SALT ECOLOGY

Broad scale intertidal habitat mapping of estuaries of the Motueka delta, 2019

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For the environment
Mō te taiao

GLOSSARY

CSSI	Compound-Specific Stable Isotope
aRPD	Apparent Redox Potential Discontinuity
EQR	Ecological Quality Rating
ETI	Estuary Trophic Index
GIS	Geographic Information System
GEZ	Gross Eutrophic Zone
HECs	High Enrichment Conditions
LCDB	Land Cover Data Base
MWTP	Motueka wastewater treatment plant
NEMP	National Estuary Monitoring Protocol
OMBT	Opportunistic Macroalgal Blooming Tool
SIDE	Shallow Intertidal-Dominated Estuary
SOE	State of Environment (monitoring)
SSRTRE	Shallow Short-Residence Tidal River mouth Estuary
TDC	Tasman District Council

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BACKGROUND

This report summarises the results of broad scale habitat mapping undertaken in May 2019 of four Tasman Bay estuaries located near Motueka. The estuaries are (north to south): Riwaka (59ha), Ferrer Creek (24ha), Motueka River (108ha) and Motueka (77ha). The estuaries are part of Tasman District Council's (TDC's) long-term coastal monitoring programme. The primary purpose of the 2019 survey was to describe and map the dominant substrate and vegetation features present within each estuary including seagrass, salt marsh and macroalgae based on the framework outlined in New Zealand's National Estuary Monitoring Protocol (NEMP). Previous mapping results for 1947, 1986 and 2003 were QAQC checked and updated to address any errors in geometry or typology. These updated results were then clipped to the current mapping extent and used to assess temporal changes.

KEY FINDINGS

The first table below summarises key broad scale monitoring results for each estuary in 2019 and rates them using preliminary criteria for assessing estuary health. The second table described the temporal changes in key indicators since the 2003 baseline survey (no baseline was established for Riwaka).

		Riwaka		Ferrer Creek		Motueka River		Motueka	
Broad scale indicators	**Unit**	Value	Rating	Value	Rating	Value	Rating	Value	Rating
Mud-dominated substrate	% of intertidal area >50% mud	18.1	Poor	24.2	Poor	1.8	Good	0	Very Good
Macroalgae (OMBT)	Ecological Quality Rating (EQR)	1	Very Good	0.6	Good	1	Very Good	1	Very Good
Salt marsh extent (current)	% of intertidal area	10.4	Good	27.8	Very Good	35.7	Very Good	32.2	Very Good
Historical salt marsh extent	% of historical remaining	<40	Poor	<30	Poor	<25	Poor	<25	Poor
200m terrestrial margin	% densely vegetated	36.2	Fair	8.4	Poor	38.2	Fair	26.8	Fair
High Enrichment Conditions	ha	0	Very Good	0.6	Good	0	Very Good	0	Very Good
High Enrichment Conditions	% of estuary	0	Very Good	2.5	Good	0	Very Good	0	Very Good

		Ferrer Creek Change 2003-2019		Motueka River Change 2003-2019		Motueka Change 2003-2019	
Broad scale indicators	**Unit**						
Mud-dominated substrate	% of intertidal area >50% mud	3.4ha	↓38%* (improving)	30.5ha	↓98%* (improving)	36ha	↓100%* (improving)
Macroalgae (OMBT)	Ecological Quality Rating (EQR)	0.4	↓40% (worsening)	0	No change	0	No change
Salt marsh extent	% of intertidal area	0.3ha	↑6%* (improving)	11.3ha	↑51%* (improving)	4.9ha	↓17% (worsening)
High Enrichment Conditions	ha	0.6ha	↑(worsening)	0	No change	0	No change
High Enrichment Conditions	% of intertidal area	2.5%	↑(worsening)	0	No change	0	No change

OMBT=Opportunistic Macroalgal Blooming Tool

*Primarily reflects differences in mapping coverage or classification rather than meaningful change

Overall, the key findings were:

- For the four estuaries combined, substrates in 2019 were sand-dominated comprising 60.3ha (25% of estuary intertidal area) clean sand (<10% mud content), 46.2ha (19%) moderately muddy-sand (10-25% mud), and 96ha (39%) highly muddy-sand. Sandy-mud (50-90% mud) comprised 17.2ha (7%). Cobble and gravel was the other common substrate, being 24.2ha of the estuary area (10%).
- The muddiest estuaries were Ferrer Creek and Riwaka, whose extent of mud-dominated sediment (24% and 18%, respectively) was high in both a regional and national context. Motueka River and Motueka Estuary had very little mud (<2%). Reported reductions in mud dominance from 2003 to 2019 largely reflect improved substrate classification in 2019.
- Nuisance macroalgae were scarce, with dense, high biomass growths of the red seaweed *Gracilaria chilensis* and the establishment of High Enrichment Conditions (HECs) only present in a small area of Ferrer Creek (0.58ha, 2.5% of the intertidal area) - located in the upper reaches within soft, muddy, poorly-oxygenated sediments.
- Seagrass cover was very low (0.74ha) and found exclusively within Riwaka Estuary. Large seagrass beds were noted on the coastal sandflats of Tasman Bay seaward of the defined estuary boundaries.
- Salt marsh was relatively extensive (69ha, 28.2% of the intertidal area) comprising 40% rushland, 38% herbfield and 16% estuarine shrub. An estimated 60-75% of the historical salt marsh cover was lost prior to

1947 due to drainage, reclamation and land clearance. Although estimates are relatively coarse due to limits in the accuracy of past mapping, salt marsh overall appears to have reduced by ~20ha from 1947 to 2019. This change incorporates losses of ~4ha in Ferrer Creek, ~13ha in Motueka River and ~3ha in the Motueka. Increases since 2003 (see summary table on previous page) primarily reflect improved mapping accuracy.

- The 200m wide terrestrial margins bordering the combined estuaries was highly modified and dominated by pasture (33%), horticulture (17%) and built-up areas (9%). However, 32% remained densely vegetated with a mix of native and exotic species including gorse.
- Large parts (~50-80%) of the estuary margins are hardened through the construction of seawalls or bunds to minimise erosion or prevent tidal inundation of surrounding land. Flap-gates also cut off many naturally inundated areas from regular tidal exchange. Such changes greatly restrict available habitat and prevent the natural migration of estuarine species, particularly salt marsh, in response to predicted sea level rise.

Overall, all four estuaries have suffered from extensive historical habitat modification, in particular the removal of salt marsh, reclamation of estuary areas, and the interruption of natural flow regimes. This has significantly reduced habitat diversity, has lowered the resilience of the estuaries to future change, and severely restricts the capacity of the estuaries to respond to changing conditions, in particular predicted sea level rise. Without changes in current management approaches, the likely outcome will be a progressive reduction of salt marsh habitat over time.

Despite these past changes, all four estuaries retain significant ecological value. Ferrer Creek is currently the only estuary expressing localised symptoms of nutrient enrichment. Ferrer Creek and Riwaka Estuary, are also relatively muddy. Without reductions in current nutrient and sediment loads, these issues are likely to persist. The generally low extent of mud-dominated sediment and eutrophication in Motueka River Estuary reflects the high rate of flushing and, in the Motueka Estuary, relatively low inputs from the small catchment.

RECOMMENDATIONS

Based on the 2019 results, the following recommendations are proposed for consideration by TDC:

Broad Scale Habitat Mapping

Undertake broad scale habitat mapping at 5-year intervals, to track changes in the dominant features within each estuary. Given the potential for rapid changes to nuisance macroalgae within Ferrer Creek, annually assess the extent and state of the established beds. Due to uncertainty regarding the previous historical mapping undertaken using 1947 and 1986 aerials, review and update habitat maps and undertake an assessment of the likely extent of the estuary and surrounding salt marsh in natural state conditions. Assess and map the extent and condition of adjacent coastal seagrass, as a baseline for monitoring long term change.

Sedimentation Rate Monitoring

Assessment of the change in depth of sediment overlying buried sediment 'plates' (typically concrete pavers) has become a routine method in many NZ estuaries for obtaining information on sediment accumulation in response to catchment disturbance. In light of the extent of mud-dominated sediment and eutrophication issues in Ferrer Creek Estuary, install sediment plates at four sites. Monitor annually for 5 years and then review.

Catchment Influences

Consider sediment source tracking methods (e.g. Compound Specific Stable Isotope – CSSI), as used elsewhere in the region, to identify the main sources of mud deposited in the Riwaka and Ferrer Creek estuaries to help focus management priorities. Maintain records on the location and scale of significant catchment disturbance or land use changes (e.g. forest harvesting, road development, urban subdivision) to assist in the interpretation of broad and fine scale monitoring results.

Enhancement and Restoration

There is significant potential for ecological enhancement and restoration of all four estuaries of the Motueka delta. It is recommended that TDC develop a strategy to identify and prioritise areas for ecological enhancement and protection, including consideration of specific restoration options, e.g. replanting salt marsh, improving tidal flushing, recontouring shorelines, and removing barriers to salt marsh expansion. This approach would ideally be part of a region-wide planning initiative targeted at community uptake.

1 INTRODUCTION

1.1 GENERAL BACKGROUND

Monitoring the ecological condition of estuarine habitats is critical to their management. Estuary monitoring is undertaken by most councils in New Zealand as part of their State of the Environment (SOE) programmes. The most widely-used monitoring framework is that outlined in New Zealand's National Estuary Monitoring Protocol (NEMP; Robertson et al. 2002). The NEMP is intended to provide resource managers with a scientifically defensible, cost-effective, easy to use, nationally-applied standard protocol with which they can assess and monitor the ecological status of estuaries in their region. The results provide a valuable basis for establishing a benchmark of estuarine health in order to better understand human influences, and against which future comparisons can be made. The NEMP approach involves two main types of survey:

- Broad-scale monitoring to map estuarine intertidal habitats. This type of monitoring is typically undertaken every 5 to 10 years.
- Fine-scale monitoring (at selected sites) of estuarine biota and sediment quality. This type of monitoring is typically conducted at intervals of 5 years after initially establishing a baseline.

Tasman District Council (TDC) has in place a long-term SOE monitoring programme for estuaries. The programme is designed to detect and understand changes in key estuaries over time and determine catchment influences, especially those due to the input of nutrients and muddy sediments. The TDC programme includes regular monitoring of five estuaries: Ruataniwha, Motupipi, Waimea, Moutere and Westhaven. Monitoring at each of these locations has been undertaken periodically for the last 10-20 years, see:

https://www.tasman.govt.nz/my-council/key-documents/more/environment-reserves-and-open-space/environmental-monitoring-reports/?path=/EDMS/Public/Other/Environment/EnvironmentalMonitoring/CoastalMonitoring/Estuaries.

In addition, there has been less frequent assessment of four estuaries located on the intertidal delta near the Motueka River mouth (Fig. 1). The current report describes the methods and results of a broad-scale monitoring survey of these four estuaries undertaken in May 2019, along with a synthesis of the results of surveys from earlier years. A focus of the report is understanding changes in estuary habitat compared to a previous broad-scale survey undertaken in 2003 (Robertson et al. 2003), and to estimates of historical salt marsh cover reported for 1947 and 1986 (Tuckey et al. 2004) based on a review of aerial photography.

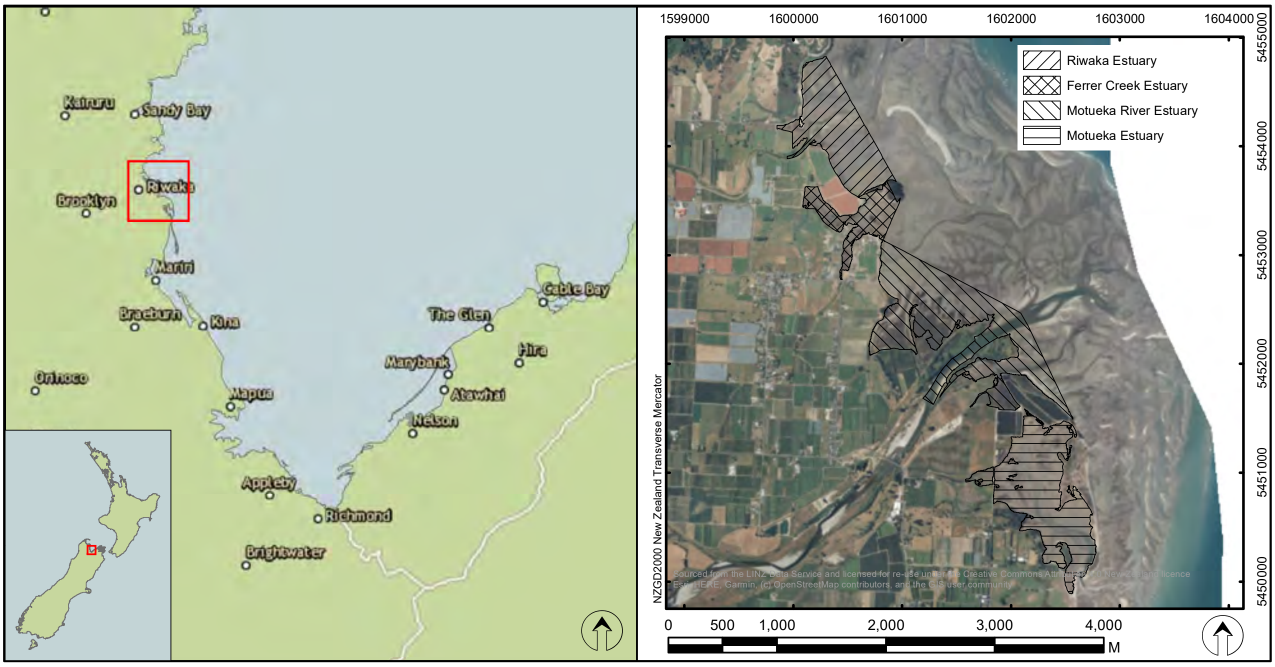


Fig. 1. Map showing the location of four estuaries of the Motueka delta.

As part of the analysis, the report includes a suite of broad-scale indicators that were not part of the original NEMP, but which have been widely adopted since the protocol was developed. These include use of improved methods for classifying macroalgae and substrate, and development of various metrics for assessing ecological condition.

1.2 BACKGROUND TO THE ESTUARIES OF THE MOTUEKA DELTA

Previous reports (e.g. Basher 2003; Robertson et al. 2003; Tuckey et al. 2004; Robertson & Stevens 2009, 2012; Stevens & Rayes 2018) all present background information on the estuaries of the Motueka delta, which is paraphrased (and expanded) below.

All of the estuaries are located high in the tidal zone and discharge across a broad (~2km wide) intertidal delta into Tasman Bay. The intertidal delta is unconfined and coastal in nature with wave energy having a significant influence on sediment dynamics.

Large freshwater flows, in particular from the Motueka River, contribute to an area of transitional lower salinity water that extends several kilometres offshore. While the entire area influenced by freshwater can be considered estuarine, specific estuary boundaries are set based on the presence of enclosing headlands (e.g. Hume et al. 2016). Thus, the defined estuary boundaries do not extend across the entire intertidal delta (Fig. 1).

Of the four estuaries being assessed in the current report, the Motueka River Estuary is the largest (108ha). It has a large catchment (Fig. 2, Table 1) and large freshwater inputs (mean annual low flow 63m^3/s). The estuary itself is short and narrow, and defined as a shallow short-residence tidal river mouth estuary (SSRTRE). It is primarily confined within flood banks throughout the lower reaches before it discharges to the coast. The large freshwater flows contribute to rapid flushing and short retention times of estuary waters, and flood scouring limits the accumulation of fine sediment within the estuary. Consequently, the estuary and coastal delta are cobble and gravel-dominated, and relatively dynamic with regard to sediment movement. The main river and estuary channel have no enclosed arms or embayments, but areas of salt marsh are present on either side in sheltered areas, often among old river flow channels.

The Riwaka Estuary to the north is a smaller (59ha) SSRTRE similar in configuration to the Motueka River Estuary in that it is also primarily confined within flood banks throughout the lower reaches before it discharges to the coast. However, due to lower flows (3.8m^3/s) and because it is largely fed from the Riwaka resurgence (James & McCallum 2015), it is less dynamic and has less flood scouring than the Motueka River Estuary. This contributes to increased deposition and retention of finer sediments within the estuary.

In contrast to these SSRTREs, the Ferrer Creek Estuary (24ha) and the Motueka Estuary (77ha) are both classified as shallow intertidal-dominated estuaries (SIDEs). They have clearly defined headlands and relatively narrow entrances that enclose a central basin with smaller side arms (most now drained and reclaimed). Remaining side arms are relatively sheltered and not subjected to significant wave energy or flood scouring, so have a much greater capacity to trap and retain fine sediment than the SSRTREs.

The intertidal areas of all four estuaries are largely unvegetated with most of the intertidal delta habitats comprising sand or cobble substrates. Salt marsh is present in the upper tidal reaches and comprises a mix of herbfield and rushland with smaller areas of macroalgae, reeds, and grasses. Background information on the ecological significance of different vegetation features is provided in Table 2.

The terrestrial margin surrounding the estuaries has been significantly modified over time. This has resulted in the direct loss of an estimated 300ha of salt marsh through drainage and reclamation for grazing, horticulture and roading.

The catchments surrounding the estuaries (Fig. 2, Table 1) are variable in size and land cover. The Motueka River Estuary catchment is very large (206,241ha) and comprises predominantly indigenous forest (39%) in the upper catchment, with exotic forest (24%) and pastoral land (16%) representing the majority of the land cover in the lower catchment. In comparison the catchment for the Motueka Estuary is just 111ha and is dominated by pasture (82%).

Table 1. Summary of catchment land cover (LCDB5 2018) for the four estuaries of the Motueka delta.

	Riwaka		Ferrer		Motueka River		Motueka	
LCDB Class and Name	Ha	%	Ha	%	Ha	%	Ha	%
1 Built-up Area (settlement)	23.0	0.3	60.8	4.2	143.2	0.1	8.0	7.2
2 Urban Parkland/Open Space	4.0	0.05			23.2	0.01		
5 Transport Infrastructure					99.3	0.05		
6 Surface Mine or Dump	1.1	0.01			15.6	0.01		
12 Landslide	2.9	0.03			116.2	0.1		
15 Alpine Grass/Herbfield					777.1	0.4		
16 Gravel or Rock	3.3	0.04			2198.8	1.1		
20 Lake or Pond					33.1	0.02		
21 River					295.1	0.1		
30 Short-rotation Cropland	8.9	0.1	48.3	3.3	131.2	0.1		
33 Orchard, Vineyard or Other Perennial Crop	271.8	3.2	552.0	37.7	1613.0	0.8	2.5	2.2
40 High Producing Exotic Grassland	711.9	8.3	288.7	19.7	30996.8	15.0	38.5	34.7
41 Low Producing Grassland	143.8	1.7	21.1	1.4	1585.8	0.8	52.6	47.4
43 Tall Tussock Grassland	45.0	0.5			10214.3	5.0		
46 Herbaceous Saline Vegetation	5.9	0.1	2.8	0.2	17.0	0.01	6.2	5.6
47 Flaxland					4.0	0.00		
50 Fernland	654.7	7.7	143.1	9.8	2067.7	1.0		
51 Gorse and/or Broom	642.9	7.5	49.5	3.4	3379.3	1.6		
52 Manuka and/or Kanuka	114.7	1.3	8.1	0.6	10061.3	4.9		
54 Broadleaved Indigenous Hardwoods	1051.6	12.3	82.3	5.6	3527.9	1.7		
55 Sub Alpine Shrubland	49.6	0.6			2358.3	1.1		
56 Mixed Exotic Shrubland	2.9	0.03	3.8	0.3	177.2	0.1		
64 Forest - Harvested	55.6	0.7	8.5	0.6	6809.1	3.3		
68 Deciduous Hardwoods	43.3	0.5	0.2	0.0	776.2	0.4		
69 Indigenous Forest	3239.4	37.9	103.8	7.1	79872.6	38.7		
71 Exotic Forest	1463.9	17.1	89.6	6.1	48948.0	23.7	3.2	2.9
Grand Total	8540	100	1463	100	206241	100	111.0	100

Table 2. Overview of the ecological significance of various vegetation types.

Terrestrial margin vegetation: 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 food source and habitat for a variety of species in waterway riparian zones, provides shade to help moderate stream temperature fluctuations, and improves estuary biodiversity.

Salt marsh: Salt marsh (vegetation able to tolerate saline conditions where terrestrial plants are unable to survive) is important in estuaries 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. Salt marsh generally has the densest cover in sheltered and more strongly freshwater-influenced upper estuary areas, and is relatively sparse in the lower (more exposed and saltwater dominated) parts of an estuary. The tidal limit of salt marsh growth for most species is restricted to above the height of mean high-water neap tide.

Seagrass: 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. Although tolerant of a wide range of conditions, seagrass is vulnerable to fine sediments in the water column (reducing light), sediment smothering (burial), excessive nutrients (primarily secondary impacts from macroalgal smothering), and sediment quality (particularly if there is a lack of oxygen and production of sulphides).

Opportunistic macroalgae: Opportunistic macroalgae are a primary symptom of estuary eutrophication (nutrient enrichment). They are highly effective at utilising excess nitrogen, enabling them to outcompete other seaweed species and, at nuisance levels, can form mats on the estuary surface that adversely impact underlying sediments and fauna, other algae, fish, birds, seagrass, and salt marsh. Macroalgae that becomes detached (e.g. *Ulva* spp.) can also accumulate and decay in subtidal areas and on shorelines causing oxygen depletion and nuisance odours and conditions. One species in NZ, *Gracilaria chilensis*, can become entrained in sediments (i.e. grow within the sediment matrix) and establish persistent growths that trap fine sediment and lead to surface smothering of habitat. Trapped sediments provide a source of nutrients that facilitate further algal growth, and lead to other changes in the sediment that become difficult to reverse.

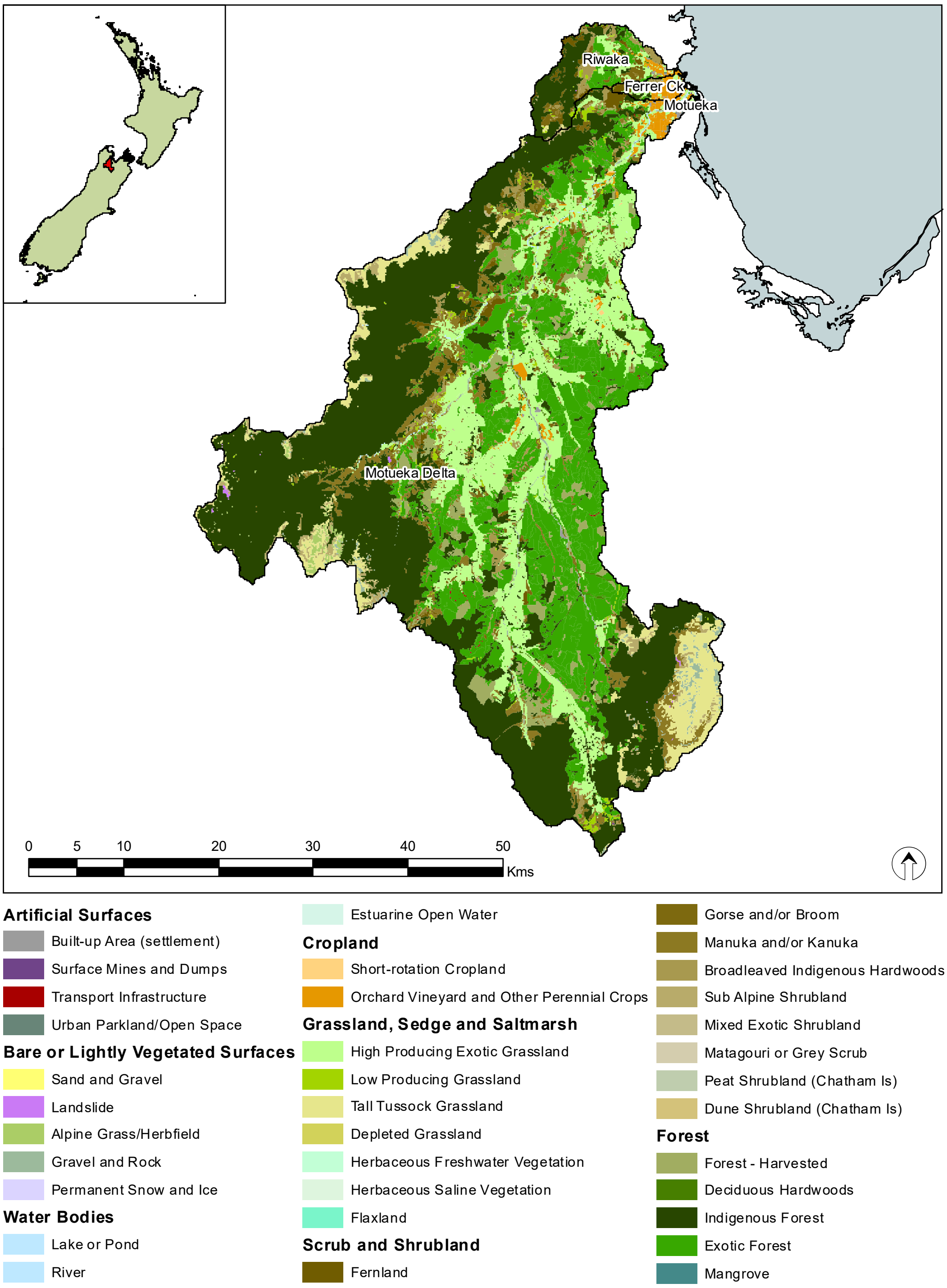


Fig. 2. Map of catchment land cover (LCDB5 2018) for the four estuaries on the Motueka delta.

Despite past modification of the estuaries and surrounding land, they are valued for their aesthetic appeal, rich biodiversity, shellfish, wastewater assimilation, duck shooting, whitebaiting, fishing, walking, and scientific interest. The wider delta habitat includes several small islands and spits, with some recognised as internationally important sites for local and migrant shorebirds.

Key pressures identified in an ecological vulnerability assessment (Robertson & Stevens 2012) were excessive subtidal muddiness, climate change, reclamation of high value habitat, and loss of natural terrestrial margin.

2 BROAD SCALE METHODS

2.1 OVERVIEW

Broad-scale surveys involve describing and mapping estuaries according to the dominant surface habitat features (substrate and vegetation) present. This procedure combines the use of aerial photography, detailed ground truthing, and digital mapping using Geographic Information System (GIS) technology. Once a baseline map has been constructed, changes in the position and/or size or type of dominant habitats can be monitored by repeating the mapping exercise. Broad-scale mapping is typically carried out during the period September to May when most plants are still visible and seasonal vegetation has not died back. Aerial photographs are ideally assessed at a scale of less than 1:5000, as at a broader scale it becomes difficult to accurately determine changes in habitats over time.

Broad scale mapping of the estuaries of the Motueka delta in 2019 used 1:3000 colour aerial photographs (~0.03m/pixel resolution) flown for LINZ in early 2019 and supplied by TDC. Ground truthing was undertaken by experienced scientists who walked the estuary in May 2019 to map the spatial extent of dominant vegetation and substrate. In the field these habitat features were drawn onto laminated aerial photographs. The broad scale features were subsequently digitised into ArcMap 10.6 shapefiles using a Wacom Cintiq21UX drawing tablet and combined with field notes and georeferenced photographs. From this information, habitat maps were produced showing the dominant estuary features (substrate, salt marsh, macroalgae and seagrass) and the vegetation and other features of the terrestrial margin.

Estuary boundaries for mapping purposes were based on the definition used in the NZ Estuary Trophic Index (ETI) (Robertson et al. 2016a) and are defined as the area between the estimated upper extent of saline intrusion (i.e. where ocean derived salts during average annual low flow are <0.5ppt) and seaward to a straight line between the outer headlands where the angle between the head of the estuary and the two outer headlands is <150^{o}. This is consistent with the New Zealand coastal hydrosystems boundaries (Hume et al. 2016) developed in support of NIWAs CLUEs estuary model.

2.2 HABITAT CLASSIFICATION AND MAPPING

Estuary vegetation was classified using an interpretation of the Atkinson (1985) system defined in the NEMP, whereby dominant estuarine plant species were used to define broad structural classes (e.g. rush, sedge, herb, grass, reed, tussock). Vegetation was coded using the two first letters of the genus and species, e.g. sea rush *Juncus kraussii*, was coded as Jukr. Plants were listed in order of dominance with subdominant species placed in parentheses, e.g. Jukr(Caed) indicates that sea rush was dominant over ice plant *(Carpobrotus edulis)*. A relative measure of vegetation height can be derived from its structural class (e.g. rushland is taller than herbfield). Terrestrial margin vegetation was classified using the Landcare Research LCDB5 numeric codes (see Table 1 and Appendix 1).

The NEMP approach to estuary substrate classification has recently been extended by Salt Ecology to record substrate beneath vegetation (salt marsh, seagrass and macroalgae) to provide a continuous substrate layer for the estuary. Furthermore, the NEMP substrate classifications themselves have been revised to provide a more meaningful classification of sediment based on mud content (Table 3).

Under the original NEMP classification, mud/sand mixtures can have a mud content ranging from 1-100% within the same class, and classes are separated only by sediment firmness (how much a person sinks), with increasing softness being a proxy measure of increasing muddiness. Not only is sinking variable between individuals (heavier people sink more readily than lighter people), but also in many cases the relationship between muddiness and sediment firmness does not hold true. Very muddy sediments may be firm to walk on, e.g. sun-baked muds or muds deposited over gravel beds. In other instances, soft sediments may have low mud contents, e.g. coarse muddy sands. Further, many of the NEMP fine sediment classes have ambiguous definitions making classification subjective, or are inconsistent with commonly accepted geological criteria (e.g. the Wentworth scale).

To address these issues, mud and sand classifications have been revised to provide additional resolution based on the estimated mud content of fine-grained substrates, with sediment firmness used as an independent descriptor (Table 3, Appendix 1). Lower-case abbreviations are used to designate sediment firmness (f=firm, s=soft, vs=very soft). Mobile substrate (m) is classified separately. Upper-case abbreviations are used to designate four fine unconsolidated substrate classes consistent with existing geological terminology (S=Sand, MS=Muddy Sand, SM=Sandy Mud, M=Mud). These are based on sediment mud content (Table 3) and reflect both biologically meaningful thresholds where key changes in sediment macrofaunal communities occur, and categories that can be subjectively assessed in the field by experienced scientists and validated by laboratory analyses.

In developing the revised classifications, care has been taken to ensure that key metrics such as the area of mud dominated habitat can be assessed using both the NEMP and the revised classifications so that comparisons with existing work can be made.

2.3 FINE SEDIMENT ASSESSMENT

2.3.1 Sediment Muddiness

The primary indicator used in the current broad scale report to assess sediment mud is the area (horizontal extent) of intertidal muddy sediment, with sediment mud content determined by laboratory analysis being a supporting indicator.

Table 3. Substrate classification codes used in the current report.

Consolidated substrate			Code
Bedrock		Rock field "solid bedrock"	RF
Coarse Unconsolidated Substrate (>2mm)			
Boulder/ Cobble/ Gravel	>256mm to 4.096m	Boulder field "bigger than your head"	BF
	64 to <256mm	Cobble field "hand to head sized"	CF
	2 to <64mm	Gravel field "smaller than palm of hand"	GF
	2 to <64mm	Shell "smaller than palm of hand"	Shel
Fine Unconsolidated Substrate (<2mm)			
Sand (S)	Low mud (0-10%)	Mobile sand	mS
		Firm shell/sand	fSS
		Firm sand	fS
		Soft sand	sS
Muddy Sand (MS)	Moderate mud (>10-25%)	Mobile muddy sand	mMS10
		Firm muddy shell/sand	fSS10
		Firm muddy sand	fMS10
		Soft muddy sand	sMS10
	High mud (>25-50%)	Mobile muddy sand	mMS25
		Firm muddy shell/sand	fMSS25
		Firm muddy sand	fMS25
		Soft muddy sand	sMS25
Sandy Mud (SM)	Very high mud (>50-90%)	Firm sandy mud	fSM
		Soft sandy mud	sSM
		Very soft sandy mud	vsSM
Mud (M)	Mud (>90%-100%)	Firm mud	fM90
		Soft muddy sand	sM90
		Very soft mud	vsM90
Zootic (living)			
		Cocklebed	CKLE
		Mussel reef	MUSS
		Oyster reef	OYST
		Sabellid field	TUBE
Artifical Substrate			
		Substrate (brg, bund, ramp, walk, wall, whf)	aS
		Boulder field	aBF
		Cobble field	aCF
		Gravel field	aGF
		Sand field	aSF

For the estuaries of the Motueka delta we derived estimates of the horizontal extent from the broad-scale mapping work described above. To validate the broad scale classifications, surface samples (0-20mm) were collected from nine representative areas and analysed for grain size (percent mud/sand/gravel). See Appendix 2 for sample site coordinates and field measurements, and Appendix 3 for laboratory methods and results.

2.3.2 Sediment Oxygenation

The apparent Redox Potential Discontinuity (aRPD) layer is a subjective measure of the enrichment state of sediments according to the depth of visible transition between oxygenated surface sediments (typically brown in colour) and deeper less oxygenated sediments (typically dark grey or black in colour). The aRPD depth provides an easily measured, time-integrated, and relatively stable measure of the sediment oxygenation conditions that infaunal communities are predominantly exposed to.

As part of broad scale mapping, sediment aRPD was assessed in representative areas by digging into the underlying sediment with a hand trowel to determine whether there were any significant areas where sediment oxygenation was depleted close to the surface. Sediments were considered to have poor oxygenation if the aRPD was consistently <5mm deep and showed clear signs of organic enrichment indicated by a distinct colour change to grey or black in the sediments. As significant sampling effort is required to map sub-surface conditions accurately, the broad scale approach is intended to be used as a preliminary screening tool to determine the need for additional sampling effort.

2.4 MACROALGAL ASSESSMENT

The NEMP provides no guidance on the assessment of macroalgae beyond recording its presence when it is a dominant feature. Because opportunistic macroalgae is the primary indicator of nutrient enrichment in SIDEs, the ETI (Robertson et al. 2016a,b) has adopted the United Kingdom Water Framework Directive (WFD-UKTAG 2014) Opportunistic Macroalgal Blooming Tool (OMBT) for macroalgal assessment. The OMBT, described in detail in Appendix 4, is a five-part multi-metric index that provides a comprehensive measure of the combined influence of macroalgal growth and distribution in an estuary. It produces an overall Ecological Quality Rating (EQR) ranging from 0 (major disturbance) to 1 (minimally disturbed) and rates estuarine condition in relation to macroalgal status within overall quality status threshold bands (bad, poor, good, moderate, high). The individual metrics that are used to calculate the EQR include:

- Percent cover of opportunistic macroalgae throughout intertidal soft sediment habitat in an estuary (the spatial extent and density of algal cover providing an early warning of potential eutrophication issues).
- Macroalgal biomass (providing a direct measure of macroalgal growth and enabling estimates of mean biomass to be made within areas affected by macroalgal growth, as well across the total estuary area).
- Extent of algal entrainment into the sediment matrix (highlighting where persistent macroalgal growths have established).

If an estuary supports <5% opportunistic macroalgal cover within the Available Intertidal Habitat (AIH), then the overall quality status is reported as 'high' with no further sampling required.

Using this approach in the estuaries of the Motueka delta, macroalgae patches were mapped to the nearest 10% using a 6-category rating scale as a guide to describe percentage cover (see Fig. 3). The focus was on opportunistic species associated with nutrient enrichment problems in New Zealand, namely *Gracilaria chilensis* and *Ulva* spp.

Within these percent cover categories, representative patches of comparable macroalgal growth were identified and the biomass and the depth of macroalgal entrainment were measured. Biomass was measured by collecting algae growing on the surface of the sediment from within a defined area (e.g. 25x25cm quadrat) and placing it in a sieve bag. The algal material was then rinsed to remove sediment. Any non-algal material including stones, shells and large invertebrate fauna (e.g. crabs, shellfish) were also removed. Remaining algae were then hand squeezed until water stopped running, and the wet weight was recorded to the nearest 10g using a 1kg Pesola light-line spring scale.

Macroalgae were defined as entrained when growing >30mm deep within sediments. When

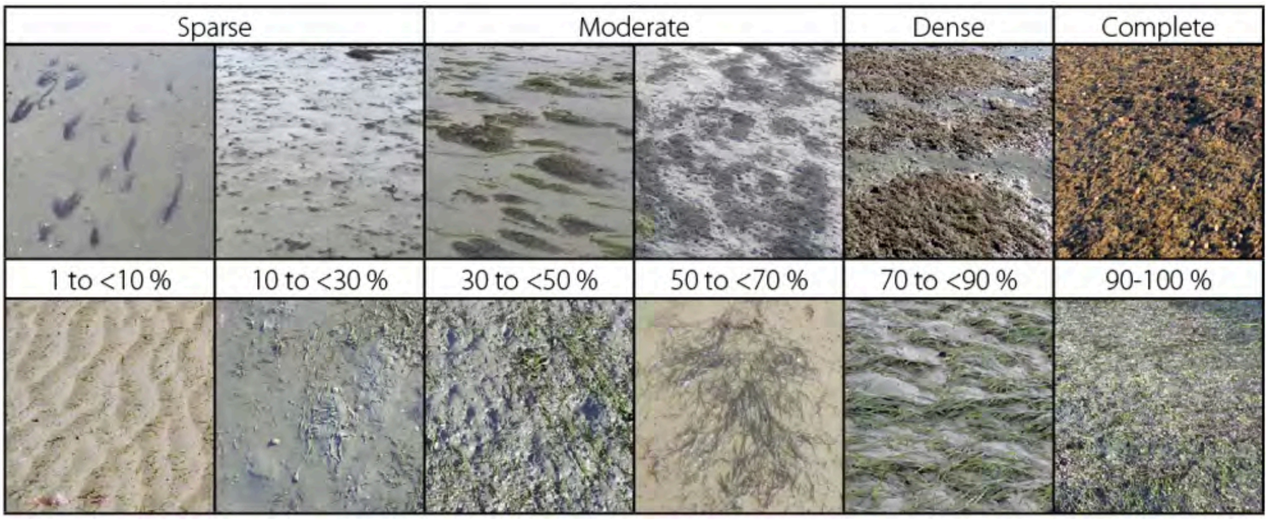


Fig. 3. Visual rating scale for percentage cover estimates. Macroalgae (top), seagrass (bottom). Modified from FGDC (2012).

sufficient representative patches had been measured to enable biomass to be reliably estimated, additional subjective biomass estimates were made following the OMBT method (WFD-UKTAG 2014).

2.5 SEAGRASS ASSESSMENT

The NEMP provides no guidance on the assessment of seagrass beyond recording its presence when it is a dominant feature. To improve on the NEMP method, the mean percent cover of discrete seagrass patches was visually assessed to the nearest 10% based on the 6-category percent cover scale in Fig. 3.

To assess temporal changes in estuary seagrass, 2019 data were compared to data from previous reports based on the extent of estuary with seagrass cover >50%. The 50% threshold was used as previous NEMP mapping had only recorded seagrass beds when present as a dominant feature (i.e. cover >50%), and it is difficult to clearly distinguish seagrass cover of <50% when assessing historical aerial photographs.

2.6 SALT MARSH ASSESSMENT

NEMP methods were used to map and categorise salt marsh (Appendix 1), with two measures used to assess salt marsh condition: i) intertidal extent (percent cover) and ii) current extent compared to estimated historical extent.

2.7 TERRESTRIAL MARGIN ASSESSMENT

Broad-scale NEMP methods were used to map the 200m terrestrial margin using the dominant land cover classification codes described in the Landcare Research Land Cover Data Base (LCDB5) detailed in Appendix 1.

2.8 DATA RECORDING, QA/QC AND ANALYSIS

Broad scale mapping is intended to provide a rapid overview of estuary condition based on the mapping of features visible on aerial photographs. The ability to correctly identify and map features is primarily determined by the resolution of available photos, the extent of ground truthing undertaken to validate features visible on photos, and the experience of those undertaking the mapping. In most instances features with readily defined edges such as rushland, rockfields, dense seagrass, etc. can be mapped at a scale of ~1:2000 to within 1-2m of their boundaries. The greatest scope for error occurs where boundaries are not readily visible on photographs, e.g. sparse seagrass beds, or where there is a transition between features that appear visually similar, e.g. sand, muddy sand, mud. Extensive mapping experience has shown that transitional boundaries can be mapped to within ±10m where they have been thoroughly ground truthed, but accuracy is unlikely to be better than ±20-50m for such features when relying on photos alone.

In 2019, field maps with ground truthing notes were scanned and imported into ArcMAP 10.6, and were used with georeferenced field photos for digitising habitat features. Following digitising, in-house scripting tools were used to check for duplicated or overlapping GIS polygons, validate typology (field codes) and calculate areas and percentages used in summary tables. Using these same tools, the 1947, 1986 and 2003 (Cawthron) GIS layers were similarly checked for any errors in basic geometry (e.g. overlapping polygons), and updated to fix any identified issues.

The 2003 assessment used the edge of the available aerial photographic coverage to define the seaward boundary of the mapping extent. Consequently, Riwaka Estuary was only partially mapped and a large portion of the seaward tidal flats were excluded. In 2003 the mapped extent was then used to define the percentage composition of key estuary features across all four estuaries. This approach does not accurately reflect the estuary extent, nor capture the different types and susceptibilities of the estuaries present. Further, it does not allow for the individual assessment of each estuary, and precludes the ability to characterise features and temporal change at a scale relevant to management. To address these limitations, the current assessment set boundaries for each estuary (see Section 2.1) consistent with the approach outlined in NZ ETI (Robertson et al. 2016a, Hume et al. 2016). To facilitate temporal comparisons, the 1947, 1986 and 2003 data were clipped to the updated boundaries and the underpinning GIS data reanalysed to produce revised summary statistics. Note that the 1947 and 1986 mapping layers provide estimates of salt marsh cover, but do not include seagrass or substrate features.

Further to the above, the 2003 substrate types were updated to reflect the revised classifications presented in Table 3. The original classification codes have been retained in the GIS attribute tables with any changes shown alongside. In addition, detailed metadata describing data sources and any changes made have been provided with each GIS layer and supplied to TDC.

During the field ground truthing, sediment grain size and macroalgal data were recorded in electronic templates custom-built using Fulcrum app software (www.fulcrumapp.com). Pre-specified constraints on data entry (e.g. with respect to data type, minimum or maximum values) ensured that the risk of erroneous data recording was minimised. Each sampling record created in Fulcrum generated a GPS position, which was exported to ArcMAP. Macroalgal OMBT scores were calculated using the WFD-UKTAG Excel template.

2.9 ASSESSMENT OF ESTUARY CONDITION AND TEMPORAL CHANGE

Broad-scale results are used primarily to assess estuary condition in response to common stressors such as fine sediment inputs, nutrient enrichment or habitat loss. In addition to the authors' interpretation of the data, results are assessed within the context of established or developing estuarine health metrics ('condition ratings'), drawing on approaches from NZ and overseas (Table 4). These metrics assign different indicators to one of four colour-coded 'health status' bands, as shown in Table 4. The condition ratings are primarily sourced from the NZ ETI (Robertson et al. 2016b). Additional supporting information on the ratings is provided in Appendix 5.

As an integrated measure of the combined presence of indicators which may result in adverse ecological outcomes, the occurrence of High Enrichment Conditions (HEC) was evaluated. HECs are defined as having sediments with elevated organic content (>1% TOC) and/or dense macroalgal cover (>50%), combined with an elevated mud content (≥25% mud) and low sediment oxygenation (aRPD <10mm). HECs are also referred to alternatively as 'Gross Eutrophic Zones' (GEZs) in the ETI (Zeldis et al. 2017).

In addition to the Table 4 indicators, the percent change from the first measured baseline is used to qualitatively describe broad changes in estuary condition over time. It is assumed that increases in high value habitat such as seagrass, salt marsh, and a densely vegetated terrestrial margin are desirable, and decreases are undesirable. The converse is true for the establishment of degraded conditions, e.g. spatial extent of sediment with elevated mud contents or HECs.

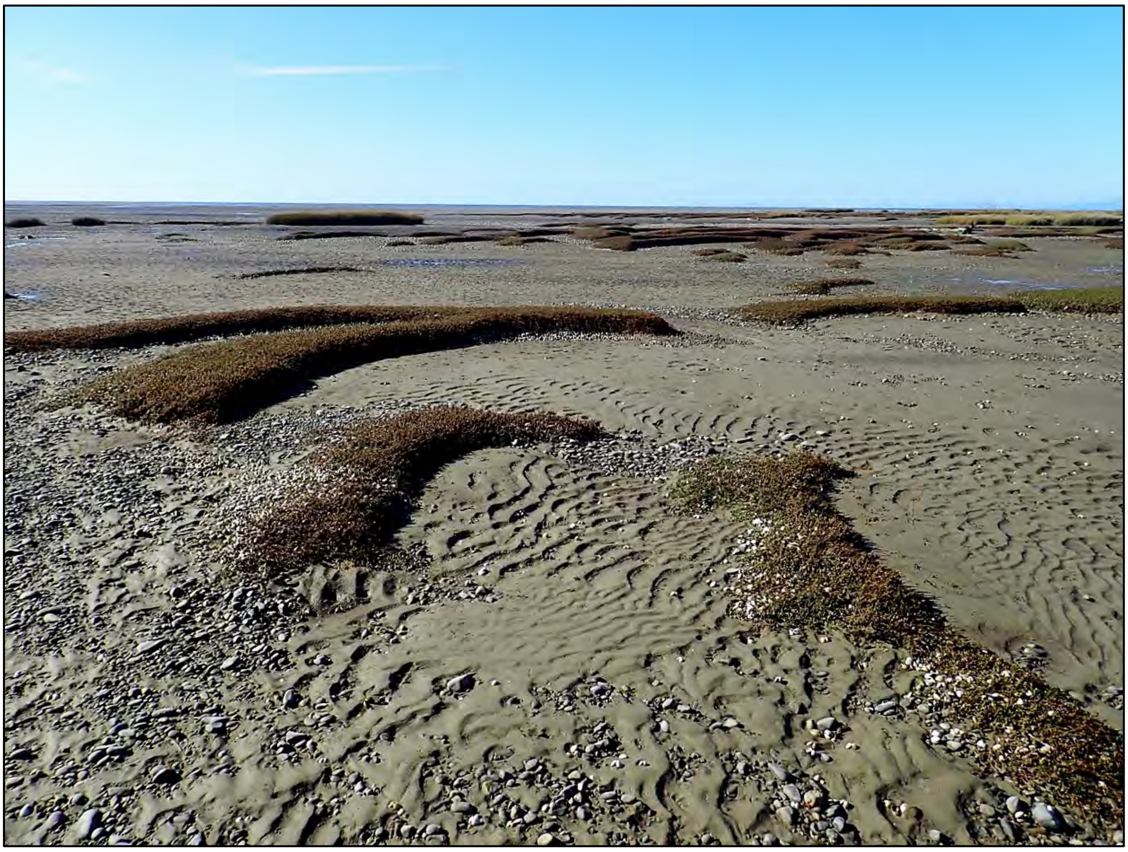
As many of the scoring categories in Table 4 are still provisional, they should be regarded only as a general guide to assist with interpretation of estuary health status. Accordingly, it is major spatio-temporal changes in the rating categories that are of most interest, rather than their subjective condition descriptors (e.g. 'poor' health status should be regarded more as a relative rather than absolute rating.

Table 4. Indicators used to assess results in the current report.

Indicator	Unit	Very Good	Good	Fair	Poor
Broad scale indicators					
Mud-dominated substrate[1]	% of intertidal area >50% mud	< 1	1-5	> 5-15	> 15
Macroalgae (OMBT)[1]	Ecological Quality Rating (EQR)	≥ 0.8 - 1.0	≥ 0.6 - < 0.8	≥ 0.4 - < 0.6	0.0 - < 0.4
Seagrass[2]	% decrease from baseline	< 5	≥ 5-10	≥ 10-20	≥ 20
Salt marsh extent (current)[2]	% of intertidal area	≥ 20	≥ 10-20	≥ 5-10	0-5
Historical salt marsh extent[2]	% of historical remaining	≥ 80-100	≥ 60-80	≥ 40-60	< 40
200m terrestrial margin[2]	% densely vegetated	≥ 80-100	≥ 50-80	≥ 25-50	< 25
High Enrichment Conditions[1]	ha	< 0.5ha	≥ 0.5-5ha	≥ 5-20ha	≥ 20ha
High Enrichment Conditions[1]	% of estuary	< 1%	≥ 1-5%	≥ 5-10%	≥ 10%
Sediment Quality					
Mud content[1]	%	< 5	5 to < 10	10 to < 25	≥ 25
aRPD depth[1]	mm	≥ 50	20 to < 50	10 to < 20	< 10

[1]*General indicator thresholds derived from a New Zealand Estuary Tropic Index, with adjustments for aRPD. See text and Appendix 5 for further explanation of the origin or derivation of the different metrics.*

[2] *Subjective indicator thresholds derived from previous broad scale mapping assessments.*



Herbfield among mobile sand and gravel on the delta of the Motueka River Estuary

3 RESULTS AND DISCUSSION

The 2019 broad scale results are summarised in the following sections, first as a general high-level overview, and then in more detail for each of the four estuaries. The supporting GIS files (supplied as a separate electronic output) provide a comprehensive data set designed for easy interrogation and to address specific monitoring and management questions.

3.1 COMBINED OVERVIEW

Table 5 and 6 and Figs 4, 5 and 6 summarise the key features of the four estuaries of the Motueka delta in May 2019. Each of the estuaries were intertidally dominated (87-96%) and between 24ha and 108ha in size. Salt marsh extent was variable, being lowest in the Riwaka (9.7%) and highest in the Motueka River (36%). Seagrass was sparse in the Riwaka (1.3%) and absent from the other estuaries, although large beds were present on the intertidal flats seaward of Riwaka Estuary. Mud-dominated sediment (>50% mud) ranged from 0% in the Motueka to 24% of the intertidal area in Ferrer Creek. Ferrer Creek also had the only beds of dense macroalgae (0.6ha), which were classified as HECs, as well as a relatively small area (8.4%) of densely-vegetated 200m terrestrial margin cover. The 200m margin cover in the other estuaries was relatively high (34-36%).

Intertidal substrates overall were dominated by sandy sediments (202ha, 83%). These were located predominantly within the lower tidal range of the estuaries near the open coast (Fig. 4). Sandy sediments were generally firm, with muddy sands (>25-50% mud) the dominant substrate class (39%). Mud-dominated sediments, located primarily in southern parts of the Riwaka Estuary and upper reaches of Ferrer Creek, were relatively uncommon (7%). Boulder, cobble and gravel substrates comprised 24.2ha (9.9%) and were most common near the lower reaches of the Motueka River, scattered within the tidally-flushed sand flats. Artificial substrate (0.2%) was a relatively minor feature and comprised steep-faced rock primarily used to stabilise and protect residential properties and roads. Zootic features, e.g. oyster reef, sabellid field, mussel reef were not recorded as a dominant cover in the estuaries.

Table 6. Summary of combined substrate composition of the four estuaries of the Motueka delta, May 2019.

Class	Dominant Substrate	Ha	%
Artificial	Artificial substrate	0.5	0.2
Boulder/Cobble/Gravel	Boulder field	0.1	0.1
	Cobble field	12.7	5.2
	Gravel field	11.4	4.7
Sand (0-10% mud)	Mobile sand	43.7	17.9
	Firm sand	16.6	6.8
Muddy Sand (>10-25% mud)	Mobile muddy sand	21.5	8.8
	Firm muddy sand	23.7	9.7
	Soft muddy sand	1.0	0.4
Muddy Sand (>25-50% mud)	Firm muddy sand	92.7	37.9
	Soft muddy sand	3.4	1.4
Sandy Mud (>50-90% mud)	Firm sandy mud	0.3	0.1
	Soft sandy mud	6.5	2.7
	Very soft sandy mud	10.4	4.3
Total		**244.4**	**100**

Table 5. Summary of key habitat features of the four estuaries of the Motueka delta, May 2019.

Estuary	Riwaka		Ferrer Creek		Motueka River		Motueka	
a. Area Summary	ha	%	ha	%	ha	%	ha	%
Intertidal area	54.9	93.8	23.2	95.7	94.0	87.2	72.4	93.7
Subtidal area	3.6	6.2	1.0	4.3	13.8	12.8	4.9	6.3
Total estuary area	58.5	100	24.2	100	107.8	100	77.3	100
b. Key intertidal features	ha	%*	ha	%*	ha	%*	ha	%*
Salt marsh	5.7	9.7	6.4	27.8	33.6	35.7	23.3	32.2
Seagrass (>50% cover)	0.7	1.3	0.0	0.0	0	0	0	0
Macroalgal beds (>50% cover)	0	0	0.6	2.5	0	0	0	0
Mud-dominated sediment (>50% mud)	9.9	18.1	5.6	24.2	1.7	1.8	0	0
*% of intertidal area								
c. 200m Densely vegetated margin	16.4	36.2	3.2	8.4	38.2	36.3	26.8	33.5

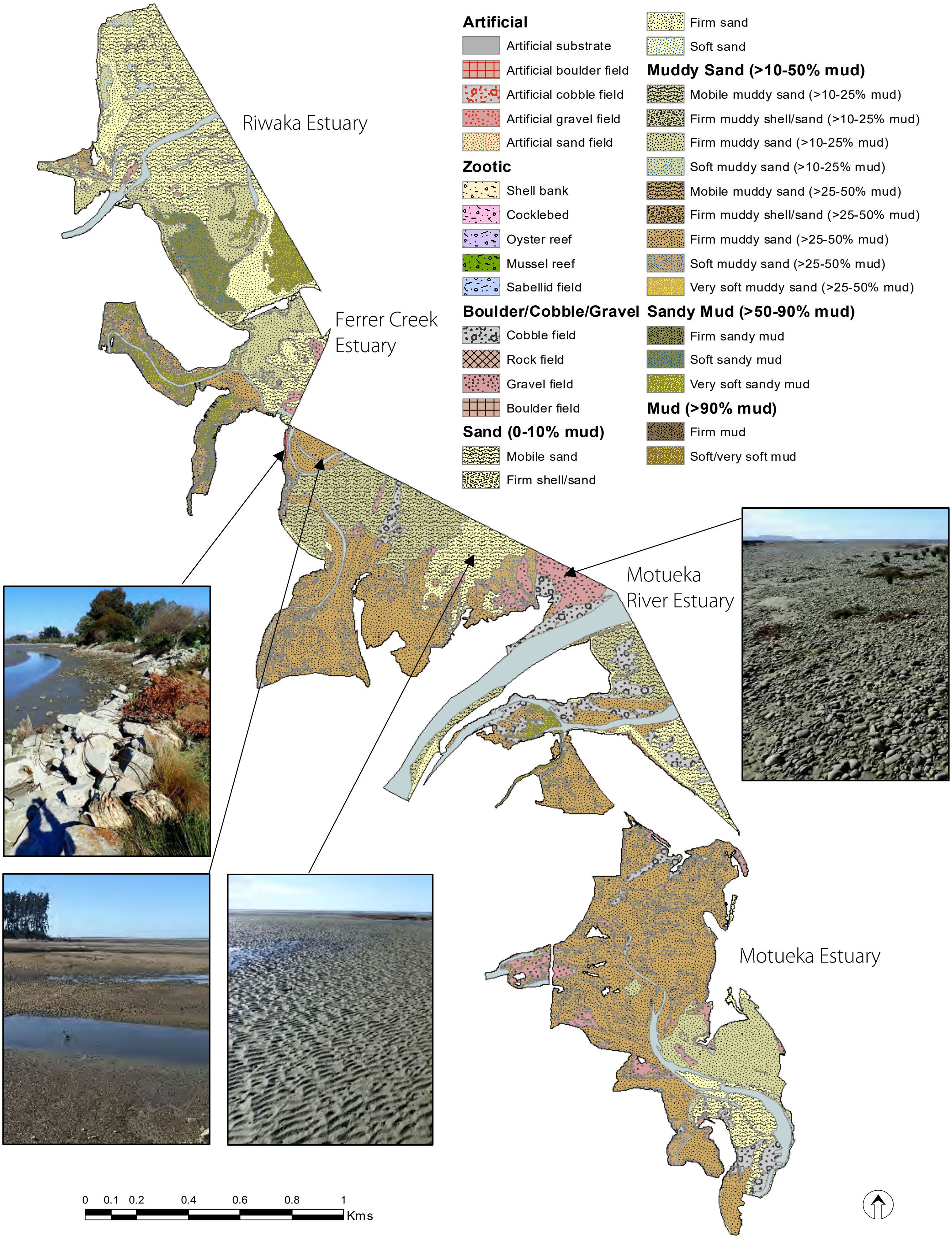


Fig. 4. Map of dominant intertidal substrate types for estuaries of the Motueka delta, May 2019.

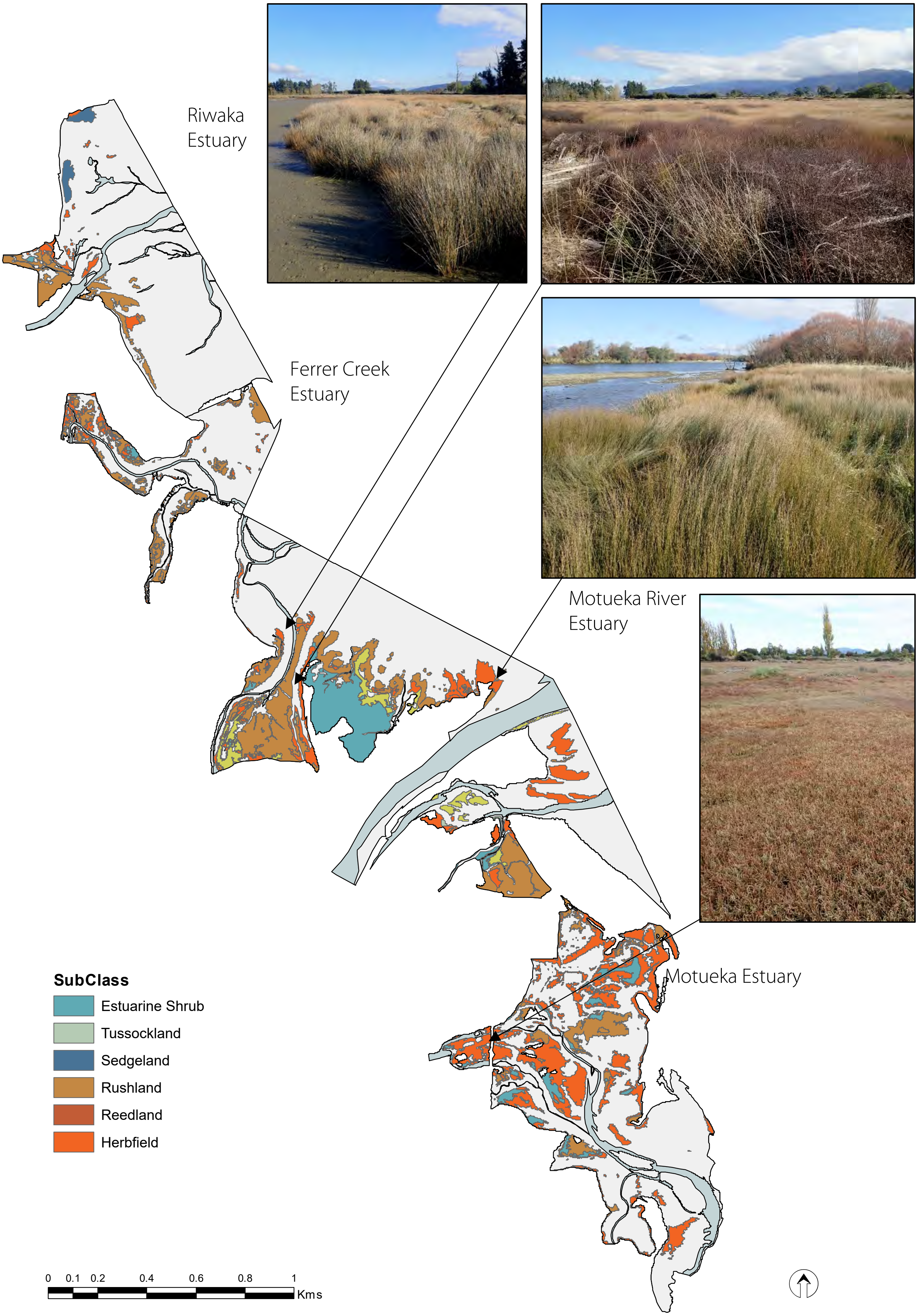


Fig. 5. Map of salt marsh extent for estuaries of the Motueka delta, May 2019.

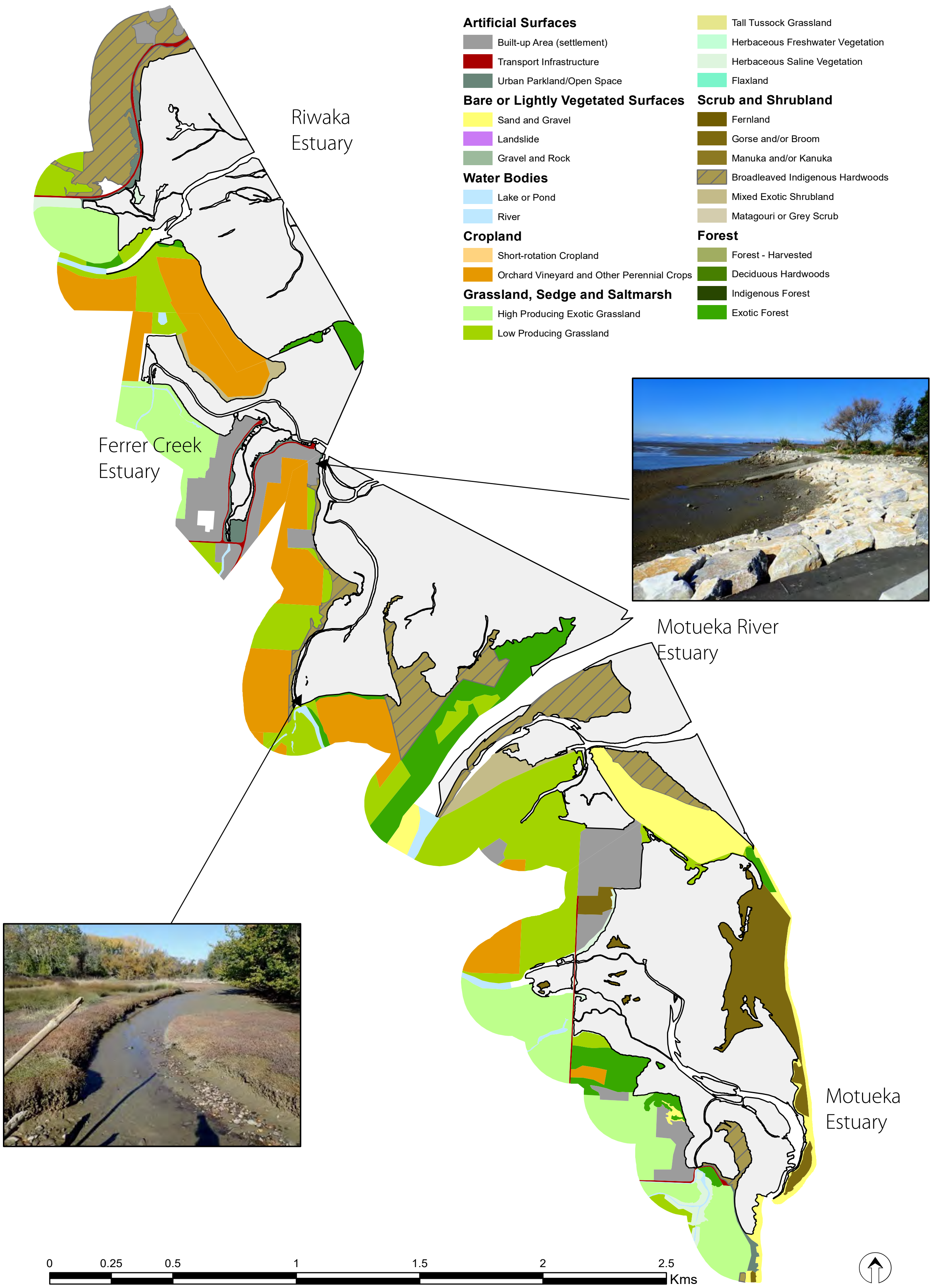


Fig. 6. Map of 200m terrestrial margin land cover for estuaries of the Motueka delta, May 2019.

3.2 RIWAKA ESTUARY

3.2.1 Intertidal substrate

Table 7 and Fig. 7 show intertidal substrate was relatively diverse. It was dominated by mobile and firm sands with a mud content less than 10% (34.3ha, 63%), and firm muddy sands with a mud content of 10-25% (7.7ha, 14%). The dominance of sand likely reflects exposure of the tidal flats to regular flushing by waves and tidal currents, the limited presence of enclosed arms or embayments to trap muds, and the river being sourced from a large karst spring (resurgence) (James & McCallum 2015).

Mud-dominated habitat (>50% mud content) was also present and comprised 9.9ha (18.1%) of which 9.6ha was classified as soft or very soft, and 0.3ha as firm. The soft/very soft muds were primarily located within a relatively sheltered deposition zone adjacent to Outer Island in the south, and 200-300m west (landward) of a raised coastal shellbank.

Artificial substrate, comprising steep-faced rock seawalls, covered a relatively small area of the estuary 0.2ha (0.4%) but extended along much of the margin including the Riwaka-Kaiteriteri Road and adjacent to horticultural and pastoral land historically reclaimed from the estuary. Other hard substrates (e.g. gravel fields) comprised only 0.3ha (0.5%) and were present on the delta of the Riwaka River.

Table 7. Summary of dominant intertidal substrate, Riwaka Estuary, May 2019.

Class	Dominant Substrate	2019 Ha	2019 %
Artificial	Artificial substrate	0.2	0.4
Gravel	Gravel field	0.3	0.5
Sand (0-10% mud)	Mobile sand	25.0	45.6
	Firm sand	9.3	17.0
Muddy Sand (>10-25% mud)	Mobile muddy sand	0.3	0.6
	Firm muddy sand	7.7	14.1
	Soft muddy sand	1.0	1.7
Muddy Sand (>25-50% mud)	Firm muddy sand	0.4	0.8
	Soft muddy sand	0.6	1.1
Sandy Mud (>50-90% mud)	Firm sandy mud	0.3	0.6
	Soft sandy mud	5.6	10.2
	Very soft sandy mud	4.0	7.3
Total		**54.9**	**100**

3.2.2 Opportunistic Macroalgae

No significant macroalgal growth was observed on the intertidal flats, and only a sparse 1-5% cover of *Ulva* spp. among seagrass beds (see Section 3.2.4). This equates to a 'very good' rating according to the categories presented in Table 4.

Riwaka Estuary looking southeast toward Ferrer Creek. Photo credit: Getty images.

3.2.3 High Enrichment Conditions (HECs)

No significant HEC areas were observed within Riwaka Estuary in 2019. This equates to a 'very good' rating according to the categories in Table 4.

3.2.4 Seagrass

Fig. 7 and Table 8 show that 0.74ha of intertidal seagrass beds with a moderate (50%) cover were present in 2019 (Table 8). These were located low in the tidal range in sandy sediments and were part of extensive beds that extended further seaward than the estuary boundary defined for the present study. Seagrass appears unable to survive high on the shore and within the upper part of the estuary, most likely due to conditions being too dry and/or hot over the summer, but appears healthy and was growing in moderate to dense (>50% cover) beds in the broader coastal area. These beds were not included in past mapping coverage, but are evident on aerial photos since 2001, indicating they have been relatively stable over time. However, there have been large changes in coastal sediment patterns with mobile spits and sand accumulation influencing the specific location of beds. Mapping the coastal seagrass would

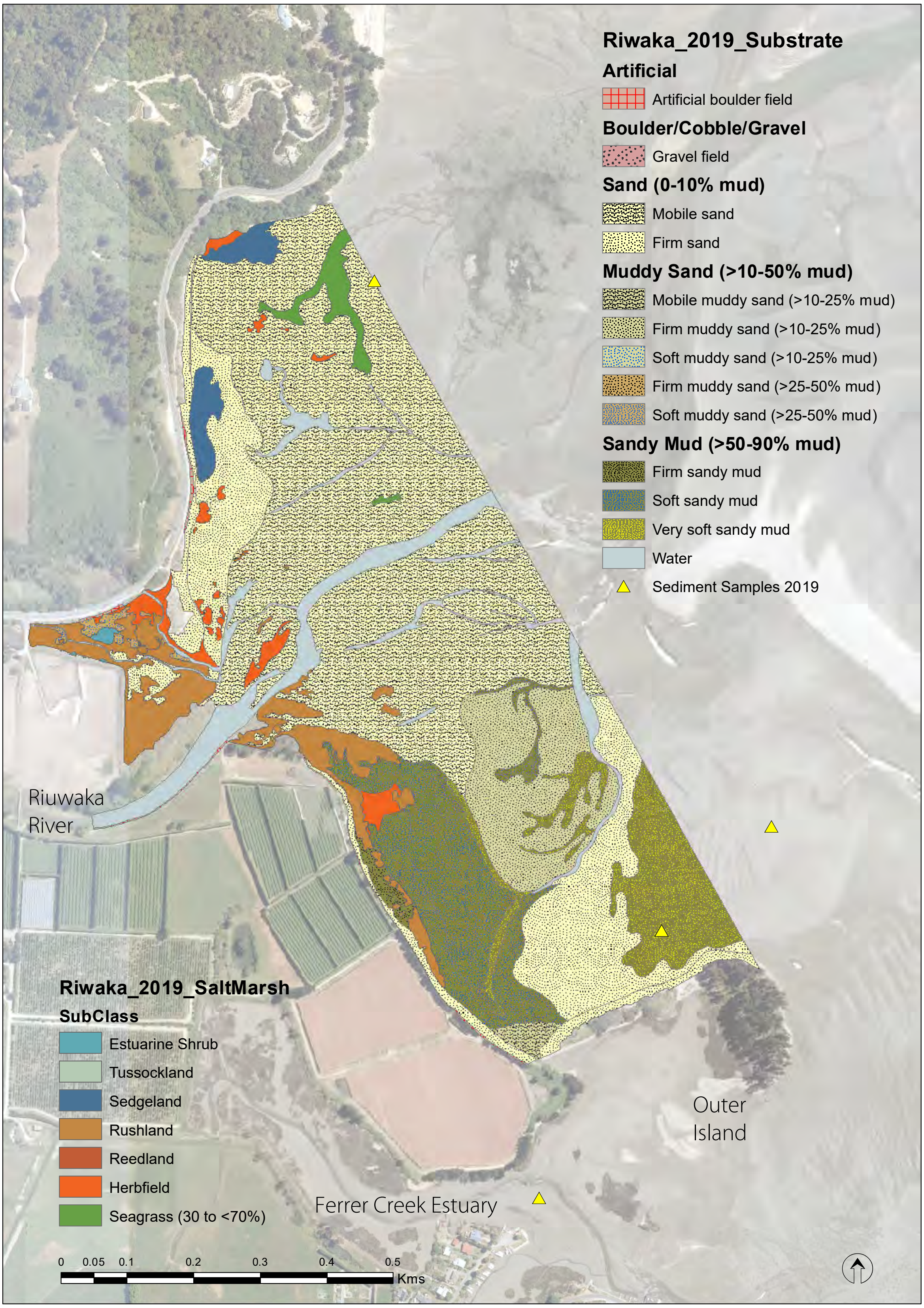


Fig. 7. Map of dominant intertidal substrate types, seagrass and salt marsh extent, and location of sediment grain size samples, Riwaka Estuary, May 2019.

determine the extent of existing beds and provide a valuable baseline against which future change can be assessed. Temporal changes cannot be assessed as seagrass was not mapped in the 1947 and 1986 desktop assessments (Tuckey et al. 2004), and the 2003 survey (Robertson et al. 2003) excluded most of Riwaka Estuary from its coverage.

Table 8. Summary of seagrass percent cover by area, Riwaka Estuary, May 2019

Seagrass Class	% Cover	Ha
>30-70% Moderate	50	0.74
Total		**0.74**

3.2.5 Salt marsh

Table 9 and Fig. 7 summarise the 2019 salt marsh mapping results. Salt marsh covered 5.7ha (10.3%) of the intertidal area with most located on the western margins on either side of the Riuwaka River and to the northwest adjacent to the Riwaka-Kaiteriteri Road. The dominant cover was rushland (62.5%), predominantly found in the upper intertidal reaches in the central-west and north of the estuary, and herbfield (19.2%) and sedgeland (17.0%) which was most extensive north of Riuwaka River. Estuarine shrub was relatively scarce (1.3%) and confined to the west of the estuary.

Searush in the northwest of Riwaka Estuary

Jointed wire rush in Riwaka Estuary

Table 9. Summary of dominant salt marsh cover, Riwaka Estuary, May 2019

Class, dominant and subdominant species	Ha	%
Estuarine Shrub	0.1	1.3
Plagianthus divaricatus (Salt marsh ribbonwood)	0.01	
Apodasmia similis (Jointed wirerush)	0.1	
Sedgeland	1.0	17.0
Schoenoplectus pungens (Three square)	1.0	
Rushland	3.5	62.5
Apodasmia similis (Jointed wirerush)	0.03	
Juncus kraussii (Searush)		
Sarcocornia quinqueflora (Glasswort)	0.4	
Juncus kraussii (Searush)	0.2	
Apodasmia similis (Jointed wirerush)	0.01	
Selliera radicans (Remuremu)	1.6	
Samolus repens (Primrose)		
Sarcocornia quinqueflora (Glasswort)	1.3	
Selliera radicans (Remuremu)	0.1	
Herbfield	1.1	19.2
Samolus repens (Primrose)	0.1	
Juncus kraussii (Searush)		
Apodasmia similis (Jointed wirerush)	0.01	
Sarcocornia quinqueflora (Glasswort)		
Samolus repens (Primrose)	0.1	
Juncus kraussii (Searush)	0.6	
Selliera radicans (Remuremu)		
Samolus repens (Primrose)		
Sarcocornia quinqueflora (Glasswort)	0.2	
Grand Total	5.7	100

Rushland was dominated by searush (*Juncus kraussii*) with smaller areas of jointed wirerush (*Apodasmia similis*) on the upper tidal fringe. Sedgeland comprised three square (*Schoenoplectus pungens*), while salt marsh ribbonwood (*Plagianthus divaricatus*) was the dominant estuarine shrub. On the exposed tidal flats within sand and gravel substrates, low growing salt and desiccation-tolerant herbfield species dominated, primarily glasswort (*Sarcocornia quinqueflora*), with smaller areas of primrose (*Samolus repens*) and remuremu (*Selliera radicans*). Herbfield species were uncommon in mud-dominated substrate.

Temporal salt marsh changes cannot be assessed as salt marsh was not mapped in 1947, appeared to be only partially mapped in 1986, and the 2003 survey (Robertson et al. 2003) excluded most of Riwaka Estuary from its coverage. However, 1947 aerial photographs show a sandspit north of the Riuwaka River that once supported a substantial area of salt marsh. By 1986 the sandspit and associated salt marsh were no longer present, most likely eroded by the Riuwaka River mouth moving northwards. While these natural losses have been important, the majority of historical salt marsh losses have been the direct result of reclamation and drainage including the construction and modification of Riwaka-Kaiteriteri Road, and land development from horticulture, pastoral farming and residential subdivision. There have also be localised losses as a consequence of damage from recreational vehicles.

Mixed salt marsh in front of dense margin

3.2.6 Terrestrial margin

The results of the 200m terrestrial margin mapping are presented in Table 10 and Fig. 8. The majority of the margin has been highly modified through conversion to pasture (30.9%) and horticulture (23.3%), with smaller areas comprising built-up areas (settlements), urban parkland and roading (7.5%).

Table 10. Summary of 200m terrestrial margin land cover, Riwaka Estuary, May 2019

LCDB Class Number and Name		%
1	Built-up Area (settlement)	2.5
2	Urban Parkland/Open Space	2.7
5	Transport Infrastructure	2.3
21	River	1.0
33	Orchard Vineyard & Other Perennial Crops	23.3
40	High Producing Exotic Grassland	13.9
41	Low Producing Grassland	17.0
44	Depleted Grassland	1.1
46	Herbaceous Saline Vegetation	2.1
54	Broadleaved Indigenous Hardwoods	32.6
56	Mixed Exotic Shrubland	0.3
71	Exotic Forest	1.2
Total		100
Total dense vegetated 200m margin (LCDB classes 45-71)		36.2

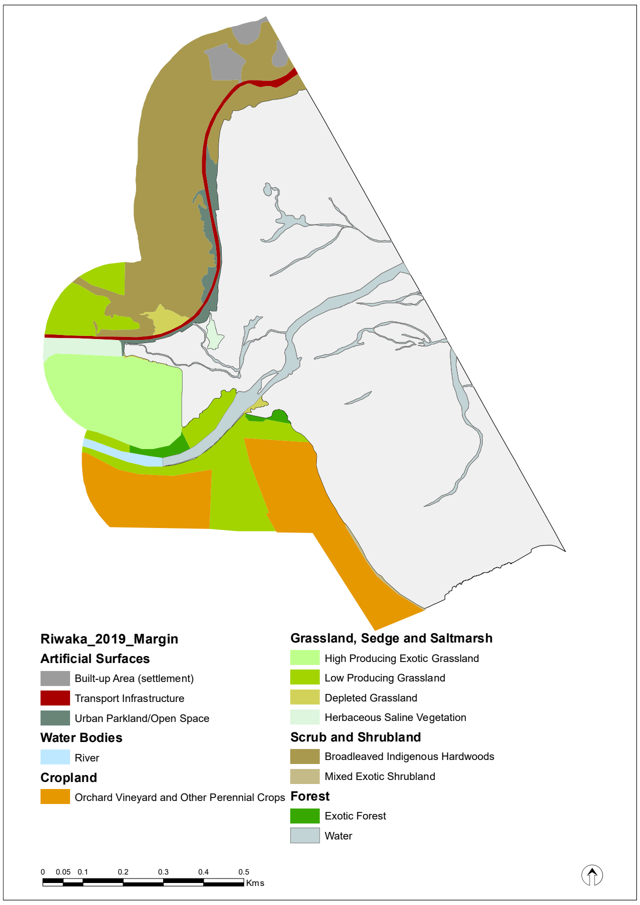


Fig. 8. Map of 200m terrestrial margin land cover, Riwaka Estuary, May 2019.

A large section of the northern margin remains densely vegetated (32.6%), dominated by broadleaved indigenous hardwoods.

The construction of seawalls, bunds and flap-gates has disrupted the natural connectivity between the land and the estuary and will prevent the migration of estuarine species in response to predicted sea level rise. This may be one reason why no whitebait spawning has been recorded in the Riuawaka River. Without changes in management approaches, the presence of physical barriers will likely result in a progressive reduction of salt marsh habitat over time.

3.2.7 Summary of key indicators and ratings

Table 11 presents a summary of the values and ratings applied to key indicators in Riwaka Estuary. Overall, despite significant historical losses of salt marsh and modification of the estuary margin, the estuary retains valuable and reasonably intact. Nutrient enrichment and associated growths of nuisance macroalgae are not currently causing any problems. The extent of mud-dominated habitat is the most important current issue for management.

Recent sediment may be related to inputs following Cyclone Gita with Riwaka receiving a 146.9mm rainfall event on 20 February 2018, flooding many rivers and streams, and delivering sediment and debris to the coastal environment. However, previous mapping by Robertson et al. (2003), while only including part of the estuary (meaning temporal changes cannot be easily assessed), indicated that a similar area was likely mud-dominated in 2003.

Table 6. Summary of key indicator ratings, Riwaka Estuary, May 2019.

Broad scale indicators	Unit	Value	2019 Rating	Change 2003-2019	
Mud-dominated substrate	% of intertidal area >50% mud	24.2%	Poor	3.4ha	↓ 38%* (improving)
Macroalgae (OMBT)	Ecological Quality Rating (EQR)	0.6	Good	0.4	↓ 40% (worsening)
Salt marsh extent (current)	% of intertidal area	27.8%	Very Good	0.3ha	↑ 6%* (improving)
Historical salt marsh extent	% of historical remaining	<30%	Poor	-	-
200m terrestrial margin	% densely vegetated	8.4%	Poor	-	-
High Enrichment Conditions	ha	0.6ha	Good	0.6ha	↑ (worsening)
High Enrichment Conditions	% of estuary	2.5%	Good	2.5%	↑ (worsening)

*Primarily reflects differences in mapping coverage or classification rather than meaningful change

3.3 FERRER CREEK

3.3.1 Intertidal substrate

Table 12 and Fig. 9 show intertidal substrate was dominated by sandy sediments (16.7ha, 71.6%) located predominantly within the lower intertidal flats. Sandy sediments were mostly firm, with a mud content less than 25%.

Mud-dominated habitat (sediment with >50% mud content) comprised 5.6ha (24.2%) of the intertidal area and was classed as soft or very soft. Mud-dominated sediment was concentrated within the Ferrer Creek and Little Sydney Creek arms, extending to their confluence in the lower estuary.

Hard substrates (e.g. cobble and gravel) comprised 0.8ha (3.8%) and were dominated by gravel fields which extended seaward from the lower reaches of Ferrer Creek onto the coastal flats. Artificial substrate (0.1ha, 0.4%) comprised predominantly steep-faced rock and earth margins reclaimed for transport infrastructure (e.g. road, boat ramp, carpark) and as seawalls to protect residential properties from erosion.

Table 12. Summary of dominant intertidal substrate, Ferrer Creek, May 2019.

		2019	
Class	Dominant Substrate	Ha	%
Artificial	Artificial substrate	0.1	0.4
Cobble/	Cobble field	0.03	0.1
Gravel	Gravel field	0.8	3.7
Sand	Mobile sand	3.7	15.9
(0-10% mud)	Firm sand	1.1	4.7
Muddy Sand	Mobile muddy sand	0.2	0.7
(>10-25% mud)	Firm muddy sand	5.4	23.3
Muddy Sand (>25-50% mud)	Firm muddy sand	6.3	27.0
Sandy Mud	Soft sandy mud	0.8	3.6
(>50-90% mud)	Very soft sandy mud	4.8	20.6
Total		**23.2**	**100**

3.3.2 Opportunistic macroalgae

Table 13 and Fig. 10 summarise macroalgal condition within Ferrer Creek Estuary, with further detail on the location of mapped macroalgal patches and measured algal densities presented in Appendix 4.

There were no growths of opportunistic macroalgae on the tidal flats of the lower estuary or in the Little Sydney Creek arm. The only area where macroalgae were present was within the southern arm of Ferrer Creek where there was 0.6ha of high density (80-90% cover) of the red seaweed *Gracilaria chilensis*. This was growing within the sediments (entrained >3cm) in soft and poorly oxygenated mud-dominated substrate. In these areas *Gracilaria* had a mean biomass of >2059g/m^2, above the threshold of ~1000g/m^2 where it is likely to cause prolonged adverse ecological effects to sediment macrofauna (see Appendix 4).

The combined presence of soft, poorly oxygenated muds and dense macroalgae is likely related, with macroalgae effective at trapping and helping to stablise muds and, in turn, the increased deposition and retention of sediment and sediment-bound nutrients fuelling macroalgal growth in these areas. This situation is likely exacerbated by restricted tidal flushing in the upper estuary.

The OMBT EQR for the estuary was 0.6, which is rated as 'good' based on the criteria in Table 4, but on the verge of the 'fair' threshold. The high degree of macroalgal entrainment (which indicates growths are likely to be persistent), and the high biomass present, indicate localised nuisance conditions in this arm of the estuary.

No macroalgae beds were reported within Ferrer Creek Estuary in 2003 suggesting the macroalgal expansion has occurred since that time.

3.3.3 High Enrichment Conditions (HECs)

The area of Ferrer Creek Estuary where HECs have established was relatively small (0.58ha, 2.4%) and mirrored that of high biomass macroalgal growths (Fig. 10) which were in sulphide-rich sediments with low oxygenation (aRPD depth close to the surface), and high organic contents. While these localised areas are highly enriched with poor sediment quality, the estuary overall was rated as 'good' for this indicator using the criteria in Table 4.

Because persistent areas of HECs should not be present in well flushed estuaries like Ferrer Creek, the establishment of such conditions since the 2003 baseline survey is of concern.

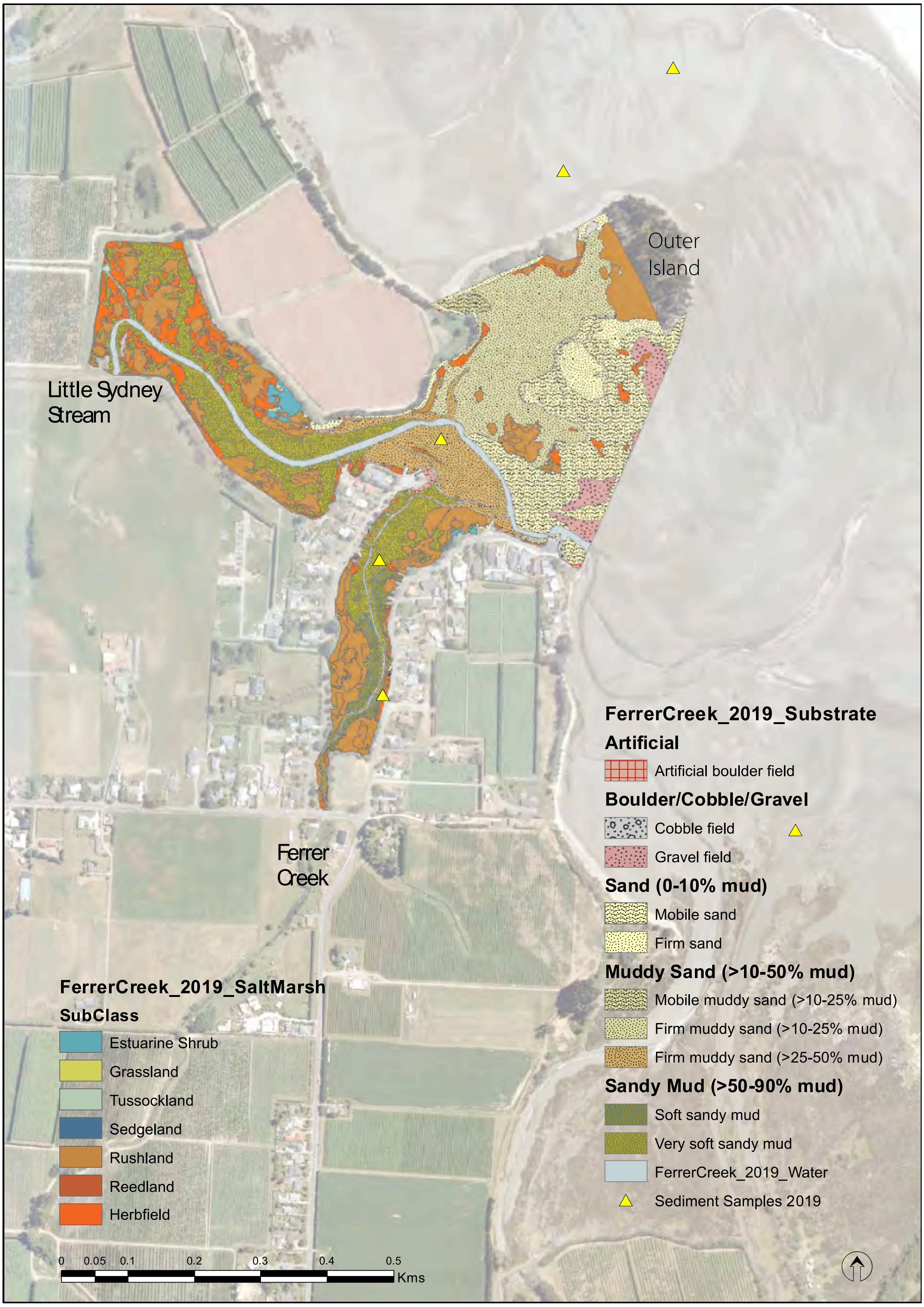


Fig. 9. Map of dominant intertidal substrate types, salt marsh extent, and location of sediment grain size samples, Ferrer Creek, May 2019.

Table 7. Summary of OMBT input metrics and calculation of overall macroalgal ecological quality rating, Ferrer Creek, May 2019.

Metric	Face Value	Final Equidistant Score (FEDS)	Quality Status
AIH - Available Intertidal Habitat (ha)	24.2		
Percentage cover of AIH (%) = (Total % Cover / AIH) x 100 where Total % cover = Sum of {(patch size)/100} x average % cover for patch	2.1	0.916	High
Biomass per AIH (g.m-2) = Total Biomass/AIH where Total biomass = Sum of (patch size x average patch biomass)	50	0.901	High
Biomass of Affected Area (g.m-2) = Total biomass / AA where Total biomass = Sum of (>5% cover patch size x average patch biomass)	2059	0.294	Poor
Presence of Entrained Algae (%) = (No. quadrats or area (ha) with entrained algae / total no. of quadrats or area (ha)) x 100	100	0	Bad
Affected Area (*use the lowest of the following two metrics*)		0.904	High
Affected Area, AA (ha) = Sum of all patch sizes (macroalgal cover >5%)	*0.6*	*0.988*	*High*
Size of AA in relation to AIH (%) = (AA / AIH) x 100	*2.4*	*0.904*	*High*
Overall Macroalgal Ecological Quality Rating - EQR (Average of FEDS)		0.6	Good

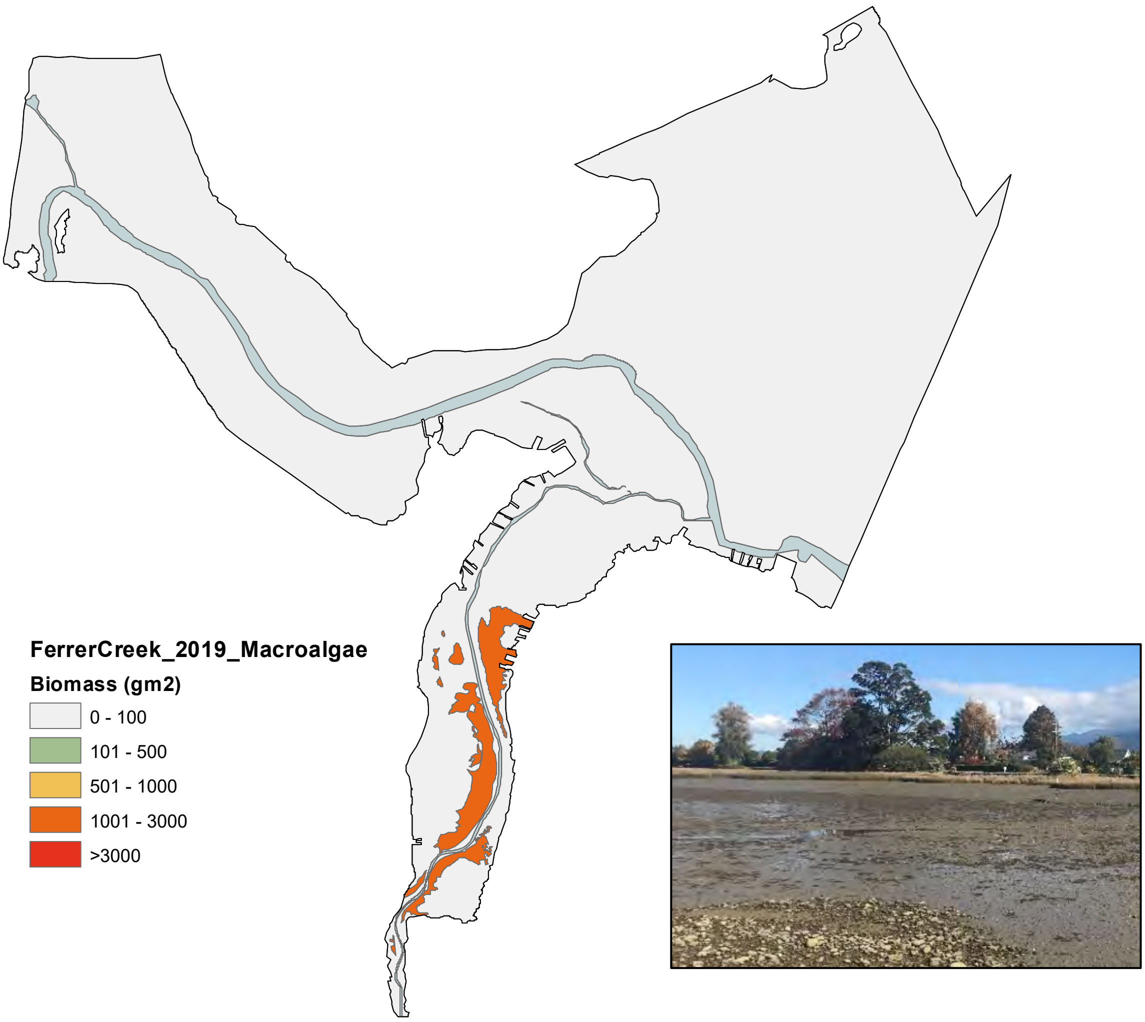


Fig. 10. Map of intertidal macroalgal biomass (g/m² wet weight), Ferrer Creek, May 2019.

3.3.4 Seagrass

No seagrass beds were observed within Ferrer Creek Estuary in 2019, consistent with previous reports.

3.3.5 Salt marsh

Table 14 and Fig. 9 summarise the 2019 salt marsh mapping results. The area of intertidal salt marsh (6.4ha, 27.8%) was rated 'very good'. The most extensive salt marsh areas were located in the upper arms, with isolated patches within the lower estuary basin and on the western side of Outer Island.

The salt marsh cover comprised rushland (70.7%), herbfield (25.7%) and estuarine shrubs (3.6%). Rushland was dominated by searush (*Juncus kraussii*) with smaller areas of jointed wirerush (*Apodasmia similis*) growing primarily within sandy mud in the upper arms, and in muddy sands in the lower estuary.

Primrose (foreground), searush (central) and salt marsh ribbonwood (background)

Extensive patches of Primrose in the northern arm

Primrose (*Samolus repens*) was the dominant herbfield species present in the muddier upper arms, with salt and desiccation-tolerant glasswort (*Sarcocornia quinqueflora*) on sand and gravel substrates on the exposed tidal flats of the lower estuary. Salt marsh ribbonwood (*Plagianthus divaricatus*) was the dominant estuarine shrub cover in a small part of the northern arm, and was common as a subdominant species near the terrestrial margin within rushland.

Table 14. Summary of dominant salt marsh cover, Ferrer Creek, May 2019.

Class, dominant and subdominant species	Ha	%
Estuarine Shrub	0.2	3.6
Plagianthus divaricatus (Salt marsh ribbonwood)	0.00	
Carpobrotus edulis (Ice Plant)	0.01	
Festuca arundinacea (Tall fescue)		
Ulex europaeus (Gorse)	0.02	
Juncus kraussii (Searush)		
Apodasmia similis (Jointed wirerush)	0.20	
Rushland	4.6	70.7
Apodasmia similis (Jointed wirerush)	0.28	
Festuca arundinacea (Tall fescue)	0.02	
Juncus kraussii (Searush)	1.40	
Plagianthus divaricatus (Salt marsh ribbonwood)	0.11	
Sarcocornia quinqueflora (Glasswort)	0.09	
Samolus repens (Primrose)	0.01	
Juncus kraussii (Searush)	0.24	
Festuca arundinacea (Tall fescue)	0.02	
Apodasmia similis (Jointed wirerush)	1.14	
Plagianthus divaricatus (Salt marsh ribbonwood)	0.07	
Samolus repens (Primrose)	0.10	
Samolus repens (Primrose)	1.09	
Herbfield	1.7	25.7
Samolus repens (Primrose)	1.2	
Juncus kraussii (Searush)	0.1	
Plagianthus divaricatus (Salt marsh ribbonwood)	0.0	
Sarcocornia quinqueflora (Glasswort)		
Juncus kraussii (Searush)	0.1	
Suaeda novaezelandiae (Sea blite)	0.0	
Sarcocornia quinqueflora (Glasswort)	0.0	
Carpobrotus edulis (Ice Plant)	0.0	
Juncus kraussii (Searush)	0.0	
Samolus repens (Primrose)	0.1	
Juncus kraussii (Searush)	0.0	
Sarcocornia quinqueflora (Glasswort)		
Selliera radicans (Remuremu)	0.0	
Samolus repens (Primrose)	0.0	
Selliera radicans (Remuremu)		
Sarcocornia quinqueflora (Glasswort)		
Samolus repens (Primrose)	0.0	
Grand Total	6.4	100

Changes in mapped salt marsh extent since 1947 are summarised in (Fig. 11), although it is noted that these represent coarse estimates only. Overall, there has been a ~38% reduction reported since 1947, the vast majority occurring prior to 1986. Salt marsh extent prior to 1947 has not been assessed but substantial reclamation and drainage is likely to have occurred prior to this time and the historical (natural state) salt marsh extent can reasonably be assumed to have been much larger than that reported in 1947.

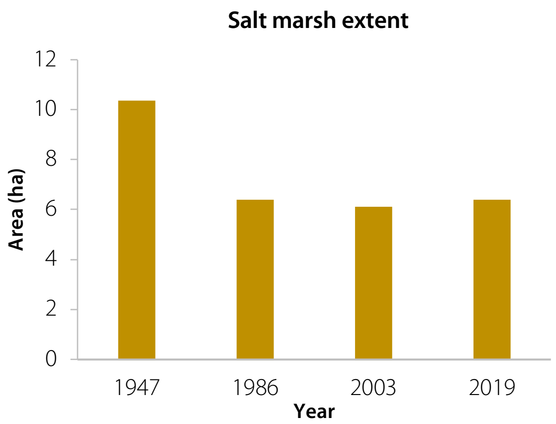


Fig. 9. Historical salt marsh extent, Ferrer Creek, 1947-2019.

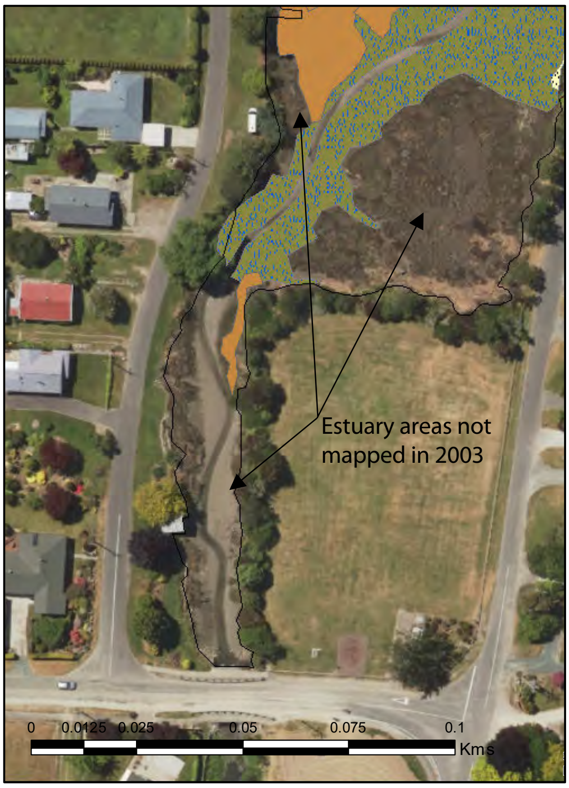


Fig. 8. Ferrer Creek showing 2003 mapping in relation to actual estuary boundary.

The small (4.7%) reported increase from 2003 to 2019 is primarily attributed to an area of salt marsh present in 2003 not being included in the mapping coverage at that time (Fig. 12). In general, salt marsh extent appears to have remained relatively consistent since 1986 with areas for potential expansion limited by the presence of seawalls, roading and residential, horticultural and pastoral land development.

3.3.6 Terrestrial margin

The results of the 200m terrestrial margin mapping are presented in Table 15 and Fig. 13. The majority of the margin has been highly modified and comprises pasture (30.4%), urban development (27.4%), and horticulture (24.8%). Only 8.4% of the margin was densely vegetated and this was predominantly pine forest located on Outer Island.

The loss of vegetative buffering capacity on land surrounding the estuary, and associated habitat diversity, has been a consequence of extensive historical drainage of wetland and salt marsh areas.

Table 8. Summary of 200m terrestrial margin land cover, Ferrer Creek, May 2019.

LCDB Class Number and Name		%
1	Built-up Area (settlement)	27.4
2	Urban Parkland/Open Space	3.8
5	Transport Infrastructure	2.3
20	Lake or Pond	0.4
21	River	1.2
30	Short rotation Cropland	1.3
33	Orchard Vineyard & Other Perennial Crops	24.8
40	High Producing Exotic Grassland	24.9
41	Low Producing Grassland	4.3
44	Depleted Grassland	1.2
46	Herbaceous Saline Vegetation	0.1
54	Broadleaved Indigenous Hardwoods	0.04
56	Mixed Exotic Shrubland	3.4
71	Exotic Forest	4.9
Total		100
Total dense vegetated 200m margin (LCDB classes 45-71)		8.4

The presence of roads, stopbanks, retaining walls and shoreline armouring further reduces the natural connectivity between the land and sea in most places and greatly restricts opportunities for the natural migration of estuarine plant species in response to predicted sea level rise.

In addition, flap-gates located at the head of Ferrer Creek arm (Fig. 13, photo right) and Little Sydney Stream have altered tidal dynamics, effectively shortening the estuary and turning what was once extensive brackish salt marsh habitat into a confined freshwater habitat within drained pastoral land. Flap-gates are one of the first barriers to upstream fish movement. Where direct passage is not impeded by closed flap-gates or sills, in many cases the velocities generated at these outlets exceed what most migratory species can cope with, thereby limiting access to prime spawning habitat. No whitebait spawning has been found on Ferrer Creek and only a very small amount in Little Sydney Creek. The regular clearance of drains also disrupts habitat and may contribute to fine mud in the estuary.

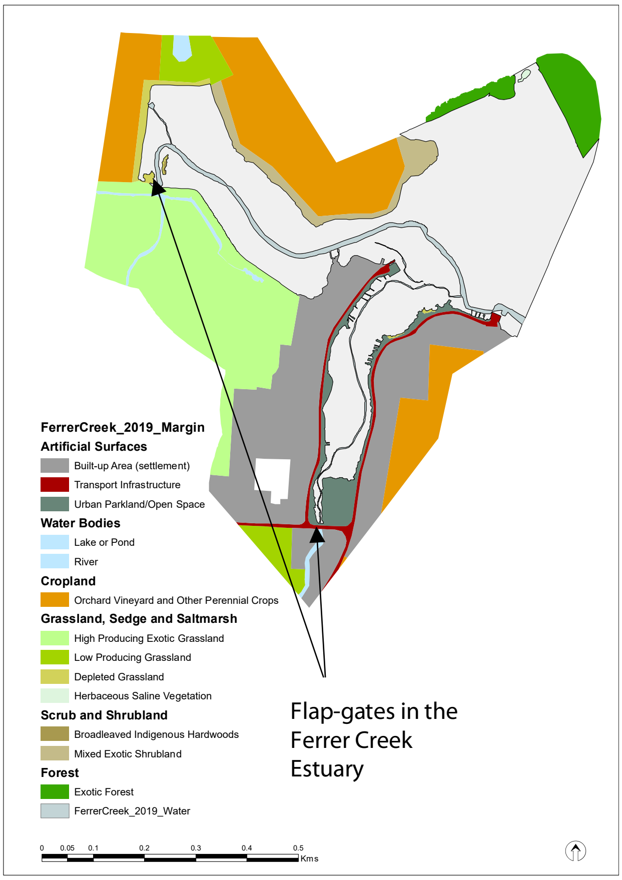


Fig. 13. Map of 200m terrestrial margin land cover, Ferrer Creek, May 2019.

Flap-gates constricting the natural estuary boundary

3.3.7 Summary of key indicators and ratings

Table 16 presents a summary of the values and rating applied to key indicators in Ferrer Creek Estuary.

Overall, despite significant historical losses of salt marsh and modification of the estuary margin, the estuary retains valuable and has reasonably intact areas of salt marsh.

Growths of persistent nuisance macroalgae associated with nutrient enrichment, and HEC areas, are evident and have developed since 2003. These areas are likely to cause significant adverse ecological impacts on sediment-dwelling animals and, once established, are generally slow to recover. Such conditions are not typically present in well-flushed shallow intertidally dominated estuaries but can occur when nutrient inputs are significantly elevated. Ferrer Creek currently has a predicted nitrogen areal load of 299mg/m^2/d (excluding point source inputs). This is above the 100mg/m^2/d threshold at which most macroalgal problems are evident in similar NZ estuaries (see Robertson et al. 2016b). Therefore, a reduction in nutrient inputs, or an increase in flushing, will likely be required to reduce macroalgal growth and HEC areas.

The extent of mud-dominated habitat remains 'poor' but has potentially improved since 2003 in the more open sections of the lower estuary. However, this may also reflect changes in mapping classification between the 2003 and 2019 surveys. Regardless, there appears to have been very little change in the upper estuary arms where the very high sediment mud content is likely to limit macrofauna to a relatively low diversity community dominated by mud-tolerant species.

Table 9. Summary of key indicator ratings, Ferrer Creek Estuary, May 2019, and changes since 2003.

Broad scale indicators	Unit	Value	2019 Rating	Change 2003-2019	
Mud-dominated substrate	% of intertidal area >50% mud	24.2%	Poor	3.4ha	↓ 38%* (improving)
Macroalgae (OMBT)	Ecological Quality Rating (EQR)	0.6	Good	0.4	↓ 40% (worsening)
Salt marsh extent (current)	% of intertidal area	27.8%	Very Good	0.3ha	↑ 6%* (improving)
Historical salt marsh extent	% of historical remaining	<30%	Poor	-	-
200m terrestrial margin	% densely vegetated	8.4%	Poor	-	-
High Enrichment Conditions	ha	0.6ha	Good	0.6ha	↑ (worsening)
High Enrichment Conditions	% of estuary	2.5%	Good	2.5%	↑ (worsening)

*Primarily reflects differences in mapping coverage or classification rather than meaningful change

3.4 MOTUEKA RIVER ESTUARY

3.4.1 Intertidal substrate

Table 17 and Fig. 14 show intertidal substrate of the Motueka River Estuary was dominated by sandy sediments (77.7ha, 83%) located predominantly throughout the lower tidal flats. Sandy sediments were primarily firm or mobile, 35ha with a mud content of ~0-25%, and 43ha with a mud content of ~25-50%. Mud-dominated habitat (>50% mud content) comprised 1.7ha (2%), most confined within a small embayment in a secondary flood path near the Motueka wastewater treatment plant (MWTP).

Hard substrates (e.g. boulder, cobble and gravel) comprised 14.3ha (15%) and were widespread within the lower reaches of the Motueka River and in patches within coastal sand flats. A relatively large gravel and cobble deposit was present on the true left side of the Motueka River mouth. Artificial substrate (0.2%) comprised steep-faced rock seawalls in front of residential property in the north-west.

Substrates within vegetated areas were relatively consistent - predominantly firm muddy sand and gravel within herbfields, and muddier sands among rushland.

Table 17. Summary of dominant intertidal substrate, Motueka River Estuary, May 2019.

Class	Dominant Substrate	2019 Ha	2019 %
Artificial	Artificial substrate	0.2	0.2
Boulder/Cobble/ Gravel	Boulder field	0.1	0.2
	Cobble field	9.0	9.5
	Gravel field	5.2	5.6
Sand (0-10% mud)	Mobile sand	10.2	10.8
	Firm sand	3.7	4.0
Muddy Sand (>10-25% mud)	Mobile muddy sand	21.0	22.4
Muddy Sand (>25-50% mud)	Firm muddy sand	40.8	43.4
	Soft muddy sand	2.0	2.1
Sandy Mud (>50-90% mud)	Soft sandy mud	0.03	0.03
	Very soft sandy mud	1.6	1.7
Total		**94.0**	**100**

Gravel field and herbfield at the Motueka River mouth

Mobile sand in the north-western estuary

3.4.2 Opportunistic macroalgae

No significant macroalgal growth was observed within Motueka River Estuary in 2019. This equates to a 'very good' rating according to Table 4 categories.

3.4.3 High Enrichment Conditions (HECs)

There were no HEC areas observed within Motueka River Estuary in 2019. This equates to a 'very good' rating according to Table 4 categories.

3.4.4 Seagrass

No seagrass beds were observed within Motueka River Estuary in 2019, consistent with previous reports.

3.4.5 Salt marsh

Table 18 and Fig. 14 summarise the 2019 salt marsh mapping results.

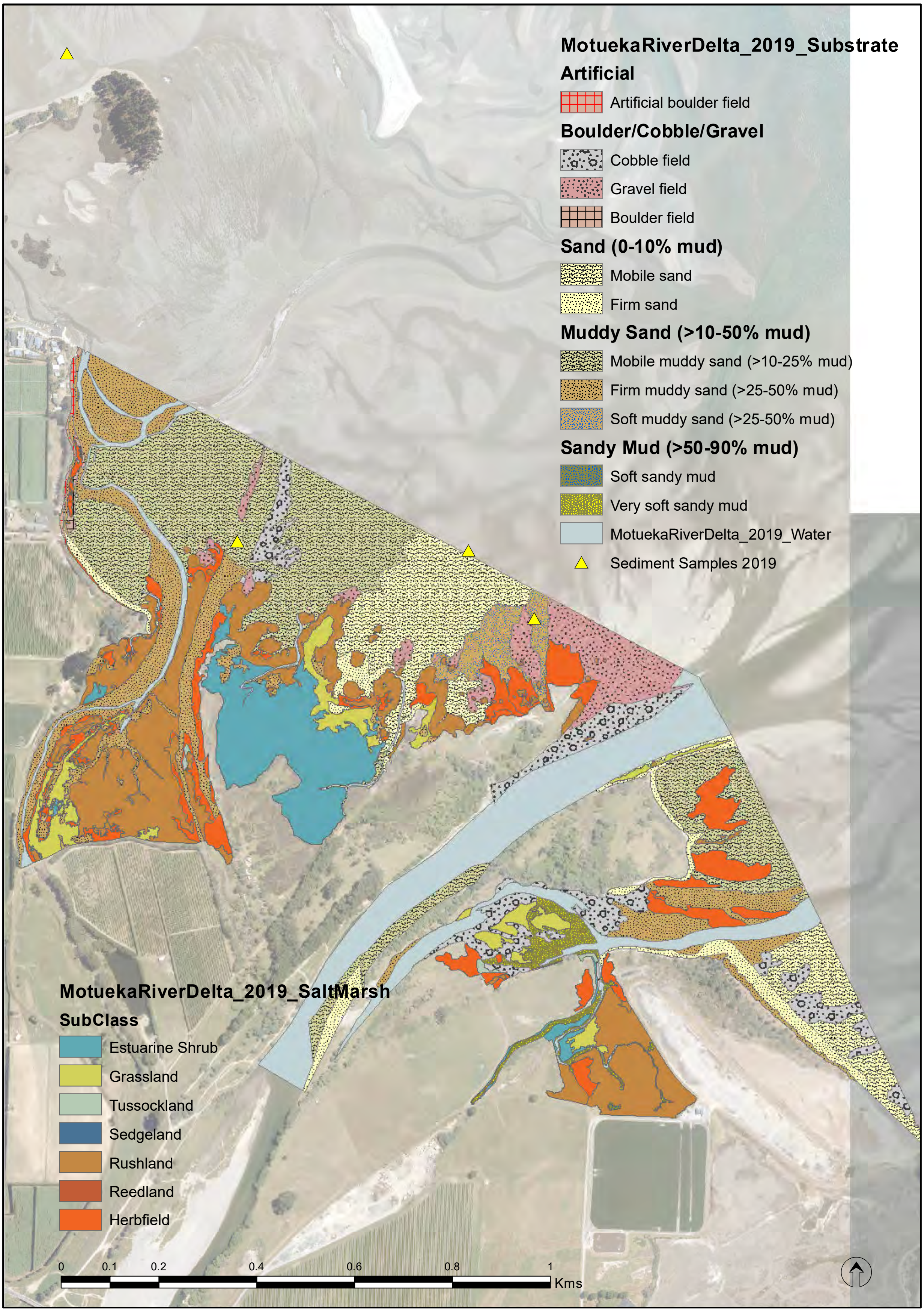


Fig. 14. Map of dominant intertidal substrate types and salt marsh extent, and location of sediment grain size samples, Motueka River Estuary, May 2019.

Salt marsh covered 33.6ha (35.7%) and was rated 'very good' according to the Table 4 categories. Very little salt marsh was present on the well flushed and coarse substrates of the Motueka River bank, with the most extensive areas of salt marsh located to the northwest and to the south adjacent to the MWTP. In the northwest particularly, salt marsh beds were relatively wide and intact, although in many areas, drainage channels have impacted on the areas regularly tidally inundated.

Saltmarsh near the MWTP

The dominant salt marsh cover was rushland (43%), and estuarine shrub (24%) located in the upper tidal reaches, and herbfield (22%) most extensive on the intertidal flats either side of the river mouth. Rushland was dominated by jointed wirerush (*Apodasmia similis*) commonly with a sub-dominant cover of searush (*Juncus kraussii*) and salt marsh ribbonwood (*Plagianthus divaricatus*), the latter the dominant estuarine shrub cover near Motueka River. The regionally rare and nationally declining sea sedge *Carex litorosa* was present in relatively dense patches on the south side of the western arm (see photo below).

Large beds of the nationally declining sea sedge *Carex litorosa* in the western arm of the Motueka River Estuary

Table 18. Summary of dominant salt marsh cover, Motueka River Estuary, May 2019.

Class, dominant and subdominant species	Ha	%
Estuarine Shrub	8.0	23.8
Plagianthus divaricatus (Salt marsh ribbonwood)	0.1	
Festuca arundinacea (Tall fescue)	6.9	
Juncus kraussii (Searush)	0.2	
Festuca arundinacea (Tall fescue)	0.2	
Apodasmia similis (Jointed wirerush)	0.1	
Apodasmia similis (Jointed wirerush)		
Juncus kraussii (Searush)	0.1	
Lupinus arboreus (Tree lupin)	0.4	
Grassland	3.5	10.4
Festuca arundinacea (Tall fescue)	0.3	
Plagianthus divaricatus (Salt marsh ribbonwood)	1.0	
Apodasmia similis (Jointed wirerush)	1.0	
Samolus repens (Primrose)		
Sarcocornia quinqueflora (Glasswort)	0.7	
Selliera radicans (Remuremu)	0.5	
Tussockland	0.1	0.4
Carex litorosa (Sea sedge)	0.04	
Sarcocornia quinqueflora (Glasswort)	0.04	
Samolus repens (Primrose)		
Selliera radicans (Remuremu)	0.01	
Selliera radicans (Remuremu)		
Samolus repens (Primrose)	0.1	
Rushland	14.4	43.0
Apodasmia similis (Jointed wirerush)	2.5	
Cyperus eragrostis (Umbrella sedge)		
Festuca arundinacea (Tall fescue)	0.1	
Juncus kraussii (Searush)	1.0	
Festuca arundinacea (Tall fescue)	0.2	
Plagianthus divaricatus (Salt marsh ribbonwood)	4.4	
Samolus repens (Primrose)	0.9	
Plagianthus divaricatus (Salt marsh ribbonwood)	1.2	
Sarcocornia quinqueflora (Glasswort)		
Samolus repens (Primrose)	0.1	
Samolus repens (Primrose)		
Selliera radicans (Remuremu)	0.1	
Juncus kraussii (Searush)	0.5	
Apodasmia similis (Jointed wirerush)	0.2	
Plagianthus divaricatus (Salt marsh ribbonwood)	3.2	
Sarcocornia quinqueflora (Glasswort)		
Carex litorosa (Sea sedge)	0.1	
Samolus repens (Primrose)	0.01	
Herbfield	7.5	22.4
Samolus repens (Primrose)	0.05	
Sarcocornia quinqueflora (Glasswort)	0.4	
Juncus kraussii (Searush)	0.1	
Selliera radicans (Remuremu)	0.1	
Selliera radicans (Remuremu)	2.4	
Carex litorosa (Sea sedge)	0.1	
Sarcocornia quinqueflora (Glasswort)	0.5	
Sarcocornia quinqueflora (Glasswort)	0.5	
Carex litorosa (Sea sedge)	0.2	
Samolus repens (Primrose)		
Selliera radicans (Remuremu)	0.7	
Samolus repens (Primrose)	0.1	
Selliera radicans (Remuremu)	0.01	
Samolus repens (Primrose)	1.8	
Carex litorosa (Sea sedge)	0.3	
Juncus kraussii (Searush)	0.1	
Sarcocornia quinqueflora (Glasswort)	0.1	
Grand Total	33.6	100

Throughout the upper intertidal reaches of the estuary salt tolerant tall fescue (*Festuca arundinacea*), was present in patches, often bordering salt marsh ribbonwood.

On the exposed tidal sand and gravel flats, species composition was dominated by salt and desiccation-tolerant herbfield species, namely primrose (*Samolus repens*), remuremu (*Selliera radicans*) and glasswort (*Sarcocornia quinqueflora*).

The extent of mapped salt marsh in the estuary has reduced by ~28% since 1947 (Fig. 15), the greatest losses occurring between 1947 and 1986, in part a consequence of construction of the MWTP. Following the retirement of a treatment pond, ~4.5ha of land has been planted in a variety of native plants (see photo below).

Restorative plantings in the retired MWTP soakage beds

This area of planting is in a very low-lying area and is likely to be inundated by seawater in the forseeable future. While salt marsh may develop in this location, the majority of the recent plantings are terrestrial species and their long-term future is uncertain.

Although there is a reported 50% increase in salt marsh extent from 2003 to 2019 (Fig. 15), salt marsh appears unlikely to have expanded significantly over this period and the change most likely reflects differences in mapping coverage. For example, a large area of salt marsh on the southern side of the Motueka River was present but not included in the 2003 mapping coverage (Fig. 16).

Salt marsh extent prior to 1947 has not been assessed but substantial reclamation and drainage is likely to have occurred before this time, and the historical (natural state) salt marsh extent can reasonably be assumed to have been much larger than that reported in 1947.

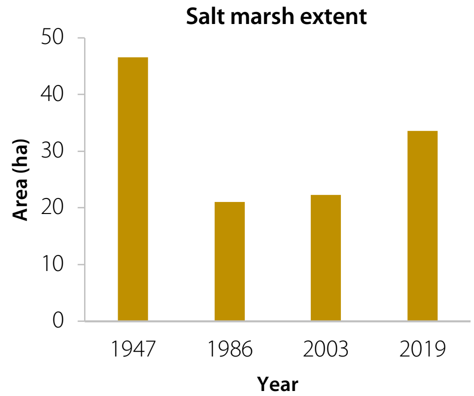


Fig. 15. Historical salt marsh extent, Motueka River Estuary, 1947-2019.

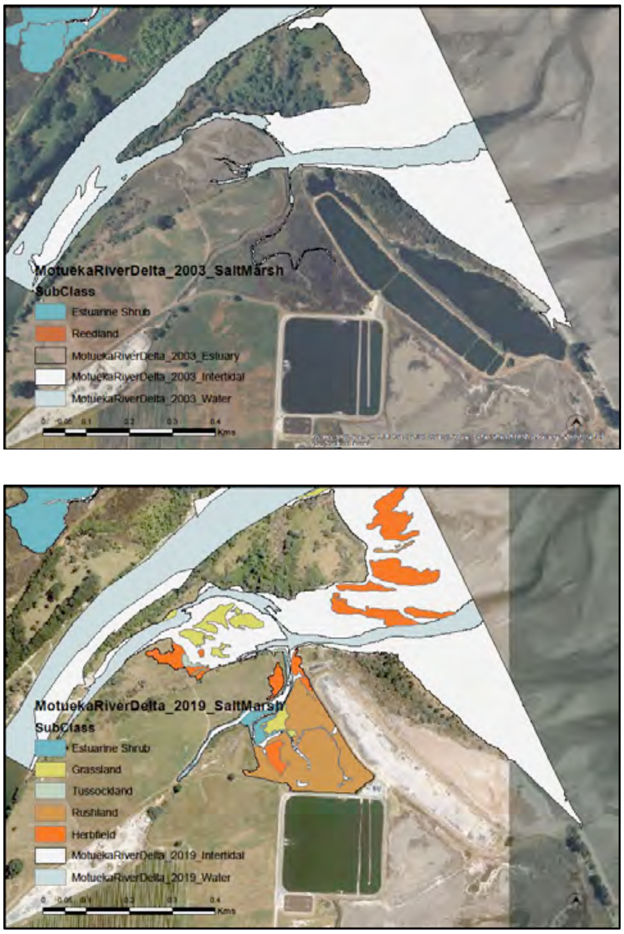


Fig. 16. Detail of mapped salt marsh extent in 2003 (top) and 2019 (bottom), highlighting gaps in the 2003 coverage, Motueka River Estuary.

As a consequence of earth bunds and seawalls bordering pasture, horticulture, residential properties and roads, there is now very little capacity for salt marsh to expand in response to predicted sea level rise

3.4.6 Terrestrial margin

The results of the 200m terrestrial margin mapping are presented in Table 19 and Fig. 17. Dense vegetation accounts for 36.3% of the margin, and is primarily located either side of the Motueka River mouth where there is also a large area of unvegetated sand (11.1%) present as a consequence of recent coastal erosion in the southeast.

Table 19. Summary of 200m terrestrial land cover, Motueka River Estuary, May 2019.

LCDB Class Number and Name		%
1	Built-up Area (settlement)	3.4
2	Urban Parkland/Open Space	0.03
10	Sand and Gravel	11.1
20	Lake or Pond	0.1
21	River	1.4
33	Orchard Vineyard & Other Perennial Crops	19.1
41	Low Producing Grassland	28.5
54	Broadleaved Indigenous Hardwoods	20.8
56	Mixed Exotic Shrubland	3.3
71	Exotic Forest	12.2
Total		100
Total dense vegetated margin (LCDB classes 45-71)		**36.3**

Elsewhere, much of the margin has been modified and comprises pasture (28.5%) and horticulture (19.1%). These modified areas are primarily surrounded by seawalls and earth bunds, with extensive drainage channels and flap-gates to prevent tidal inundation of reclaimed land. These features disrupt the natural connectivity between the land and sea and greatly restrict opportunities for the natural migration of estuarine plant species in response to predicted sea level rise.

Although the reduction of vegetative buffering capacity on land surrounding the estuary, and associated losses of habitat diversity, have been extensive, there has been recent extensive replanting of coastal species following the removal of the MWTP soakage beds. Although falling outside the boundary of the mapped Motueka River Estuary as they are terrestrial areas not flooded by the sea, these restorative plantings represent a significant enhancement of ecological value and habitat diversity.

Rushland bordered by pne trees and horticulture

Steep-faced rock seawall in the northwest estuary

Flap-gate in the northern arm

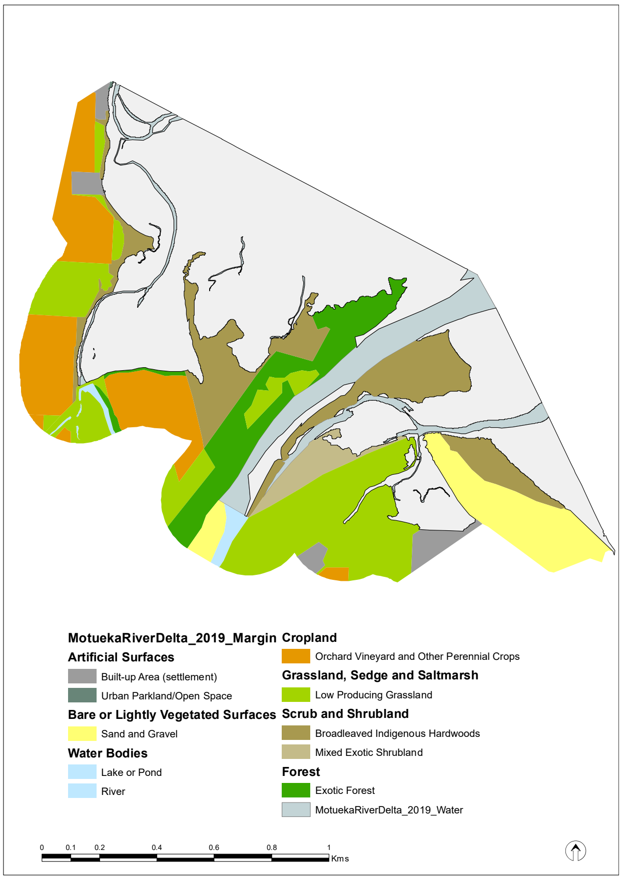


Fig. 17. Map of 200m terrestrial margin land cover, Motueka River Estuary, May 2019.

3.4.7 Summary of key indicators and ratings

Table 20 presents a summary of the values and ratings applied to key indicators in Motueka River Estuary. Overall, despite significant historical losses of salt marsh and modification of the estuary margin, the estuary retains valuable and extensive areas of salt marsh. However, these areas are under pressure from the invasion of terrestrial grasses and weeds as a consequence of extensive drainage, and to a lesser extent from coastal erosion. The apparent increase in salt marsh extent since 2003 reflects more accurate mapping of estuary boundaries in 2019 rather than a significant change.

No growths of persistent nuisance macroalgae associated with nutrient enrichment, or HEC areas were evident. This is in spite of the large catchment (206,082ha) and high nutrient inputs (nitrogen areal load 2,117mg/m^2/d). However, due to the nature of the estuary being an SSRTRE, nutrients tend to be flushed directly into Tasman Bay rather than retained.

The gravel and cobble dominance of the estuary is a result of its high degree of flushing and thus the extent of mud-dominated habitat was small and has potentially improved since 2003 in the more open sections of the lower estuary. However, this may also reflect changes in mapping classification between the 2003 and 2019 surveys.

Tall fescue at the upper tidal reaches of the estuary adjacent to jointed wirerush

Table 10. Summary of key indicator ratings, Motueka River Estuary, May 2019, and changes since 2003.

Broad scale indicators	Unit	Value	2019 Rating	Change 2003-2019	
Mud-dominated substrate	% of intertidal area >50% mud	1.8	Good	30.5ha	↓98%*(improving)
Macroalgae (OMBT)	Ecological Quality Rating (EQR)	1	Very Good	0	No change
Salt marsh extent (current)	% of intertidal area	35.7	Very Good	11.3ha	↑51%*(improving)
Historical salt marsh extent	% of historical remaining	<25	Poor	-	-
200m terrestrial margin	% densely vegetated	38.2	Fair	-	-
High Enrichment Conditions	ha	0	Very Good	0	No change
High Enrichment Conditions	% of estuary	0	Very Good	0	No change

*Primarily reflects differences in mapping coverage or classification rather than meaningful change

3.5 MOTUEKA ESTUARY

3.5.1 Intertidal substrate

Table 21 and Fig. 18 show intertidal substrates of Motueka Estuary were sand-dominated (63.6ha, 88%). Firm muddy sand (>25-50% mud) accounted for 45ha (62%) of total substrate and was located mainly in the upper intertidal flats where substrates were often dried out and cracked, likely due to the estuary being perched high in the tidal range. The small area of soft muddy sand (>25-50% mud) suggests that the upper estuary sediments are likely, at times, to become soft, especially during winter when rainfall is generally more common and exposure to sunlight (which facilitates sediment drying and cracking) is reduced.

Further seaward, sediments became progressively less muddy, consisting of firm muddy sands with ~10-25% mud content covering 10.6ha (15%), and firm and mobile sand with <10% mud covering 7.2ha (10%) near the entrance. Cobble and gravel comprised the remaining 8.7ha (12%) and were most common near the estuary entrance. No mud-dominated substrate (sediment with >50% mud content) was recorded.

The distribution of substrate types largely follows the tidal prism, with the upper reaches of the estuary, which receive only a very shallow inundation of tidal water (on large tides), being the muddiest, while the more regularly inundated, strongly tidally flushed and wave impacted substrates near the entrance being the least muddy.

Firm muddy sand (25-50% mud) in the upper Motueka Estuary

Firm muddy sand (10-25%mud) in the lower Motueka Estuary

Extensive cobble fields in the lower Motueka Estuary

Table 21. Summary of dominant intertidal substrate, Motueka Estuary, May 2019.

Class	Dominant Substrate	2019 Ha	2019 %
Cobble/Gravel	Cobble field	3.7	5.1
	Gravel field	5.0	6.9
Sand (0-10% mud)	Mobile sand	4.8	6.7
	Firm sand	2.4	3.3
Muddy Sand (>10-25% mud)	Firm muddy sand	10.6	14.6
Muddy Sand (>25-50% mud)	Firm muddy sand	45.1	62.3
	Soft muddy sand	0.7	1.0
Total		**72.4**	**100**

3.5.2 Opportunistic macroalgae

No significant macroalgae growth was observed within Motueka Estuary in 2019. This equates to a 'very good' rating according to Table 4 categories.

3.5.3 High Enrichment Conditions (HECs)

There were no HEC areas observed within Motueka Estuary in 2019. This equates to a 'very good' rating according to Table 4 categories.

3.5.4 Seagrass

No seagrass beds were observed within Motueka Estuary in 2019, consistent with previous reports.

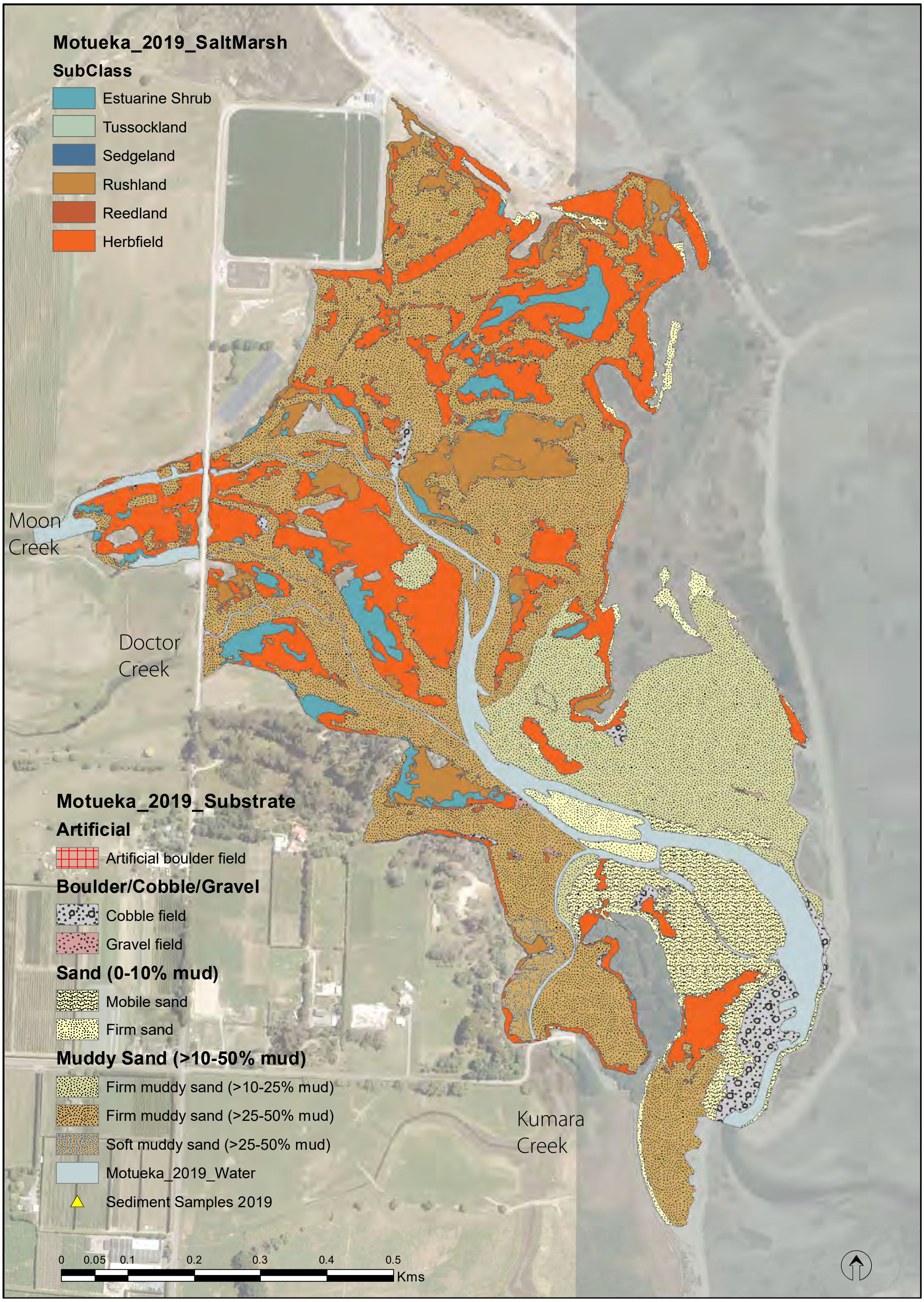


Fig. 18. Map of dominant intertidal substrate types and salt marsh extent, Motueka Estuary, May 2019.

3.5.5 Salt marsh

Table 22 and Fig. 18 summarise the 2019 salt marsh mapping results. Salt marsh covered 23.3ha (32.2%) and was rated 'very good' according to Table 4 categories. The dominant cover of salt marsh was herbfield (67.8%), and rushland (20.2%), predominantly growing throughout the central basin in the upper tidal range.

Herbfield species composition was dominated by glasswort (*Sarcocornia quinqueflora*) accompanied by sea blite (*Suaeda novaezelandiae*), primrose (*Samolus repens*) and remuremu (*Selliera radicans*). These were almost exclusively growing in sand dominated substrates on tidal flats.

Extensive herbfield growing in the upper tidal flats

Rushland was dominated by searush (*Juncus kraussii*) with smaller pockets of jointed wirerush (*Apodasmia similis*). These species were growing at a higher tidal elevation to herbfields around the estuary margin and on raised islands within the central basin. Some small patches of shore tussock (*Stipa stipoides*) were also found in these areas, and tall fescue grassland was a common sub-dominant cover.

Rushland and herbfield growing on raised islands

The dominant estuarine shrub was salt marsh ribbonwood (*Plagianthus divaricatus*) growing adjacent to, and among, rushland near the upper tidal extent. Overall the species complex was relatively diverse (Table 22) and showed a strong gradient across the tidal range from shrubs in the upper shore to rushland and then herbfield as the saline influence increased.

Salt marsh ribbonwood, tall fescue, gorse and herbfield at the estuary edge.

Fig. 19 shows a reduction of ~11% of salt marsh since 1947, although the accuracy of the previous mapping makes this value uncertain. Some losses can be attributed directly to the construction of the MWTP, including construction of the access road (causeway) built through the western margin of the estuary, as well as the installation of multiple flap-gates and seawalls to assist in draining and protecting reclaimed pastoral land from tidal inundation.

Salt marsh extent prior to 1947 has not been assessed but substantial reclamation and drainage is likely to have occurred before this time, and the historical (natural state) salt marsh extent can reasonably be assumed to have been much larger than that reported in 1947. Since 2003 there has been a 4.9ha (17%) reduction in salt marsh. Some of this change is likely due to improved mapping but there are areas of obvious loss. One example is the area south of the estuary (Fig. 20) where the spring fed Kumara Creek has been cut off from the estuary by flap-gates, salt marsh has been cleared for pasture, and natural drainage channels modified or filled in. Conservatively, this has resulted in the loss of an estimated ~50ha of salt marsh compared to natural state conditions, double the salt marsh area now remaining. Salt marsh losses of ~25ha around Moon Creek and Doctor Creek to the west are also likely, indicating the remaining salt marsh is likely less than 25% of the natural cover, which is a condition rating of 'poor'.

Table 22. Summary of dominant salt marsh cover, Motueka Estuary, May 2019.

Class, dominant and subdominant species	Ha	%
Estuarine Shrub	2.8	12.1
Plagianthus divaricatus (Salt marsh ribbonwood)	0.9	
Ammophila arenaria (Marram grass)	0.2	
Juncus kraussii (Searush)	0.5	
Sarcocornia quinqueflora (Glasswort)	0.4	
Apodasmia similis (Jointed wirerush)		
Festuca arundinacea (Tall fescue)	0.1	
Muehlenbeckia complexa (Wire vine)	0.02	
Stipa stipoides	0.01	
Ulex europaeus (Gorse)	0.02	
Muehlenbeckia complexa (Wire vine)	0.6	
Sarcocornia quinqueflora (Glasswort)	0.1	
Rushland	4.7	20.2
Apodasmia similis (Jointed wirerush)	0.002	
Plagianthus divaricatus (Salt marsh ribbonwood)		
Festuca arundinacea (Tall fescue)	0.1	
Juncus kraussii (Searush)	0.8	
Apodasmia similis (Jointed wirerush)	0.03	
Sarcocornia quinqueflora (Glasswort)	0.3	
Suaeda novaezelandiae (Sea blite)	0.1	
Plagianthus divaricatus (Salt marsh ribbonwood)	0.3	
Festuca arundinacea (Tall fescue)	0.1	
Sarcocornia quinqueflora (Glasswort)	0.3	
Plagianthus divaricatus (Salt marsh ribbonwood)	0.1	
Samolus repens (Primrose)	2.0	
Suaeda novaezelandiae (Sea blite)	0.6	
Stipa stipoides		
Plagianthus divaricatus (Salt marsh ribbonwood)	0.1	
Herbfield	15.8	67.8
Samolus repens (Primrose)	0.1	
Sarcocornia quinqueflora (Glasswort)	0.01	
Sarcocornia quinqueflora (Glasswort)	3.6	
Festuca arundinacea (Tall fescue)	0.02	
Juncus kraussii (Searush)	1.9	
Apodasmia similis (Jointed wirerush)	0.4	
Samolus repens (Primrose)	1.6	
Stipa stipoides	0.6	
Samolus repens (Primrose)	0.1	
Selliera radicans (Remuremu)	0.2	
Apodasmia similis (Jointed wirerush)	0.01	
Suaeda novaezelandiae (Sea blite)	0.6	
Suaeda novaezelandiae (Sea blite)	2.5	
Juncus kraussii (Searush)	4.0	
Muehlenbeckia complexa (Wire vine)	0.1	
Selliera radicans (Remuremu)		
Samolus repens (Primrose)		
Juncus kraussii (Searush)	0.2	
Sarcocornia quinqueflora (Glasswort)	0.04	
Total	23.3	100

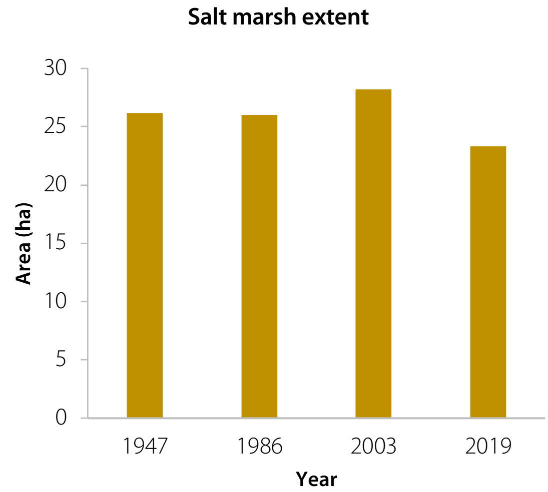


Fig. 19. Historical salt marsh extent Motueka Estuary, 1947-2019.

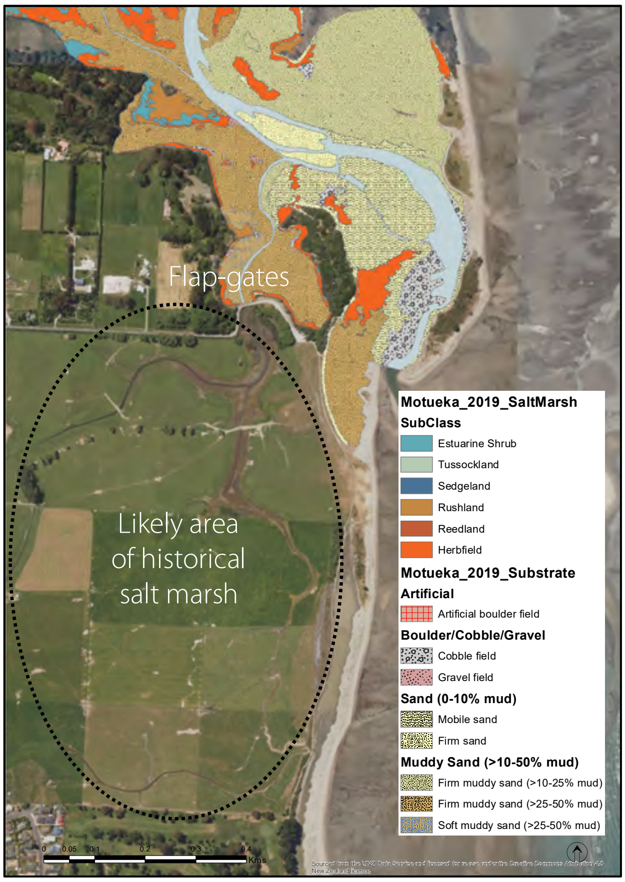


Fig. 20. Likely area of historic salt marsh south of Motueka Estuary (Kumara Creek).

3.5.6 Terrestrial margin

The results of the 200m terrestrial margin mapping are presented in Table 23 and Fig. 21. Dense vegetation accounts for 34% of the margin, and is primarily located on the seaward spit enclosing the estuary. This area is dominated by gorse (*Ulex europaeus*) which, while generally considered a weed, does offer some functional value in protecting the estuary margins from erosion. However, in terms of maintaining and enhancing native biodiversity, it is not a high value species. This coastal spit also has a relatively large area of unvegetated sand (5%). Elsewhere, much of the margin has been modified and comprises pasture (41%) and built-up area (12%), much of the latter includes the MWTP and ponds. These modified areas are primarily surrounded by seawalls and earth bunds, with extensive drainage channels and flap-gates to prevent tidal inundation of reclaimed land.

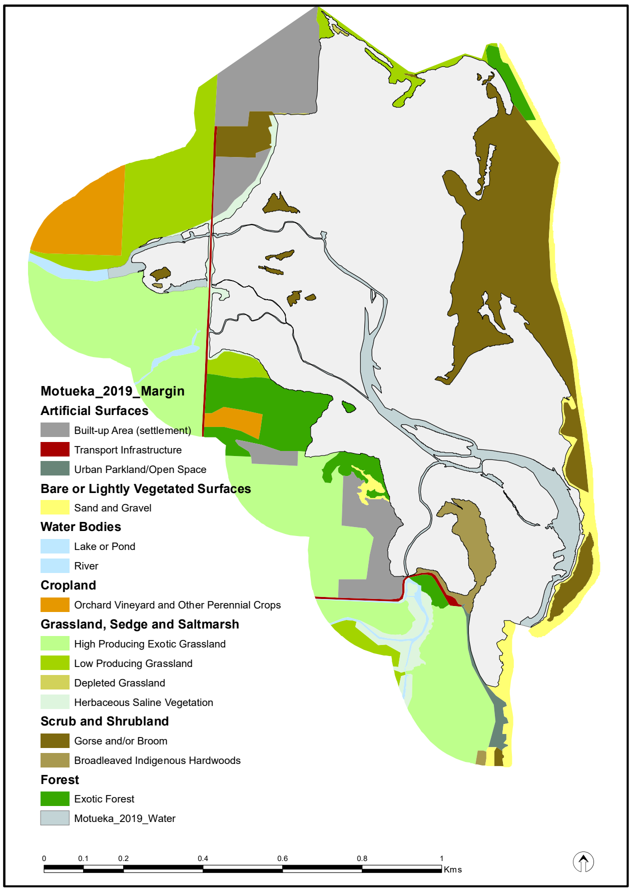


Fig. 21. Map of 200m terrestrial margin land cover, Motueka Estuary, May 2019.

These features disrupt the natural connectivity between the land and sea and greatly restrict opportunities for the natural migration of estuarine plant species in response to predicted sea level rise.

Table 23. Summary of 200m terrestrial margin land cover, Motueka Estuary, May 2019.

LCDB Class Number and Name		%
1	Built-up Area (settlement)	11.9
2	Urban Parkland/Open Space	0.7
5	Transport Infrastructure	0.9
10	Sand and Gravel	5.3
20	Lake or Pond	0.3
21	River	1.2
33	Orchard Vineyard & Other Perennial Crops	5.2
40	High Producing Exotic Grassland	30.2
41	Low Producing Grassland	10.8
44	Depleted Grassland	0.1
46	Herbaceous Saline Vegetation	2.9
51	Gorse and/or Broom	20.8
54	Broadleaved Indigenous Hardwoods	2.3
71	Exotic Forest	7.4
Total		100
Total dense vegetated 200m margin (LCDB classes 45-71)		33.5

Moon Creek culverts under Thorp Street on the western estuary margin

Pasture and gorse on bunds near Moon Creek

3.5.7 Summary of key indicators and ratings

Table 24 presents a summary of the values and ratings applied to key indicators in Motueka Estuary.

Overall, despite significant historical losses of salt marsh and modification of the estuary margin, the estuary retains valuable and extensive salt marsh areas. However, these areas are under pressure from the invasion of terrestrial grasses and weeds as a consequence of extensive drainage.

Coastal erosion has also recently begun to impact on the seaward margins of the estuary and there is a potential for this area to change relatively rapidly in the coming years.

No growths of persistent nuisance macroalgae associated with nutrient enrichment, or HEC areas were evident.

The extent of mud-dominated habitat was small and has potentially improved since 2003 in the more open sections of the lower estuary. However, this result may also reflect changes in mapping classification between the 2003 and 2019 surveys.

The margins of the estuary present some very good opportunities for enhancing salt marsh habitat and for allowing the estuary to return to a more natural state through the removal of flap-gates and seawalls.

Table 24. Summary of key indicator ratings, Motueka Estuary, May 2019, and changes since 2003.

Broad scale indicators	Unit	Value	2019 Rating	Change 2003-2019	
Mud-dominated substrate	% of intertidal area >50% mud	0	Very Good	36ha	↓100%*(improving)
Macroalgae (OMBT)	Ecological Quality Rating (EQR)	1	Very Good	0	No change
Salt marsh extent (current)	% of intertidal area	32.2	Very Good	4.9ha	↓17% (worsening)
Historical salt marsh extent	% of historical remaining	<25	Poor	-	-
200m terrestrial margin	% densely vegetated	26.8	Fair	-	-
High Enrichment Conditions	ha	0	Very Good	0	No change
High Enrichment Conditions	% of estuary	0	Very Good	0	No change

*Primarily reflects differences in mapping coverage or classification rather than meaningful change

4 SYNTHESIS AND RECOMMENDATIONS

4.1 SYNTHESIS OF KEY FINDINGS

The key broad scale indicator results and ratings for all four estuaries of the Motueka delta are presented in Tables 25, 26 and 27, with additional supporting data used to assess estuary condition presented in Table 28 and Appendix 5. Fig. 22 shows the extent of intertidal mud in each estuary compared to other estuaries in the region and nationally.

Each of the estuaries are discussed individually below and, where possible, comparisons are made with past mapping data to assess temporal change. However, the current work, which included an assessment of data quality and accuracy, revealed a relatively high level of error and uncertainty in the results of past assessments, in terms of both mapping coverage as well as the classification of specific features. While beyond the scope of the current brief to address any identified issues and gaps, it highlights that reported temporal changes should be treated with caution, and the most likely cause of any changes be considered, e.g. differences may in many cases be reliably attributed to mapping improvements rather than actual changes. Overall, the key findings were:

- Substrates in 2019 were sand-dominated comprising 60.3ha (25%) clean sand (0-10% mud); 46.2ha (19%) moderately muddy-sand (10-25% mud); and 96ha (39%) highly muddy-sand (25-50% mud). Sandy-mud (50-90% mud) comprised 17.2 (7%). Cobble and gravel was the other common substrate, 24.2ha (10%).
- The muddiest estuaries were Ferrer Creek (24% mud-dominated) and Riwaka (18%), where the mud extent was moderately high in both a regional and national context (Fig. 22). The extent of mud in the Motueka River Estuary and Motueka Estuary was very low (<2%). Reported reductions in mud dominance from 2003 to 2019 largely reflect more accurate substrate classification in 2019.
- Nuisance macroalgae were scarce, with dense, high biomass growths of the red seaweed *Gracilaria chilensis* and the establishment of High Enrichment Conditions (HECs) only present in a small area of Ferrer Creek (0.58ha, 2.5% of the intertidal area). This was located in the upper reaches within soft, muddy, poorly-oxygenated

Table 25. Summary of key broad scale indicator results and ratings (2019) for four estuaries of the Motueka delta.

		Riwaka		Ferrer Creek		Motueka River		Motueka	
Broad scale indicators	Unit	Value	Rating	Value	Rating	Value	Rating	Value	Rating
Mud-dominated substrate	% of intertidal area >50% mud	18.1	Poor	24.2	Poor	1.8	Good	0	Very Good
Macroalgae (OMBT)	Ecological Quality Rating (EQR)	1	Very Good	0.6	Good	1	Very Good	1	Very Good
Salt marsh extent (current)	% of intertidal area	10.4	Good	27.8	Very Good	35.7	Very Good	32.2	Very Good
Historical salt marsh extent	% of historical remaining	<40	Poor	<30	Poor	<25	Poor	<25	Poor
200m terrestrial margin	% densely vegetated	36.2	Fair	8.4	Poor	38.2	Fair	26.8	Fair
High Enrichment Conditions	ha	0	Very Good	0.6	Good	0	Very Good	0	Very Good
High Enrichment Conditions	% of estuary	0	Very Good	2.5	Good	0	Very Good	0	Very Good

Table 26. Summary of changes in key indicators compared to available baseline data, 2003-2019.

Broad scale indicators	Unit	Ferrer Creek Change 2003-2019		Motueka River Change 2003-2019		Motueka Change 2003-2019	
Mud-dominated substrate	% of intertidal area >50% mud	3.4ha	↓38%* (improving)	30.5ha	↓98%* (improving)	36ha	↓100%* (improving)
Macroalgae (OMBT)	Ecological Quality Rating (EQR)	0.4	↓40% (worsening)	0	No change	0	No change
Salt marsh extent	% of intertidal area	0.3ha	↑6%* (improving)	11.3ha	↑51%* (improving)	4.9ha	↓17% (worsening)
High Enrichment Conditions	ha	0.6ha	↑ (worsening)	0	No change	0	No change
High Enrichment Conditions	% of intertidal area	2.5%	↑ (worsening)	0	No change	0	No change

OMBT=Opportunistic Macroalgal Blooming Tool

*Primarily reflects differences in mapping coverage or classification rather than meaningful change

Table 27. Summary of previous mapping results and salt marsh change from 1947-2019.

Estuary	Riwaka	Ferrer Creek				Motueka River				Motueka			
Year	2019	1947	1986	2003	2019	1947	1986	2003	2019	1947	1986	2003	2019
Intertidal area	54.9	-	-	21.3	23.2	-	-	80.6	94.0	-	-	72.3	72.4
Subtidal area	3.6	-	-	1.4	1.0	-	-	16.1	13.9	-	-	5.5	4.9
Estuary area	58.5	-	-	22.7	24.2	-	-	96.7	107.9	-	-	77.9	77.3
Salt marsh extent (ha)	5.7	10.4	6.4	6.1	6.4	46.5	21.1	22.2	33.6	26.2	26.0	28.2	23.3
Estuarine shrub	*0.2*		*0.05*	*0.05*	*0.2*	*33.7*	*13.8*	*9.7*	*8.0*	*3.3*	*3.7*	*4.7*	*2.8*
Grassland		*0.4*	*0.1*					*0.1*	*3.5*	*0.2*			
Tussockland									*0.1*				
Reedland							*0.2*	*0.1*		*0.4*	*0.2*	*0.2*	
Rushland	*4.6*	*9.9*	*6.1*	*5.6*	*4.6*	*12.7*	*6.0*	*10.2*	*14.4*	*11.9*	*9.8*	*10.1*	*4.7*
Herbfield	*1.7*	*0.1*	*0.2*	*0.5*	*1.7*	*0.1*	*1.2*	*2.1*	*7.5*	*10.3*	*12.2*	*13.3*	*15.8*
Mud-dominated sediment	9.9	-	-	9.0	5.6	-	-	32.2	1.7	-	-	36.6	0.0
Macroalgal beds (>50% cover)	0	-	-	0	0.6	-	-	0	0	-	-	0	0
Seagrass (>50%cover)	0.7	-	-	0	0	-	-	0	0	-	-	0	0
High Enrichment Conditions (HECs)	0	-	-	0	0.6	-	-	0	0	-	-	0	0
Change in salt marsh (ha)				ha	%			ha	%			ha	%
1947-2019	-	-	-	-3.9	-38	-	-	-13.0	-28	-	-	-2.8	-11
1986-2019	-	-	-	0.05	1	-	-	12.5	59	-	-	-2.7	-10
2003-2019	-	-	-	0.3	6	-	-	11.3	51	-	-	-4.9	-17
Change in mud-dominated substrate (ha)				ha	%			ha	%			ha	%
2003-2019	-			-3.4	-38			-30.5	-95			-36.6	-100

Table 28. Supporting data used to assess estuary ecological condition.

Supporting Condition Measure	Riwaka	Ferrer Creek	Motueka River	Motueka
[1] Mean freshwater flow (m^3/s)	3.77*	0.4	63.1	0.02
[1] Catchment Area (Ha)	8540*	1435	206082	112
[2] Catchment nitrogen load (TN/yr)	63.15	26.43	747.1	1.02
[2] Catchment phosphorus load (TP/yr)	7.2	0.7	141.8	0.1
[1] Catchment sediment load (KT/yr)	5.4	0.5	287	0.002
[2] Estimated N areal load in estuary ($mg/m^2/d$)	296	299	2117	4
[2] Estimated P areal load in estuary ($mg/m^2/d$)	34	8	402	0.2
[1] CSR:NSR ratio	1.1	1.3	1.1	1.5
CSR/NSR ratio with 50% natural wetland attenuation	2.2	2.7	2.2	2.9
[1] Trap efficiency (sediment retained in estuary)	10%**	89%	0%	97%
[1] Estimated rate of sed. trapped in estuary (mm/yr)	0.6	1.2	0.4	0.0

[1] Hicks et al. 2019. *Values not included in Hicks et al. 2019 derived from CLUES. **Authors estimate.

[2] CLUES version 10.3, Run date: April 2020

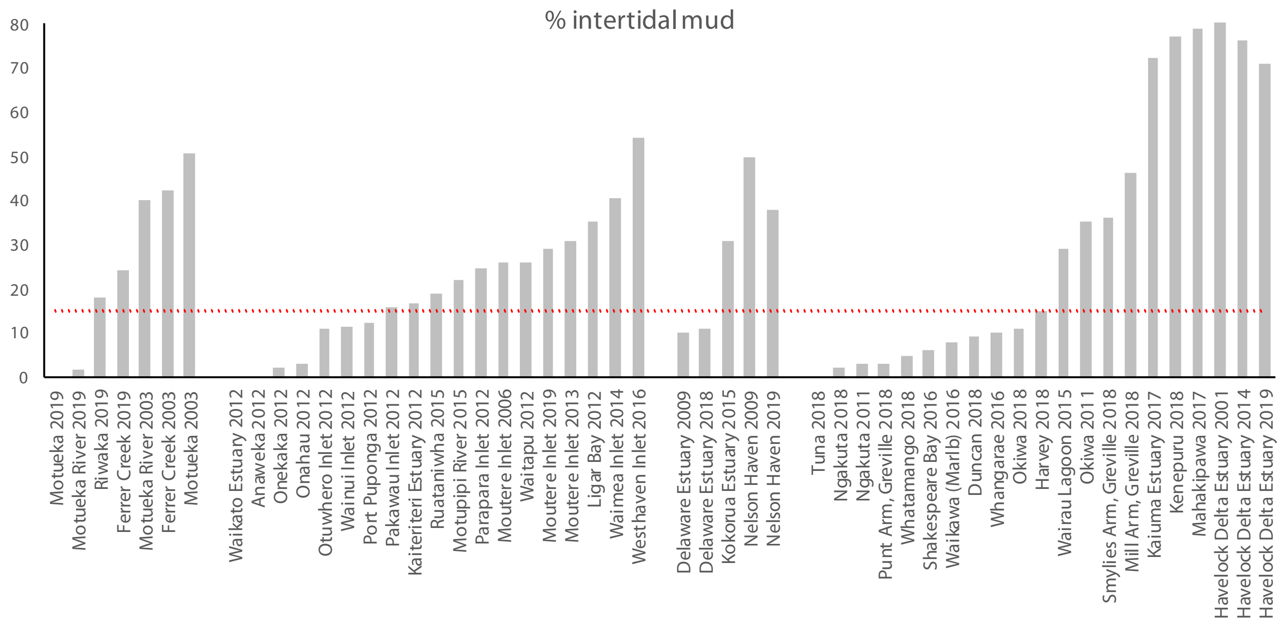
sediments.

- Seagrass cover was very low (0.74ha) and found exclusively within Riwaka Estuary. Large seagrass beds were noted on the coastal sandflats of Tasman Bay between the Riuwaka River Mouth and Tapu Bay.
- Large parts of the estuary margin are hardened through the construction of seawalls or earth bunds to minimise erosion or prevent inundation of surrounding land. Flap-gates also cut off many naturally inundated areas from regular tidal exchange. Such changes greatly restrict available habitat and prevent the natural migration of estuarine species, particularly salt marsh in response to predicted sea level rise.
- The 200m wide terrestrial margin bordering the

estuary was highly modified and dominated by pasture (33%), horticulture (17%) and built-up areas (9%). However, 32% remained densely vegetated with a mix of native and exotic species including gorse, blackberry and other weeds.

- Salt marsh was relatively extensive (69ha, 28.2% of the intertidal area) comprising 40% rushland, 38% herbfield. and 16% estuarine shrub. An estimated 60-75% of the historical salt marsh cover has been lost to drainage, reclamation and land clearance prior to 1947 (Fig. 23). Since that time salt marsh has reduced by a further ~20ha (24%), but appears to have remained relatively stable since 1986. These estimates are relatively coarse due to limits in the coverage or accuracy of past mapping.

Although many of these changes have been historical (e.g. prior to the earliest available broad



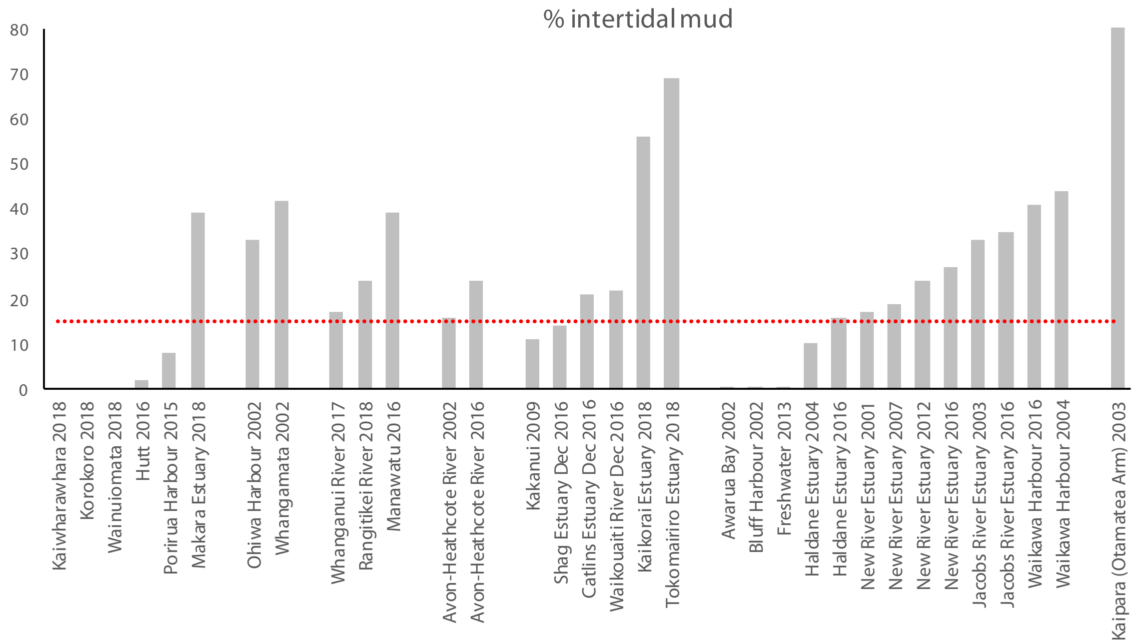


Fig. 22. Percentage of intertidal estuary with soft mud habitat for various NZ tidal lagoon and delta estuaries. Source: data from regional council monitoring reports (2003-2019). Red dashed line indicates 'POOR' condition rating threshold.

scale salt marsh mapping results derived from 1947 aerial photographs), there have been ongoing losses in estuary salt marsh and extent since that time.

Salt marsh losses since 1947 range from 11 to 38% and have occurred predominantly around the mouth of the Motueka River, and in the upper arms of the Motueka and Ferrer Creek estuaries (Fig. 23). Changes in Riwaka Estuary are not able to be assessed as, to date, this area has not been included in historical mapping. Smaller losses of salt marsh are apparent from 2003 to 2019 in similar locations.

The impact of these historical losses cannot be put into context without understanding their overall magnitude, and a key piece of information missing is the likely natural extent of the estuaries and their salt marsh cover. Although estimates of likely salt marsh losses have been included in Table 25, these are based on a preliminary estimate of historical estuary boundaries derived from current aerial imagery.

It would be of value to improve these estimates by combining available data on land elevation (e.g. LIDAR) with historical photographs, maps, paintings and descriptions to provide a more robust measure. This further work is highly worthwhile on the basis that there is a high cost to salt marsh loss and a clear benefit from ensuring further losses are avoided and habitat is reinstated where appropriate. The estimated ecosystem services value of salt marsh is NZ$368,220 per ha per year (Costanza et al. 2014). These values include habitat and ecological community services, food and water provisioning, filtering of contaminants, erosion control, carbon sequestration, buffering of floods and coastal storm surges, and cultural and recreational services. In virtually all cases, the cost of salt marsh loss greatly exceeds that of retaining existing salt marsh and allowing its natural expansion.

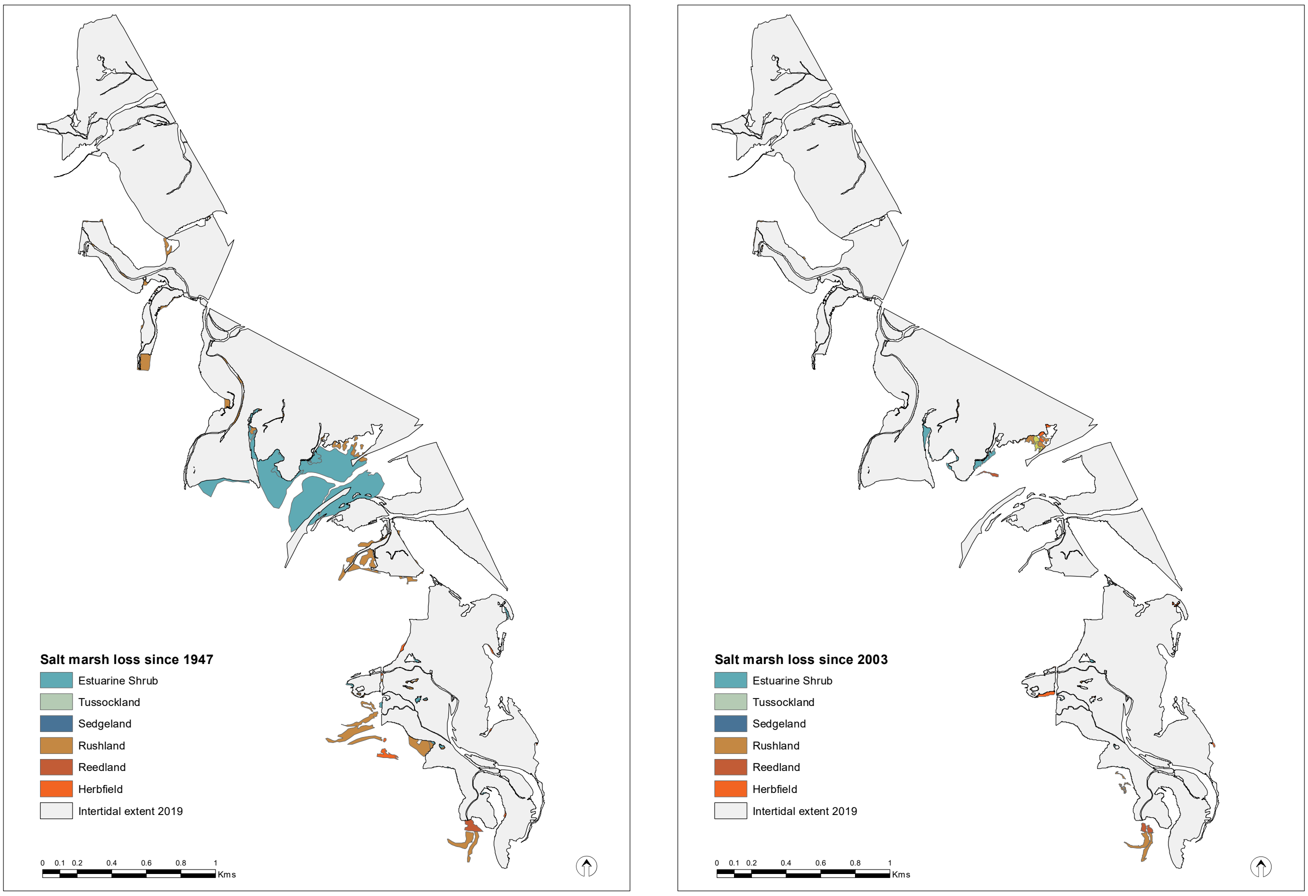


Fig. 23. Location and type of salt marsh losses reported since 1947 (left) and 2003 (right) from the estuaries of the Motueka delta.

Currently, the presence of seawalls, earth bunds, roading and residential development means there is little capacity for salt marsh to expand in response to predicted sea level rise. Without changes in management approaches, the likely outcome will be a progressive reduction of salt marsh habitat over time.

Despite historical losses the remaining salt marsh extent was rated 'good' or 'very good' in all estuaries in 2019 reflecting the presence of a variety of common estuarine species and relatively intact beds.

Mud-dominated sediment was a particular issue (rating of 'poor') for the Riwaka and Ferrer Creek estuaries. Fig. 22 shows that these estuaries were moderately high in terms of mud in a regional and national context, and that there has been an apparent decrease in muddiness since 2003 across all four estuaries on the Motueka delta. While it is possible that all the estuaries have improved over the past 15 years, it is also possible that the changes relate to differences in the mapping classifications applied in the two surveys. Support for the latter is provided by NIWA's national estuary sediment load estimator (Hicks et al. 2019) which predicts sediment trapping efficiencies for the estuaries, and rates of net sediment deposition based on current and natural state land cover. The ratio of the Current Sediment Load compared to the Natural Sediment Load (CSL/NSL ratio), applying a natural state wetland attenuation of 50%, ranges from ~2.2–2.9. This suggests current sediment inputs are likely to be contributing to a moderate ongoing increase in estuary muddiness, rather than a reduction in muddiness.

This view is further supported by the sediment accretion estimates in Hicks et al. (2019) which are in the same relative order as the measured extents of mud-dominated sediment in the estuaries (Table 25), highlighting the relationship between catchment land cover, estuary type, and fine sediment retention and accumulation.

The type of estuary is also an important determinant of its likely muddiness. Estuaries with high sediment inputs but low retention and high flows (e.g. Motueka River), flush sediment very effectively. Consequently, they remain dominated by coarse gravels and cobbles with fine sediment discharged directly to the open coast. In contrast, less well flushed estuaries like Ferrer Creek retain a much higher proportion of sediment inputs and can therefore exhibit stronger symptoms of degradation despite lower relative sediment mass loads.

Specific sources of fine sediments to the estuaries cannot be determined from the available data, but there have been previous concerns about erosion from land disturbance and forestry activities on the Separation Point granite (e.g. Fahey & Coker 1989) as well as on the Moutere gravels from pastoral or orchard development (Basher 2003). A recent study by Gibbs and Woodward (2018) using compound specific stable isotope (CSSI) source tracking of sediment in Moutere and Waimea estuaries, found that a substantial proportion of fine sediment originated from forest harvesting. As the Riwaka and Motueka River catchments have similar areas of land cover in exotic forestry to the Moutere and Waimea catchments respectively, it is reasonable to assume that a comparable pattern of sediment input may result if land management practices are similar. In addition to CSSI, other forensic methods (e.g. radioactive isotope or carbon dating, pollen analyses) could also be used to determine sediment sources, if considered a priority by TDC. While the sources of sediment remain undefined, localised activities such as drain clearance are known to contribute to the mobilisation and release of fine sediment present in streamways near the estuaries.

With regard to other key indicators, the general absence of nuisance macroalgal growth and areas with HECs are consistent with relatively low nutrient inputs, or high flushing rates. For example, the areal load of nitrogen to the Motueka River Estuary is high (2,117mg/m^2/d), but retention time in the estuary is insufficient to result in significant nuisance growths of either phytoplankton or macroalgae, due to the dominance of freshwater flows flushing most nutrients directly out to Tasman Bay. Such flushing explains the absence of nutrient enrichment issues in this estuary and in other similar estuary types in New Zealand (see Robertson et al. 2016b, Robertson & Stevens 2016).

In contrast, the nutrient load to Ferrer Creek Estuary, while still elevated, is much lower (299mg/m^2/d), but the estuary is exhibiting signs of elevated sediment accumulation and nutrient enrichment in the sheltered upper arms, reflecting that it is less well flushed and retains nutrients more readily.

Overall, all four estuaries have suffered from extensive historical habitat modification, in particular the removal of salt marsh, reclamation of estuary areas, and the interruption of natural flow regimes. These changes have significantly reduced habitat diversity, lowered the resilience of the estuary to future change, and severely restrict the capacity of the estuaries to respond to changing conditions, in particular to predicted sea level rise. Without changes in current management approaches, the likely outcome will be a progressive reduction of salt marsh habitat over time.

Despite these past changes, all four estuaries retain significant ecological value. Ferrer Creek is currently the only estuary expressing localised symptoms of eutrophication. Ferrer Creek and Riwaka Estuary, are also relatively muddy. Without reductions in current nutrient and sediment loads, these issues are likely to persist. The generally low extent of mud-dominated sediment and eutrophication in Motueka River Estuary reflects the high rate of flushing and, in the Motueka Estuary, relatively low inputs from the small catchment.

4.2 RECOMMENDATIONS

Riwaka, Ferrer Creek, Motueka River and Motueka estuaries have been identified by TDC as a priority for monitoring because of their high ecological and human use values, and because of their potential vulnerability to elevated sedimentation and localised eutrophication issues. Based on the 2019 results, the following recommendations are proposed for consideration by TDC:

4.2.1 Broad Scale Habitat Mapping

In order to track changes in the dominant features within each estuary, undertake broad scale habitat mapping at 5-yearly intervals.

Given the potential for rapid changes to nuisance macroalgae within Ferrer Creek, annually assess the extent and state of the established beds.

Due to uncertainty regarding the previous historical mapping undertaken using 1947 and 1986 aerials, review and update habitat maps and undertake an assessment of the likely extent of the estuary and surrounding salt marsh in natural state conditions.

Assess and map the extent and condition of adjacent coastal seagrass, as a baseline for monitoring long term change.

4.2.2 Sedimentation Rate Monitoring

Assessment of the change in depth of sediment overlying buried sediment 'plates' (typically concrete pavers) has become a routine method in many NZ estuaries for obtaining information on sediment accumulation in response to catchment disturbance (e.g. Hunt 2019, Townsend & Lohrer 2015). In light of the extent of mud-dominated sediment and eutrophication issues in Ferrer Creek Estuary, install sediment plates at four sites. Monitor annually for 5 years and then review.

To determine if sediments are getting muddier in the absence of sediment accretion, consideration should be given to analysing a composite sediment sample for grain size at each sediment plate site to establish a baseline against which future change can be assessed.

4.2.3 Catchment Influences

Consider sediment source tracking methods (e.g. Compound Specific Stable Isotope – CSSI), as used elsewhere in the region, to identify the main sources of mud deposited in the Riwaka and Ferrer Creek estuaries to help focus management priorities.

Maintain records on the location and scale of significant catchment disturbance or land use changes (e.g. forest harvesting, road development, urban subdivision) to assist in the interpretation of monitoring results. Such information will complement high level national scale data such as the Landcare Research Land Cover Database (LCDB) assessed from satellite imagery. It would also be prudent to reassess modelled catchment sediment and nutrient load predictions following any significant change in catchment land use, or when national models (e.g. NIWA CLUES model, suspended sediment yield estimator) are updated.

4.2.4 Enhancement and Restoration

There is significant potential for the ecological enhancement and restoration of all four estuaries of the Motueka delta. It is recommended that TDC develop a strategy to identify and prioritise areas for ecological enhancement and protection, including specific restoration options, e.g. replanting salt marsh, improving tidal flushing, recontouring shorelines, and removing barriers to salt marsh expansion. This work would ideally be part of a region-wide planning initiative targeted at community uptake.

A key component of the strategy would be to delineate low-lying areas previously within the estuaries, or likely to be impacted by sea level rise, using GIS-based mapping techniques and existing coastal LIDAR data. These outputs can be used to encourage the protection or expansion of salt marsh on private land adjacent to the estuaries, and to facilitate planning for the managed retreat of salt marsh.

Further, opportunities for creating new habitat or increasing and enhancing the vegetative buffering capacity of the estuaries should be explored through existing work wherever possible, e.g. requirements to increase the number and size of causeway culverts, block flap-gates, avoid or remove unnecessary shoreline barriers, or undertake supplementary planting as part of future road maintenance or protection works.

5 REFERENCES CITED

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

Basher L. 2003. The Motueka and Riwaka catchments: A technical report summarising the present state of knowledge of the catchments, management issues and research needs for integrated catchment management. Landcare Research. 122p.

Costanza R, de Groot R, Sutton P, Sander van der Ploeg S, Anderson SJ. Kubiszewski I, Farber S, Turner K. 2014. Changes in the global value of ecosystem services. Global Environmental Change 26 (2014) 152–158.

Fahey BD, Coker RJ. 1989. Forest road erosion in the granite terrain of Southwest Nelson, New Zealand. Journal of Hydrology (NZ) 28. 123-141p.

Gibbs M, Woodward B. 2018. Waimea and Moutere Sediment Sources by Land Use. NIWA Client Report No 2018026HN. Prepared for Tasman District Council under Envirolink contract, CO1X1632 1749-7STDC130. 63p.

Hicks M, Semademi-Davies A, Haddadchi A, Shankar U, Plew D. 2019. Updated sediment load estimator for New Zealand. NIWA Client Report No. 2018341CH, prepared for Ministry for the Environment. January 2019. 190p.

Hume T, Gerbeaux P. Hart D, Kettles H, Neale D. 2016. A classification of New Zealand's coastal hydrosystems. NIWA Client Report HAM2016-062: 112.

Hunt S. 2019. Regional Estuary Monitoring Programme (REMP) intertidal sedimentation measurements, results and review of methodologies. Waikato Regional Council Technical Report 2019/04.

James T, McCallum J. 2015. State of the Environment Report: River Water Quality in Tasman District 2015. Prepared for Tasman District Council. 79p.

Robertson BM, Tuckey B, Gillespie P. 2003. Broad scale mapping of Motueka River intertidal delta habitats. Cawthron Report No.782. 14p.

Robertson BM, Gillespie PA, Asher RA, Frisk S, Keeley NB, Hopkins GA, Thompson SJ, Tuckey BJ. 2002. Estuarine Environmental Assessment and Monitoring: A National Protocol. Part A. Development, Part B. Appendices, and Part C. Application. Prepared for supporting Councils and the Ministry for the Environment, Sustainable Management Fund Contract No. 5096. Part A. 93p. Part B. 159p. Part C. 40p plus field sheets.

Robertson BM, Stevens L 2009. State of the Environment Report, Estuaries of Tasman District. Prepared by Wriggle Coastal Management for Tasman District Council. 54p.

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

Robertson B. Stevens L. 2016. Manawatu-Wanganui Estuaries. Habitat Mapping, Vulnerability Assessment and Monitoring Recommendations Related to Issues of Eutrophication and Sedimentation. Prepared for Envirolink Medium Advice Grant: 1624-HZLC127 Assessment of the susceptibility of Horizons' estuaries to nutrient enrichment and sedimentation. MBIE/NIWA Contract No:CO1X1513. 102pp + appendices.

Robertson BM, Stevens L, Robertson B, Zeldis J, Green M, Madarasz-Smith A, Plew D, Storey R, Hume T, Oliver M. 2016a. NZ Estuary Trophic Index Screening Tool 1: Determining eutrophication susceptibility using physical and nutrient load data. Prepared for Envirolink Tools Project: Estuarine Trophic Index, MBIE/NIWA Contract No: C01X1420. 47p.

Robertson BM, Stevens L, Robertson B, Zeldis J, Green M, Madarasz-Smith A, Plew D, Storey R, Hume T, Oliver M. 2016b. NZ Estuary Trophic Index Screening Tool 2: determining monitoring indicators and assessing estuary trophic state. Prepared for Envirolink Tools Project: Estuarine Trophic Index MBIE/NIWA Contract No: C01X1420. 68p.

Stevens LM, Rayes C. 2018. Summary of the Eutrophication Susceptibility and Trophic State of Estuaries in the Tasman Region. Report prepared by Wriggle Coastal Management for Tasman District Council. 16p.

Townsend M, Lohrer D. 2015. ANZECC Guidance for Estuary Sedimentation. NIWA Client Report No: HAM2015-096. Prepared for Ministry for the Environment. 45p

Tuckey BJ, Robertson B, Strickland R. 2004. Broad Scale Mapping of Motueka River Intertidal Delta Habitats using Historical Aerial Photographs. Cawthron Report No. 903. 33p.

WFD-UKTAG. 2014. UKTAG Transitional and Coastal Water Assessment Method Macroalgae Opportunistic Macroalgal Blooming Tool. Water Framework Directive ‐ United Kingdom Technical Advisory Group. Retrieved from: http://www.wfduk.org/sites/default/files/Media/ Characterisation of the water environment/Biological Method Statements/TraC Macroalgae OMBT UKTAG MethodStatement.PDF

Zeldis J, Whitehead A, Plew D, Madarasz-Smith A, Oliver M, Stevens L, Robertson B, Storey R, Burge O, Dudley B. 2017. The New Zealand Estuary Trophic Index (ETI) Tools: Tool 2 - Assessing Estuary Trophic State using Measured Trophic Indicators. Ministry of Business, Innovation and Employment Envirolink Tools: C01X1420.

APPENDICES

APPENDIX 1. BROADSCALE HABITAT CLASSIFICATION DEFINITIONS

Estuary vegetation was classified using an interpretation of the Atkinson (1985) system described in the NEMP (Robertson et al. 2002) with minor modifications as listed.
Revised substrate classes were developed by Salt Ecology to more accurately classify fine unconsolidated substrate.
Terrestrial margin vegetation was classified using the field codes included in the Landcare Research Land Cover Database (LCDB5) - see following page.

VEGETATION (mapped separately to the substrates they overlie and ordered where commonly found from the upper to lower tidal range).

Estuarine shrubland: Cover of estuarine shrubs in the canopy is 20-80%. Shrubs are woody plants <10 cm dbh (density at breast height).
Tussockland: Tussock cover is 20-100% and 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 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*.
Sedgeland: Sedge cover (excluding tussock-sedges and reed-forming sedges) is 20-100% and exceeds that of any other growth form or bare ground. "Sedges have edges". If the stem is clearly triangular, it's a sedge. If the stem is flat or rounded, it's probably a grass or a reed. Sedges include many species of *Carex, Uncinia*, and *Scirpus*.
Grassland[1]: Grass cover (excluding tussock-grasses) is 20-100% and exceeds that of any other growth form or bare ground.
Introduced weeds[1]: Introduced weed cover is 20-100% and exceeds that of any other growth form or bare ground.
Reedland: Reed cover is 20-100% and 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*.
Lichenfield: Lichen cover is 20-100% and exceeds that of any other growth form or bare ground.
Cushionfield: Cushion plant cover is 20-100% and 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.
Rushland: Rush cover (excluding tussock-rushes) is 20-100% and exceeds that of any other growth form or bare ground. A tall grass-like, often hollow-stemmed plant. Includes some species of *Juncus* and all species of *Apodasmia (Leptocarpus)*.
Herbfield: Herb cover is 20-100% and 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.
Seagrass meadows: Seagrasses are the sole marine representatives of the Angiospermae. 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 and are mapped.
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 chlorophyll, 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. Macroalgal density, biomass and entrainment are classified and mapped.
Note NEMP classes of Forest and Scrub are considered terrestrial and have been included in the terrestrial Land Cover Data Base (LCDB) classifications.
[1]Additions to the NEMP classification.

SUBSTRATE (physical and zoogenic habitat)
Sediment texture is subjectively classified as: **firm** if you sink 0-2 cm, **soft** if you sink 2-5cm, **very soft** if you sink >5cm, or **mobile** - characterised by a rippled surface layer.

Artificial substrate: 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, stop-gates. Commonly sub-grouped into artificial: substrates (seawalls, bunds etc), boulder, cobble, gravel, or sand.
Rock field: Land in which the area of basement 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. They 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. They 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. They are named from the leading plant species when plant cover is ≥1%.
Sand: Granular beach sand with a low mud content 0-10%. No conspicuous fines evident when sediment is disturbed.
Sand/Shell: Granular beach sand and shell with a low mud content 0-10%. No conspicuous fines evident.
Muddy sand (Moderate mud content): Sand/mud mixture dominated by sand, but has an elevated mud fraction (i.e. >10-25%). Granular when rubbed between the fingers, but with a smoother consistency than sand with a low mud fraction. Generally firm to walk on.
Muddy sand (High mud content): Sand/mud mixture dominated by sand, but has an elevated mud fraction (i.e. >25-50%). Granular when rubbed between the fingers, but with a much smoother consistency than muddy sand with a moderate mud fraction. Often soft to walk on.
Sandy mud (Very high mud content): Mud/sand mixture dominated by mud (i.e. >50%-90% mud). Sediment rubbed between the fingers is primarily smooth/silken but retains a granular component. Sediments generally very soft and only firm if dried out or another component, e.g. gravel, prevents sinking.
Mud (>90% mud content): Mud dominated substrate (i.e. >90% mud). Smooth/silken when rubbed between the fingers. Sediments generally only firm if dried out or another component, e.g. gravel, prevents sinking.
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

Table of modified NEMP substrate classes and list of Landcare Land Cover Database (LCDB5) classes.

Consolidated substrate			Code
Bedrock		Rock field "solid bedrock"	RF
Coarse Unconsolidated Substrate (>2mm)			
Boulder/ Cobble/ Gravel	>256mm to 4.096m	Boulder field "bigger than your head"	BF
	64 to <256mm	Cobble field "hand to head sized"	CF
	2 to <64mm	Gravel field "smaller than palm of hand"	GF
	2 to <64mm	Shell "smaller than palm of hand"	Shel
Fine Unconsolidated Substrate (<2mm)			
Sand (S)	Low mud (0-10%)	Firm shell/sand	fSS
		Mobile sand	mS
		Firm sand	fS
		Soft sand	sS
Muddy Sand (MS)	Moderate mud (>10-25%)	Firm muddy shell/sand	fSS10
		Mobile muddy sand	mMS10
		Firm muddy sand	fMS10
		Soft muddy sand	sMS10
	High mud (>25-50%)	Firm muddy shell/sand	fSS25
		Mobile muddy sand	mMS25
		Firm muddy sand	fMS25
		Soft muddy sand	sMS25
Sandy Mud (SM)	Very high mud (>50-90%)	Firm sandy mud	fSM
		Soft sandy mud	sSM
		Very soft sandy mud	vsSM
Mud (M)	Mud (>90%)	Firm mud	fM90
		Soft or very soft mud	sM90
Zootic (living)			
		Cocklebed	CKLE
		Mussel reef	MUSS
		Oyster reef	OYST
		Sabellid field	TUBE
Artifical Substrate			
		Substrate (brg, bund, ramp, walk, wall, whf)	aS
		Boulder field	aBF
		Cobble field	aCF
		Gravel field	aGF
		Sand field	aSF

Artificial Surfaces
1 Built-up Area (settlement)
2 Urban ParklandOpen Space
5 Transport Infrastructure
6 Surface Mines and Dumps
Bare or Lightly Vegetated Surfaces
10 Sand and Gravel
12 Landslide
14 Permanent Snow and Ice
15 Alpine Grass/Herbfield
16 Gravel and Rock
Water Bodies
20 Lake or Pond
21 River
Cropland
30 Short-rotation Cropland
33 Orchard Vineyard & Other Perennial Crops
Grassland, Sedge and Saltmarsh
40 High Producing Exotic Grassland
41 Low Producing Grassland
43 Tall-Tussock Grassland
44 Depleted Grassland
45 Herbaceous Freshwater Vegetation
46 Herbaceous Saline Vegetation
Scrub and Shrubland
47 Flaxland
50 Fernland
51 Gorse and/or Broom
52 Manuka and/or Kanuka
54 Broadleaved Indigenous Hardwoods
55 Sub Alpine Shrubland
56 Mixed Exotic Shrubland
58 Matagouri or Grey Scrub
Forest
64 Forest - Harvested
68 Deciduous Hardwoods
69 Indigenous Forest
71 Exotic Forest

Field codes used in the current report

Salt marsh Class	Species/Category	Code
Estuarine Shrub	Plagianthus divaricatus (Salt marsh ribbonwood)	Pldi
Gorse and/or Broom	Ulex europaeus (Gorse)	Uleu
Grassland	Festuca arundinacea (Tall fescue)	Fear
Tussockland	Phormium tenax (New Zealand flax)	Phte
	Poa astonii (Blue shore tussock)	Poas
	Stipa stipoides	Stst
Sedgeland	Schoenoplectus pungens (Three square)	Scpu
Rushland	Apodasmia similis (Jointed wirerush)	Lesi
	Ficinia (Isolepis) nodosa (Knobby clubrush)	Isno
	Juncus kraussii (Searush)	Jukr
Herbfield	Carpobrotus edulis (Ice Plant)	Caed
	Samolus repens (Primrose)	Sare
	Sarcocornia quinqueflora (Glasswort)	Saqu
	Selliera radicans (Remuremu)	Sera
	Suaeda novaezelandiae (Sea blite)	Suno

Substrate Class	Category	Code
Artificial	Artificial substrate	aS
	Artificial boulder field	aBF
	Earth bund	Bund
	Seawall	Wall
Transport Infrastructure	Walkway	walk
Bedrock	Rock field	RF
Boulder/Cobble/Gravel	Cobble field	CF
	Gravel field	GF
	Shell bank	shel
Sand	Mobile sand (0-10% mud)	mS
	Firm shell/sand (0-10% mud)	fSS
	Firm sand (0-10% mud)	fS
	Soft sand (0-10% mud)	sS
Muddy Sand	Mobile muddy sand (>10-25% mud)	mMS10
	Firm muddy sand (>10-25% mud)	fMS10
	Soft muddy sand (>10-25% mud)	sMS10
	Mobile muddy sand (>25-50% mud)	mMS25
	Firm muddy sand (>25-50% mud)	fMS25
	Soft muddy sand (>25-50% mud)	sMS25
Sandy Mud	Firm sandy mud (>50-90% mud)	fSM
	Soft sandy mud (>50-90% mud)	sSM
	Very soft sandy mud (>50-90% mud)	vsSM
Mud	Firm mud (>90% mud)	fM90
Zootic	Cocklebed	CKLE
	Mussel reef	MUSS
	Oyster reef	OYST
	Sabellid field	TUBE

APPENDIX 2. SUBSTRATE CLASSIFICATION VALIDATION RESULTS

Sampling locations (May 2019) and supporting data for the validation of substrate classifications are presented in the following Table.

Sediment samples were collected from fine unconsolidated substrates representative of the wider estuary and classified in the field based on the criteria described in Appendix 1 (Field Code in table below). Samples corresponding to these classes were subsequently analysed for grain size (Appendix 3) to provide validation of the classification applied. There was generally a high level of concordance between the field code applied and the measured sediment grain size.

FieldCode	MudPct	Station	NZTM East	NZTM North
mS	2.3	Sed1	1600369	5454708
mS	2.7	Sed8	1601621	5452725
fMS25	31.3	Sed5	1600529	5452948
fMS25	37.4	Sed6	1600617	5453332
fMS25	34.4	Sed7	1601149	5452744
sMS25	42.8	Sed2	1600800	5453734
sSM	68.2	Sed9	1601755	5452586
vsSM	66.0	Sed3	1600966	5453889
sM90	91.2	Sed4	1600524	5453150

APPENDIX 3. LABORATORY METHODS AND RESULTS

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Certificate of Analysis

SPv1

Client:	Salt Ecology Limited	**Lab No:**	2171418
Contact:	Leigh Stevens	**Date Received:**	07-May-2019
	C/- Salt Ecology Limited	**Date Reported:**	13-Jun-2019
	21 Mount Vernon Place	**Quote No:**	98856
	Washington Valley	**Order No:**	
	Nelson 7010	**Client Reference:**	TDC Motueka Delta
		Submitted By:	Leigh Stevens

Sample Type: Sediment

Sample Name:		RIWA-TASM SED 1 03-May-2019	RIWA-TASM SED 2 03-May-2019	RIWA-TASM SED 3 03-May-2019	FERR-TASM SED F1 03-May-2019	FERR-TASM SED F2 03-May-2019
Lab Number:		2171418.1	2171418.2	2171418.3	2171418.4	2171418.5
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	78	74	67	67	81
3 Grain Sizes Profile as received						
Fraction >/= 2 mm	g/100g dry wt	< 0.1	0.8	0.1	0.4	23.7
Fraction < 2 mm, >/= 63 µm	g/100g dry wt	97.6	56.4	33.9	8.4	45.0
Fraction < 63 µm	g/100g dry wt	2.3	42.8	66.0	91.2	31.3

Sample Name:		MTKA-TASM SED M1 03-May-2019	MTKA-TASM SED M2 03-May-2019	MTKA-TASM SED M3 03-May-2019	FERR-TASM SED F3 03-May-2019	
Lab Number:		2171418.6	2171418.7	2171418.8	2171418.9	
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	81	78	42	76	-
3 Grain Sizes Profile as received						
Fraction >/= 2 mm	g/100g dry wt	0.4	0.5	< 0.1	1.0	-
Fraction < 2 mm, >/= 63 µm	g/100g dry wt	65.2	96.7	31.8	61.6	-
Fraction < 63 µm	g/100g dry wt	34.4	2.7	68.2	37.4	-

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment

Test	**Method Description**	**Default Detection Limit**	**Sample No**
Individual Tests			
Dry Matter for Grainsize samples (sieved as received)	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-9
3 Grain Sizes Profile as received			
Fraction >/= 2 mm	Wet sieving with dispersant, as received, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-9
Fraction < 2 mm, >/= 63 µm	Wet sieving using dispersant, as received, 2.00 mm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-9
Fraction < 63 µm	Wet sieving with dispersant, as received, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-9

APPENDIX 4. OPPORTUNTISTIC 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 waterbody. 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 (%'age 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 A1).

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. >1kg.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 A1. The final face value thresholds and metrics for levels of the ecological quality status.

ECOLOGICAL QUALITY RATING (EQR)	High	Good	Moderate	Poor	Bad
	≥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 should be 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 categories in Table A1:

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 A2).

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 A2 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.

REFERENCES

DETR, 2001. Development of ecological quality objectives with regard to eutrophication. Final report, unpublished.

Foden, J., Wells, E., Scanlan, C., Best M.A. 2010. Water Framework Directive development of classification tools for ecological assessment: Opportunistic Macroalgae Blooming. UK TAG Report for Marine Plants Task Team, January 2010, Publ. UK TAG.

Hull, S.C., 1987. Macroalgal mats and species abundance: a field experiment. Estuar. Coast. Shelf Sci. 25, 519-532.

Lowthion, D., Soulsby, P.G., and Houston, M.C.M. 1985. Investigation of a eutrophic tidal basin: 1. Factors affecting the distribution and biomass of macroalgae. Marine Environmental Research 15: 263–284.

Raffaelli, D., Hull, S., Milne, H., 1989. Long-term changes in nutrients, weedmats and shore birds in an estuarine system. Cah. Biol. Mar. 30, 259–270.

WFD-UKTAG (Water Framework Directive – United Kingdom Technical Advisory Group) 2014. UKTAG Transitional and Coastal Water Assessment Method Macroalgae Opportunistic Macroalgal Blooming Tool. Retrieved from http://www.wfduk.org/sites/default/files/Media/Characterisation of the water environment/Biological Method Statements/TraC Macroalgae OMBT UKTAG Method Statement.PDF.

Wither, A., 2003. Guidance for sites potentially impacted by algal mats (green seaweed). EC Habitats Directive Technical Advisory Group report WQTAG07c.

Table A2. 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	399.99	≥0.6	<0.8	0.2
	Moderate	≤1000	>500	499.99	≥0.4	<0.6	0.2
	Poor	≤3000	>1000	1999.9	≥0.2	<0.4	0.2
	Bad	≤6000	>3000	2999.9	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	399.99	≥0.6	<0.8	0.2
	Moderate	≤1000	>500	499.99	≥0.4	<0.6	0.2
	Poor	≤3000	>1000	1999.9	≥0.2	<0.4	0.2
	Bad	≤6000	>3000	2999.9	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	149.99	≥0.2	<0.4	0.2
	Bad	≤6000	>250	5749.9	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

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

Ferrer Creek Estuary - location of macroalgal patches and data summary, May 2019.

ValidCode	Pct_Cover	PatchID	CrsPctCov	Biomassgm2	Origin	DomHab	Area_ha
Grch	80	2	Dense (70 to <90%)	2560	Estuarine	Gracilaria chilensis	0.290942
Grch	90	1	Complete (>90%)	1560	Estuarine	Gracilaria chilensis	0.184848
Grch	100	1	Complete (>90%)	1560	Estuarine	Gracilaria chilensis	0.107146
Bare	0	None	Trace (<1%)	0			22.590192

Ferrer Creek Estuary

0 0.05 0.1 0.2 0.3 0.4 0.5 Kms

APPENDIX 5. ADDITIONAL NOTES SUPPORTING TABLE 4 RATINGS

Sedimentation Mud Content

Sediments with mud contents of <25% are generally relatively firm to walk on. When mud contents increase above ~25%, sediments start to become softer, more 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, and sediment bound nutrients and heavy metals whose concentrations typically increase with increasing mud content. Consequently, muddy sediments are often poorly oxygenated, nutrient rich, can have elevated heavy metal concentrations 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 re-suspension of fine muds, impacting on seagrass, birds, fish and aesthetic values.

Soft Mud Percent Cover

Sediments with >25% mud content have been shown to result in a degraded macroinvertebrate community (Robertson et al. 2015, 2016), and an excessive mud content decreases water clarity, lowers biodiversity and affects aesthetics and access. Because estuaries are sinks for sediments, the presence of large areas of soft mud are likely to lead to major and detrimental ecological changes that could be very difficult to reverse. In particular, the widespread presence of sediments dominated by fine mud indicates where changes in land management may be needed. In most instances sediments with >25% mud content are soft and can be identified using the NEMP protocols based on how much a person sinks when walking (Robertson et al. 2002). If an estuary is suspected of having >25% mud content but has substrate that remains firm to walk on (e.g. dried muds, presence of underlying gravels), it is recommended that particle grain size analyses of relevant areas be used to determine the extent of the estuary with sediment mud contents greater than 25%.

Apparent Redox Potential Discontinuity (aRPD)

aRPD depth, the visually apparent transition between oxygenated sediments near the surface and deeper more anoxic sediments, is a primary estuary condition indicator as it is a direct measure of time integrated sediment oxygenation. Knowing if the aRPD is close to the surface is important for three main reasons:

The closer to the surface anoxic sediments are, the less habitat there is available for most sensitive macroinvertebrate species. The tendency for sediments to become anoxic is much greater if the sediments are muddy. Anoxic sediments contain toxic sulphides and support very little aquatic life. As sediments transition from oxic to anoxic, a "tipping point" is reached where nutrients bound to sediment under oxic conditions, becomes released under anoxic conditions to potentially fuel algal blooms that can degrade estuary quality.

In sandy porous sediments, the aRPD layer is usually relatively deep (greater than 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 less than 1cm (Jørgensen and Revsbech 1985) unless bioturbation by infauna oxygenates the sediments.

Opportunistic Macroalgae

The presence of opportunistic macroalgae is a primary indicator of estuary eutrophication, and when combined with high mud and low oxygen 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 WFD-UKTAG (Water Framework Directive – United Kingdom Technical Advisory Group), 2014; Robertson et al 2016a,b; Zeldis et al. 2017), with results combined with those of other indicators to determine overall condition.

Seagrass

Seagrass (*Zostera muelleri*) grows in soft sediments in most NZ estuaries. It is widely acknowledged that the presence of healthy seagrass beds enhances estuary biodiversity and particularly improves benthic ecology (Nelson 2009). 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 are likely to indicate an increase in these types of pressures.

The assessment metric used is the percent change from baseline measurements.

Salt marsh

Salt marshes 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 salt marsh grows in the upper estuary margins above mean high water neap (MHWN) tide where vegetation stabilises fine sediment transported by tidal flows. Salt marsh zonation is commonly evident, resulting from the combined influence of factors including salinity, inundation period, elevation, wave exposure, and sediment type. Highest salt marsh 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, salt marsh is commonly dominated by relatively low diversity rushland and herbfields. Below this, the MHWN to Mean Sea Level (MSL) range is commonly unvegetated or limited to either mangroves or *Spartina*, the latter being able to grow to MLWN. Further work is required to develop a comprehensive salt marsh metric for NZ. As an interim measure, the % of the intertidal area comprising salt marsh is used to indicate salt marsh condition, with a supporting metric proposed of % loss from Estimated Natural State Cover. This assumes that a reduction in natural state salt marsh cover corresponds to a reduction in ecological services and habitat values. The interim condition ratings proposed for these ratings are Very Good 80-100%, Good 60-80%, Fair 40-60%, and Poor <40%. The "early warning trigger" for initiating management action/further investigation is a trend of a decreasing salt marsh area.

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 salt marsh and estuary. This buffer is sensitive to a wide range of pressures including land reclamation and drainage, margin development, flow regulation, sea level rise, grazing, and weed invasion. A dense buffer 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 less than 50% of the estuary with a densely vegetated 200m terrestrial margin. Land cover at a catchment-wide scale is also a very valuable metric. Landcare Research provide regular national-scale GIS layers (Land Cover Data Base - LCDB) which can be used to develop relationships between estuary state and land cover type, and changes in catchment land cover over time.

REFERENCES

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

Nelson, Walter G. (ed.) 2009. Seagrasses and Protective Criteria: A Review and Assessment of Research Status. Office of Research and Development, National Health and Environmental Effects Research Laboratory, EPA/600/R-09/050.

Robertson B, Gillespie P, Asher R, Frisk S, Keeley N, Hopkins G, Thompson S, Tuckey B 2002. Estuarine Environmental assessment and monitoring: A national protocol part A. Development of the monitoring protocol for New Zealand estuaries. Introduction, rationale and methodology.

Sustainable Management Fund Contract No. 5096, Cawthron Institute, Nelson, New Zealand. 93p.

Robertson, B.M., Stevens, L., Robertson, B.P., Zeldis, J., Green, M., Madarasz-Smith, A., Plew, D., Storey, R., Hume, T. and Oliver, M. 2016a, b. NZ Estuary Trophic Index. Screening Tool 1. Determining eutrophication susceptibility using physical and nutrient load data (47p). Screening Tool 2. Determining Monitoring Indicators and Assessing Estuary Trophic State (68p). Prepared for Envirolink Tools Project: Estuarine Trophic Index MBIE/NIWA Contract No: C01X1420.

Robertson, B.P., Gardner, J.P.A. and Savage, C., 2015. Macrobenthic – mud relations strengthen the foundation for benthic index development : A case study from shallow, temperate New Zealand estuaries. Ecological Indicators, 58, pp.161–174. Available at: http://dx.doi.org/10.1016/j.ecolind.2015.05.039.

Robertson, B.P., Savage, C., Gardner, J.P.A., Robertson, B.M. and Stevens, L.M. 2016. Optimising a widely-used coastal health index through quantitative ecological group classifications and associated thresholds. Ecological Indicators, 69, pp.595–605.

WFD-UKTAG (Water Framework Directive – United Kingdom Technical Advisory Group) 2014. UKTAG Transitional and Coastal Water Assessment Method Macroalgae Opportunistic Macroalgal Blooming Tool.http://www.wfduk.org/sites/default/files/Media/Characterisation of the water environment/Biological Method Statements/TraC Macroalgae OMBT UKTAG Method Statement.PDF.

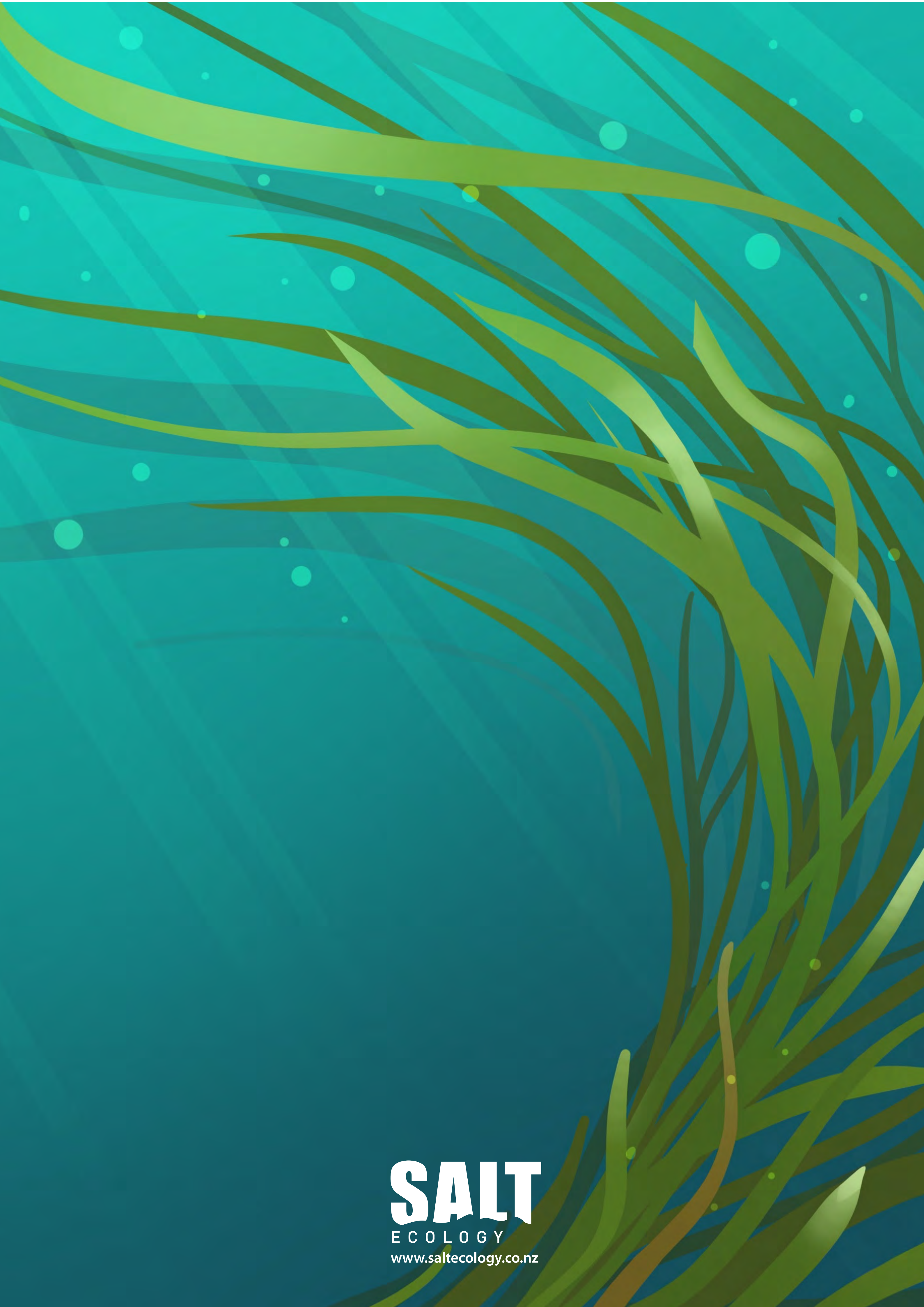
Zeldis J, Whitehead A, Plew D, Madarasz-Smith, A, Oliver M, Stevens L, Robertson B, Storey R, Burge O, Dudley B. 2017. The New Zealand Estuary Trophic Index (ETI) Tools: Tool 2 - Assessing Estuary Trophic State using Measured Trophic Indicators. Ministry of Business, Innovation and Employment Envirolink Tools: C01X1420.

APPENDIX 6. SUMMARY OF HISTORICAL DATA

Summary data extracted from GIS files provided by TDC and modified following QAQC checks, or sourced directly from Robertson et al. (2003) and Tuckey et al. (2004).

Key Estuary features (ha)	Riwaka	Ferrer Creek				Change: 2003-2019		Motueka River				Change: 2003-2019		Motueka				Change: 2003-2019	
Year	2019	1947	1986	2003	2019	ha	%	1947	1986	2003	2019	ha	%	1947	1986	2003	2019	ha	%
Intertidal area	54.9			21.3	23.2					80.6	94.0					72.3	72.4		
Subtidal area	3.6			1.4	1.0					16.1	13.9					5.5	4.9		
Estuary area	58.5			22.7	24.2					96.7	107.9					77.9	77.3		
Saltmarsh extent	5.7	10.4	6.4	6.1	6.4	0.3	6	46.5	21.1	22.2	33.6	11.3	51	26.2	26.0	28.2	23.3	-4.9	-17
Estuarine shrub	0.2		0.05	0.05	0.2	0.2	338	33.7	13.8	9.7	8.0	-1.7	-18	3.3	3.7	4.7	2.8	-1.9	-40
Grassland		0.4	0.1							0.1	3.5	3.4	2551	0.2					
Tussockland											0.1	0.1	n/a						
Reedland									0.2	0.1		-0.1	-100	0.4	0.2	0.2		-0.2	-100
Rushland	4.6	9.9	6.1	5.6	4.6	-1	-17	12.7	6.0	10.2	14.4	4	42	11.9	9.8	10.1	4.7	-5	-53
Herbfield	1.7	0.1	0.2	0.5	1.7	1.2	248	0.1	1.2	2.1	7.5	5.4	256	10.3	12.2	13.3	15.8	2.6	19
Seagrass (>50%cover)	0.7																		
Macroalgal beds (>50% cover)					0.6														
High Enrichment Conditions (HECs)					0.6														

		Riwaka		Ferrer Creek				Motueka River				Motueka			
		2019		2003		2019		2003		2019		2003		2019	
Class	Dominant Substrate	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Salt marsh*	Undefined			6.1	28.6			22.2	27.6			28.2	38.9		
Artificial	Artificial substrate	0.2	0.4			0.1	0.4	0.2	0.3	0.2	0.2	0.2	0.3		
Bedrock	Rock field			0.003	0.02										
Boulder/Cobble/ Gravel	Boulder field									0.1	0.2				
	Cobble field			0.1	0.4	0.03	0.1	19.0	32.7	9.0	9.5	1.4	3.2	3.7	5.1
	Gravel field	0.3	0.5			0.8	3.7			5.2	5.6	0.1	0.1	5.0	6.9
Sand (0-10% mud)	Mobile sand	25.0	45.6	4.8	31.7	3.7	15.9	3.7	6.3	10.2	10.8			4.8	6.7
	Firm sand	9.3	17.0	1.3	8.8	1.1	4.7	3.2	5.6	3.7	4.0	5.4	12.1	2.4	3.3
	Firm shell/sand											0.7	1.6		
Muddy Sand (>10-25% mud)	Mobile muddy sand	0.3	0.6			0.2	0.7			21.0	22.4				
	Firm muddy sand	7.7	14.1			5.4	23.3							10.6	14.6
	Soft muddy sand	1.0	1.7												
Muddy Sand (>25-50% mud)	Firm muddy sand	0.4	0.8			6.3	27.0			40.8	43.4			45.1	62.3
	Soft muddy sand	0.6	1.1							2.0	2.1			0.7	1.0
Sandy Mud (>50-90% mud)	Firm sandy mud	0.3	0.6	4.1	26.7			26.4	45.2			14.3	32.3		
	Soft sandy mud	5.6	10.2	4.9	32.3	0.8	3.6	5.8	10.0	0.03	0.03	22.3	50.6		
	Very soft sandy mud	4.0	7.3			4.8	20.6			1.6	1.7				
Zootic	Oyster reef											0.02	0.04		
Total		**54.9**	**100**	**21.4**	**100**	**23.2**	**100**	**80.5**	**100**	**94.0**	**100**	**72.6**	**100**	**72.4**	**100**
*substrate within salt marsh not specified in 2003															
Mud-dominated sediment		9.9	18.1	9.0	59.0	5.6	24.2	32.2	55.2	1.7	1.8	36.6	82.9	0.0	0.0



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