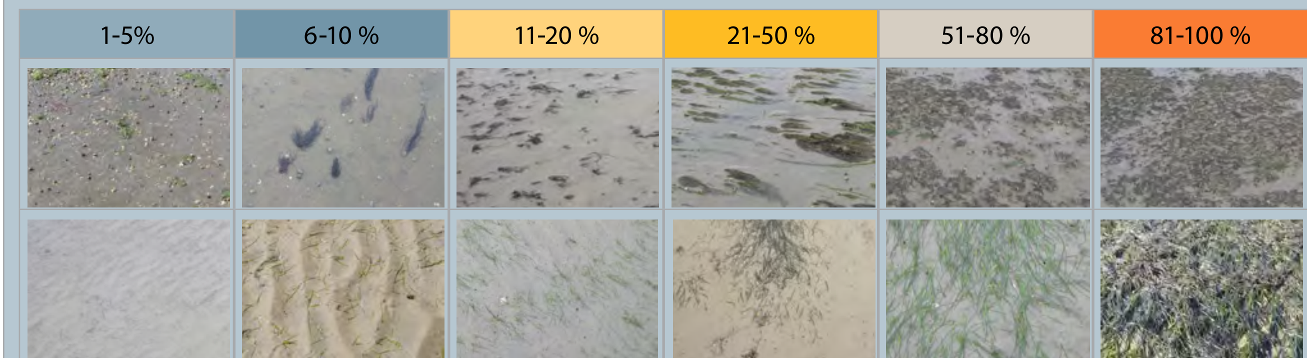
Appendix 1 lists the definitions used to classify substrate and vegetation. The composition of vegetation was classified using an interpretation of the Atkinson (1985) system, where the dominant plant species were coded by using the two first letters of their Latin genus and species names e.g. marram 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 using a 6 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 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 some of the 2013 results to be compared to changes from the 2006 survey (Clark et al. 2006), and 1947 and 1988 historical photos (Clark and Gillespie 2007), with condition ratings used to indicate likely historical changes. However, because these previous Cawthron surveys omit obvious seagrass, saltmarsh and macroalgae beds, and have a number of data or interpretation errors, it is recommended that the current survey be used as a future baseline.

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 Moutere Inlet 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
Very Small 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 6-10%)+(4.5 x %cover 11-20%)+(7.5 x %cover 21-50%))/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 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. 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 ERP
High	11-30% of estuary	Monitor yearly. Initiate ERP
Very High	>30% of estuary	Monitor yearly. Initiate ERP

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 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 yearly. Initiate ERP
Large Increase	Increase in area of cover (ha) 16-50% from baseline	Post baseline, monitor yearly. Initiate ERP
Very Large Increase	Increase in area of cover (ha) >50% from baseline	Post baseline, monitor yearly. Initiate ERP

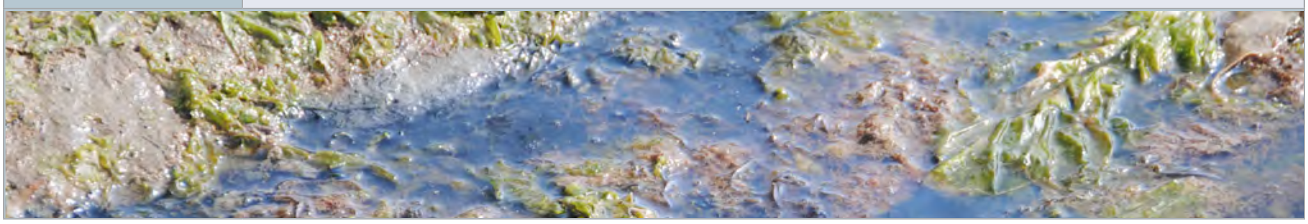
GROSS EUTROPHIC CONDITIONS (AREA)

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 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: $SC=((0 \times \%seagrass\ cover <1\%)+(0.5 \times \%cover\ 1\text{-}5\%)+(2 \times \%cover\ 6\text{-}10\%)+(3.5 \times \%cover\ 11\text{-}20\%)+(6 \times \%cover\ 21\text{-}50\%)+(9 \times \%cover\ 51\text{-}80\%)+(12 \times \%cover >80\%))/100.$

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

SEAGRASS CONDITION RATING

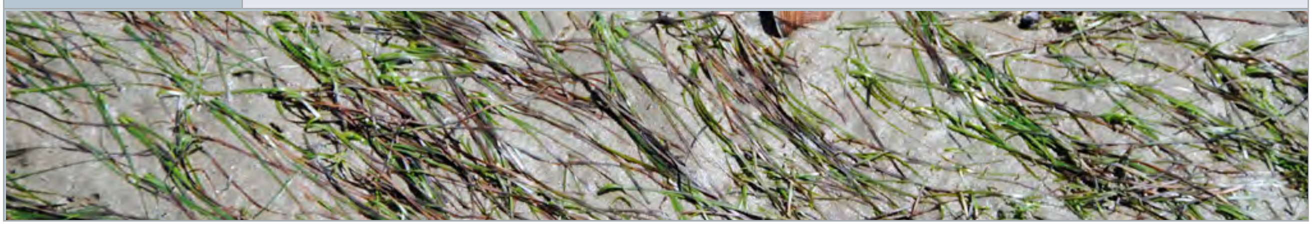
CONDITION RATING	DEFINITION (+Seagrass Coefficient)	RECOMMENDED RESPONSE
Poor	Very Low (0.0 - 0.2)	Post baseline, monitor 5 yearly. Initiate ERP
Fair	Low (0.2 - 0.8)	Post baseline, monitor 5 yearly. Initiate ERP
	Low Low-Moderate (0.8 - 1.5)	Post baseline, monitor 5 yearly. Initiate ERP
Good	Low-Moderate (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 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. 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 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 200m 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 200m 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 200m 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 200m 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

Soft mud, tube-worm reef, cobble and gravel habitat, and perched tidal flats - Moutere Inlet, Dec. 2012.

Broad scale habitat mapping uses measures of the area of soft mud, macroalgal cover, gross eutrophic zones, 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 2013 are presented in the following sections. In 2013, a total of 769ha of estuary was mapped, comprising 48ha covered by water at low tide, 636ha unvegetated intertidal flats, 82ha tidal saltmarsh, and 2ha seagrass. The mapping extent mirrored as much as possible that presented in Clark and Gillespie (2007) for 1947, 1988 and 2006, to facilitate the comparison of results for key indicators. Consequently, the Moutere Delta, mapped as part of the recent coastal risk assessment (Robertson and Stevens 2012) has not been included in the current summary but is presented in Appendix 2.

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. 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.

Results (summarised in Table 3 and Figure 3) show that although firm sand and firm mud/sand were the dominant substrates (51% of the intertidal area), soft and very soft muds (274ha, 38%) were very extensive. The soft mud condition rating places the estuary in the "poor" category and is a key contributor to degraded conditions within the estuary. Most of the mud is located in natural settlement areas in the central estuary basin between the two entrances, along the edges of low tide flow channels, on the southwest flats in the upper estuary, and within flow restricted embayments, particularly north of Wharf Road.

Also notable is the position of extensive tidal flats perched high in the tidal range. This infilling has greatly reduced the tidal volume of the estuary, and the flats now remain exposed over the majority of the tidal cycle (conditions generally unfavourable for seagrass and many sediment dwelling animals). Defining estuary bathymetry and the tidal prism using LIDAR data recently collected by TDC would be very useful.

Outside muddy areas, firm sands dominant near the estuary entrances, along with rock, cobble, and gravel fields, and biogenic reefs (e.g. worm, oyster mussel and sponge beds) - areas all in good condition.

Table 3. Summary of dominant intertidal substrate, Moutere Inlet, Jan. 2013.

Dominant Substrate	Area Ha	Percentage	Comments
Built structure	4.8	0.7	Predominantly steep faced rock and earth margins of reclaimed land and roads.
Boulder field	0.1	0.0	Small area where the Moutere River enters the main estuary basin.
Cobble field	4.9	0.7	Common adjacent to reclaimed shorelines and at estuary entrances.
Gravel field	58.6	8.1	Most extensive near estuary entrances, and along high tide shorelines.
Oyster reef	0.1	0.0	Narrow reefs on channel banks, mostly within the Wharf Road embayment.
Sabellid field	0.9	0.1	Most common near channel margins by the estuary entrances.
Shell bank	1.1	0.2	Most common near channel margins by the estuary entrances.
Mobile sand	6.1	0.8	Most common near channel margins by the estuary entrances.
Firm sand	56.9	7.9	Predominantly in the central estuary by the southern (Kina) entrance.
Firm muddy sand	312.4	43.4	Most common as raised tidal flats near the estuary entrances and among saltmarsh.
Soft mud	115.8	16.1	Concentrated on the Kina side of the southeast flats, and flow restricted embayments.
Very soft mud	158.2	22.0	Concentrated in flow restricted embayments, and deposition zones in the central basin.
TOTAL	**720**	**100**	

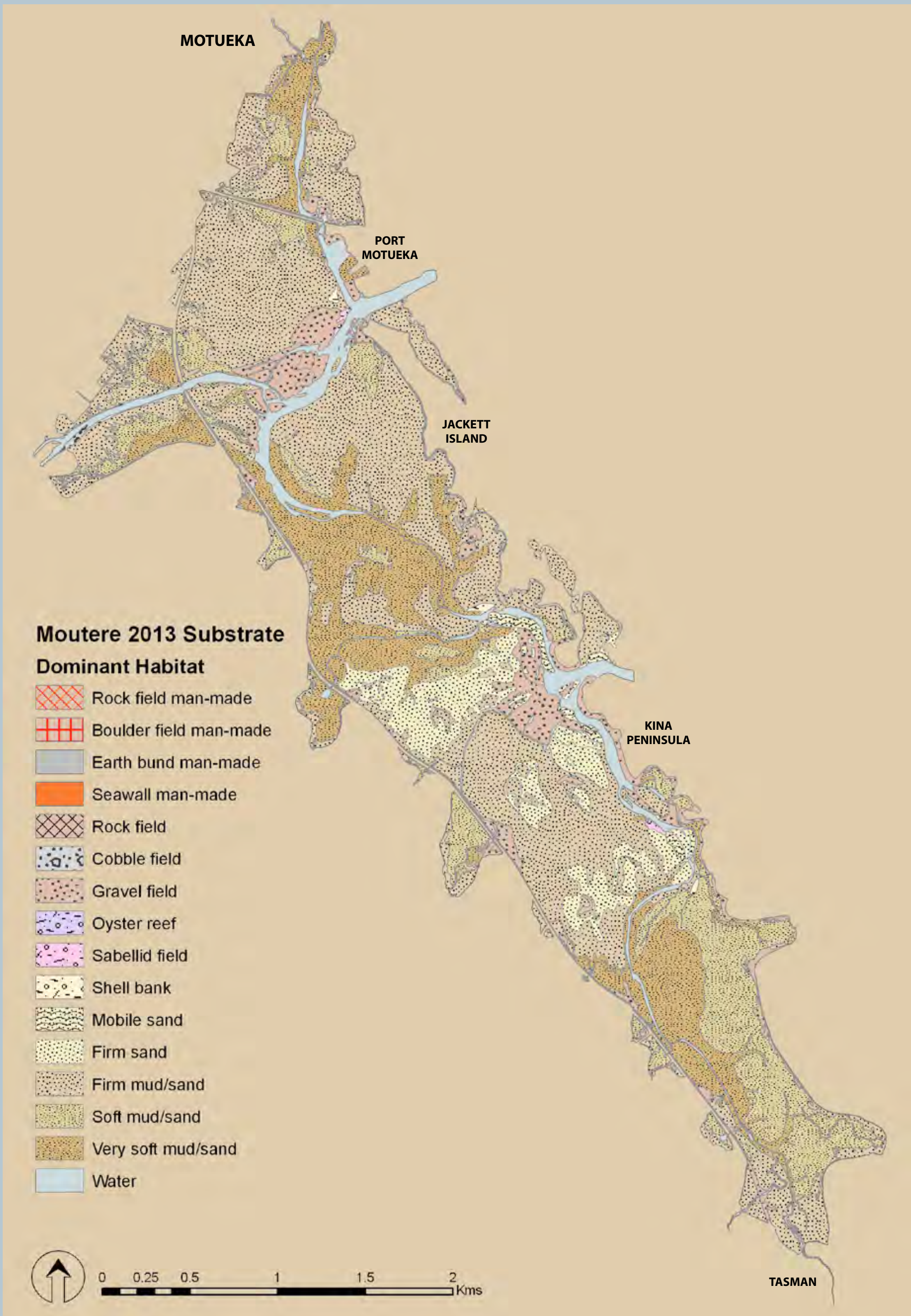


Figure 3. Map of Substrate Types - Moutere Inlet, Jan. 2013.

BROAD SCALE MAPPING (CONT.)

SOFT MUD % COVER CONDITION RATING

2006 POOR (14%)

2013 POOR (38%)

SOFT MUD AREA CHANGE RATING

2006-2013 LARGE INCREASE

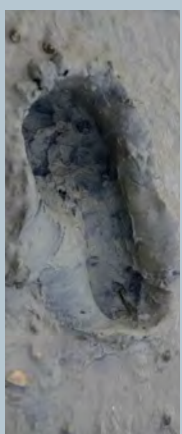
CHANGES IN ESTUARY SOFT MUD 2006-2013

The percent cover of major substrate classes in the Moutere Inlet in 2006 and 2013 are summarised in Table 4. The area dominated by soft mud has increased very significantly (175ha) from 2006 to 2013. Using the 2006 data as a baseline, the soft mud change condition rating is “poor”. The large increase in mud extent corresponds with a large increase in the mud content within sediments (41-77%) recorded in the fine scale results (Robertson and Stevens 2013) over the same time period.

Table 4. Broad substrate categories, Moutere Inlet, 2006 and 2013.

Substrate Class	2006		2013	
	Area (ha)	Percent	Area (ha)	Percent
Boulder/Cobble/Gravel	46	6.5	64	8.8
Shell/Oyster/Mussel/Tubeworm	1	0.2	2	0.3
Firm Sands and Muddy Sands	559	79.3	375	52.1
Soft and Very Soft Muds	99	14.0	274	38.1
Other	0.0	0.0	5	0.7
TOTAL	705	100	720	100

Temporarily dried soft muds in the upper estuary.



Deep soft muds in the central basin.

A small component of the increased mud extent (<5ha of 175ha) is attributable to a change in classification from 2006 to 2013. Soft muds that dry hard over the summer (see inset photo) were classified as firm mud in 2006, but as soft mud in 2013.

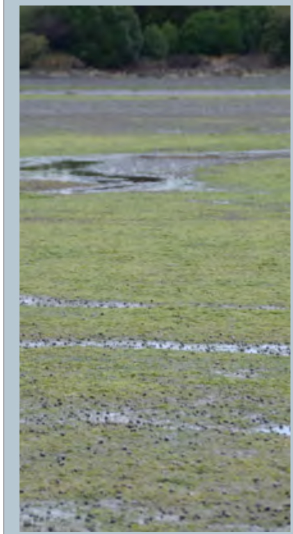
Overall however, the large increase in mud is real. Macroalgal beds have expanded in size by ~27ha since 2006 (see following section for more detail) and are trapping and concentrating muds in natural settlement zones. In addition, since 2006 over 35ha of firm muddy sand in the embayments on the west of the estuary, and over 60ha of unvegetated intertidal sediment on the southeast flats near Kina, on the cusp of being classified as soft mud in 2006, have now transitioned to soft or very soft muds. Consequently previously sand-dominated areas have become mud-dominated, while sediment conditions have degraded (e.g. increased organic content, reduced oxygenation, transition to mud-tolerant communities, increased mud content) as shown in the 2013 fine scale monitoring (Robertson & Stevens 2013).

The increase in muddiness is not yet reflected in sedimentation rate measurements collected by TDC since 2008 which show average deposition of <1mm/year in the upper tidal reaches of the estuary (Appendix 3), with the largest increase (1.8mm) affected by a raised culvert under SH60 at one site. This is partly because sedimentation rates are not currently measured in the central basin of the estuary where the greatest increase in muds have been evident. Consequently, additional plates in these areas, and at the fine scale monitoring sites, are recommended. However, a shift to mud dominated sediments can also occur independently of changes in sediment levels from both sediment pore spaces getting filled with fine material, as well as changes to the sand matrix - increased fine mud promoting the slippage of coarser sand particles past each other, making the substrate less cohesive and more liquefied. Consequently, you sink into the muddy sands as the coarse sand particles, lubricated by fine muds and silts and water, are no longer able to effectively lock together and hold you up.

The large increase in mud within the estuary is a cause of significant concern. Potential sources of sediment inputs to the estuary between 2006 and 2013 should be investigated to determine whether the increase is a response to direct inputs from development of the surrounding catchment, from flood deposition, or from reworking of sediment within the estuary. One very obvious potential catchment source is soil loss from conversion of forestry land to pasture or rural-residential land use in catchments draining the west of the estuary. There was a high rate of logging in this area in 2007-2008 to beat the imposition of the government’s Climate Change (Forestry Sector) Regulations 2008 (Trevor James, TDC, pers. comm. August 2013).

Another important change in the estuary has been the removal of ~0.8ha of causeway (creating a new gravel bed and saltmarsh) following realignment of the coastal highway near Tasman. This has reconnected a previously restricted embayment to the main body of the estuary, greatly improving tidal exchange and enhancing ecological functioning. It is recommended that tidal exchange to the many estuary embayments around the estuary be increased whenever the opportunity allows, particularly the Wharf Road embayment.

BROAD SCALE MAPPING (CONT.)



Extensive macroalgal (*Ulva*) cover near the western side of Jackett Island.

LOW DENSITY MACROALGAL CONDITION RATING
2013 LOW

HIGH DENSITY MACROALGAL CONDITION RATING
2013 HIGH

MACROALGAL COVER CHANGE RATING
2006-2013 VERY LARGE INCREASE

MACROALGAL COVER

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 intertidal macroalgal survey (Table 5 and Figure 4) showed:

- The majority of the intertidal area (80%) was rated as having a low/very low percentage cover.
- There was a significant percentage of high-very high nuisance macroalgal cover (11%, 71ha).
- The dominant macroalgae were the green alga *Ulva lactuca* (which grows rapidly throughout the estuary and in channel areas wherever substrate allows and growing conditions are favourable) and the red alga *Gracilaria chilensis* (growing predominantly in soft muds within deposition zones).
- The most extensive macroalgal growths were near channel areas in the central basin, the southeast flats and the Wharf Road embayment.
- Dense macroalgal cover commonly coincided with the presence of soft, poorly oxygenated, muds.

The Macroalgal Coefficient (MC) for low density cover within the estuary was 0.36 (Table 6). This fits a condition rating of "low", reflecting predominantly low growth across most of the estuary. However, the high density macroalgae cover is rated as "high" with 11% of the estuary experiencing dense (>50%) macroalgal growths. Many of these high growth areas also had nuisance conditions with rotting macroalgae and poorly oxygenated and sulphide rich sediments causing significant degradation in the central basin, and localised degradation within many of the embayments.

Table 5. Summary of macroalgal cover, Moutere Inlet, Jan. 2013.

Percentage Cover	Area (ha)	Percentage	Dominant Species
<1%	483	75.7	-
1-5%	26	4.1	*U. lactuca*
5-10%	40	6.3	*U. lactuca, G. chilensis*
10-20%	4	0.6	*U. lactuca, G. chilensis*
20-50%	15	2.3	*U. lactuca, G. chilensis*
50-80%	33	5.1	*U. lactuca, G. chilensis*
>80%	38	5.9	*G. chilensis, U. lactuca*
	638	**100**	

CHANGES IN MACROALGAL COVER 1947, 1988, 2006, 2013

Although historical macroalgal coefficients cannot be derived, past mapping of dominant macroalgal cover (Clark et al. 2006, Clark and Gillespie 2007) enables broad trends in macroalgal growth to be assessed (Table 6). These results show a steady increase in the area of dense macroalgal growth from very low to high and places the change rating in the "very large increase" category. This primarily reflects the steady expansion of macroalgae in soft sediment areas in the central basin.

While the low density MC rating prior to 2013 is likely to have been "good" or "very good", it is also highly likely that low density macroalgal cover has increased over time in line with the high density macroalgal cover trend.

Table 6. Summary of dense (>50%) macroalgal cover, Moutere Inlet, 1947, 1988, 2006, 2013.

Year	Area (ha)	%	Low Density Rating	High Density Rating	Comment
1947[1]	3.4	0.6	-	VERY LOW	Restricted to a single area in the central basin.
1988[1]	18.6	3.0	-	LOW	Extensive in central basin, developing in the Wharf Road embayment.
2006[1,2]	43.3[4]	7.2	-	MOD	Central basin, Wharf Road (and other) embayments, southeast flats.
2013[3]	70.3	11.0	0.3	HIGH	Central basin, Wharf Road (and other) embayments, southeast flats.

[1]Clark and Gillespie (2007). Note the 1988 aerial photos indicate macroalgal cover has been underestimated in the historical assessment.
[2]Clark et al. (2006). [3]Current report. [4]Erroneous value of 6.3ha reported in Clark et al. (2006). Corrected estimate (43.3ha) derived from GIS output and report summary data.

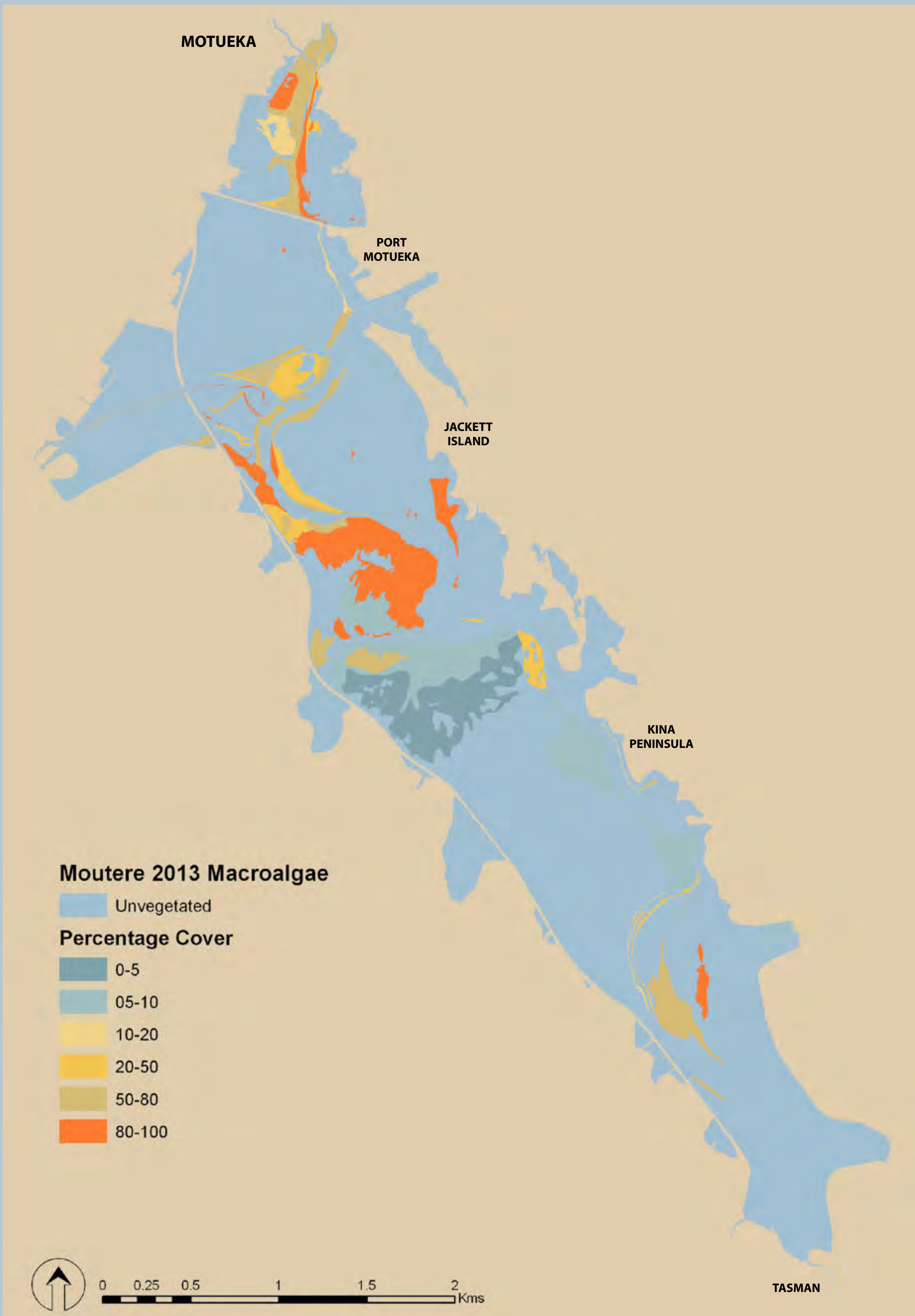


Figure 4. Map of Macroalgal Cover - Moutere Inlet, Jan. 2013.

BROAD SCALE MAPPING (CONT.)

GROSS EUTROPHIC AREA CONDITION RATING

1947 GOOD

2006 POOR

2013 VERY POOR

GROSS EUTROPHIC AREA CHANGE RATING

1947-2013 VERY LARGE INCREASE

GROSS EUTROPHIC CONDITIONS

When sediments exhibit combined symptoms of high macroalgal growth (>50% cover), a high mud content, a shallow RPD, elevated nutrient and organic concentrations, and displacement of invertebrates sensitive to organic enrichment, 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 can establish that is very difficult to reverse. These conditions are most likely to occur on the relatively sheltered tidal flats of an estuary, areas that are also those most favourable for high value seagrass habitat.

CHANGES IN GROSS EUTROPHIC CONDITIONS 2006-2013

A condition rating has been developed that recognises that gross eutrophic conditions should not be present in short residence time estuaries (like Moutere Inlet), with their presence providing a clear signal that the assimilative capacity of the estuary is being exceeded. The 2013 condition rating places the estuary in the "very poor" category with 60ha (9%) of the estuary in a severely degraded state.

Eutrophic conditions are known to have been present prior to 2013, and their likely worst case extent has been estimated in Table 7 for 1947 and 2006 based on Clark and Gillespie (2007). While the accuracy of the baseline is coarse, there has been a clear increase in the gross eutrophic areas in the estuary over time (Table 7, Figure 5).

The most degraded sites are concentrated in natural deposition zones within the estuary (Figure 6), where the combined influence of flocculation at the saltwater/freshwater interface, relatively sheltered tidal flats (dissipating flow velocities), and limited tidal flushing, all serve to concentrate catchment inputs of sediments and nutrients, and provide suitable conditions for the growth of macroalgae.

Table 7. Extent of gross eutrophic zones in Moutere Inlet, 1947, 2006, 2013.

Year	1947[1]	2006[1]	2013
Area (ha)	1	37	60
Percent (%)	0.2%	6%	9%

[1] Estimated based on summary data presented in Clark and Gillespie (2007).

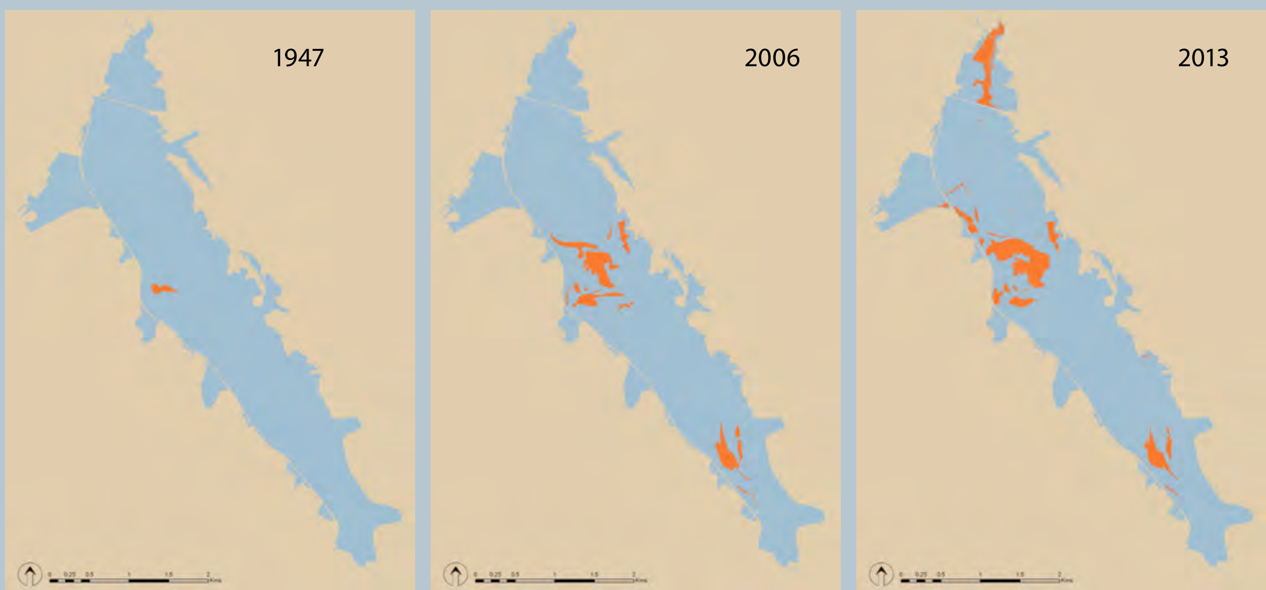


Figure 5. Location of gross eutrophic zones in Moutere Inlet, 1947, 2006, 2013.

Figure 6. Examples of gross eutrophic zones within Moutere Inlet showing smothering by dense macroalgal growth (top left), excessive muddiness and high sulphide/low oxygen sediment conditions (top right), and extensive cover in the central estuary (middle photo) and Wharf Road embayment (lower photo).

BROAD SCALE MAPPING (CONT.)

Seagrass beds near low tide channels by the Kina entrance.

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 2013 intertidal seagrass survey (Table 8 and Figure 7) showed:

- Most of the intertidal area (99.7%) was rated as having a "low" or "very low" percentage cover.
- Seagrass beds were located low in the tidal range, primarily near channels by the Kina entrance.
- Despite their small size (2 ha), beds appeared resilient and in good condition.

The Seagrass Coefficient (SC) was "very low" (0.03), a condition rating of "poor".

Table 8. Summary of seagrass *(Z. muelleri)* cover, Moutere Inlet, Jan. 2013.

Percentage Cover	Area (ha)	Percentage
<1%	684	99.7
1-5%	0	0.0
5-10%	0	0.0
10-20%	0	0.0
20-50%	0	0.0
50-80%	0	0.0
>80%	2.0	0.3
	686	**100**

SEAGRASS COEFFICIENT CONDITION RATING
2013 POOR

SEAGRASS AREA CHANGE RATING
1947-2013 VERY LARGE DECREASE

Clark and Gillespie (2007) report no seagrass in the estuary in 1947, 0.2ha in 1988, and 0.9ha in 2006. However, the existing seagrass beds are evident in the 1947 photos, and indicate that they have been able to maintain a foothold in the estuary despite significant modification of the estuary since 1947 (primarily saltmarsh clearance and roading development). Because the estuary had already been significantly modified prior to 1947, seagrass beds are likely to have been far more extensive historically.

The current location of seagrass appears restricted to well flushed lower channel areas near the estuary mouth which are largely free of mud and regularly bathed with clean seawater. Seagrass appears unable to establish on the perched intertidal flats of the estuary, most likely due to a combination of dessication (long periods of exposure between tides), excessive muddiness, and poor water clarity.

The obvious trend of declining seagrass apparent from aerial photos suggests a very large decrease (>50% loss) since 1947.

Figure 7. Map of Seagrass Cover - Moutere Inlet, Jan. 2013.

BROAD SCALE MAPPING (CONT.)

SALTMARSH % COVER CONDITION RATING
2013 MODERATE

Saltmarsh reclamation on private land near Batchelor Ford Road.

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 9 and Figure 8 summarise the results of the 2013 saltmarsh mapping. The area of remaining saltmarsh (82ha, 10.6%) fits the condition rating of "moderate".

Key findings were:

- The most extensive saltmarsh areas were located in the northwest and southwest regions.
- The dominant saltmarsh was rushland (55%), and herbfield (36%).
- Introduced weeds were a common subdominant cover near the terrestrial margin.
- Recent saltmarsh loss through reclamation and drainage was evident in the northwest.
- A saltmarsh and margin restoration project is underway near Tasman (see photo below) following causeway removal and road realignment.

Table 9. Summary of saltmarsh cover, Moutere Inlet, Jan. 2013.

Class	Dominant Vegetation	Area (ha)	Percentage
Estuarine Shrub		4.8	6%
	Plagianthus divaricatus (Saltmarsh ribbonwood)	4.8	6%
Tussockland		0.1	0%
	Phormium tenax (New Zealand flax)	0.1	0%
Sedgeland		0.6	1%
	Schoenoplectus pungens (Three square)	0.6	1%
Grassland		1.1	1%
	Festuca arundinacea (Tall fescue)	1.1	1%
Duneland		0.02	0%
	Ammophila arenaria (Marram grass)	0.02	0%
Rushland		45.3	55%
	Apodasima similis (Jointed wirerush)	0.5	1%
	Isolepis ficinia (Knobby clubrush)	0.04	0%
	Juncus kraussii (Searush)	44.8	55%
Reedland		0.2	0%
	Typha orientalis (Raupo)	0.2	0%
Herbfield		29.2	36%
	Sarcocornia quinqueflora (Glasswort)	29.1	36%
	Samolus repens (Primrose)	0.1	0%
	Carpobrotus edulis (Ice plant)	0.0	0%
TOTAL		**82**	**100%**

Saltmarsh restoration at Tasman following causeway removal and realignment of the State Highway.

Figure 8. Map of Saltmarsh Vegetation - Moutere Inlet, Jan. 2013.

3. RESULTS AND DISCUSSION (CONTINUED)

BROAD SCALE MAPPING (CONT.)

The estuary saltmarsh was characterised primarily by rushland in the upper intertidal reaches (often with a mix of saltmarsh ribbonwood, gorse and grassland at the inland margins), with extensive herbfields common seaward of the rushland.



Within the main basin of the estuary, very little saltmarsh is present adjacent to SH60 where the steep, reclaimed, armoured shoreline prevents saltmarsh from establishing through a combination of inundation and wave erosion. Instead, most remaining saltmarsh is now confined within the embayments landward of the highway. These all have restricted tidal flows, excessive muds, and most also have modified margins from roading and reclamations.




These modified margins create extensive barriers to the migration of saltmarsh in response to sea level rise (SLR), and are apparent around most of the estuary. In these areas, and where natural cliffs flank the estuary on the Kina Peninsula, saltmarsh is likely to be inundated and displaced over time where inland migration is not possible.



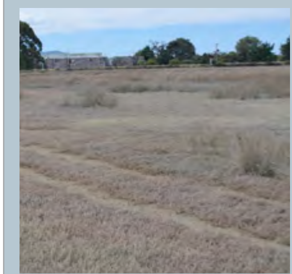

Other saltmarsh impacts have resulted from localised rubbish dumping, and from the damming of the Easton embayment for irrigation water/amenity use.


Small islands within the inlet (e.g. Lizard and Preece) support areas with a remaining natural transition from saltmarsh to terrestrial native scrub and forest and are included in DOC's restoration initiatives in the estuary.

BROAD SCALE MAPPING (CONT.)

SALTMARSH AREA CHANGE RATING
LARGE DECREASE

1947-1988 LARGE DECREASE
1988-2006 SMALL DECREASE
2006-2013 SMALL INCREASE



Vehicle tracks through saltmarsh and sandflats.

CHANGES IN SALTMARSH COVER 1947-2013

The condition rating for saltmarsh measures a percentage change from an established baseline. Based on the summary information in Table 10, and using 1947 data as a baseline, the 2013 saltmarsh condition rating is rated as a "large decrease" (11-50% decrease) in saltmarsh. This is in addition to the significant loss of saltmarsh and the surrounding terrestrial margin that occurred prior to 1947 but has not been well documented.

The key change since 1947 has been the large loss of estuarine shrub, tussockland, rushland, and herbfield, primarily through reclamation and margin development. In particular, the construction of the coastal highway through the west of the estuary displaced large areas of saltmarsh and now divides much of the remaining saltmarsh from the main body of the estuary.

Although small changes are evident between the 1988, 2006 and 2013 results, these are difficult to interpret and primarily relate to variation in the extent and interpretation of mapped features. The small increase from 2006 to 2013 is largely attributable to saltmarsh planting that has been undertaken to offset road impacts (reclamation and declamation) that have occurred following the recent NZTA realignment of the coastal highway SH60.

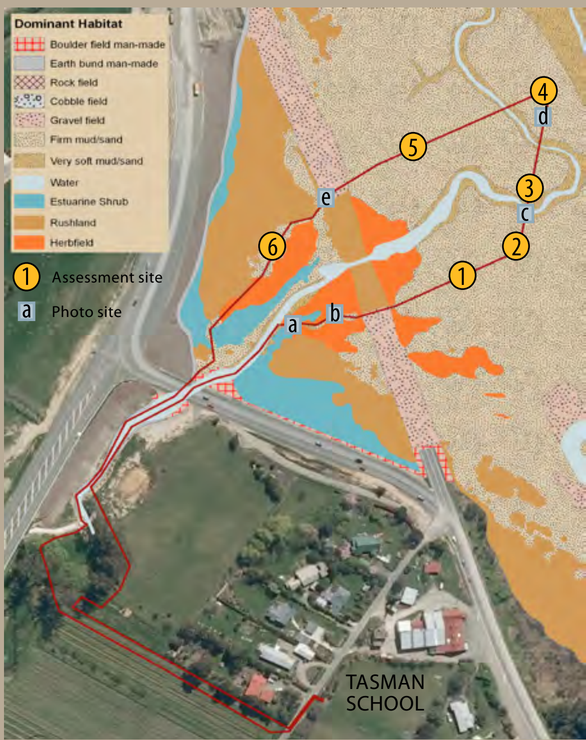
However, ongoing losses of saltmarsh have continued through reclamation and drainage of the estuary margins, with localised impacts also evident from vehicle traffic (>5km of tracks, 0.5-1ha) throughout the estuary (see sidebar photos), and the Muddy Buddy adventure fun run (see boxes on following pages).

Table 10. Summary of saltmarsh cover, Moutere Inlet, 1947, 1988, 2006, 2013.

Vegetation Class	1947		1988		2006		2013	
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Estuarine Shrub	14.6	1.8	5.7	0.7	3.0	0.4	4.8	0.6
Tussockland	1.6	0.2	1.3	0.2	0.3	0.0	0.1	0.0
Sedgeland	0.0	0.0	0.1	0.0	0.2	0.0	0.6	0.1
Grassland	0.0	0.0	0.0	0.0	0.4	0.0	1.1	0.1
Reedland	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0
Rushland	82.3	10.2	40.8	5.3	43.6	5.7	44.1	5.7
Herbfield	52.4	6.5	31.4	4.1	29.1	3.8	30.5	4.0
TOTAL	151	18.7	79	10.4	77	10.1	81	10.6

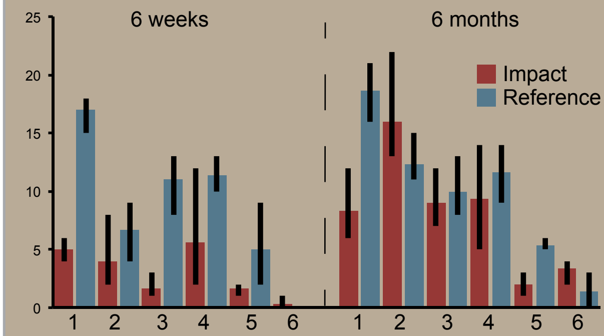
Although recent losses are relatively small, because saltmarsh around the estuary has already been greatly reduced, further reductions of this important habitat are highly undesirable. It is also obvious that the ongoing margin development continuing on private land adjacent to the estuary is both further diminishing saltmarsh and, through drainage and reclamation, is removing many of the low lying margins favoured by saltmarsh and flanking wetlands. 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.

Rushes and herbfield on a small gravel bed near Jackett Island.

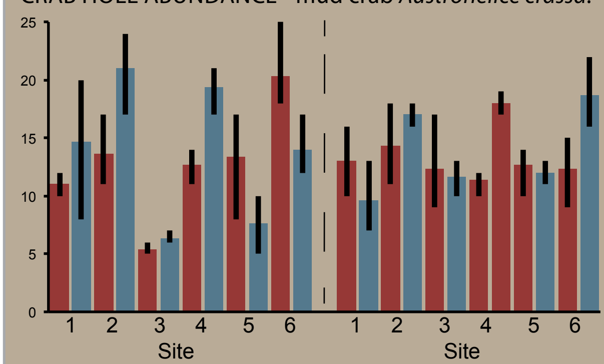


Muddy Buddy Fun Run course (2012) showing dominant substrate and vegetation, impact assessment sites, and photo assessment sites (see facing page). Photo TDC, 2008.

EPIFAUNA ABUNDANCE - mud snail *Amphibola crenata.*



CRAB HOLE ABUNDANCE - mud crab *Austrohelice crassa.*



Mean abundance and range(n=3) per 0.25m^2 quadrat.

The Muddy Buddy Adventure Fun Run is a fund-raising community event run by Tasman School in conjunction with Sport Tasman. Participants follow a flagged 1.5km route from Tasman School that passes 500m through an adjacent orchard, 300m down a streambed, before winding through 150m of saltmarsh and 550m of mudflats. It encompasses a total estuary area of ~0.35ha (0.05% of the estuary), including 0.07ha (750m^2) of saltmarsh.

Since 2010, the event has steadily gained popularity with participant numbers increasing annually from ~290 in 2010, to 1400 in 2013. With the increase in participants, and because it passes through sensitive habitat, concern has been raised about the potential impact of the event. To this end, monitoring undertaken by Tasman School students, DOC, and TDC, saw the course altered in 2013 to minimise impacts on plants, waterways and nesting birdlife. In addition, TDC funded a brief assessment on the features impacted and their recovery in the estuary.

The latter included mapping of dominant habitat features (see inset figure), assessment of sediment oxygenation, and photo documentation of changes over time in representative areas (see facing page). This was undertaken immediately before, during and after the 2012 event. The same measures were repeated 6 weeks and 6 months later, with visible animals and crab holes also counted at 6 impacted and 6 reference sites (see inset figure) to provide a low cost indication of disturbance and recovery of the wider sediment community.

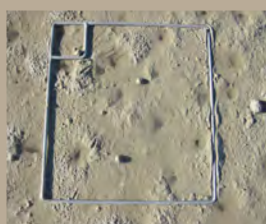
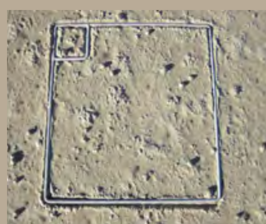
Because most of the course is located on perched, muddy mid-tidal flats which are exposed for most of the tidal cycle, animals were generally scarce. No plants were growing on the intertidal flats. Photos show that surface disturbance of the muddy intertidal flats was minor and returned relatively quickly to a point where visual impacts were not obvious (see quadrat photos below, row 'd' photos on facing page).

It is also noteworthy that the entire upper estuary was coated in a layer of fine mud when the 6 month assessment was undertaken, indicating that inputs of mud to this part of the estuary are continuing, resulting in ongoing degradation.

Saltmarsh impacts were confined to a total area <100m^2 (primarily because of careful course setting), but persisted for >6 months, with minor impacts from the previous event still evident after 12 months. Saltmarsh cover (searush and glasswort) reduced by ~80% where it was trampled, but signs of recovery were evident after 6 months. Additional saltmarsh disturbance was evident along parts of the Muddy Buddy course where the intertidal flats have been accessed to create "rock art" sculptures. It is also clear that saltmarsh in this part of the estuary is still responding to disturbance and flow changes following recent removal of a 0.8ha section of SH60 causeway, and associated road realignment and reinstatement of saltmarsh.

Sediment RPD was <1cm before the event (in a poor condition primarily due to excessive fine mud), and showed no appreciable change following the event.

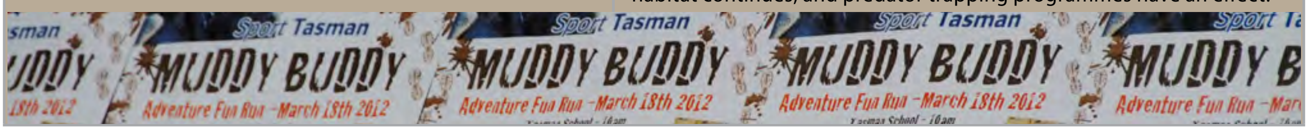
Quadrat counts showed a clear reduction in epifauna (mud snails) 6 weeks after the event (see top inset graph), with abundances generally returning to similar levels to nearby reference sites after 6 months.

Site 1 quadrats: 6 week impact (left) and reference (right).

Crab hole counts showed a more rapid return to pre-impact levels with little evidence of impact after 6 months (see lower inset graph).

Based on past alterations to the estuary in this area, primarily the extensive infilling of the intertidal flats with muds, the direct impact to intertidal sediments from the Muddy Buddy are considered to be relatively minor and reversible. Impacts to saltmarsh are localised, but take a significantly longer time to recover. Disturbance to wildlife appears minimal at present (as wildlife has yet to reestablish), but may become more significant if breeding populations of species like banded rail flourish as ongoing enhancement and growth of saltmarsh and margin habitat continues, and predator trapping programmes have an effect.

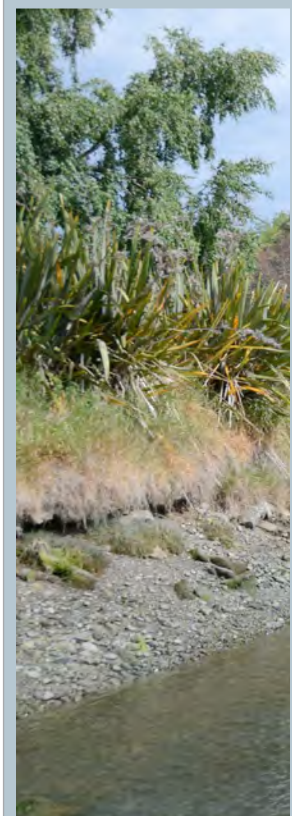


BEFORE	DURING	+1 HOUR	+ 6 WEEKS	+6 MONTHS

BROAD SCALE MAPPING (CONT.)

VEGETATED MARGIN % COVER CONDITION RATING
2006 POOR
2013 POOR

VEGETATED MARGIN CHANGE RATING
2006-2013 NO SIGNIFICANT CHANGE



Margin areas in the Wharf Road embayment (above) and by SH60 (right).

200m 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 11 and Figure 9) showed:

- The mapped 200m wide terrestrial margin buffer was dominated by horticulture (36%), grassland (21%) and residential and industrial development (21%).
- Scrub and forest (17%) was virtually all located on Kina Peninsula and Jackett Island.
- Most of the immediate estuary margin (67%) had been modified by roading, causeways, seawalls, or reclamations - the western estuary margin being almost completely modified.

The area of densely vegetated terrestrial buffer (17%) fits the condition rating of "poor", with no significant overall change evident from 2006.

The dominant feature of the western side of the estuary was the extensive presence of roading and artificial seawalls along the estuary edge. In these areas, there was a relatively abrupt change from terrestrial cover to the estuary, and very limited natural buffering capacity remained. To offset the effects of reclamation associated with widening of parts of SH60, $40k is being put into margin restoration near Tasman, while restoration is being undertaken independently at the northern end of the inlet by Keep Motueka Beautiful.

Ongoing development and drainage of wetland and saltmarsh areas on private land (removing the vegetative buffering capacity) are of concern.

Table 11. Summary of 200m terrestrial margin, Moutere Inlet, Jan 2013.

Class	Dominant Cover	Percentage
Forest		14.9%
	Exotic forest	1.8%
	Mixed native and exotic forest	13.1%
Scrub		2.5%
	Mixed native and exotic scrub	2.1%
	Native scrub	0.3%
Grassland		21.3%
	Grassland	3.9%
	Maintained park/amenity area	7.7%
	Pasture	9.8%
Reedland	*Typha orientalis* (Raupo)	0.1%
Horticulture		35.9%
Industrial		7.7%
Residential		12.8%
Built Feature	Road	4.2%
Total		**100%**

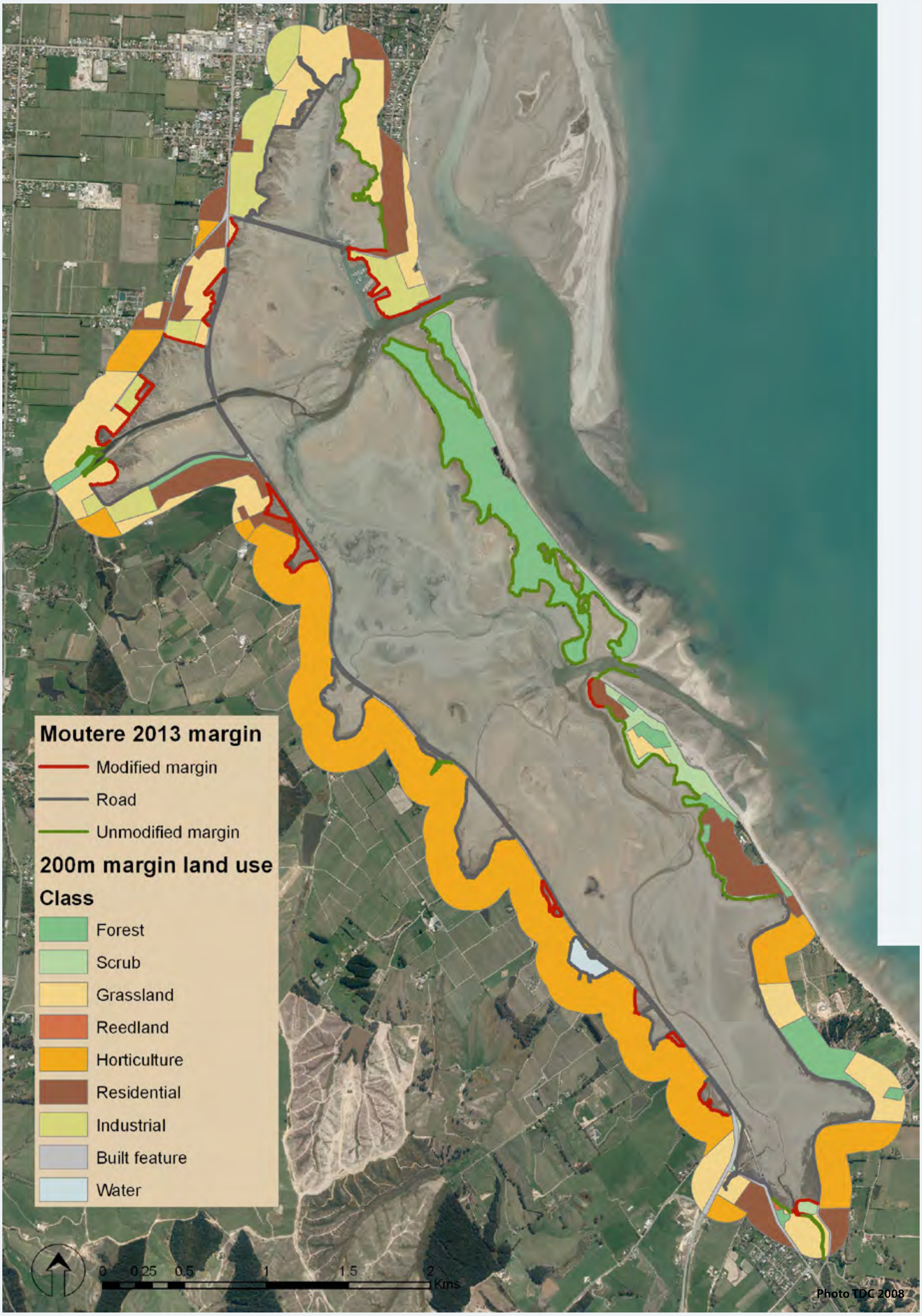


Figure 9. Map of 200m Terrestrial Margin Vegetation - Moutere Inlet, Jan. 2013.

4. SUMMARY AND CONCLUSIONS

Table 12 summarises condition ratings in relation to the key issues addressed by the broad scale monitoring (i.e. sediment, eutrophication and habitat modification).

Table 12. Summary of broad scale condition ratings for Moutere Inlet, 1947, 1988, 2006, 2013.

Major Issue	Indicator	1947	1988	2006	2013	Change from Baseline
Sediment	Soft mud area	unknown	unknown	POOR	POOR	LARGE INCREASE
Eutrophication	Low density macroalgal cover	GOOD*	GOOD*	GOOD	GOOD	TRENDING UP = WARNING
	High density macroalgal cover	VERY LOW*	LOW*	MODERATE	HIGH	VERY LARGE INCREASE
	Gross eutrophic condition area	GOOD	MODERATE*	POOR	VERY POOR	VERY LARGE INCREASE
Habitat Modification	Seagrass area	FAIR*	POOR*	POOR	POOR	VERY LARGE DECREASE
	Saltmarsh area	HIGH	MODERATE	MODERATE	MODERATE	LARGE DECREASE
	Densely vegetated margin area	POOR*	POOR*	POOR	POOR	NO SIGNIFICANT CHANGE

*estimated value

The 2013 broad scale mapping results show that while large sections of the estuary remain in good condition, there has been a significant decline in most estuary condition indicators since 1947, the exception being the extent of densely vegetated margin which had largely been already lost.

While the estuary remains predominantly sandy (51% firm sand and firm mud/sand), soft and very soft mud now cover 38% of the surface sediments in the estuary. There has been a huge increase in the area of soft mud (from 99ha to 274ha) since 2006. Most is located in the central basin, and in sheltered embayments around the estuary - areas that act as natural settling areas for fine sediment.

Macroalgal growth remained relatively low throughout most of the lower estuary, although dense beds of both *Gracilaria* and *U. lactuca* were present in the central basin and near low tide channels. High density *Gracilaria* beds in the centre and north of the estuary were 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 ~1ha in 1947, to 37ha in 2006 and to 60ha in 2013. The macroinvertebrate community in these areas is likely to be severely degraded (little animal life can establish in anoxic sediments, and surface feeding species are generally few in number and limited to those tolerant of poor conditions). Such conditions limit the food availability for fish and birdlife, and show the estuary's capacity to assimilate catchment nutrient and sediment loads is currently exceeded in these locations. These symptoms serve a clear warning that problems are likely to continue to worsen and begin to impact on the wider estuary if management action is not taken.

Small seagrass (*Zostera*) beds are present (2ha), primarily near low tide channels near the Kina entrance. They appear resilient (many of the remaining beds are evident in the 1947 aerial photos), but are likely to be restricted in their range due to excessive muddiness in the estuary, and have clearly declined in their coverage since 1947.

Around the estuary edges, saltmarsh vegetation was still prominent (82ha, 10.6% of the estuary), of which 55% was rushland and 36% herbfield. From 1947 to 2013, there was a large reduction in saltmarsh cover (151ha to 82ha), primarily due to reclamation and road development, most impacts occurring on the western side of the estuary. Further roading impacts have occurred in the last 5 years following realignment and partial declamation of SH60, while ongoing reclamation and drainage is evident on private land adjacent to the estuary. Saltmarsh remained most extensive within estuary embayments, and on tidal flats in the north and south of the estuary by Tasman and Motueka.

The estuary 200m terrestrial margin was dominated by horticulture (36%), grassland (21%), and residential and industrial development (21%) with only 17% in forest/scrub. Artificial shoreline structures (e.g. rockwalls, floodbanks, causeways) were a dominant feature around 67% of the estuary, and severely restrict the area available for saltmarsh growth. In many of these areas, saltmarsh vegetation was either absent or restricted to narrow bands which greatly limits its role in natural buffering of the estuary from sediment and nutrient inputs. There was no significant change in the percentage of the margin that was densely vegetated from 2006 to 2013 (most forest and scrub has been cleared previously), although ongoing drainage of saltmarsh on private land was apparent in several locations.

5. MONITORING

Moutere Inlet has been identified by TDC as a priority for monitoring, and is a key part of TDC's coastal monitoring programme being undertaken in a staged manner throughout the Tasman district. Based on the 2013 monitoring results and condition ratings, the following monitoring recommendations are proposed by Wriggle for consideration by TDC:

Broad Scale Habitat Mapping.
Continue with the programme of 5 yearly broad scale habitat mapping, focussing on the main issues of sedimentation and eutrophication, with saltmarsh and the terrestrial margin assessed on a 10 yearly cycle unless obvious changes are observed. Next monitoring due in February/March 2018.

Macroalgal Monitoring.
Undertake a rapid visual assessment of macroalgal growth annually, and initiate broad scale macroalgal mapping if conditions appear to be worsening over the 5 years before broad scale mapping is scheduled to be repeated.

Fine Scale Monitoring.
Two years of fine scale monitoring at Sites A and B have now been completed (2006 and 2013). It is recommended that TDC monitor annually for the next two years to establish a baseline, and thereafter at 5 yearly intervals.

Sedimentation Rate Monitoring.
Because sedimentation is a priority issue in the estuary it is recommended that sediment plate depths be measured annually, and additional plates be deployed in the highly eutrophic locations where sediment is rapidly accumulating.

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.

Catchment Landuse.
Track and map key broad scale changes in catchment landuse (5 yearly).

6. MANAGEMENT

Sedimentation and nutrient enrichment have been identified as major issues in Moutere Inlet. To address these issues, it is recommended that catchment nutrient and sediment guideline criteria be developed for the estuary. Input load assessments should then be undertaken to assess the extent to which current catchment loads are likely to meet guidelines. If catchment loads exceed the estuary's guideline criteria, then sources of elevated loads in the catchment should be identified, and management undertaken to minimise their adverse effects on estuary uses and values.

Such assessments would greatly benefit from the tidal prism of the estuary being determined using LIDAR data recently collected by TDC. The LIDAR data will also highlight the estuary margins most likely to be impacted by predicted sea level rise and should underpin planning to facilitate the expansion of estuary margins in response to predicted sea level rise, and to encourage expansion of the vegetated terrestrial margin in suitable locations where opportunities arise.

Any opportunities to increase the tidal exchange to embayments should be taken.

7. ACKNOWLEDGEMENTS

Many thanks to Maz Robertson (Wriggle) for assistance with fieldwork, and to Trevor James (Coastal Scientist, Tasman District Council) for his support with this work. Thanks also to Trevor James, Ros Squire, Rob Smith and Dennis Bush-King for their comments on the report.

8. REFERENCES

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

Clark, K. and Gillespie P. 2007. Historical broad scale mapping of Moutere Inlet (1947, 1988 and 2004). Prepared for Tasman District Council. Cawthron Report No. 1234. 19p.

Clark, K., Stevens, L., and Gillespie P. 2006. Broad scale mapping of Moutere Inlet. Prepared for Tasman District Council. Cawthron Report No. 1037. 19p.

Gillespie, P. and Clark, K. 2006. Moutere Inlet fine scale benthic baseline 2006. Prepared for Tasman District Council. Cawthron Report No. 1183. 18p.

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

Robertson, B.M. and Stevens, L. 2013. Moutere Inlet fine scale monitoring 2012/2013. Report prepared for Tasman District Council. 25p.

Robertson, B.M. and Stevens, L. 2012. Tasman Coast - Waimea Inlet to Kahurangi Point, habitat mapping, risk assessment and monitoring recommendations. Report prepared for Tasman District Council. 167p.

Robertson, B.M., and Stevens, L. 2008. Southland Coast: Te Waewae Bay to the Catlins, habitat mapping, risk assessment and monitoring recommendations. Report prepared by Wriggle Coastal Management for Environment Southland. 165p.

Robertson, B.M., and Stevens, L.M. 2007. New River Estuary 2007. Broad scale Habitat Mapping and Sedimentation Rate. Report prepared by Wriggle Coastal Management for Environment Southland. 34p.

Robertson, B.M., and Stevens, L.M. 2006. Southland Estuaries State of Environment Report 2001-2006. Report prepared by Wriggle Coastal Management for Environment Southland. 45p plus appendices.

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.

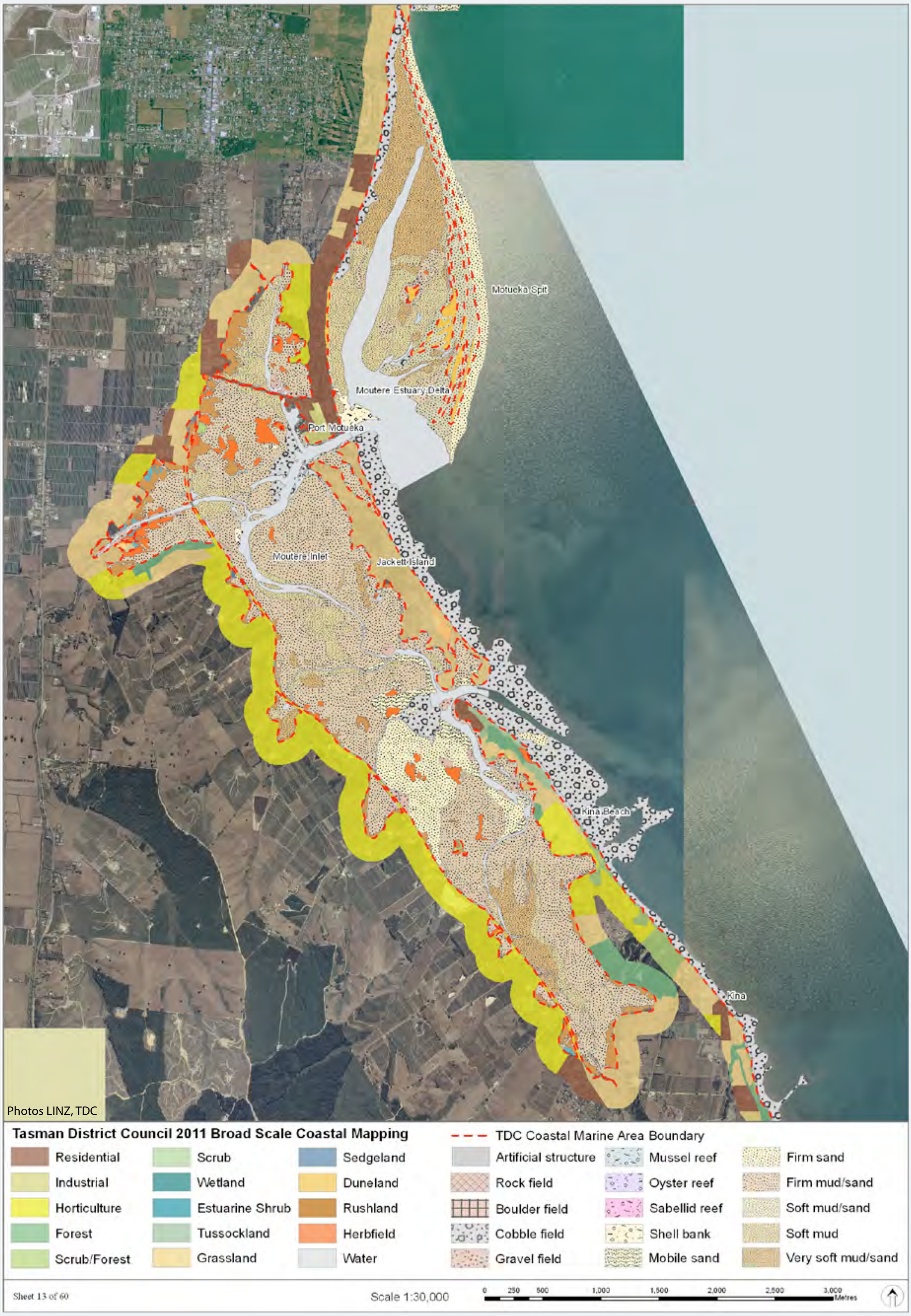
Cockle bed /Mussel reef/ Oyster reef: Area that is dominated by both live and dead cockle shells, or one or more mussel or oyster species respectively.

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.

APPENDIX 2. BROAD SCALE HABITAT MAP OF MOUTERE INLET AND MOUTERE DELTA.



Map source: Robertson and Stevens (2012).

NOTE: The Moutere Estuary data shown is that prepared by Clark et al. (2006) and provided to Wriggle as GIS shapefiles by TDC in 2011. The Moutere Delta and terrestrial margins were mapped by Wriggle in 2011 and presented in Robertson and Stevens (2012). GIS shapefiles are held by TDC.

APPENDIX 3. MOUTERE INLET SEDIMENTATION RATE MEASUREMENTS, 2008-2013.

Sediment plates installed, monitored, and data supplied by Trevor James, TDC. Values =mean depth to buried plate (mm).

Moutere River Robinson Road								
Site	NZMG 260	25/09/08	12/03/09	30/09/09	4/10/10	7/09/11	7/09/12	30/08/13
NE	E2510762 N6006789	26.0	26.5	25.7	25.5	25.3	26.1	25.9
NW	E2510735 N6006798	29.3	29.5	28.6	28.2	28.8	28.4	28.2
SW	E2510723 N6006770	15.8	15.5	15.1	15	15.3	15.1	15
SE	E2510522 N6006761	28.3	29	29.3	28.9	29	29.7	29.4
Mean Annual Change (mm)			1.1	-1.8	-1.1	0.8	0.9	-0.8
Mean Annual Change from 2008 baseline (mm)								-0.2
Moana Loop								
Site	NZMG 260	25/09/08	12/03/09	30/09/09	4/10/10	7/09/11	7/09/12	30/08/13
NE	E2511632 N6005143	28.0	29	29.1	29.1	29.7	29.9	30.5
NW	E2511598 N6005149	23.2	23	23	23.5	23.8	24.2	24.8
SW	E2511393 N6005125	33.6	33	33.3	34.2	35	35.5	36.6
SE	E2511621 N6005113	28.8	29.5	29.6	29.9	30.8	31.3	32.4
Mean Annual Change (mm)			0.9	0.5	1.7	2.6	1.6	3.4
Mean Annual Change from 2008 baseline (mm)								1.8
Strong-Eden Loop								
Site		25/09/08	12/03/09	30/09/09	4/10/10	7/09/11	7/09/12	30/08/13
NE	E2512334 N6004468	28.9	28.5	28.8	28.6	28.7	28.6	29.3
NW	E2512305 N6004477	28.0	28	28.2	28	28	27.9	28.6
SW	E2512296 N6004445	30.6	30.5	30.2	30.5	30.3	30.4	31.3
SE	E2512326 N6004437	29.2	29	29.1	28.8	29.1	29.1	29.9
Mean Annual Change (mm)			-0.7	0.3	-0.4	0.2	-0.1	3.1
Mean Annual Change from 2008 baseline (mm)								0.4
Tasman								
Site	NZMG 260	25/09/08	12/03/09	30/09/09	4/10/10	7/09/11	7/09/12	30/08/13
NE	E2514303 N6002750	28.4	28	27.8	28	28.3	28.1	27.5
NW	E2514279 N6002768	28.4	28	27.9	28	28.7	27.9	27.5
SW	E2514267 N6002741	29.8	29.5	29.5	29	29.3	29.2	29
SE	E2514291 N6002724	33.2	33	33	32.8	32.9	32.9	32.4
Mean Annual Change (mm)			-1.3	-0.3	-0.4	1.4	-1.1	-1.7
Mean Annual Change from 2008 baseline (mm)								-0.6