coastalmanagement

Motupipi Estuary 2015

Broad Scale Habitat Mapping

Prepared for
Tasman District Council
June 2015

Cover Photo: Eastern Arm of the Motupipi Estuary looking towards entrance, 2015.

Saltmarsh in the Eastern Arm of the Motupipi Estuary, 2015.

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by

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All photos by Wriggle except where noted otherwise.

Contents

List of Figures

List of Tables

MOTUPIPI ESTUARY - EXECUTIVE SUMMARY

Motupipi Estuary is a moderate-sized (169ha), shallow, well-flushed, seawater-dominated, tidal lagoon type estuary with one tidal opening, and two main basins. The western arm dominated by the Motupipi River responds more like a tidal river system than the seawater-dominated elevated eastern basin, which drys rapidly and remains exposed for much of the tidal cycle. Much of the immediate estuary margin is directly bordered by developed pasture/rural land, roads, and seawalls. Causeways separate small sections of saltmarsh from the main estuary.

The Motupipi Estuary is part of Tasman District Council's (TDC's) coastal State of the Environment (SOE) monitoring programme. This report summarises the results of 2015 broad scale habitat mapping of the estuary. The following sections summarise broad scale monitoring results (from the current report and previous studies), risk indicator ratings, overall estuary condition, and monitoring and management recommendations.

BROAD SCALE RESULTS

- Intertidal flats were dominated by sand (57%), mud (36%) and cobble (5%).
- Soft mud (32.2ha) covered 36% of the unvegetated intertidal habitat, and was concentrated in the east and west arms of the estuary.
- Opportunistic macroalgal growth (*Ulva lactuca* , *U. intestinalis* and *Gracilaria chilensis*) was sparse (4.4% of the available intertidal habitat) and no gross eutrophic zones were present.
- Seagrass covered 1.7ha (2%) of the estuary, confined primarily to the shallow edges of the Motupipi River. Associated with substrate changes, seagrass extent and density had decreased slightly in the lower estuary since 2007. Extensive subtidal seagrass beds were also present in the largely spring fed Motupipi River channel.
- Saltmarsh covered 38% of the estuary (60.5ha) of which 68% was rushland, 15% herbfield, 7% sedgeland and 7% estuarine shrub. A decline in saltmarsh of ~50% from natural state cover was estimated, primarily as a result of drainage and reclamation of the estuary margins. Recent localised losses (1-2ha) were also evident in the west arm following land drainage and reclamation.
- The densely vegetated 200m margin cover (forest, scrub, tussock, and duneland) of the estuary was low/moderate (25%).
- The majority of the upper tidal reaches of the estuary (~65%) have been modified with the edge hardened or armoured as a consequence of reclamation (e.g. most of the areas flanked by pasture) and, to a lesser extent, roading, seawalls, or flood control measures.

RISK INDICATOR RATINGS (indicate risk of adverse ecological impacts)

Major Issue	Indicator	2015 risk rating	Estimated Change from Natural State	Change since 2007
Sediment	Soft mud (% cover)	VERY HIGH	Natural state unknown	Small decrease (3.7ha, 10%)
Eutrophication	Macroalgal Growth (EQC)	VERY LOW	No significant change	No significant change
	Gross Eutrophic Conditions (ha)	VERY LOW	No significant change	No significant change
Habitat Modification	Seagrass Change (since 2007)	LOW	Natural state unknown	Small decrease
	Saltmarsh (% loss from estimated natural state)	MODERATE	~50% loss	Localised decrease (1-2ha)
	Saltmarsh (vegetated % of available habitat)	VERY LOW	No significant change	No significant change
	200m Vegetated Terrestrial Margin	HIGH	~75% loss	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 2015 broad scale mapping results indicate that overall there is currently a "MODERATE-HIGH" risk of adverse impacts to the estuary ecology occurring. The primary issue in the estuary is the large extent of soft mud (36% of the estuary), and to a lesser extent, extensive historical habitat modification, primarily through the displacement and reclamation of saltmarsh, ingress of terrestrial weeds, and the conversion of much of the densely vegetated terrestrial margin to pasture. There has been relatively little recent saltmarsh loss other than localised areas in the west of the estuary. Eutrophication, expressed through indicators of macroalgal growth and the presence of gross eutrophic conditions, was not a significant issue, with phytoplankton blooms in the upper estuary (Motupipi River) highlighting nutrient inputs currently exceed the assimilative capacity only in this small part of the estuary.

The key consequence of the extent of mud and habitat modification in Motupipi Estuary is a reduction in the ecological value of these important habitat features, including a reduced capacity to assimilate sediment and nutrient inputs, and reduced supporting habitat to birds and fish, particularly whitebait and shellfish.

RECOMMENDED MONITORING AND MANAGEMENT

It is recommended that broad scale habitat mapping be repeated every 5 years (next due in 2020), unless obvious changes are observed in the interim, focussing on the main issue of fine sediment, as well as saltmarsh and terrestrial margin changes.

Fine scale monitoring, last undertaken in 2007, is recommended for 2016, and then at 5 yearly intervals.

It is recommended that sediment plates continue to be monitored annually by TDC for sedimentation rate, with grain size also analysed to establish a baseline of sediment mud content.

Because the area of soft mud has recently decreased, no further action is recommended unless ongoing sedimentation rate or mud content measures indicate significant changes in mud are occurring. If mud increases are evident, it is recommended that the sediment inputs to the estuary be estimated to determine the likely extent of human influenced change, and an assessment be made of current management of human influenced sediment sources to ensure Best Management Practices (BMPs) are being applied within the catchment.

1. INTRODUCTION

Developing an understanding of the condition and risks to coastal and estuarine habitats is critical to the management of these important resources. These objectives, along with understanding change in condition/trends, are key objectives of Tasman District Council's State of the Environment Estuary monitoring programme. 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, Motueka Delta, Motupipi, Ruataniwha and Whanganui estuaries as priorities for monitoring.

For Motupipi Estuary, the monitoring and management process consists of three components developed from the National Estuary Monitoring Protocol (NEMP) (Robertson et al. 2002) as follows:

1. **Ecological Vulnerability Assessment** (EVA) of the estuary to major issues (see Table 1) and appropriate monitoring design. A region-wide EVA has been completed and is reported on in Robertson and Stevens (2012), with Motupipi Estuary specifically assessed in 2008 (Robertson and Stevens 2008).
2. **Broad Scale Habitat Mapping** (NEMP approach). This component (see Table 1) documents the key habitats within the estuary, and changes to these habitats over time. Broad scale mapping of Motupipi Estuary was undertaken in 2007 (Stevens and Robertson 2008), and included an assessment of historical vegetation cover from 1943 and 1984 aerial photographs. The current report describes broad scale habitat mapping undertaken in early 2015.
3. **Fine Scale Monitoring** (NEMP approach). Monitoring of physical, chemical and biological indicators (see Table 1). This component, which provides detailed information on the condition of Motupipi Estuary, was undertaken in 2008 (Robertson and Stevens 2008a).

In 2014, TDC commissioned Wriggle Coastal Management to undertake broad scale monitoring of Motupipi Estuary. The current report describes the following work undertaken in March 2015:

- 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.

Motupipi Estuary has been previously summarised (Robertson and Stevens 2012). It is a moderate-sized (169ha), shallow, well-flushed, seawater-dominated, tidal lagoon type estuary with one tidal opening, and two main basins. Because the Moutpipi River flows relatively directly through the western arm to the entrance, this part of the estuary responds more like a tidal river system than the seawater-dominated eastern basin, which is relatively elevated, drying rapidly and remaining exposed for much of the tidal cycle. There is an extensive coastal intertidal delta seaward of the mouth, and a barrier sandspit extends to the west of the entrance.

The catchment (41km^2) is dominated by high producing pasture (45%), native forest and scrub (37%) and exotic forestry (8%), with much of the immediate estuary margin directly bordered by developed pasture/rural land, roads, and seawalls. Causeways separate small sections of saltmarsh from the main estuary.

The upper estuary experiences salinity stratification during stable baseflows (i.e. salt wedge effect). The resulting high salinity bottom layer is generally more stable (less well-flushed) and therefore experiences nuisance phytoplankton blooms when nutrient inputs are elevated (Robertson and Stevens 2008a). Historically, the Takaka landfill was sited on the margin, but heavy metals, used as an indicators of potential toxicants, were very low at fine scale monitoring sites (Robertson and Stevens 2008b).

Ecologically, habitat diversity is moderate to high with much of its intertidal vegetation intact, extensive shellfish beds, large areas of saltmarsh (38% of estuary), and some seagrass (1.6% of estuary). However, the estuary is excessively muddy (36% soft and very soft mud in 2015), and much of the natural vegetated margin has been lost and developed for grazing. Since 1943 there has been a loss of 28ha of saltmarsh through drainage and reclamation, However, significant saltmarsh modification is likely to have occurred prior to this.

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. The inlet is a valuable nursery area for marine and freshwater fish, an extensive shellfish resource, and is very important for birdlife.

Recent vulnerability assessments (Robertson and Stevens 2008, 2012) identified excessive muddiness and disease risk as the major estuary stressors, with habitat loss, and changes in biota as a result of climate change, rated as moderate issues in the estuary. Localised eutrophication is present in poorly flushed upper estuary arms at times, while toxicity was not considered significant, although there are localised areas with elevated mud contents which are likely to concentrate sediment bound nutrients and heavy metals.

The Motupipi Estuary is currently recommended for monitoring every five years with the results used to help determine the extent to which the estuary is affected by major estuary issues (Table 1), both in the short and long term.

Table 1. Summary of the major environmental issues affecting most New Zealand estuaries.

1. Sediment Changes

Because estuaries are a sink for sediments, their natural cycle is to slowly infill with fine muds and clays (Black et al. 2013). 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 with fine sediments. Today, average sedimentation rates in our estuaries are typically 10 times or more higher than before humans arrived (e.g. see Abrahim 2005, Gibb and Cox 2009, Robertson and Stevens 2007, 2010, and Swales and Hume 1995). Soil erosion and sedimentation can also contribute to turbid conditions and poor water quality, particularly in shallow, wind-exposed estuaries where re-suspension of fine sediments is common. These changes to water and sediment result in negative impacts to estuarine ecology that are difficult to reverse (e.g. Gibbs and Hewitt 2004). They include;

- habitat loss such as the infilling of saltmarsh and tidal flats,
- prevention of sunlight from reaching aquatic vegetation such as seagrass meadows,
- increased toxicity and eutrophication by binding toxic contaminants (e.g. heavy metals and hydrocarbons) and nutrients,
- a shift towards mud-tolerant benthic organisms which often means a loss of sensitive shellfish (e.g. pipi) and other filter feeders; and
- making the water unappealing to swimmers.

Recommended Key Indicators:

Issue	Recommended Indicators	Method
Sediment Changes	Soft Mud Area	GIS Based Broad scale mapping - estimates the area and change in soft mud habitat over time.
	Seagrass Area/biomass	GIS Based Broad scale mapping - estimates the area and change in seagrass habitat over time.
	Saltmarsh Area	GIS Based Broad scale mapping - estimates the area and change in saltmarsh habitat over time.
	Mud Content	Grain size - estimates the % mud content of sediment.
	Water Clarity/Turbidity	Secchi disc water clarity or turbidity.
	Sediment Toxicants	Sediment heavy metal concentrations (see toxicity section).
	Sedimentation Rate	Fine scale measurement of sediment infilling rate (e.g. using sediment plates).
	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).

2. Eutrophication

Eutrophication is a process that adversely affects the high value biological components of an estuary, in particular through the increased growth, primary production and biomass of phytoplankton, macroalgae (or both); loss of seagrass, changes in the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services (Ferriera et al. 2011). Susceptibility of an estuary to eutrophication is controlled by factors related to hydrodynamics, physical conditions and biological processes (National Research Council, 2000) and hence is generally estuary-type specific. However, the general consensus is that, subject to available light, excessive nutrient input causes growth and accumulation of opportunistic fast growing primary producers (i.e. phytoplankton and opportunistic red or green macroalgae and/or epiphytes - Painting et al. 2007). In nutrient-rich estuaries, the relative abundance of each of these primary producer groups is largely dependent on flushing, proximity to the nutrient source, and light availability. Notably, phytoplankton blooms are generally not a major problem in well flushed estuaries (Valiela et al. 1997), and hence are not common in the majority of NZ estuaries. Of greater concern are the mass blooms of green and red macroalgae, mainly of the genera *Cladophora, Ulva,* and *Gracilaria* which are now widespread on intertidal flats and shallow subtidal areas of nutrient-enriched New Zealand estuaries. They present a significant nuisance problem, especially when loose mats accumulate on shorelines and decompose, both within the estuary and adjacent coastal areas. 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 (Anderson et al. 2002, Valiela et al. 1997).

Recommended Key Indicators:

Issue	Recommended Indicators	Method
Eutrophication	Macroalgal Cover	Broad scale mapping - macroalgal cover/biomass over time.
	Phytoplankton (water column)	Chlorophyll a concentration (water column).
	Sediment Organic and Nutrient Enrichment	Chemical analysis of sediment total nitrogen, total phosphorus, and total organic carbon concentrations.
	Water Column Nutrients	Chemical analysis of various forms of N and P (water column).
	Redox Profile	Redox potential discontinuity profile (RPD) using visual method (i.e. apparent Redox Potenial Depth - aRPD) and/or redox probe. Note: Total Sulphur is also currently under trial.
	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).

Table 1. Summary of major environmental issues affecting New Zealand estuaries (continued).

3. 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 (e.g. Stewart et al. 2008). 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. Human diseases linked to such organisms include gastroenteritis, salmonellosis and hepatitis A (Wade et al. 2003). 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.

Recommended Key Indicators:

Issue	Recommended Indicators	Method
Disease Risk	Shellfish and Bathing Water faecal coliforms, viruses, protozoa etc.	Bathing water and shellfish disease risk monitoring (Council or industry driven).

4. Toxic Contamination

NZ has seen a huge range of synthetic chemicals introduced to the coastal environment, particularly from increasing development over the last 60-80 years through urban and agricultural stormwater runoff, groundwater contamination, industrial discharges, oil spills, antifouling agents, leaching from boat hulls, and air pollution. Many of them are toxic even in minute concentrations, and of particular concern are polycyclic aromatic hydrocarbons (PAHs), heavy metals, polychlorinated biphenyls (PCBs), endocrine disrupting compounds, and pesticides. When they enter estuaries these chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to marine life and humans. In addition, natural toxins can be released by macroalgae and phytoplankton, often causing mass closures of shellfish beds, potentially hindering the supply of food resources, as well as introducing economic implications for people depending on various shellfish stocks for their income. For example, in 1993, a nationwide closure of shellfish harvesting was instigated in NZ after 180 cases of human illness following the consumption of various shellfish contaminated by a toxic dinoflagellate, which also lead to wide-spread fish and shellfish deaths (de Salas et al. 2005). Decay of organic matter in estuaries (e.g. macroalgal blooms) can also cause the production of sulphides and ammonia at concentrations exceeding ecotoxicity thresholds.

Recommended Key Indicators:

Issue	Recommended Indicators	Method
Toxins	Sediment Contaminants	Chemical analysis of heavy metals (total recoverable cadmium, chromium, copper, nickel, lead and zinc) and any other suspected contaminants in sediment samples.
	Biota Contaminants	Chemical analysis of suspected contaminants in body of at-risk biota (e.g. fish, shellfish).
	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).

5. Habitat Loss

Estuaries have many different types of high value habitats including shellfish beds, seagrass meadows, saltmarshes (rushlands, herbfields, reedlands etc.), tidal flats, 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 such 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 being 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 (IPCC 2007 and 2013, Kennish 2002).

Recommended Key Indicators:

Issue	Recommended Indicators	Method
Habitat Loss	Saltmarsh Area	Broad scale mapping - estimates the area and change in saltmarsh habitat over time.
	Seagrass Area	Broad scale mapping - estimates the area and change in seagrass habitat over time.
	Vegetated Terrestrial Buffer	Broad scale mapping - estimates the area and change in buffer habitat over time.
	Shellfish Area	Broad scale mapping - estimates the area and change in shellfish habitat over time.
	Unvegetated Habitat Area	Broad scale mapping - estimates the area and change in unvegetated habitat over time, broken down into the different substrate types.
	Sea level	Measure sea level change.
	Others e.g. Freshwater Inflows, Fish Surveys, Floodgates, Wastewater Discharges	Various survey types.

Figure 1. Motupipi Estuary, Golden Bay, showing main estuary zones.

OVERVIEW OF ESTUARY CONDITION

Estuaries are coastal transitional waters that are formed when freshwater from rivers flows into, and mixes with, saltwater from the ocean. Many are highly valued by humans and contain a wide variety of plant and animal life. In good condition, they provide more life per square metre than the richest New Zealand farmland. Their high value lies in two main characteristics; i. the wide diversity of habitats they offer, and ii. their natural ability to collect and assimilate sediment and nutrients from the surrounding catchment and inflowing tidal waters. If either of these features are degraded, then the estuary condition deteriorates and the value to humans and estuary plants and animals is lessened. The condition of an estuary is commonly reflected by the extent and intensity of development in the surrounding catchment. They are typically in one of three contrasting states: PRISTINE, MODERATE, OR DEGRADED.

PRISTINE: In a pristine state, estuaries have high water clarity, low nutrient and sediment inputs, high sediment quality (very little mud), and high biodiversity. They retain an intact saltmarsh and terrestrial margin that buffers against weed and pest invasions, assimilates sediment and nutrients, and provides key habitat for birds and fish. Disease risk and toxicity are low, and there are no extensive growths of nuisance macroalgae (e.g. *Ulva* (sea lettuce) and *Gracilaria*), microalgae or phytoplankton.

MODERATE: Following initial catchment development, sediment, nutrient, and faecal bacteria inputs typically increase, and modification of the estuary margin (primarily by drainage and reclamation) is common. Increased nutrients cause a shift to increased eutrophication, evident in low-moderate nuisance macroalgal growth, and increased phytoplankton production. This, along with increased fine sediment deposition, starts to reduce sediment oxygenation and water clarity. The increasing inputs of fine sediment may also lead to a reduction in seagrass populations and a shift in the macroinvertebrate community to one more tolerant of fine muds.

DEGRADED: With more intensive catchment development, soft muds commonly accumulate in the upper estuary and on sheltered tidal flats, and water clarity decreases further. The combined effects of sediment smothering and reduced light levels may contribute to the loss of seagrass and shellfish beds. Aggressive macrophyte growth is encouraged by high sediment and nutrient inputs. Farm runoff, human wastewater, and inputs from urban and agricultural stormwater increase disease risk and toxicity, and as a result can constrain bathing and shellfish gathering, particularly after rainfall events. Further habitat loss, particularly of remaining upper intertidal saltmarsh and terrestrial buffer vegetation, increasingly degrades bird habitat and whitebait spawning areas, facilitates the encroachment of weeds and pests into saltmarsh areas, reduces natural assimilation and filtering of sediment and nutrients, and reduces the important role saltmarsh plays in flood attenuation e.g. bank stabilisation, decreased flow velocity, temporal spreading of flow peaks. Protection of developed margins from erosion and inundation becomes an increasing issue.

Motupipi Estuary is currently in a moderately degraded condition, with the key stressor being sediment (excessive muddiness).

2. METHODS

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. Appendix 1 lists the definitions used to classify substrate and saltmarsh vegetation. 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).

The results are then used with risk indicators to assess estuary condition in response to common stressors.

For the current study, rectified ~0.4m/pixel resolution colour aerial photos flown by LINZ in 2012/13 were laminated (scale of 1:3,000) and used by experienced scientists who walked the area in March 2015 to ground-truth the spatial extent of dominant vegetation and substrate types (Figure 3, Appendix 4). The "iGIS HD" Ipad app. was used to show live position tracking on aerial photos (via an inbuilt GPS accurate to ~5m), and to log field notes. When present, macroalgae and seagrass patches were mapped to the nearest 5% using a 6 category percent cover rating scale as a guide to describe density (see Figure 2 below).

Broad scale habitat features were digitised into ArcMap 10.2 shapefiles using a Wacom Cintiq21UX drawing tablet, and combined with field notes and georeferenced photographs to produce habitat maps showing the dominant cover of: substrate, macroalgae (e.g. *Ulva, Gracilaria*), seagrass, saltmarsh vegetation, and the 200m wide terrestrial margin vegetation/landuse. These broad scale results are summarised in Section 4, 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. An example of the detail available on the GIS files is presented in Figure 3.

Macroalgae was further assessed by identifying patches of comparable growth, and enumerating each patch by measuring biomass and the degree of macroalgal entrainment within sediment. When macroalgae was present, the presence of soft muds and surface sediment anoxia were also noted to assess whether gross nuisance conditions had established. Results were interpreted using a multi-index approach that included:

- percent cover of opportunistic macroalgae (the spatial extent and density of algal cover providing an early warning of potential eutrophication issues).
- macroalgal biomass (providing a direct measure of areas of excessive growth).
- extent of algal entrainment in sediment (highlighting where nuisance condition have a high potential for establishing and persisting).
- gross eutrophic zones (highlighting significant sediment degradation by measuring where there is a combined presence of high algal cover or biomass, low sediment oxygenation, and soft muds).

The key component of the interpretative assessment of macroalgae is the use of a modified Opportunistic Macroalgal Blooming Tool (OMBT). The OMBT, described in detail in Appendix 2, is a 5 part multimetric index that produces an overall Ecological Quality Rating (EQR) ranging from 0 (major disturbance) to 1 (minimally disturbed) and which is placed within overall quality status threshold bands (i.e. bad, poor, good, moderate, high) to rate macroalgal condition (Table 2). This integrated index provides a comprehensive measure of the combined influence of macroalgal growth and distribution in the estuary.

The georeferenced spatial habitat maps provide a robust baseline of key indicators. Wherever possible, 2015 results have been compared to previous results (1942, 1984, 2007) noting in some instances improvements have been made since then in the classification and mapping of key parameters like seagrass and macroalgae.

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

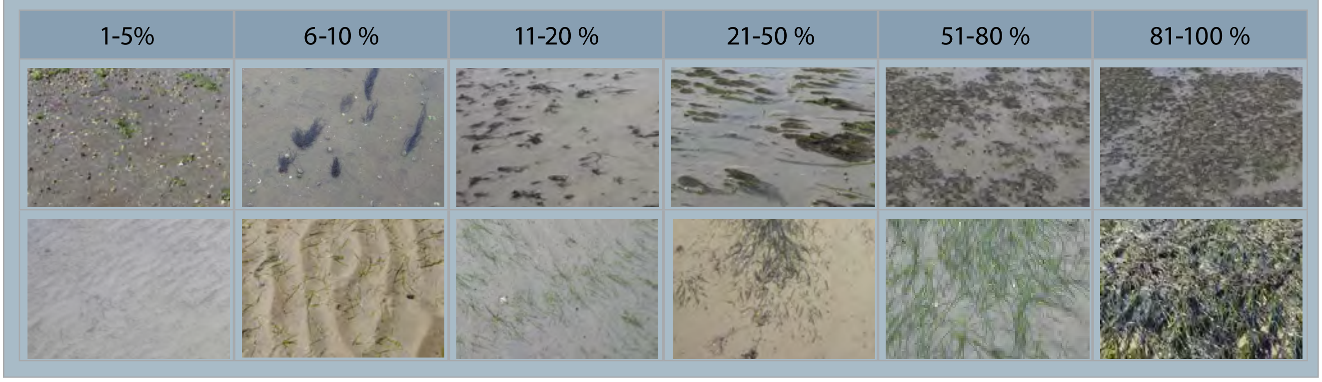


Figure 3. Motupipi Estuary - mapped estuary extent and examples of field photos of selected habitats.

3. ESTUARY RISK INDICATOR RATINGS

The estuary monitoring approach used by Wriggle has been established to provide a defensible, cost-effective way to help quickly identify the likely presence of the predominant issues affecting NZ estuaries (i.e. eutrophication, sedimentation, disease risk, toxicity and habitat change; Table 1), and to assess changes in the long term condition of estuarine systems. The design is based on the use of primary indicators that have a documented strong relationship with water or sediment quality.

In order to facilitate this assessment process, "risk indicator ratings" have also been proposed that assign a relative level of risk (e.g. very low, low, moderate, high, very high) of specific indicators adversely affecting intertidal estuary condition (see Table 2 below). Each risk indicator rating is designed to be used in combination with relevant information and other risk indicator ratings, and under expert guidance, to assess overall estuarine condition in relation to key issues, and make monitoring and management recommendations. When interpreting risk indicator results we emphasise:

- The importance of taking into account other relevant information and/or indicator results before making management decisions regarding the presence or significance of any estuary issue.
- That rating and ranking systems can easily mask or oversimplify results. For instance, large changes can occur within the same risk category, but small changes near the edge of one risk category may shift the rating to the next risk level.
- Most issues will have a mix of primary and secondary ratings, primary ratings being given more weight in assessing the significance of indicator results. It is noted that many secondary estuary indicators will be monitored under other programmes and can be used if primary indicators reflect a significant risk exists, or if risk profiles have changed over time.
- Ratings have been established in many cases using statistical measures based on NZ estuary data. However, where such data is lacking, or has yet to be processed, ratings have been established using professional judgement, based on our experience from monitoring numerous NZ estuaries. Our hope is that where a high level of risk is identified, the following steps are taken:
    1. Statistical measures be used to refine indicator ratings where information is lacking.
    2. Issues identified as having a high likelihood of causing a significant change in ecological condition (either positive or negative), trigger intensive, targeted investigations to appropriately characterise the extent of the issue.
    3. The outputs stimulate discussion regarding what an acceptable level of risk is, and how it should best be managed.

The indicators and interim risk ratings used for the Motupipi Estuary broad scale monitoring programme are summarised in Tables 2 and 3, along with supporting notes explaining the use and justifications for each indicator. The basis underpinning most of the ratings is the observed correlation between an indicator and the presence of degraded estuary conditions from a range of tidal lagoon estuaries throughout NZ. Work to refine and document these relationships is ongoing.

Table 2. Summary of estuary condition risk indicator ratings used in the present report.

INDICATOR	RISK RATING				
	Very Low	Low	Moderate	High	Very High
Soft mud (% cover)	<2%	2-5%	>5-15%	>15-25%	>25%
Gross Eutrophic Conditions (ha)	<0.5ha	0.5-5ha	6-20ha	20-30ha	>30ha
Macroalgal Ecological Quality Rating	≥0.8 - 1.0	≥0.6 - <0.8	≥0.4 - <0.6	≥0.2 - <0.4	0.0 - <0.2
Seagrass Coefficient (SC)	>7.0	>4.5-7.0	>1.5-4.5	>0.2 - 1.5	0.0 - 0.2
Saltmarsh (% remaining from estimated natural state)	>80-100%	>60-80%	>40-60%	>20-40%	<20%
Saltmarsh Extent (vegetated % of available saltmarsh habitat)	>80-100%	>60-80%	>40-60%	>20-40%	<20%
Vegetated 200m Terrestrial Margin	>80-100%	>50-80%	>25-50%	>5-25%	<5%

See NOTES on following page, and Appendix 2 for further information.

3. ESTUARY RISK INDICATOR RATINGS (CONTINUED)

Table 3. Summary of indicators used to rate opportunistic macroalgal quality.

MACROALGAL INDICATORS (OBMT approach - WFD_UKTAG 2014 - see Appendix 2 for details)					
QUALITY RATING	Very Good	Good	Moderate	Poor	Bad
EQR (Ecological Quality Rating)	≥0.8 - 1.0	≥0.6 - <0.8	≥0.4 - <0.6	≥0.2 - <0.4	0.0 - <0.2
% cover on Available Intertidal Habitat (AIH)	0 - ≤5	>5 - ≤15	>15 -≤25	>25 - ≤75	>75 - 100
Affected Area (AA) [>5% macroalgae] (ha)*	≥0 - 10	≥10 - 50	≥50 - 100	≥100 - 250	≥250
AA/AIH (%)*	≥0 - 5	≥5 - 15	≥15 - 50	≥50 - 75	≥75 - 100
Average biomass (g.m^2) of AIH	≥0 - 100	≥100 - 500	≥500 - 1000	≥1000 - 3000	≥3000
Average biomass (g.m^2) of AA	≥0 - 100	≥100 - 500	≥500 - 1000	≥1000 - 3000	≥3000
% algae entrained >3cm deep	≥0 - 1	≥1 - 5	≥5 - 20	≥20 - 50	≥50 - 100

*Only the lower EQR of the 2 metrics, AA or AA/AIH is used in the final EQR calculation - see Appendix 2 for further detail.

NOTES to Table 2:

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. In particular, excessive mud decreases water clarity, lowers biodiversity and affects aesthetics and access. Its presence indicates where changes in land management may be needed.

Sedimentation Rate. Elevated sedimentation rates are likely to lead to major and detrimental ecological changes within estuary areas that could be very difficult to reverse, and indicate where changes in land use management may be needed. Note the very low risk category is based on a typical NZ pre-European average rate of <1mm/year, which may underestimate sedimentation rates in soft rock catchments.

Sedimentation Mud Content. Below mud contents of 20-30% sediments are relatively incohesive and firm to walk on. Above this, they become sticky and cohesive and are associated with a significant shift in the macroinvertebrate assemblage to a lower diversity community tolerant of muds. This is particularly pronounced if elevated mud contents are contiguous with elevated total organic carbon concentrations, which typically increase with mud content, as do the concentrations of sediment bound nutrients and heavy metals. Consequently, muddy sediments are often poorly oxygenated, nutrient rich, and on intertidal flats of estuaries can be overlain with dense opportunistic macroalgal blooms. High mud contents also contribute to poor water clarity through ready resuspension of fine muds, impacting on seagrass, birds, fish and aesthetic values.

Redox Potential Discontinuity (RPD): RPD depth, the transition between oxygenated sediments near the surface and deeper anoxic sediments, is a primary estuary condition indicator as it is a direct measure of whether nutrient and organic enrichment exceeds levels causing nuisance (anoxic) conditions. Knowing if the RPD close to the surface is important for two main reasons:

1. As the RPD layer gets close to the surface, a "tipping point" is reached where the pool of sediment nutrients (which can be large), suddenly becomes available to fuel algal blooms and to worsen sediment conditions.
2. Anoxic sediments contain toxic sulphides and support very little aquatic life.

In sandy porous sediments, the RPD layer is usually relatively deep (>3cm) and is maintained primarily by current or wave action that pumps oxygenated water into the sediments. In finer silt/clay sediments, physical diffusion limits oxygen penetration to <1cm (Jørgensen and Revsbech 1985) unless bioturbation by infauna oxygenates the sediments. The tendency for sediments to become anoxic is much greater if the sediments are muddy.

Gross Eutrophic Conditions. Gross eutrophic conditions occur when sediments exhibit combined symptoms of: a high mud content, a shallow apparent Redox Potential Discontinuity (aRPD) 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:

Opportunistic Macroalgae. Opportunistic macroalgae is a primary indicator of estuary eutrophication, and when combined with gross eutrophic conditions (see previous) can cause significant adverse ecological impacts that are very difficult to reverse. Thresholds used to assess this indicator are derived from the OMBT (see Section 2 and Appendix 2), with results combined with those of other indicators to determine overall condition.

Seagrass. 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 seldom found above mean sea level (MSL), and is vulnerable to fine sediments in the water column and sediment quality (particularly if there is a lack of oxygen and production of sulphide), rapid sediment deposition, excessive macroalgal growth, high nutrient concentrations, and reclamation. Decreases in seagrass extent is likely to indicate an increase in these types of pressures.

A continuous index (the seagrass coefficient - SC) has been developed to rate seagrass condition based on the percentage cover of seagrass in defined categories using the following equation: ***SC=((0 x %seagrass cover <1%)+(0.5 x %cover 1-5%)+(2 x %cover 6-10%)+(3.5 x %cover 11-20%)+(6 x %cover 21-50%)+(9 x %cover 51-80%)+(12 x %cover >80%))/100.*** The "early warning trigger" for initiating management action is a trend of a decreasing Seagrass Coefficient.

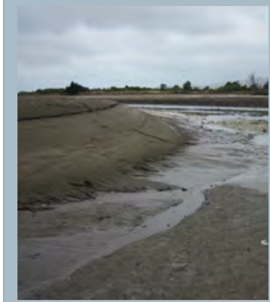
Saltmarsh. Saltmarshes have high biodiversity, are amongst the most productive habitats on earth, and have strong aesthetic appeal. They are sensitive to a wide range of pressures including land reclamation, margin development, flow regulation, sea level rise, grazing, wastewater contaminants, and weed invasion. Most NZ estuarine saltmarsh grows in the upper estuary margins above mean high water neap (MHWN) tide where vegetation stabilises fine sediment transported by tidal flows. Saltmarsh zonation is commonly evident, resulting from the combined influence of factors including salinity, inundation period, elevation, wave exposure, and sediment type. Highest saltmarsh diversity is generally present above mean high water spring (MHWS) tide where a variety of salt tolerant species grow including scrub, sedge, tussock, grass, reed, rush and herb fields. Between MHWS and MHWN, saltmarsh is commonly dominated by relatively low diversity rushland and herbfields. Below this, the MHWN to MSL range is commonly unvegetated or limited to either mangroves or *Spartina*, the latter being able to grow to MLWN. The proposed interim risk rating of % loss from Estimated Natural State Cover assumes that a reduction in saltmarsh cover corresponds to a reduction in ecological services and habitat values. It it further assumed that saltmarsh should be growing throughout the majority of the available saltmarsh habitat (tidal area above MHWN), and that where this does not occur, ecological services and habitat values are reduced. The "early warning trigger" for initiating management action/further investigation is a trend of a decreasing saltmarsh area or saltmarsh growing over <80% of the available habitat.

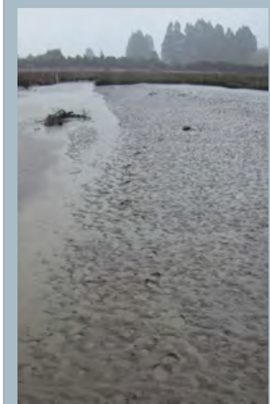
Vegetated Margin. The presence of a terrestrial margin dominated by a dense assemblage of scrub/shrub and forest vegetation acts as an important buffer between developed areas and the saltmarsh and estuary. This buffer is sensitive to a wide range of pressures including land reclamation, margin development, flow regulation, sea level rise, grazing, wastewater contaminants, and weed invasion. It protects the estuary against introduced weeds and grasses, naturally filters sediments and nutrients, and provides valuable ecological habitat. Reduction in the vegetated terrestrial buffer around the estuary is likely to result in a decline in estuary quality. The "early warning trigger" for initiating management action is <50% of the estuary with a densely vegetated margin.

See Appendix 2 for further information supporting these ratings.

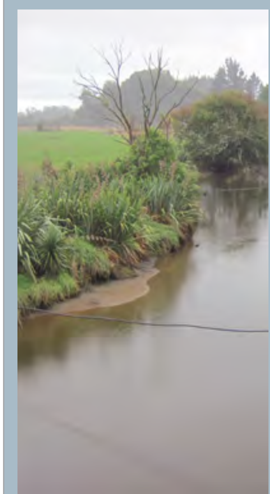
4. RESULTS AND DISCUSSION

BROAD SCALE MAPPING





Sand, cobble, and mud flats in Motupipi Estuary.



Example of the small areas of intertidal soft mud in the upper Motupipi Estuary.

The 2015 broad scale habitat mapping ground-truthed and mapped all intertidal substrate and vegetation including the dominant land cover of the terrestrial margin, with the six dominant estuary features summarised in Table 4. The estuary was characterised by extensive intertidal flats (56% of estuary), saltmarsh (38%), and a small area of subtidal water within low tide channels (6%). Seagrass and dense (>50% cover) opportunistic macroalgae were both sparse (1% cover each) and restricted to the low tide channel of the Motupipi River. The extent of the 200m wide terrestrial margin dominated by a densely vegetated buffer was moderate (25%), pasture dominating the 200m terrestrial margin (70%).

- In the following sections, various factors related to each of these habitats (e.g. area of soft mud) are used to apply risk ratings to assess key estuary issues of sedimentation, eutrophication, and habitat modification. Trends in broad scale features have been assessed based on the most relevant of either estimates of natural state cover or previous broad scale mapping results for 2007, 1984, and 1943.
- In addition, the supporting GIS files underlying this written report provide a detailed spatial record of the key features present throughout the estuary. These are intended as the primary supporting tool to help the Council address a wide suite of estuary issues and management needs, and to act as a baseline to assess future change.

Table 4. Summary of dominant broad scale features in Motupipi Estuary, 2015.

	Dominant Estuary Feature	Ha	% of Estuary
1.	Intertidal flats (excluding saltmarsh)	89.2	56%
2.	Opportunistic macroalgal beds (>50% cover) [included in 1. above]	1.7	1%
3.	Seagrass (>50% cover) [included in 1. above]	1.7	1%
4.	Saltmarsh	60.8	38%
5.	Subtidal waters	9.9	6%
	Total Estuary	**160**	**100%**
6.	Terrestrial Margin - % of 200m wide estuary buffer densely vegetated (e.g. scrub, shrub, forest)		25%

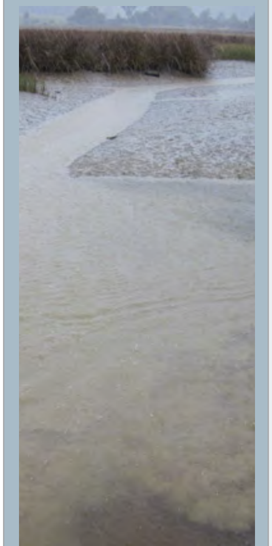
4.1. INTERTIDAL FLATS (EXCLUDING SALTMARSH)

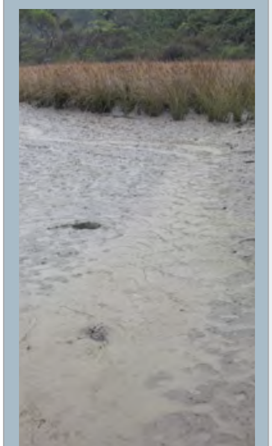
Results (summarised in Table 5 and Figure 4) show the dominant intertidal substrate was sand (mobile, firm, and firm muddy sand, 57.3%) followed by soft mud (30.7%), and very soft mud (5.4%). Cobble (4.8%) was also prominent. These substrates were all generally well oxygenated (aRPD >1cm), reflecting high tidal flushing of both arms, as well as extensive river flushing of the western arm. The lower estuary (see Figure 1 for general zones) had a relatively diverse mix of clean (non-muddy) substrates, while the middle east arm was dominated by sand, and the middle west arm dominated by mud. The upper estuary had only small areas of intertidal soft mud, and is predominantly subtidal (subtidal areas not included in the NEMP mapping).

Table 5. Summary of dominant intertidal substrate, Motupipi Estuary, 2015.

Estuary Location	Lower		Middle (East)		Middle (West)		Upper		TOTAL	
Substrate Area	ha	%	ha	%	ha	%	ha	%	ha	%
Artificial Structure	0.04	0.24	0.02	0.03	0.05	0.26			0.1	0.1
Rock field	0.12	0.8	0.13	0.2	0.02	0.1			0.3	0.3
Boulder field			0.07	0.1					0.1	0.1
Cobble field	3.84	26.1	0.00	0.0	0.45	2.4			4.3	4.8
Gravel field					0.02	0.1			0.02	0.03
Oyster reef	0.77	5.2			0.00	0.0			0.8	0.9
Shell bank	0.34	2.3	0.01	0.0					0.3	0.4
Mobile sand	4.12	28.0	1.33	2.4	1.07	5.7			6.5	7.3
Firm sand	0.27	1.8	0.15	0.3					0.4	0.5
Firm mud/sand	2.58	17.6	39.3	70.5	2.27	12.1			44.2	49.6
Soft mud	2.62	17.9	14.7	26.4	10.1	53.8			27.4	30.7
Very soft mud					4.78	25.5	0.01	100	4.8	5.4
TOTAL	**14.7**	**100**	**55.8**	**100**	**18.7**	**100**	**0.0**	**100**	**89.2**	**100**

Figure 4. Map of dominant habitat types - Motupipi Estuary, 2015.





Examples of mud mobilised and washed to sea during rain in the east arm of Motupipi Estuary.

Tires removed from Motupipi Estuary following the 2011 floods - photo Trevor James, TDC.

Soft Mud Habitat.

Where soil erosion from catchment disturbance exceeds the assimilative capacity of an estuary, adverse estuary impacts are expected from increased muddiness and turbidity, shallowing, increased nutrients, increased organic matter degradation by anoxic processes (e.g. sulphide production), increased contaminant concentrations (where fine muds provide a sink for catchment contaminants like heavy metals), and alterations to saltmarsh, seagrass, fish and invertebrate communities. In particular, multiple studies have shown estuarine macroinvertebrate communities to be adversely affected by mud accumulation, both through direct and indirect mechanisms including: declining sediment oxygenation, smothering, and compromisation of feeding habits (e.g. see Mannino and Montagna 1997; Rakocinski et al. 1997; Peeters et al. 2000; Norkko et al. 2002; Ellis et al. 2002; Thrush et al. 2003; Lohrer et al. 2004; Sakamaki and Nishimura 2009; Jones et al. 2011; Wehkamp and Fischer 2012; Robertson 2013).

Because of such consequences, three key measures are used to assess soft mud:

i. **Horizontal extent** (area of soft mud) - broad scale indicator (see rating in Table 2)
ii. **Vertical buildup** (sedimentation rate) - fine scale assessment using sediment plates (or retrospectively through historical coring). Ratings are currently under development as part of National ANZECC guidelines.
iii. **Sediment mud content** - fine scale indicator - recommended guideline is no increase from established baseline.

The area of intertidal soft mud is the primary sediment indicator used in the current broad scale report. Figure 4 shows that soft mud habitat was concentrated in Motupipi Estuary around the upper intertidal flats of both arms, along the banks of the Motupipi River, and the edges of smaller streams entering the estuary. The most extensive areas of very soft mud were in the middle west arm. This is thought to predominantly reflect a hydrodynamic boundary, with the settlement of fine sediments promoted in these areas by changes in freshwater flow velocities (particularly where the Motupipi River enters the middle estuary), combined with salinity driven flocculation. The relatively low incidence of muds in the lower east arm is thought to primarily reflect strong tidal flows which limit settlement and facilitate the export of fine sediments from this part of the estuary.

The risk of detrimental impacts to estuarine biota was assessed as “VERY HIGH” based on the large area of soft mud relative to the intertidal habitat area (32.2ha, 36%), combined with a large (23mm average) deposit of soft mud (and significant flood debris) in the upper east arm (measured in May 2012 following the Dec 2011 floods - the second highest rainfall event in a populated area in NZ). Despite this recent deposition, there has been an overall reduction in mud area of 3.7ha (10%) since then, highlighted by the red shaded areas in Figure 5. Based on the large amount of mud seen being washed from the east arm during rain events during mapping in 2015, it appears most likely that the muds have been exported to Golden Bay, as opposed to being redistributed within the estuary (see photos).

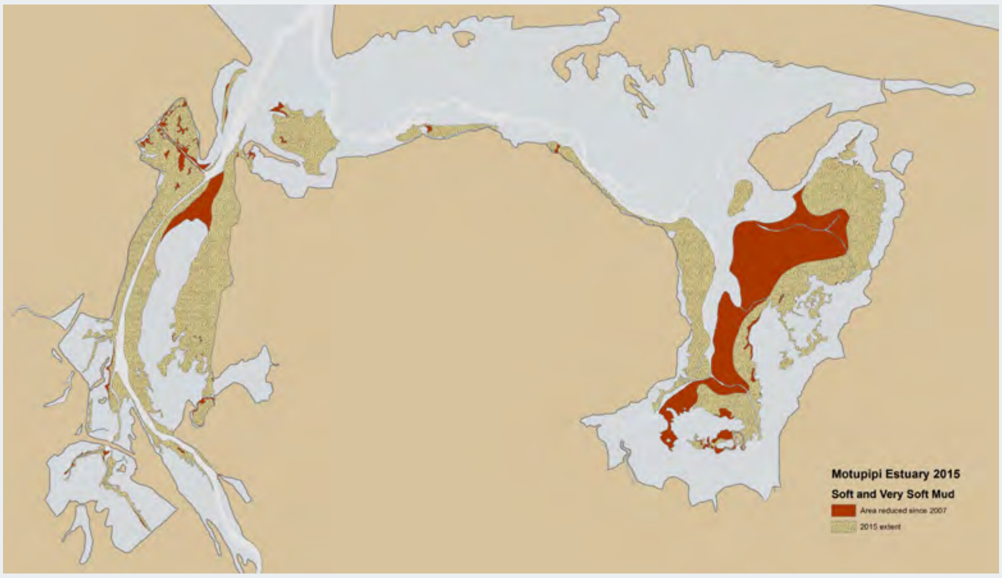


Figure 5. Reduction in soft mud area (red) between 2007 and 2015, Motupipi Estuary.

4.2. OPPORTUNISTIC MACROALGAE

Opportunistic macroalgae are a primary symptom of estuary eutrophication. They are highly effective at utilising excess nitrogen, enabling them to out-compete other seaweed species and, at nuisance levels, can form mats on the estuary surface which adversely impact underlying sediments and fauna, other algae, fish, birds, seagrass, and saltmarsh. Decaying macroalgae can also accumulate subtidally and on shorelines causing oxygen depletion and nuisance odours and conditions. The greater the density, persistence, and extent of macroalgal entrainment within sediments, the greater the subsequent impacts.

Opportunistic macroalgal growth was assessed by mapping the spatial spread and density of macroalgae in the Available Intertidal Habitat (AIH) (Figure 6), and calculating an "Ecological Quality Rating" (EQR) using the Opportunistic Macroalgal Blooming Tool (OMBT) described in Appendix 2.

The EQR score can range from zero (major disturbance) to one (reference/minimally disturbed) and relates to a quality status threshold band (i.e. bad, poor, good, moderate, high - Section 3, Table 2). The individual metrics that are used to calculate the EQR (spatial extent, density, biomass, and degree of sediment entrainment of macroalgae within the affected intertidal area), are also scored and have quality status threshold bands to guide key drivers of change.

Opportunistic macroalgal growth was confined to relatively small areas in the low tide channels of the western arm and the lower estuary, with no growth observed in the east arm (Figure 6). When present, macroalgae was relatively dense (average biomass >700g/m^2 wet weight) and comprised a dominant cover of either the red alga *Gracilaria chilensis* (lower estuary mid channel areas) or the green algae *Ulva lactuca* and *Ulva intestinalis* (middle and upper estuary). These growths were not entrained within the underlying sediments, were not causing nuisance conditions, and no significant gross eutrophic zones were present. Symptoms of eutrophication were evident however through the presence of extensive microalgal films growing along the channel margins and tidal flats in the west arm, and phytoplankton (cryptophytes) blooming in the high salinity bottom water of deep pool areas in the upper estuary. The latter symptoms, discussed previously by Robertson and Stevens (2008), are caused by the combined influence in this part of the estuary of high nutrient concentrations, low dilution, stable baseflows with limited turbulent mixing, and restricted flushing. The resulting reduction in water clarity and decreased sediment oxygenation are likely to cause localised adverse effects to fish and macroinvertebrates, as well as possible impacts to seagrass through reduced water clarity.

Overall the risk of detrimental effects being caused by excessive macroalgal growth were assessed as "VERY LOW" based on an overall opportunistic macroalgal EQR of 0.84, a quality status of "VERY GOOD" (Table 6), indicating the estuary is not expressing significant symptoms of eutrophication.

The presence of regular phytoplankton blooms in the upper estuary highlights that current nutrient concentrations, when entrained in stratified waters in the upper estuary, are contributing to minor localised nuisance conditions, but it is noted that the DRP concentration in the Motupipi River is now about 30% of what it was 15 years ago due to the ceasing of whey discharges over 20 years ago (TDC data, Trevor James, 2015).

Table 6. Summary of intertidal opportunistic macroalgal cover, Motupipi Estuary, March 2015.

Metric	Face Value	Final Equidistant Score (FEDS)	Quality Status
AIH - Available Intertidal Habitat (ha)	89		
Percentage cover of AIH (%) = (Total % Cover / AIH} x 100 *where Total % cover = Sum of {(patch size) / 100} x average % cover for patch*	1.8	0.9	Very Good
Biomass of AIH (g.m^{-2}) = Total biomass / AIH *where Total biomass = Sum of (patch size x average patch biomass)*	32.2	0.9	Very Good
Biomass of Affected Area (g.m^{-2}) = Total biomass / AA *where Total biomass = Sum of (>5% cover patch size x average patch biomass)*	732.1	0.5	Moderate
Presence of Entrained Algae = (No. quadrats or area (ha) with entrained algae / total no. of quadrats or area (ha)) x 100	0.0	1.0	Very Good
Affected Area (use the lowest of the following two metrics)		0.8	Very Good
Affected Area, AA (ha) = Sum of all patch sizes (with macroalgal cover >5%)	3.9	0.9	Very Good
Size of AA in relation to AIH (%) = (AA / AIH) x 100	4.4	0.8	Very Good
OVERALL MACROALGAL ECOLOGICAL QUALITY RATING - EQR (AVERAGE OF FEDS)		**0.84**	**VERY GOOD**

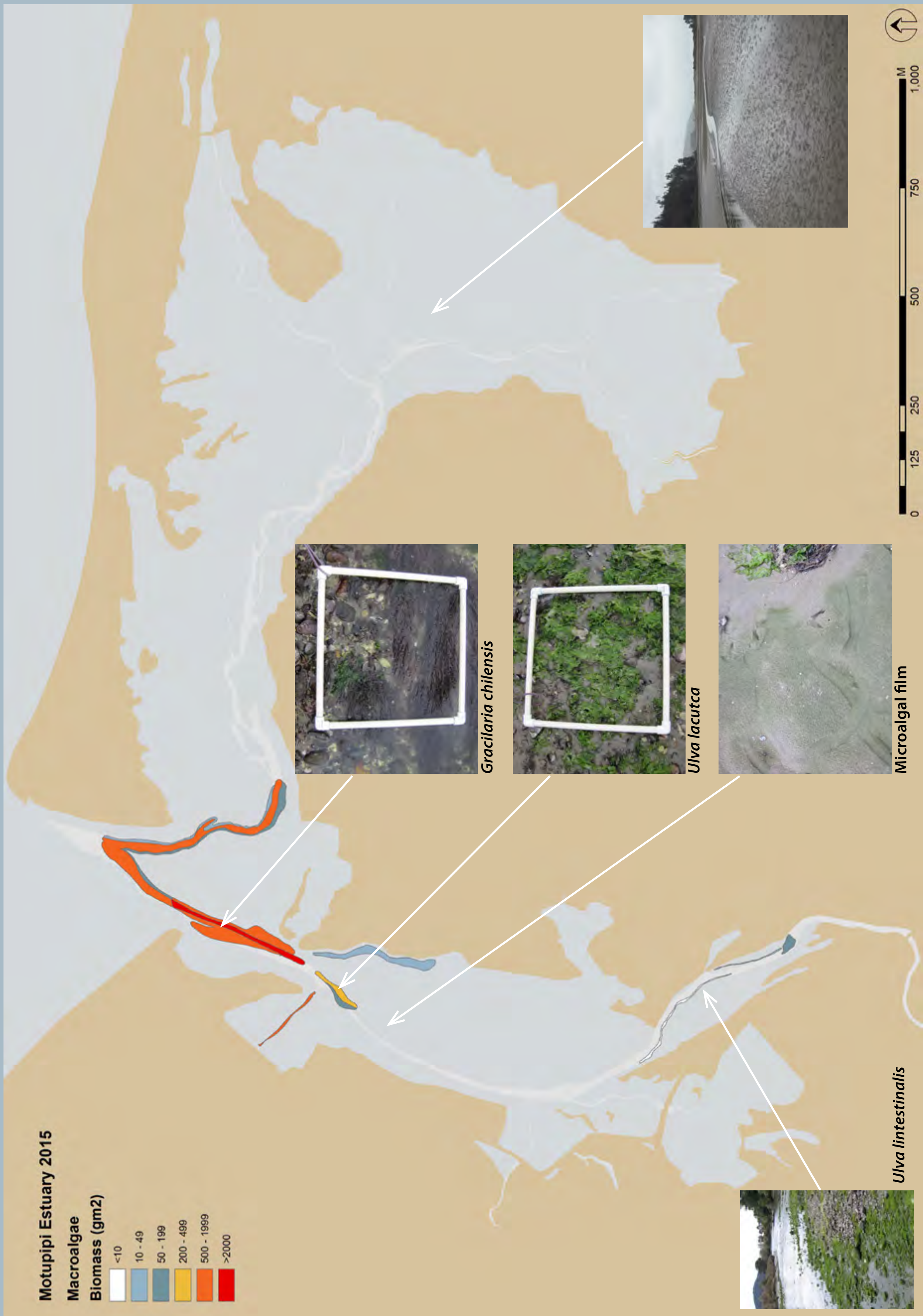
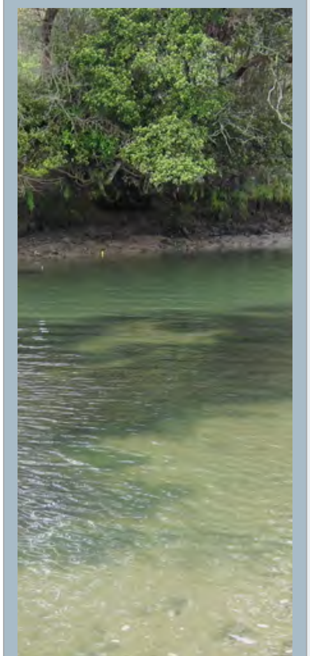


Figure 6. Map of intertidal opportunistic macroalgal biomass (g.m^{-2}) - Motupipi Estuary, 2015.

4.3. SEAGRASS

Low density seagrass in the lower Motupipi Estuary.



High density subtidal seagrass in the upper Motupipi River.

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 sulphides).

Table 7 and Figure 8 summarise the results of the 2015 survey of the available seagrass habitat (mapped intertidal estuary area minus saltmarsh).

- The vast majority of the intertidal estuary area (98%) had no seagrass growing.
- When present, seagrass was confined primarily to the shallow edges of the Motupipi River, with another small patch present in the lower channel of the east arm.
- Dense intertidal seagrass beds (>50% cover) were very sparse (0.07ha) and present only in upper estuary channel areas.
- Uncommon for the upper reaches of NZ estuaries, extensive subtidal seagrass beds were also present in the largely spring fed Motupipi River channel which provides relatively clear and stable flows throughout the year.

Based on the small area of cover relative to the available intertidal habitat area (a seagrass Coefficient (SC) of 0.1) the risk of detrimental impacts to estuarine seagrass was assessed as "VERY HIGH".

Seagrass cover, first mapped in 2007 (Stevens and Robertson 2007), provides a baseline against which recent changes can be measured. There was no significant change in dense seagrass beds evident from 2007 to 2015. Over the same period, a small reduction in the extent of low density beds (<50% cover) was recorded in the lower Motupipi River. This change in mapped extent is primarily due to lower river levels in 2015 allowing for better determination of seagrass extent. However, it was also apparent that there had been a minor shift in seagrass density with some 20-50% cover areas in 2007 reducing to 10-20% cover in 2015. This was associated with changes in the substrate of the lower estuary where soft muds present in 2007 had been either eroded, or overlain by fresh sand deposits between 2007 and 2015. Such physical disturbance is highly likely to account for the minor density changes evident.

Table 7. Summary of seagrass *(Z. muelleri)* cover, Motupipi Estuary, 2007 and 2015.

	2007		2015	
Percentage Cover	**Area (ha)**	**Percentage**	**Area (ha)**	**Percentage**
0 (unvegetated intertidal)	83.3	97.1	87.5	98.1
1-5%	0.0	0.0	0	0
5-10%	0.06	0.1	0	0
10-20%	0.32	0.4	0.75	0.8
20-50%	2.01	2.3	0.86	1.0
50-80%	0.07	0.1	0.07	0.1
>80%	0.0	0.0	0	0
	85.8	**100**	**89.2**	**100**

NOTE: the increase in total intertidal area mapped from 2007 to 2015 is due to lower river levels in 2015 enabling better delineation of intertidal extent.

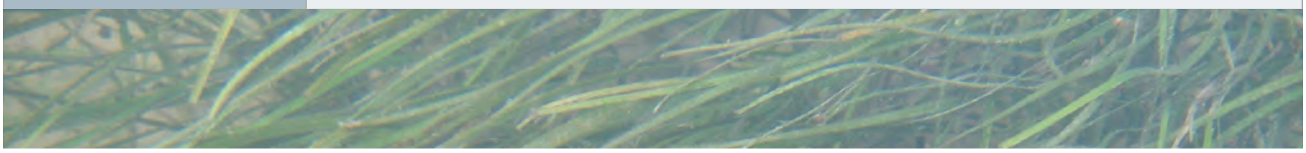
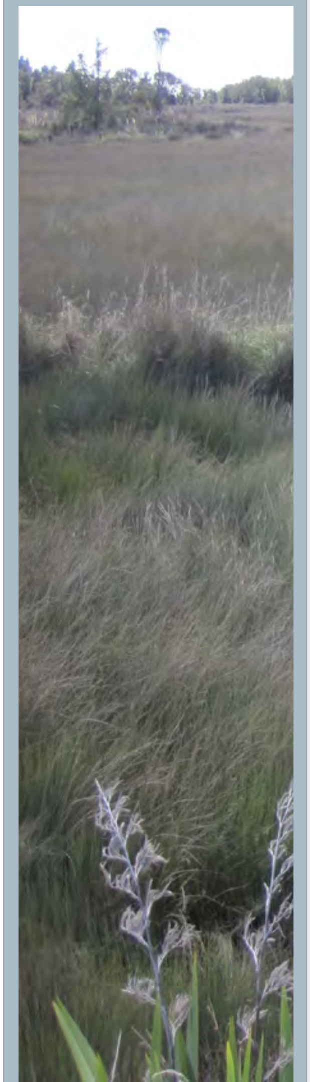
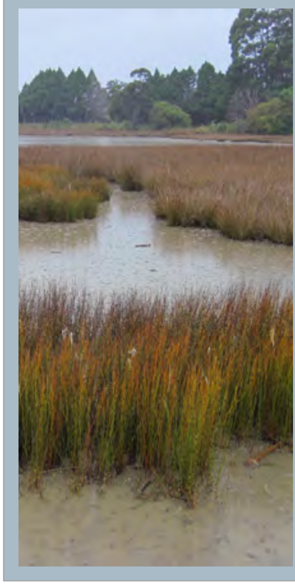


Figure 7. Map of intertidal seagrass cover - Motupipi Estuary, 2015.

4.4. SALTMARSH





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. Saltmarsh generally has the most dense cover in the sheltered and more strongly freshwater influenced upper estuary, and relatively sparse cover in the lower (more exposed and saltwater dominated) parts of the estuary, with the lower limit of saltmarsh growth limited for most species to above the height of mean high water neap (MHWN).

Two measures were used to assess saltmarsh condition, i. loss compared to estimated natural state cover, and ii. percent cover within the available saltmarsh habitat - defined as the area between MHWN and the upper tidal extent.

Table 8 and Figure 8 summarise the results of the 2015 saltmarsh mapping and show 60.5ha of saltmarsh was present. Based on the estimated natural extent of estuary saltmarsh, roughly assessed at ~120ha using aerial photos and LIDAR data of estuary elevations provided by TDC, present saltmarsh cover is likely to be reduced from natural cover by around 50%. Of this, around 2/3rds of the overall saltmarsh loss (~40ha) is likely to have occurred prior to 1943. This is based on earlier historical mapping by Stevens and Robertson (2007) who estimated saltmarsh losses of 21ha from 1943-1984, and 2.5ha from 1984 to 2007. A further 1.8ha was lost from 2007 to 2015 (Table 9) due to the conversion of rushland areas to pasture on farmland on the west side of the estuary. Historically, the greatest losses appear to have occurred along both the west and south sides of the western arm, and the north and east sides of the eastern arm as a consequence of land drainage and reclamation. Such historic losses fit the "MODERATE" risk indicator rating.

Of the remaining available saltmarsh habitat (the area between MHWN and the upper tidal extent), the vast majority supports healthy saltmarsh growth, a risk indicator rating of "VERY LOW". Based on this extensive growth, and only small recent saltmarsh losses, an overall risk of "MODERATE" has been applied to the estuary.

Key saltmarsh characteristics are summarised below, and in Table 9 and Figure 9:

- The dominant saltmarsh cover was rushland (68%), which comprised a mix of searush and jointed wire rush in often extensive swathes around the upper tidal margins of the estuary.
- Herbfield (15%) and Sedgeland (7%) were extensive in the middle and lower estuary seaward of rushland (lower in the tidal range).
- Around the upper tidal extent of the estuary there were a mix of species including Estuarine Shrub - ribbonwood (7%), Grassland - tall fescue (2.5%), Scrub - gorse (0.5%), Tussockland - flax (0.4%) and Reedland - raupo (0.3%).
- Introduced weeds were a conspicuous subdominant cover near the terrestrial margin, and included common species such as gorse, broom, blackberry, willows, and introduced grasses.
- Introduced iceplant (*Carpobrotus edulis*) was common along the upper tidal range of the lower estuary where it appears to be displacing native herbfields.

Table 8. Dominant saltmarsh cover, Motupipi Estuary, 2015.

Class	Dominant species	Ha	%
Scrub	*Ulex europaeus (Gorse)*	0.3	0.5
Estuarine Shrub	*Plagianthus divaricatus (Saltmarsh ribbonwood)*	4.2	7.0
Tussockland	*Phormium tenax (New Zealand flax)*	0.2	0.4
Sedgeland	*Schoenoplectus pungens (Three-square)*	4.3	7.1
Grassland	*Festuca arundinacea (Tall fescue)*	1.5	2.5
Duneland	*Ammophila arenaria (Marram grass)*	0.1	0.1
Rushland	*Juncus kraussii (Searush)*	40.9	67.5
Reedland	*Typha orientalis (Raupo)*	0.2	0.3
Herbfield	*Sarcocornia quinqueflora (Glasswort)*	8.9	14.7
Total		**60.5**	**100%**

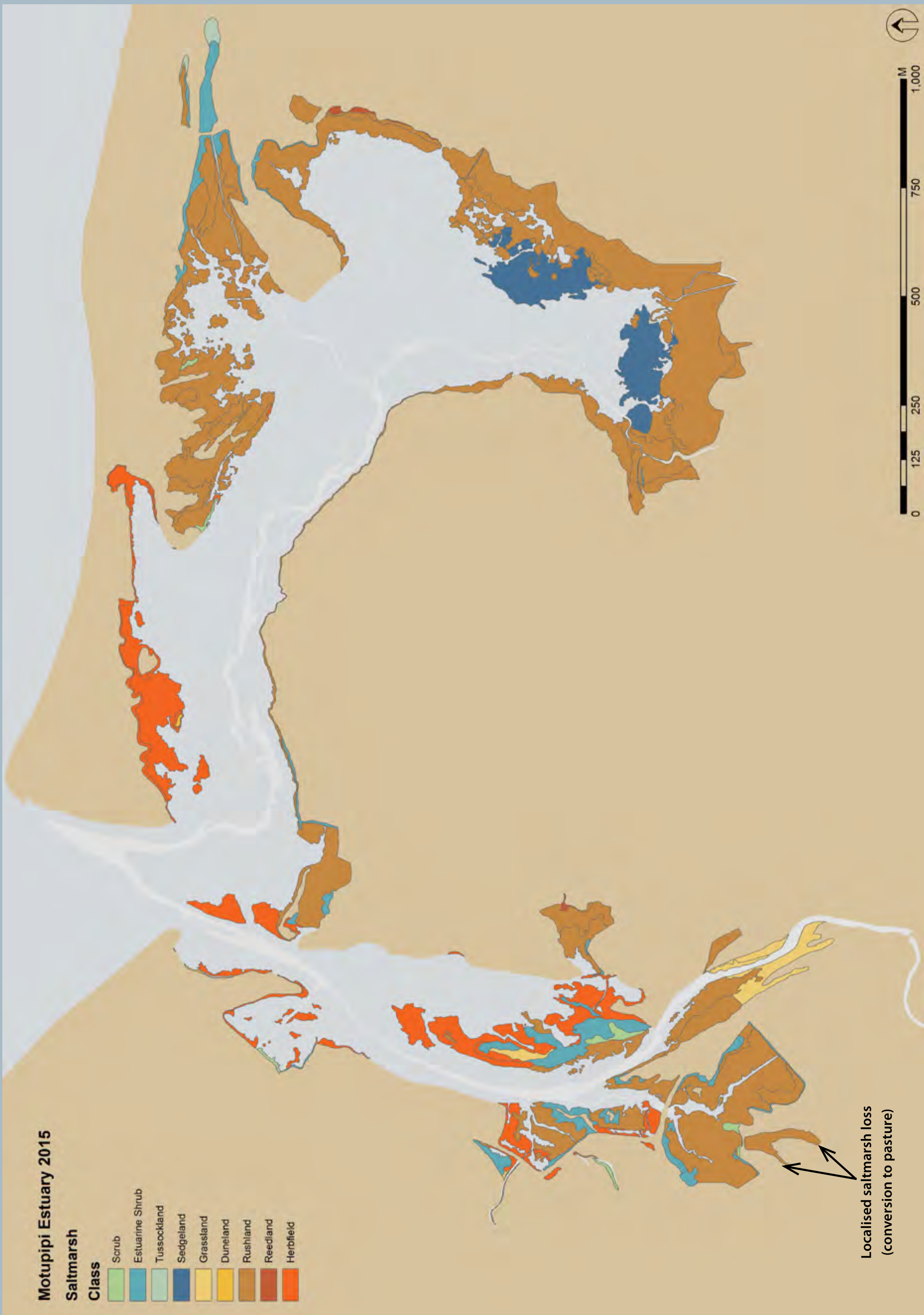


Figure 8. Map of dominant saltmarsh cover - Motupipi Estuary, 2015.

Table 9. Dominant saltmarsh cover, Motupipi Estuary, 2015.

Class	Dominant Species	Primary subdominant sp.	1943		1984		2007		2015	
			Ha	%	Ha	%	Ha	%	Ha	%
Scrub					0.2	0.3	0.3	0.5	0.3	0.5
	Ulex europaeus	*Ulex europaeus*			0.1	0.1	0.1	0.2	0.1	0.2
		Ficinia (Isolepis) nodosa			0.1	0.1	0.1	0.2	0.1	0.1
		Plagianthus divaricatus					0.1	0.2	0.1	0.2
Estuarine Shrub			7.6	8.6	5	6.8	4.5	7.2	4.2	7.0
	Plagianthus divaricatus	*Plagianthus divaricatus*	1.3	1.5	0.7	1.0	0.7	1.1	0.5	0.8
		Festuca arundinacea					0.1	0.2	0.1	0.2
		Juncus kraussii	1.2	1.4	0.4	0.5	0.4	0.6	0.6	1.0
		Apodasmia (Leptocarpus) similis	4.5	5.1	2.7	3.7	2.2	3.5	1.4	2.4
		Muehlenbeckia complexa					0.1	0.2	0.1	0.1
		Phormium tenax			0.1	0.1	0.1	0.2	0.1	0.1
		Sarcocornia quinqueflora	0.6	0.7	0.6	0.8	0.6	1.0	1.1	1.8
		Ulex europaeus			0.5	0.7	0.4	0.6	0.4	0.6
Tussockland					0.2	0.3	0.2	0.3	0.2	0.4
	Phormium tenax	*Phormium tenax*			0.2	0.3	0.2	0.3	0.05	0.1
		Typha orientalis							0.2	0.3
Sedgeland			5.9	6.7	4.1	5.6	4.5	7.2	4.3	7.1
	Schoenoplectus pungens		5.9	6.7	4.1	5.6	4.5	7.2	4.3	7.1
Grassland			1.4	1.6	1.5	2.0	1.5	2.4	1.5	2.5
	Festuca arundinacea	*Festuca arundinacea*					0.01	0.0	0.01	0.0
		Juncus kraussii	0.2	0.2	1.3	1.8	0.3	0.5	0.3	0.6
		Apodasmia (Leptocarpus) similis	1.2	1.4			1	1.6	1.0	1.6
		Plagianthus divaricatus			0.2	0.3	0.2	0.3	0.2	0.3
Duneland			3.3	3.7	9	12.3	0.05	0.1	0.1	0.1
	Undetermined duneland		3.3	3.7	9	12.3		0.0		0.0
	Ammophila arenaria	*Ficinia (Isolepis) nodosa*					0.03	0.0	0.03	0.0
		Ulex europaeus					0.02	0.0	0.02	0.0
Rushland			61.1	69.0	44.4	60.6	42.5	68.3	40.9	67.5
	Juncus kraussii	*Juncus kraussii*	15.9	18.0	24.1	32.9	23.3	37.4	10.8	17.8
		Carpobrotus edulis					0.2	0.3	0.2	0.3
		Apodasmia (Leptocarpus) similis	22.8	25.8	6.4	8.7	6	9.6	18.4	30.4
		Plagianthus divaricatus	4.5	5.1	3.1	4.2	3.1	5.0	2.9	4.8
		Samolus repens			0.1	0.1		0.0		0.0
		Sarcocornia quinqueflora	2.6	2.9	0.3	0.4	0.3	0.5	0.3	0.6
		Typha orientalis					0.4	0.6	0.3	0.5
	Apodasmia (Leptocarpus) similis	*Apodasmia (Leptocarpus) similis*	2.8	3.2	2.1	2.9	2.1	3.4	3.2	5.3
		Juncus kraussii	11	12.4	8.1	11.1	7	11.2	4.5	7.5
		Plagianthus divaricatus	1.4	1.6			0.05	0.1	0.05	0.1
		Samolus repens			0.2	0.3	0.2	0.3	0.2	0.3
Reedland					0.1	0.1	0.1	0.2	0.2	0.3
	Typha orientalis	*Typha orientalis*					0.02	0.0	0.04	0.1
		Phormium tenax		0.0	0.1	0.1	0.1	0.2	0.1	0.2
Herbfield			9.2	10.4	8.7	11.9	8.5	13.7	8.9	14.7
	Carpobrotus edulis	*Carpobrotus edulis*			0.1	0.1	0.1	0.2	0.1	0.1
		Muehlenbeckia complexa					0.3	0.5	0.03	0.1
		Sarcocornia quinqueflora					0.003	0.0	0.00	0.0
		Suaeda novae-zelandiae						0.0	0.04	0.1
	Samolus repens	*Selliera radicans*	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2
	Sarcocornia quinqueflora	*Sarcocornia quinqueflora*	6.8	7.7	3.5	4.8	3.4	5.5	3.6	5.9
		Juncus kraussii	1.9	2.1	0.6	0.8	0.5	0.8	0.5	0.9
		Apodasmia (Leptocarpus) similis	0.4	0.5	0.2	0.3	0.2	0.3	0.3	0.5
		Plagianthus divaricatus			0.1	0.1	0.1	0.2	0.1	0.1
		Selliera radicans			0.5	0.7	0.5	0.8	0.5	0.8
		Suaeda novae-zelandiae			3.6	4.9	3.2	5.1	3.3	5.4
	Suaeda novae-zelandiae	*Carpobrotus edulis*					0.4	0.6	0.4	0.7
Total (Ha)			**88.5**		**73.3**		**62.3**		**60.5**	

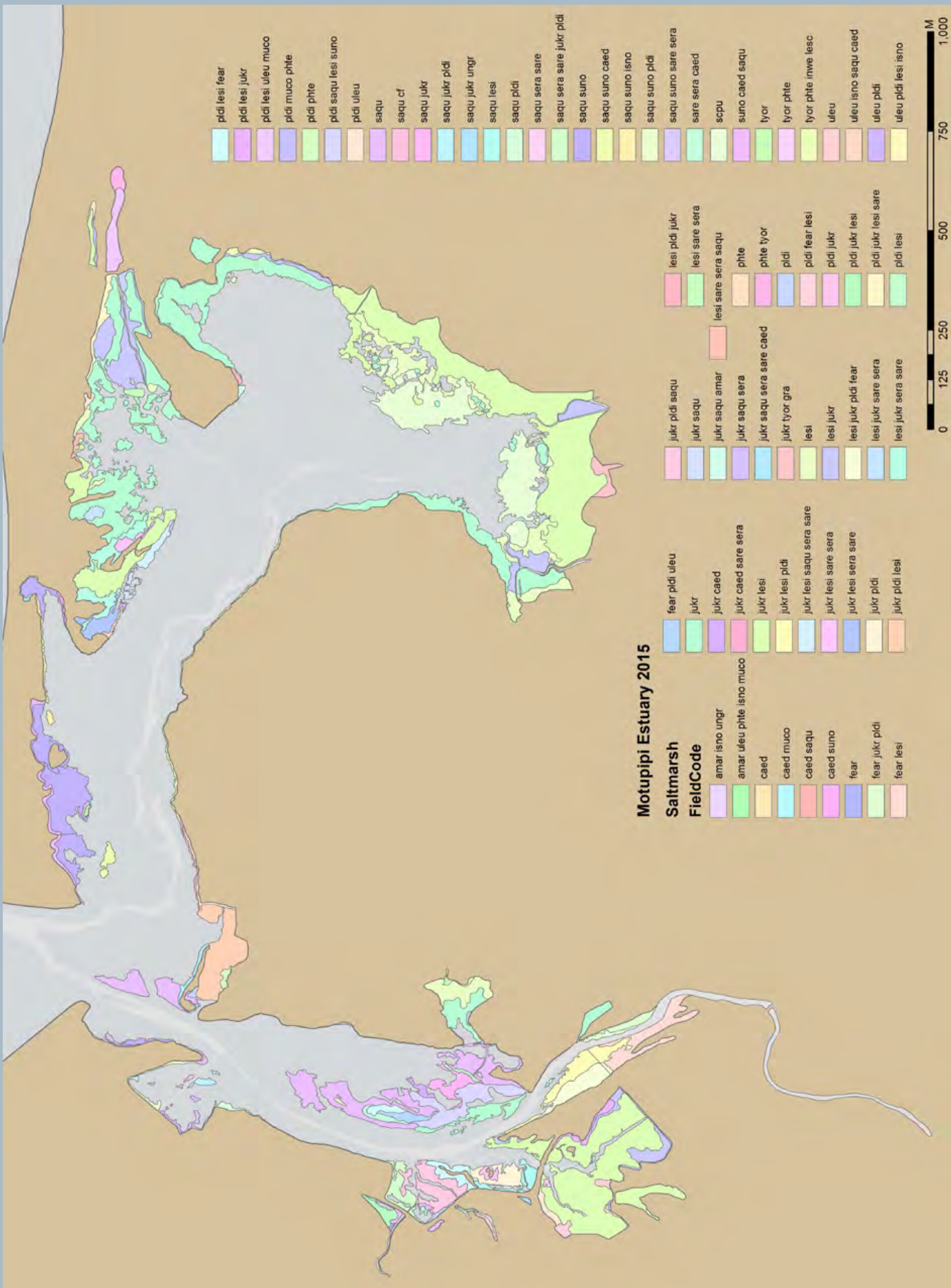
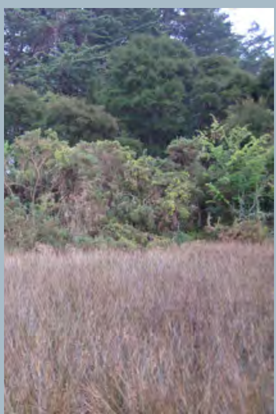
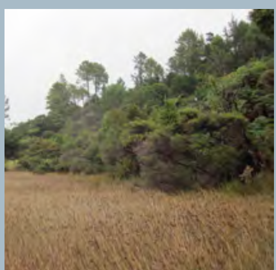
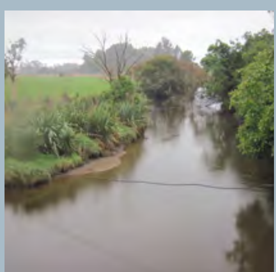


Figure 9. Example of dominant saltmarsh species assemblages (extracted from supporting GIS files) - Motupipi Estuary, 2015.

4.5. 200m TERRESTRIAL MARGIN







Margin areas around Motupipi Estuary highlighting grassland, exotic trees and introduced weeds, native bush, and riparian strips.

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 of the estuary (Table 10 and Figure 10) showed:

- Dense buffering vegetation covered 25% of the 200m margin and comprised a mix of native and exotic scrub and forest (22%), most located on the central estuary hillsides between the two arms, and duneland (3%) growing along the barrier spit near the estuary entrance.
- Since 2007, a series of slips had come down off the steep central estuary hillsides between the two arms, depositing muds and tree debris into the upper margins of the estuary.
- The remaining 200m wide terrestrial margin buffer was dominated by grassland, predominantly high productivity pasture (70%), and small areas of rural residential development (3%).
- In addition, much of the estuary edge (~70%) has been modified through steepening and edge hardening or armouring as a consequence of reclamation (e.g. along most of the estuary edges flanked by pasture), and to a lesser extent, roading and flood control measures.

Remaining areas of the estuary margins had extensive pastoral and, to a lesser extent, rural residential development with associated drainage, flood, roading and erosion protection measures. These have resulted in a steepened and hardened estuary margin, often with a steep or vertical face along the edge of past reclamations, and around which very little buffering vegetation remains. This, combined with associated drainage of wetland and saltmarsh areas, channelisation of streams, and the restriction of tidal flows to smaller embayments in the estuary significantly compromises the estuary's natural capacity to respond to climate change related sea level rise and to assimilate and buffer against inputs of sediment and nutrients. The habitat lost as a consequence is further expected to have had significant adverse impacts on native fish spawning and bird habitat.

While relatively small in extent, recent drainage of saltmarsh and conversion to pasture in the west of the estuary was evident, and highlights ongoing incremental saltmarsh losses that should be assessed and managed on a site specific basis.

Overall, a risk rating of "MODERATE" has been applied based on 25% of the 200m terrestrial margin of the estuary having a densely vegetated cover, and because aerial photos indicate the densely vegetated terrestrial margin cover was previously much lower (hillsides between the two arms on the south of the estuary that are now bush clad were unvegetated in 1943 and 1984 - Stevens and Robertson 2007) .

Table 10. Summary of 200m terrestrial margin land cover, Motupipi Estuary, 2015.

Class	Dominant features	Percentage
Forest	Predominantly mixed native and exotic scrub and forest on steep central estuary hillsides and plantings around houses and amenity areas.	1
Scrub/Forest		14
Scrub	Gorse, flax, and ribbonwood at estuary edge, native scrub on hillsides.	7
Tussockland	Flax in the south eastern arm	<1
Grassland	High producing pasture	70
Built feature	Roads	1
Duneland	On the barrier spit near the estuary entrance	3
Residential	Low density rural residential properties	3
Water	Motupipi River	<1
Total		**100%**

Figure 10. Map of 200m Terrestrial Margin - Dominant Land Cover, Motupipi Estuary, 2015.

5. SUMMARY AND CONCLUSIONS

Broad scale habitat mapping undertaken in March 2015, combined with risk indicator ratings in relation to the key estuary stressors (i.e. sediment, eutrophication and habitat modification), and changes from baseline conditions (Table 11), have been used to assess overall estuary condition.

Based on the combined ratings, the estuary is considered to face an overall "MODERATE-HIGH" risk of adverse impacts to estuary ecology. This is based primarily on the large extent of estuary substrate dominated by mud (32.2ha, 36%). While there has been extensive historical habitat modification - primarily through the displacement and reclamation of saltmarsh, ingress of terrestrial weeds, and the conversion of much of the densely vegetated terrestrial margin to pasture - there has been relatively little recent saltmarsh loss other than small areas of localised drainage and reclamation in the west of the estuary.

Eutrophication, expressed through indicators of macroalgal growth and the presence of gross eutrophic conditions, was not present as a significant issue overall. Phytoplankton blooms in the upper estuary (Motupipi River) highlight nutrient inputs currently exceed the assimilative capacity of the estuary in only this localised area.

Table 11. Summary of broad scale risk indicator ratings for Motupipi Estuary, 2015, and changes from estimated natural state conditions and previous mapping in 2007.

Major Issue	Indicator	2015 risk rating	Estimated Change from Natural State	Change since 2007
Sediment	Soft mud (% cover)	VERY HIGH	Natural state unknown	Small decrease (3.7ha, 10%)
Eutrophication	Macroalgal Growth (EQC)	VERY LOW	No significant change	No significant change
	Gross Eutrophic Conditions (ha)	VERY LOW	No significant change	No significant change
Habitat Modification	Seagrass Change (since 2007)	LOW	Natural state unknown	Small decrease
	Saltmarsh (% loss from estimated natural state)	MODERATE	~50% loss	Localised decrease (1-2ha)
	Saltmarsh (vegetated % of available habitat)	VERY LOW	No significant change	No significant change
	200m Vegetated Terrestrial Margin	HIGH	~75% loss	No significant change

The large area of soft mud is the primary issue facing the estuary. Encouragingly, since 2007 there has been a 10% (3.7ha) reduction in the area of soft mud despite the estimated sediment inputs to Motupipi Estuary being relatively high (12.8Kt/yr, NIWA CLUES model - Robertson and Stevens 2012). The reduction in mud extent shows the estuary has some capacity to naturally flush muds from the intertidal flats, with field observations indicating this mud is being exported from the estuary to Golden Bay, rather than being redistributed within the estuary. However, sedimentation rate monitoring undertaken by TDC shows sediment levels in representative estuary deposition zones have increased since 2007 at an average of 1.2mm/year in the west arm and 2.7mm/yr in the east arm (Appendix 5).

Because the area of soft mud has recently decreased, no broad scale monitoring further to that presented in Section 6 below is recommended. However because of the ongoing deposition being recorded at the sedimentation rate monitoring sites, it is recommended that sediment grain size also be measured annually to assess changes in sediment mud content. If sediment deposition or mud content increases over the next 5 years, it is recommended that fine sediment inputs to the estuary be estimated to determine the likely extent of human influenced change, and an assessment be made of the management of human influenced sediment sources to ensure Best Management Practices (BMPs) are being applied within the catchment. Ensuring BMPs are implemented will minimise sediment related problems in the estuary and nearshore coastal environment of Golden Bay.

6. MONITORING

Motupipi Estuary 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 Tasman district. Based on the 2015 monitoring results and risk indicator ratings, particularly those related to fine sediment, the following monitoring recommendations are proposed by Wriggle for consideration by TDC:

Broad Scale Habitat Mapping, Including Macroalgae.
Continue broad scale habitat mapping at 5 yearly intervals, unless obvious changes are observed in the interim, focussing on the main issue of sediment. Next monitoring recommended for January 2020.

6. MONITORING (CONTINUED)

Fine Scale Monitoring.
Because fine scale monitoring has only been undertaken once previously (in 2007) it is recommended that fine scale sampling be repeated in 2017, and then at five yearly intervals.

Sedimentation Rate Monitoring.
Because fine sediment is the priority issue in the estuary it is recommended that established sediment plates continue to be measured annually by TDC, and sediment also be analysed for grain size at these sites to establish a baseline and determine if sediments are getting muddier.

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

7. MANAGEMENT

Manage future shoreline armouring and saltmarsh drainage on a site specific basis.

Because of extensive historical terrestrial margin saltmarsh losses, and minor ongoing margin development around the estuary, it is recommended that saltmarsh areas located on private land be identified and TDC consider advising landowners of the ecological value of remaining, but vulnerable, stands. Where LIDAR data are available they could also be used to identify the areas most likely to be influenced by predicted sea level rise to assist in future planning for the managed retreat or reinstatement of saltmarsh.

Ensure Best Management Practices (BMPs) are being applied to human influenced sediment sources within the catchment.

8. ACKNOWLEDGEMENTS

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APPENDIX 1. BROAD SCALE HABITAT CLASSIFICATION DEFINITIONS.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Very soft 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 >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.

ESTUARY CONDITION RISK RATINGS FOR KEY INDICATORS

Developed by Wriggle Coastal Management

June 2014

GUIDELINES FOR USE

The estuary monitoring approach used by Wriggle has been established to provide a defensible, cost-effective way to help quickly identify the likely presence of the predominant issues affecting NZ estuaries (i.e. eutrophication, sedimentation, disease risk, toxicity and habitat change), and to assess changes in the long term condition of estuarine systems. The design is based on the use of primary indicators that have a documented strong relationship with water or sediment quality. In order to facilitate this process, "risk indicator ratings" have been proposed that assign a relative level of risk of adversely affecting estuarine conditions (e.g. very low, low, moderate, high, very high) to each indicator. Each risk indicator rating is designed to be used in combination with relevant information and other risk indicator ratings, and under expert guidance, to assess overall estuarine condition in relation to key issues, and make monitoring and management recommendations. When interpreting risk indicator results we emphasise:

- The importance of taking into account other relevant information and/or indicator results before making management decisions regarding the presence or significance of any estuary issue.
- That rating and ranking systems can easily mask or oversimplify results. For instance, large changes can occur within a risk category, but small changes near the edge of one risk category may shift the rating to the next risk level.
- Most issues will have a mix of primary and secondary ratings, primary ratings being given more weight in assessing the significance of indicator results. It is noted that many secondary estuary indicators will be monitored under other programmes and can be used if primary indicators reflect a significant risk exists, or if risk profiles have changed over time.
- Ratings have been established in many cases using statistical measures based on NZ estuary data. However, where such data is lacking, or has yet to be processed, ratings have been established using professional judgement, based on our experience from monitoring numerous NZ estuaries. Our hope is that where a high level of risk is identified, the following steps are taken:
    1. Statistical measures be used to refine indicator ratings where information is lacking.
    2. Issues identified as having a high likelihood of causing a significant change in ecological condition (either positive or negative), trigger intensive, targeted investigations to appropriately characterise the extent of the issue.
    3. The outputs stimulate discussion regarding what an acceptable level of risk is, and how it should best be managed.

The indicators and risk ratings used in the Waimea Inlet broad scale monitoring programme, and their justifications, are summarised in the following sections.

APPENDIX 2. ESTUARY CONDITION RISK RATINGS (CONTINUED)

1. SEDIMENT: PERCENT SOFT MUD COVER

Estuaries are a sink for sediments. However, where large areas of "soft mud" are present in estuaries that are not naturally prone to such impacts, 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. "Total Soft Mud" is defined as the combination of the "soft mud" and "very soft mud" which are two indicators used to assess broad scale estuary condition in the National Estuary Monitoring Protocol (NEMP) (Robertson et al. 2002). These are defined as follows:

- Soft Mud: A mixture of mud and sand, the surface appears grey-brown (may have a black anaerobic layer below) and when a human walks on it they sink 2-5cm.
- Very Soft Mud. A mixture of mud and sand, the surface appears grey-brown and may have a black anaerobic layer below and when a human walks on it they sink >5cm.

Subsequent to the development of NEMP, the characteristics of "total soft mud" has been further defined and related to; percentage mud content (i.e. grain size), the macroinvertebrate community, and seagrass cover (see supporting evidence below). As a consequence, the characteristics of "total soft mud" are generally as follows:

"Total Soft Mud" Characteristics

- Sediments are relatively incohesive at mud contents below 20-30% (i.e. are not sticky and are relatively firm to walk on), but become cohesive and "sticky" at higher mud contents (i.e. you begin to sink into the muds).
- There is a marked shift in the macroinvertebrate assemblage when mud content exceeds 25-30% to one dominated by mud tolerant and/or species of intermediate tolerance. This shift is most apparent when elevated mud content is contiguous with high total organic carbon (TOC) concentrations.
- Seagrass (*Zostera muelleri*) cover is often absent or less than 1% for estuaries with greater than 20-30% soft mud.

These characteristics indicate that the presence of extensive areas of soft mud sediments (i.e. greater than 20-30% of the estuary as soft mud) in typical NZ tidal lagoon and tidal river estuaries means that seagrass cover is likely to be absent, the macroinvertebrate community degraded and the soft mud areas overlain with the dense nuisance beds of the red macroalga Gracilaria sp. in enclosed embayments or sheltered areas. Following on from these findings, a preliminary rating to reflect the likely risk of adverse impacts to the estuarine ecology was therefore developed (see following section).

SUPPORTING EVIDENCE

1. Total Soft Mud - Relationship to Mud Content

Based on the results from a selection of typical NZ tidal lagoon and tidal river estuaries (Table 1), the percent mud content of "Total Soft Mud" generally equates to estuarine sediments with a % mud content in the 25-100% range (i.e. the range where sediments become "cohesive" or sticky - Houwing 2000).

Table 1. Relationship between "muddiness category" and % mud content of intertidal habitat of various typical NZ estuaries.

Estuary	Muddiness Category	Human Footprint Depth (cm)	% Mud Content	Source
Porirua Harbour	Firm Muddy Sand	0-2cm	1.7-11.1%	Stevens and Robertson (2013)
	Soft Mud	2-5cm	37-49%	
	Very Soft Mud	>5cm		
Waikanae Estuary	Soft Mud	2-5cm	27-47%	Robertson and Stevens (2012a)
	Very Soft Mud	>5cm		
Hutt Estuary	Firm Muddy Sand	0-2cm	21%	Stevens and Robertson (2014a)
	Soft Mud	2-5cm	28-51%	Robertson and Stevens (2012b)
	Very Soft Mud	>5cm		
Whareama Estuary	Firm Muddy Sand	0-2cm	21%	Stevens and Robertson (2013)
	Soft Mud	2-5cm	39-86%	
	Very Soft Mud	>5cm		
Waimea Estuary	Firm Muddy Sand	0-2cm		Stevens and Robertson (2014b)
	Soft Mud	2-5cm	>25%	
	Very Soft Mud	>5cm		
Havelock Estuary	Firm Muddy Sand	0-2cm	17%	Stevens and Robertson (2015) Robertson and Stevens (2015)
	Soft Mud	2-5cm	>25%	
	Very Soft Mud	>5cm		

1. SEDIMENT: PERCENT SOFT MUD COVER (CONTINUED)

2. Mud Content - Relationship to Macroinvertebrate Community

A review of monitoring data from 25 typical NZ estuaries (shallow, short residence time estuaries) (Wriggle database 2009-2014) confirmed a "high" risk of reduced macrobenthic species richness for NZ estuaries when mud values were >25-30% mud and a "very high" risk at >55% (this last value is more tentative given the low number of data-points beyond this mud content) (Figure 1). This is supported statistically (canonical analysis of the principal coordinates (CAP) for the effect of mud content) by the increasing dissimilarity in the macrobenthic community as mud contents increase above 25-30% mud (Figure 2).

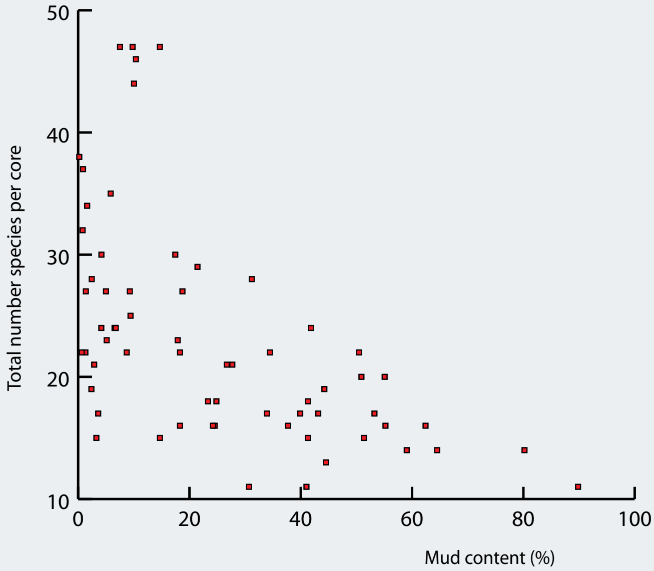

Figure 1. Sediment mud content and number of macrobenthic species per core from 12 estuaries scattered throughout NZ, and representing most NZ shallow, short residence time estuary types. (Wriggle Coastal Management database 2009-14).

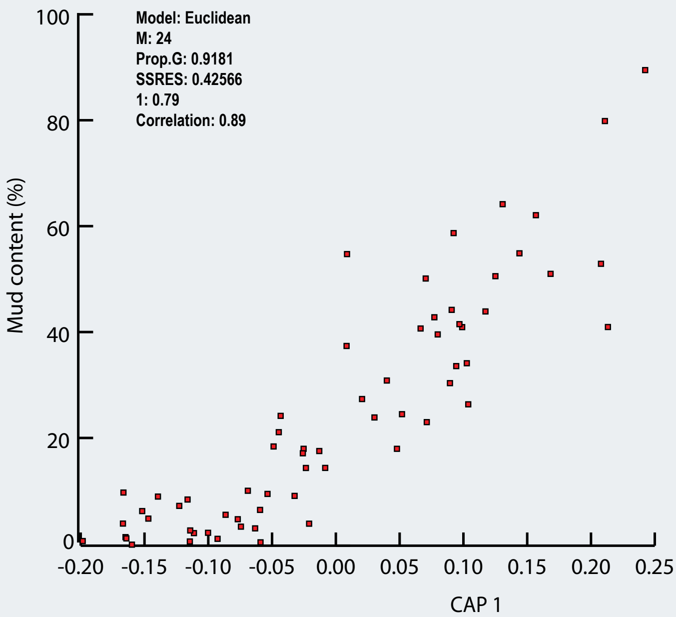

Figure. 2. Canonical analysis of the principal coordinates (CAP) for the effect of sediment mud content (exclusively) on the macroinvertebrate assemblages from 25 typical NZ estuaries (i.e. CAP1) among sites. Note: M = the number of PCO axes used for the analysis, Prop.G = the proportion of the total variation in the dissimilarity matrix explained by the first m PCO axes, SSRES = the leave-one-out residual sum of squares, 1 = the squared canonical correlation for the canonical axis, Correlation = the correlation between the canonical axis and the sediment mud content or pollution gradient.

APPENDIX 2. ESTUARY CONDITION RISK RATINGS (CONTINUED)

1. SEDIMENT: PERCENT SOFT MUD COVER (CONTINUED)

3. Total Soft Mud - Relationship to Seagrass Cover

- Tidal Lagoon and Tidal River Estuaries: Seagrass (Zostera *muelleri*) typically requires sandy sediments with a low mud content for healthy growth. Extensive broad scale mapping of seagrass cover for 45 typical NZ tidal lagoon and tidal river estuaries (shallow, residence time <3 days) indicate that seagrass cover is absent or less than 1% cover for estuaries with greater than 20-30% of the estuary area as soft mud (Figure 3). It is expected that this is primarily caused by reduced water clarity, and hence light availability, as a result of resuspension and elevated suspended sediment input loads.
- ICOLLS: Submerged aquatic vegetation (SAV) in intermittently open and closed lagoons/lakes (i.e. brackish waterbodies) in NZ can survive in some ICOLLs that are dominated by muddy sediments (Figure 4). This occurs primarily as a result of the ability of SAV (unlike Zostera) to grow up to the surface and hence obtain sufficient light for growth. ICOLLs with low SAV are generally SAV limited by reasons other than soft muds, unless the SAV is Zostera (such as in Papanui Inlet). For example, in Lake Onoke, SAV is limited by the short period opening/closing regime: in Waimatuku, SAV is limited by the very long opening period and short closed period, in Waituna SAV is limited by a combination of macroalgal/epiphyte cover and muddiness and the opening/closing regime.

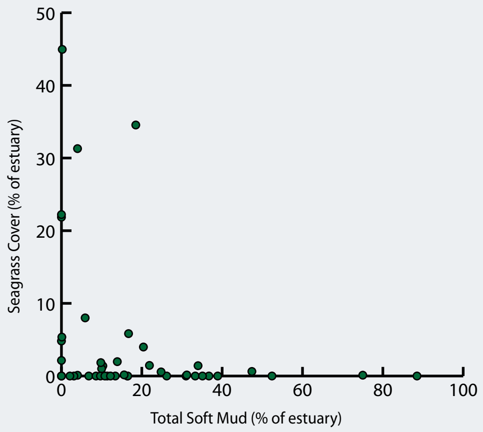

Figure 3. Percentage soft mud and seagrass cover of 45 typical NZ tidal lagoon and tidal river) estuaries (shallow, residence time <3 days) (data sourced from Wriggle Coastal Management monitoring reports 2006-2013 and Robertson et al. 2002).

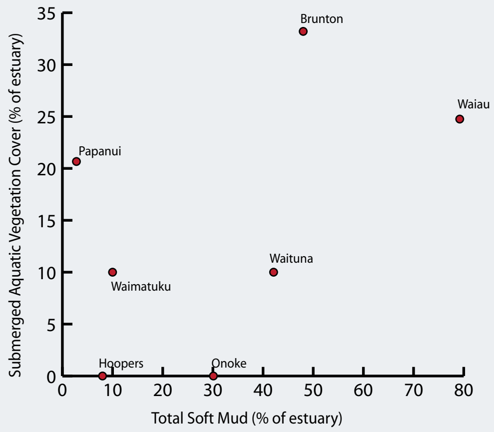

Figure 4. Percentage soft mud and seagrass cover of 7 typical NZ ICOLL estuaries (shallow, residence time variable) (data sourced from Wriggle Coastal Management monitoring reports 2006-2013).

RECOMMENDED SEDIMENT SOFT MUD PERCENT COVER RISK RATING (INTERIM)

The following rating specifies the magnitude of likely risk that the measured % soft mud will cause adverse impacts to estuarine ecology and is based on data for a wide range of NZ estuary types. These results showed that most estuaries in a dataset of 50 typical NZ estuaries fit the <10% soft mud category (Wriggle data 2001-2013).

Estuary Condition Risk Rating (Interim): Sediment Soft Mud Percent Cover					
Risk Rating	Very Low	Low	Moderate	High	Very High
Soft Mud Percent Cover	<2%	2-5%	>5-15%	>15-25%	>25%

RECOMMENDED RESEARCH

Undertake extensive grain size validation monitoring of the following habitat types: firm muddy sand, soft mud, and very soft mud to confirm and refine the measured range of % mud found in each these broad scale monitoring categories from estuaries throughout NZ.
Undertake further studies in typical NZ estuaries on % cover of mud and the incidence of gross eutrophic conditions, and adverse impacts to macroinvertebrates, seagrass, saltmarsh, fish, and/or birds.

References

Houwing, E.J. 2000. Sediment dynamics in the pioneer zone in the land reclamation area of the Wadden Sea, Groningen, The Netherlands. PhD thesis, University of Utrecht, Utrecht.

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.

2. OPPORTUNISTIC MACROALGAL BLOOMING TOOL

The UK-WFD (Water Framework Directive) Opportunistic Macroalgal Blooming Tool (OMBT) (WFD-UKTAG 2014) is a comprehensive 5 part multimetric index approach suitable for characterising the different types of estuaries and related macroalgal issues found in NZ. The tool allows simple adjustment of underpinning threshold values to calibrate it to the observed relationships between macroalgal condition and the ecological response of different estuary types. It incorporates sediment entrained macroalgae, a key indicator of estuary degradation, and addresses limitations associated with percentage cover estimates that do not incorporate biomass e.g. where high cover but low biomass are not resulting in significantly degraded sediment conditions. It is supported by extensive studies of the macroalgal condition in relation to ecological responses in a wide range of estuaries.

The 5 part multimetric OMBT, modified for NZ estuary types, is fully described below. It is based on macroalgal growth within the Available Intertidal Habitat (AIH) - the estuary area between high and low water spring tide able to support opportunistic macroalgal growth. Suitable areas are considered to consist of ***mud, muddy sand, sandy mud, sand, stony mud and mussel beds***. Areas which are judged unsuitable for algal blooms e.g. channels and channel edges subject to constant scouring, need to be excluded from the AIH. The following measures are then taken:.

1. Percentage cover of the available intertidal habitat (AIH).

The percent cover of opportunistic macroalgal within the AIH is assessed. While a range of methods are described, visual rating by experienced ecologists, with independent validation of results is a reliable and rapid method. All areas within the AIH where macroalgal cover >5% are mapped spatially.

2. Total extent of area covered by algal mats (affected area (AA)) or affected area as a percentage of the AIH (AA/AIH, %).

In large water bodies with proportionately small patches of macroalgal coverage, the rating for total area covered by macroalgae (Affected Area - AA) might indicate high or good status, while the total area covered could actually be quite substantial and could still affect the surrounding and underlying communities. In order to account for this, an additional metric established is the affected area as a percentage of the AIH (i.e. (AA/AIH)*100). This helps to scale the area of impact to the size of the water body. In the final assessment the lower of the two metrics (the AA or percentage AA/AIH) is used, i.e. whichever reflects the worse case scenario.

3. Biomass of AIH ($g.m^{-2}$).

Assessment of the spatial extent of the algal bed alone will not indicate the level of risk to a water body. For example, a very thin (low biomass) layer covering over 75% of a shore might have little impact on underlying sediments and fauna. The influence of biomass is therefore incorporated. Biomass is calculated as a mean for (i) the whole of the AIH and (ii) for the Affected Areas. The potential use of maximum biomass was rejected, as it could falsely classify a water body by giving undue weighting to a small, localised blooming problem. Algae growing on the surface of the sediment are collected for biomass assessment, thoroughly rinsed to remove sediment and invertebrate fauna, hand squeezed until water stops running, and the wet weight of algae recorded.

For quality assurance of the percentage cover estimates, two independent readings should be within +/- 5%. A photograph should be taken of every quadrat for inter-calibration and cross-checking of percent cover determination. Measures of biomass should be calculated to 1 decimal place of wet weight of sample. For both procedures the accuracy should be demonstrated with the use of quality assurance checks and procedures.

4. Biomass of AA ($g.m^{-2}$).

Mean biomass of the Affected Area (AA), with the AA defined as the total area with macroalgal cover >5%.

5. Presence of Entrained Algae (percentage of quadrats).

Algae are considered as entrained in muddy sediment when they are found growing >3cm deep within muddy sediments. The persistence of algae within sediments provides both a means for over-wintering of algal spores and a source of nutrients within the sediments. Build-up of weed within sediments therefore implies that blooms can become self-regenerating given the right conditions (Raffaelli et al. 1989). Absence of weed within the sediments lessens the likelihood of bloom persistence, while its presence gives greater opportunity for nutrient exchange with sediments. Consequently, the presence of opportunistic macroalgae growing within the surface sediment was included in the tool.

All the metrics are equally weighted and combined within the multimetric, in order to best describe the changes in the nature and degree of opportunist macroalgae growth on sedimentary shores due to nutrient pressure.

Timing: The OMBT has been developed to classify data over the maximum growing season so sampling should target the peak bloom in summer (Dec-March), although peak timing may vary among water bodies, so local knowledge is required to identify the maximum growth period. Sampling is not recommended outside the summer period due to seasonal variations that could affect the outcome of the tool and possibly lead to misclassification; e.g. blooms may become disrupted by stormy autumn weather and often die back in winter. Sampling should be carried out during spring low tides in order to access the maximum area of the AIH.

Suitable Locations: The OMBT is suitable for use in estuaries and coastal waters which have intertidal areas of soft sedimentary substratum (i.e. areas of AIH for opportunistic macroalgal growth). The tool is not currently used for assessing ICOLLs due to the particular challenges in setting suitable reference conditions for these water bodies.

Derivation of Threshold Values.

Published and unpublished literature, along with expert opinion, was used to derive critical threshold values suitable for defining quality status classes (Table A2).

- **Reference Thresholds.** A UK Department of the Environment, Transport and the Regions (DETR) expert workshop suggested reference levels of <5% cover of AIH of climax and opportunistic species for high quality sites (DETR, 2001). In line with this approach, the WFD adopted <5% cover of opportunistic macroalgae in the AIH as equivalent to High status. From the WFD North East Atlantic intercalibration phase 1 results, German research into large sized water bodies revealed that areas over 50ha may often show signs of adverse effects, however if the overall area was less than 1/5th of this adverse effects were not seen, so the High/Good boundary was set at 10ha. In all cases a reference of 0% cover for truly un-impacted areas was assumed. Note: opportunistic algae may occur even in pristine water bodies as part of the natural community functioning.
  The proposal of reference conditions for levels of biomass took a similar approach, considering existing guidelines and suggestions from DETR (2001), with a tentative reference level of <100g m^{-2} wet weight. This reference level was used for both the average biomass over the affected area and the average biomass over the AIH. As with area measurements a reference of zero was assumed.
  An ideal of no entrainment (i.e. no quadrats revealing entrained macroalgae) was assumed to be reference for un-impacted waters. After some empirical testing in a number of UK water bodies a High / Good boundary of 1% of quadrats was set.
- **Class Thresholds for Percent Cover:**
  High/Good boundary set at 5%. Based on the finding that a symptom of the potential start of eutrophication is when: (i) 25% of the available intertidal habitat has opportunistic macroalgae and (ii) at least 25% of the sediment (i.e. 25% in a quadrat) is covered (Comprehensive Studies Task Team (DETR, 2001)). This implies that an overall cover of the AIH of 6.25% (25*25%) represents the start of a potential problem.
  Good / Moderate boundary set at 15%. True problem areas often have a >60% cover within the affected area of 25% of the water body (Wither 2003). This equates to 15% overall cover of the AIH (i.e. 25% of the water body covered with algal mats at a density of 60%).
  Poor/Bad boundary is set at >75%. The Environment Agency has considered >75% cover as seriously affecting an area (Foden et al. 2010).
- **Class Thresholds for Biomass.** Class boundaries for biomass values were derived from DETR (2001) recommendations that <500 $g.m^{-2}$ wet weight was an acceptable level above the reference level of <100 $g.m^{-2}$ wet weight. In Good status only slight deviation from High status is permitted so 500 $g.m^{-2}$ represents the Good/Moderate boundary. Moderate quality status requires moderate signs of distortion and significantly greater deviation from High status to be observed. The presence of >500 $g.m^{-2}$ but less than 1,000 $g.m^{-2}$ would lead to a classification of Moderate quality status at best, but would depend on the percentage of the AIH covered. >1$kg.m^{-2}$ wet weight causes significant harmful effects on biota (DETR 2001, Lowthion et al. 1985, Hull 1987, Wither 2003).
- **Thresholds for Entrained Algae.** Empirical studies testing a number of scales were undertaken on a number of impacted waters. Seriously impacted waters have a very high percentage (>75%) of the beds showing entrainment (Poor / Bad boundary). Entrainment was felt to be an early warning sign of potential eutrophication problems so a tight High /Good standard of 1% was selected (this allows for the odd change in a quadrat or error to be taken into account). Consequently the Good / Moderate boundary was set at 5% where (assuming sufficient quadrats were taken) it would be clear that entrainment and potential over wintering of macroalgae had started.

Each metric in the OMBT has equal weighting and is combined to produce the ecological quality ratio score (EQR).

Table A2. The final face value thresholds and metrics for levels of the ecological quality status

Quality Status	High	Good	Moderate	Poor	Bad
EQR (Ecological Quality Rating)	≥0.8 - 1.0	≥0.6 - <0.8	≥0.4 - <0.6	≥0.2 - <0.4	0.0 - <0.2
% cover on Available Intertidal Habitat (AIH)	0 - ≤5	>5 - ≤15	>15 -≤25	>25 - ≤75	>75 - 100
Affected Area (AA) of >5% macroalgae (ha)*	≥0 - 10	≥10 - 50	≥50 - 100	≥100 - 250	≥250
AA/AIH (%)*	≥0 - 5	≥5 - 15	≥15 - 50	≥50 - 75	≥75 - 100
Average biomass ($g.m^2$) of AIH	≥0 - 100	≥100 - 500	≥500 - 1000	≥1000 - 3000	≥3000
Average biomass ($g.m^2$) of AA	≥0 - 100	≥100 - 500	≥500 - 1000	≥1000 - 3000	≥3000
% algae >3cm deep	≥0 - 1	≥1 - 5	≥5 - 20	≥20 - 50	≥50 - 100

*N.B. Only the lower EQR of the 2 metrics, AA or AA/AIH is used in the final EQR calculation.

EQR calculation

Each metric in the OMBT has equal weighting and is combined to produce the **Ecological Quality Ratio** score (EQR).
The face value metrics work on a sliding scale to enable an accurate metric EQR value to be calculated; an average of these values is then used to establish the final water body level EQR and classification status. The EQR determining the final water body classification ranges between a value of zero to one and is converted to a Quality Status by using the following categories:

Quality Status	High	Good	Moderate	Poor	Bad
EQR (Ecological Quality Rating)	≥0.8 - 1.0	≥0.6 - <0.8	≥0.4 - <0.6	≥0.2 - <0.4	0.0 - <0.2

The EQR calculation process is as follows:

1. Calculation of the face value (e.g. percentage cover of AIH) for each metric. To calculate the individual metric face values:

- Percentage cover of AIH (%) = (Total % Cover / AIH} x 100 - *where Total % cover = Sum of {(patch size) / 100} x average % cover for patch*
- Affected Area, AA (ha) = Sum of all patch sizes (with macroalgal cover >5%).
- Biomass of AIH ($g.m^{-2}$) = Total biomass / AIH - *where Total biomass = Sum of (patch size x average biomass for the patch)*
- Biomass of Affected Area ($g.m^{-2}$) = Total biomass / AA - *where Total biomass = Sum of (patch size x average biomass for the patch)*
- Presence of Entrained Algae = (No. quadrats with entrained algae / total no. of quadrats) x 100
- Size of AA in relation to AIH (%) = (AA/AIH) x 100

2. Normalisation and rescaling to convert the face value to an equidistant index score (0-1 value) for each index (Table A3).

The face values are converted to an equidistant EQR scale to allow combination of the metrics. These steps have been mathematically combined in the following equation:

Final Equidistant Index score = Upper Equidistant range value – ({Face Value - Upper Face value range} * (Equidistant class range / Face Value Class Range)).

Table A3 gives the critical values at each class range required for the above equation. The first three numeric columns contain the face values (FV) for the range of the index in question, the last three numeric columns contain the values of the equidistant 0-1 scale and are the same for each index. The face value class range is derived by subtracting the upper face value of the range from the lower face value of the range.
Note: the table is "simplified" with rounded numbers for display purposes. The face values in each class band may have greater than (>) or less than (<) symbols associated with them, for calculation a value of <5 is given a value of 4.999'.
The final EQR score is calculated as the average of equidistant metric scores.

A spreadsheet calculator is available to download from the UK WFD website to undertake the calculation of EQR scores.

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APPENDIX 2. ESTUARY CONDITION RISK RATINGS (CONTINUED)

Table A3. Values for the normalisation and re-scaling of face values to EQR metric.

METRIC	QUALITY STATUS	FACE VALUE RANGES			EQUIDISTANT CLASS RANGE VALUES		
		Lower face value range (measurements towards the "Bad" end of this class range)	Upper face value range (measurements towards the "High" end of this class range)	Face Value Class Range	Lower 0-1 Equidistant range value	Upper 0-1 Equidistant range value	Equidistant Class Range
% Cover of Available Intertidal Habitat (AIH)	High	≤5	0	5	≥0.8	1	0.2
	Good	≤15	>5	9.999	≥0.6	<0.8	0.2
	Moderate	≤25	>15	9.999	≥0.4	<0.6	0.2
	Poor	≤75	>25	49.999	≥0.2	<0.4	0.2
	Bad	100	>75	24.999	0	<0.2	0.2
Average Biomass of AIH (g m-2)	High	≤100	0	100	≥0.8	1	0.2
	Good	≤500	>100	399.999	≥0.6	<0.8	0.2
	Moderate	≤1000	>500	499.999	≥0.4	<0.6	0.2
	Poor	≤3000	>1000	1999.999	≥0.2	<0.4	0.2
	Bad	≤6000	>3000	2999.999	0	<0.2	0.2
Average Biomass of Affected Area (AA) (g m-2)	High	≤100	0	100	≥0.8	1	0.2
	Good	≤500	>100	399.999	≥0.6	<0.8	0.2
	Moderate	≤1000	>500	499.999	≥0.4	<0.6	0.2
	Poor	≤3000	>1000	1999.999	≥0.2	<0.4	0.2
	Bad	≤6000	>3000	2999.999	0	<0.2	0.2
Affected Area (Ha)*	High	≤10	0	100	≥0.8	1	0.2
	Good	≤50	>10	39.999	≥0.6	<0.8	0.2
	Moderate	≤100	>50	49.999	≥0.4	<0.6	0.2
	Poor	≤250	>100	149.999	≥0.2	<0.4	0.2
	Bad	≤6000	>250	5749.999	0	<0.2	0.2
AA/AIH (%)*	High	≤5	0	5	≥0.8	1	0.2
	Good	≤15	>5	9.999	≥0.6	<0.8	0.2
	Moderate	≤50	>15	34.999	≥0.4	<0.6	0.2
	Poor	≤75	>50	24.999	≥0.2	<0.4	0.2
	Bad	100	>75	27.999	0	<0.2	0.2
% Entrained Algae	High	≤1	0	1	≥0.0	1	0.2
	Good	≤5	>1	3.999	≥0.2	<0.0	0.2
	Moderate	≤20	>5	14.999	≥0.4	<0.2	0.2
	Poor	≤50	>20	29.999	≥0.6	<0.4	0.2
	Bad	100	>50	49.999	1	<0.6	0.2

*N.B. Only the lower EQR of the 2 metrics, AA or AA/AIH should be used in the final EQR calculation.

APPENDIX 3. MOTUPIPI ESTUARY MACROALGAL DATA

Patch ID	Rep	Dominant species	Patch area (ha)	Percent cover of macroalgae	Presence (1) or absence (0) of entrained algae	Mean Biomass ($g.m^{-2}$ wet weight)	Mean Patch Biomass (kg wet weight)	aRPD depth (cm)	Presence (1) or absence (0) of soft mud
1	1	*Ulva lactuca*	1.25	30	0	800	10002	3	0
2	1	*Ulva lactuca Gracilaria chilensis*	0.25	50	0	50	30000	3	0
3	1	*Gracilaria chilensis Ulva lactuca*	0.38	25	0	150	563	3	0
4	1	*Gracilaria chilensis Ulva lactuca*	0.33	80	0	2700	8848	5	0
5	1	*Ulva lactuca Gracilaria chilensis*	0.46	50	0	800	3689	5	0
6	1	*Ulva lactuca Gracilaria chilensis*	0.35	80	0	1000	3498	3	0
7	1	*Ulva lactuca Gracilaria chilensis*	0.13	60	0	400	517	5	0
8	1	*Gracilaria chilensis*	0.07	15	0	120	89	5	0
9	1	*Gracilaria chilensis*	0.08	80	0	1500	1145	1	1
10	1	*Ulva intestinalis Gracilaria chilensis*	0.41	5	0	20	82	5	1
11	1	*Ulva intestinalis*	0.11	10	0	10	11	5	0
12	1	*Ulva intestinalis*	0.03	10	0	20	6	5	0
13	1	*Ulva intestinalis*	0.07	75	0	150	111	5	0
		Total	4.7ha				58560kg		

APPENDIX 3. MOTUPIPI ESTUARY MACROALGAL DATA

Figure A1. Location of macroalgal patches (>5% cover) used in assessing Motupipi Estuary, March 2015.

APPENDIX 4. MOTUPIPI ESTUARY GROUNDTRUTHING COVERAGE

Figure A2. Groundtruthing coverage, Motupipi Estuary, March 2015.

APPENDIX 5. SEDIMENTATION RATE MEASUREMENTS, 2008-2014.

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

Motupipi Estuary Upper West Arm							
Site	NZMG East	NZMG North	26/09/07	15/02/10	1/05/12	9/07/13	19/09/14
NW	2496407	6040764	248	243	249	247	252
NE	2496429	6040776	215	212	218	218	221
SE	2496442	6040753	190	192	194	206	206
SW	2496422	6040737	210	213	201	218	217
Mean Annual Change/Plate (mm)				-0.8	0.5	6.8	1.8
Mean Annual Change from 2007 baseline (mm)							1.2

Motupipi Estuary Upper East Arm							
Site	NZMG East	NZMG North	27/09/07	15/02/10	1/05/12	9/07/13	19/09/14
NE	2497860	6040405	205	211	217	224	221
SE	2497842	6040385	205	198	190	193	206
SW	2497817	6040394	200	205	215	219	217
NW	2497832	6040419	210	210	295	287	252
Mean Annual Change/Plate (mm)				1.0	23.3	1.5	-6.8
Mean Annual Change from 2007 baseline (mm)							2.7