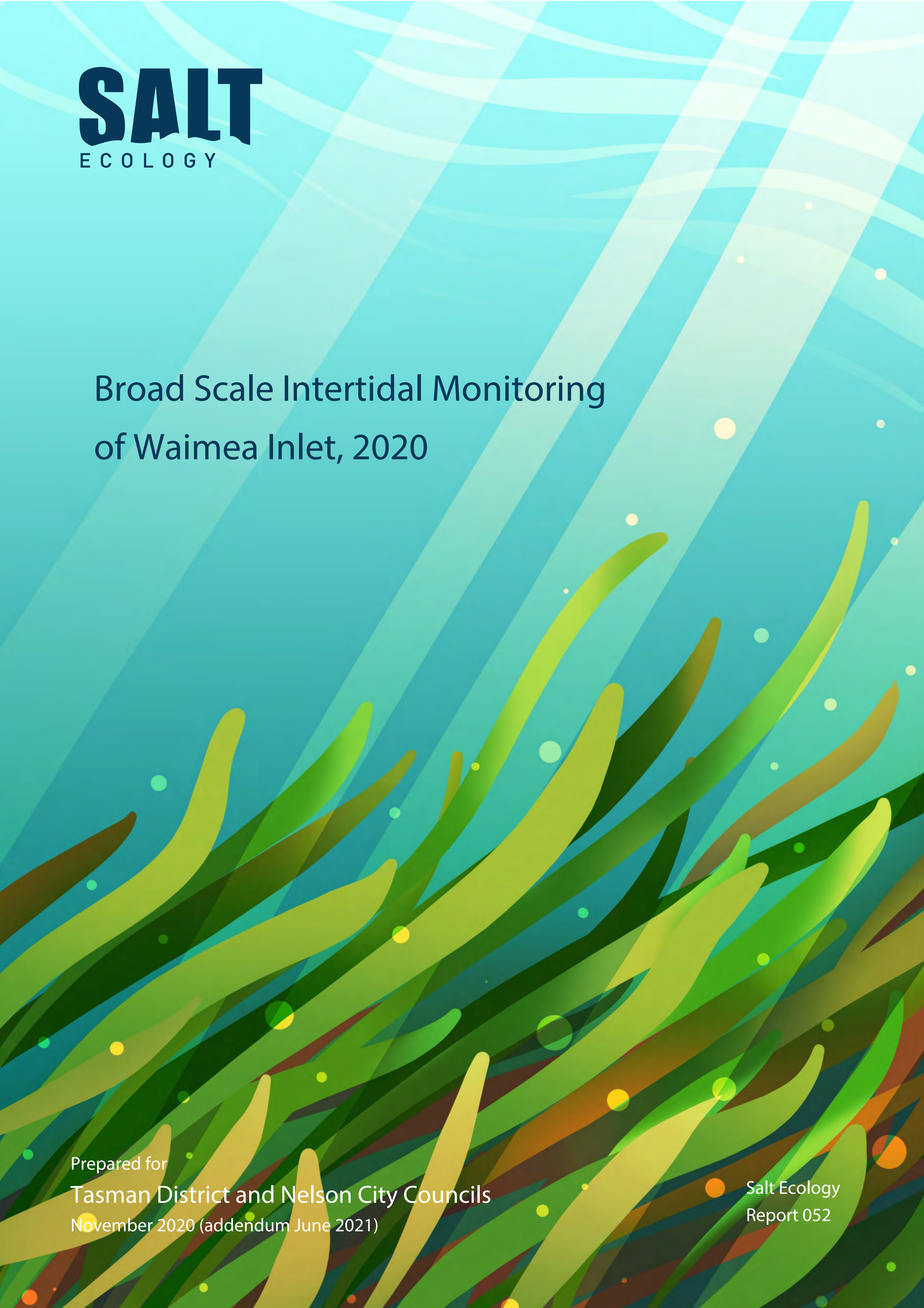

Broad Scale Intertidal Monitoring of Waimea Inlet, 2020

Prepared for
Tasman District and Nelson City Councils
November 2020 (addendum June 2021)

Salt Ecology
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Broad Scale Intertidal Monitoring of Waimea Inlet

Prepared by

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for

Tasman District and Nelson City Councils

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GLOSSARY

AIH	Available Intertidal Habitat
aRPD	Apparent Redox Potential Discontinuity
DOC	Department of Conservation
EQR	Ecological Quality Rating
ETI	Estuary Trophic Index
GIS	Geographic Information System
GEZ	Gross Eutrophic Zone
HEC	High Enrichment Conditions
LCDB	Land Cover Data Base
NCC	Nelson City Council
NEMP	National Estuary Monitoring Protocol
OMBT	Opportunistic Macroalgal Blooming Tool
SOE	State of Environment (monitoring)
TDC	Tasman District Council

ADDENDUM

June 2021: Section 3.4 reworded to clarify that apparent 36ha decline in salt marsh cover from 2006 to 2020 primarily reflected more accurate classification in 2020 rather than a recent loss of salt marsh, with most of the reported salt marsh losses occurring prior to 2006 as a result of margin development. Appendix 9 added showing spatial location of changes between 2006 and 2020.

ACKNOWLEDGEMENTS

Many thanks to Trevor James (TDC) and Paul Fisher and Vikki Ambrose (NCC) for review comments on the draft report. We are also grateful to Courtney Rayes for field assistance. The tools used to produce GIS summaries and maps were developed by Megan Southwick (Salt Ecology). Pete Inwood (TDC) provided the rectified LINZ aerials used in the mapping.

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EXECUTIVE SUMMARY

BACKGROUND

This report summarises the results of broad scale habitat mapping of Waimea Inlet undertaken in May 2020. The estuary is part of a long-term coastal monitoring programme undertaken by the Tasman District and Nelson City Council's. The primary purpose of the 2020 survey was to describe and map the dominant substrate and vegetation features present including seagrass, salt marsh and macroalgae based on the framework outlined in New Zealand's National Estuary Monitoring Protocol (NEMP). Results were compared to previous NEMP surveys (1999, 2006, 2014) and for some indicators (e.g. salt marsh extent) with earlier data from 1946, 1985 and 1990. All previous GIS data (for all years except 1990) were QA/QC checked and updated to address any errors in geometry or typology.

KEY FINDINGS

The following is a summary of key findings with respect to the indicators measured, with values compared to rating criteria for New Zealand estuaries.

- Waimea Inlet is an intertidally-dominated estuary (81% of estuary area) with a large proportion of the intertidal flats being perched high in the tidal range such that they are exposed for long parts of the tidal cycle. The catchment is dominated by indigenous and exotic forest, and pasture.
- The estuary is relatively muddy, with 46.8% of the intertidal area consisting of sediment having >50% mud content, most of which is located in deposition zones in the mid-upper intertidal basins and embayments of both the east and west arms. The input of mud-dominated sediment appears to be largely historical, with anecdotal reports of high inputs sourced, in part, following the development of orchard land in the 1950's and 1960's.
- Seagrass beds are sparse across the estuary, covering ~2% of the intertidal area and located almost exclusively near the well-flushed entrance channel and central basin of the eastern arm. There has been a decrease in the extent of the beds since 2014 (largely attributable to improved mapping accuracy), and >60% reduction since the first records in 1990 (reflecting actual losses).
- Nuisance opportunistic algal growths are uncommon. At an estuary-wide scale, the macroalgal ecological quality rating was 0.73, giving a rating of 'good'. This result is consistent with NIWA's CLUES model estimates which indicate that nutrient loads are well below the threshold where nuisance growths would be commonly encountered. Despite this situation, there were a few localised hotspots (~20ha) of persistent opportunistic macroalgae growth in 2020 (mainly of the red seaweed *Gracilaria chilensis*) where degraded 'High Enrichment Condition' (HECs) have established.
- Salt marsh remains a significant feature of the estuary (~10% of the intertidal) and is dominated by herbfield species. However, its prevalence is greatly reduced from its assumed historic extent through drainage, reclamation, margin development and channelisation. Since 1946 there has been a further reduction in salt marsh area of ~24%. Currently, initiatives are underway to enhance or restore some of this high-value habitat.
- As illustrated in previous surveys, the 200m wide terrestrial margin bordering the estuary is highly modified and comprises very few habitat features that are in their natural state. Only 18% of the margin was classified as densely vegetated in 2020, the majority of which is exotic forestry. In many areas the terrestrial margin has been highly modified by roading, causeways, seawalls, reclamations, or land clearance.

Overall, despite extensive historical habitat modification, significantly reduced habitat diversity, and large areas of mud-dominated sediments, Waimea Inlet retains many areas of very significant ecological value. However, the prevalence of mud-dominated substrate, the persistence of localised dense macroalgal beds and HEC's, and pressures on salt marsh near the estuary margin from drainage and reclamation are key broad scale habitat stressors that threaten these values. Salt marsh losses are likely to increase in future in response to sea level rise due to the current limited capacity for landward migration. Reductions in sediment loads, and targeted management of localised nutrient inputs, will be required to improve estuary condition.

Summary of broad scale condition rating scores

Indicator	Unit	1946	1985	1990	1999	2006	2014	2020
Mud-dominated substrate[1]	% of intertidal area >50% mud	na	na	33	70	40	35	38
Macroalgae (OMBT)	Ecological Quality Rating (EQR)	na	na	na	na	0.6	0.55	0.73
Seagrass (>50%)[2]	% decrease from baseline	na	na	na	51.3	47.8	47.4	62.8
Salt marsh extent (current)	% of intertidal area	12.5	9.6	7.2	8.1	11.2	10.8	9.9
Historical salt marsh extent[3]	% of historical remaining[3]	<40	<40	<40	<40	<40	<40	<40
200m terrestrial margin	% densely vegetated	na	na	na	na	na	22	18
High Enrichment Conditions	ha	na	na	na	na	na	28	20.3
High Enrichment Conditions	% of estuary	na	na	na	na	na	0.7	0.6

[1] To enable comparison across years, mud dominated substrate assessed as percentage of intertidal area excluding salt marsh

[2] Seagrass change rated for total seagrass cover (>50%)

[3] Historic salt marsh extent not formally assessed, but assumed to have been >900ha

na=not available/not appropriate

Condition rating key:

Very Good	Good	Fair	Poor

RECOMMENDATIONS

Waimea Inlet has been identified by TDC and NCC as a priority for monitoring because of its high ecological and human use values, and because it is vulnerable to elevated sedimentation and localised eutrophication issues. Based on the 2020 results, the following recommendations are proposed for consideration:

Monitoring

Broad Scale Habitat

In order to track changes in the dominant features of the estuary, undertake broad scale habitat mapping at 5-10 yearly intervals. In light of the potential for rapid changes to nuisance macroalgal beds, the extent and state of established and persistent macroalgal beds should be synoptically assessed annually to determine the need for further or more frequent monitoring.

Sedimentation Rate

Given the consistency of sedimentation rate monitoring results over the past 10 years it is recommended that sedimentation be monitored biennially.

Catchment Influences

Where localised opportunistic nuisance macroalgal growths are present, it is recommended that the potential source of nutrients to these parts of the estuary be investigated and managed as appropriate.

The councils are encouraged to maintain records on the location and scale of known catchment disturbances or land use changes to assist in the interpretation of monitoring results. 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. The use of forensic methods such as compound specific stable isotopes (CSSI) to trace the source of wider catchment sediment and nutrient inputs is also recommended.

Management and Restoration

There is significant potential for the ecological restoration of Waimea Inlet. Current strategies to identify and prioritise efforts need to account for future climate change effects, and would ideally contribute to a region-wide planning approach facilitated to assist community and stakeholder initiatives. Further, opportunities for creating new habitat or increasing and enhancing the vegetative buffering capacity of the estuary should be explored through existing work wherever possible, e.g. requirements to increase the number and size of causeway culverts, avoid or remove unnecessary shoreline barriers, or undertake supplementary planting as part of future road maintenance or protection works.

1. INTRODUCTION

1.1 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 nationally with a scientifically defensible, cost-effective and standardised approach for monitoring the ecological status of estuaries in their region. The results establish 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 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) and Nelson City Council (NCC) have undertaken monitoring of selected estuaries in their regions using the NEMP methods (since 1999) and other comparable approaches since 1990. In the Waimea Inlet (Fig. 1), the first comprehensive habitat mapping was undertaken by the Department of Conservation (DOC) in 1990 (Davidson & Moffat 1990) with the first NEMP broad and fine scale surveys undertaken with the support of TDC and NCC in 1999 and 2001, respectively (Robertson & Stevens 2008; Stevens & Robertson 2008), as part of the NEMP development. Since then, TDC and NCC have commissioned follow-up and related surveys, including:

- Broad scale mapping of historical salt marsh cover using aerial photographs from 1946 and 1985 (Tuckey & Robertson 2003).
- Repeat NEMP broad scale surveys in 2006 (Clark et al. 2008) and 2014 (Stevens & Robertson 2014).

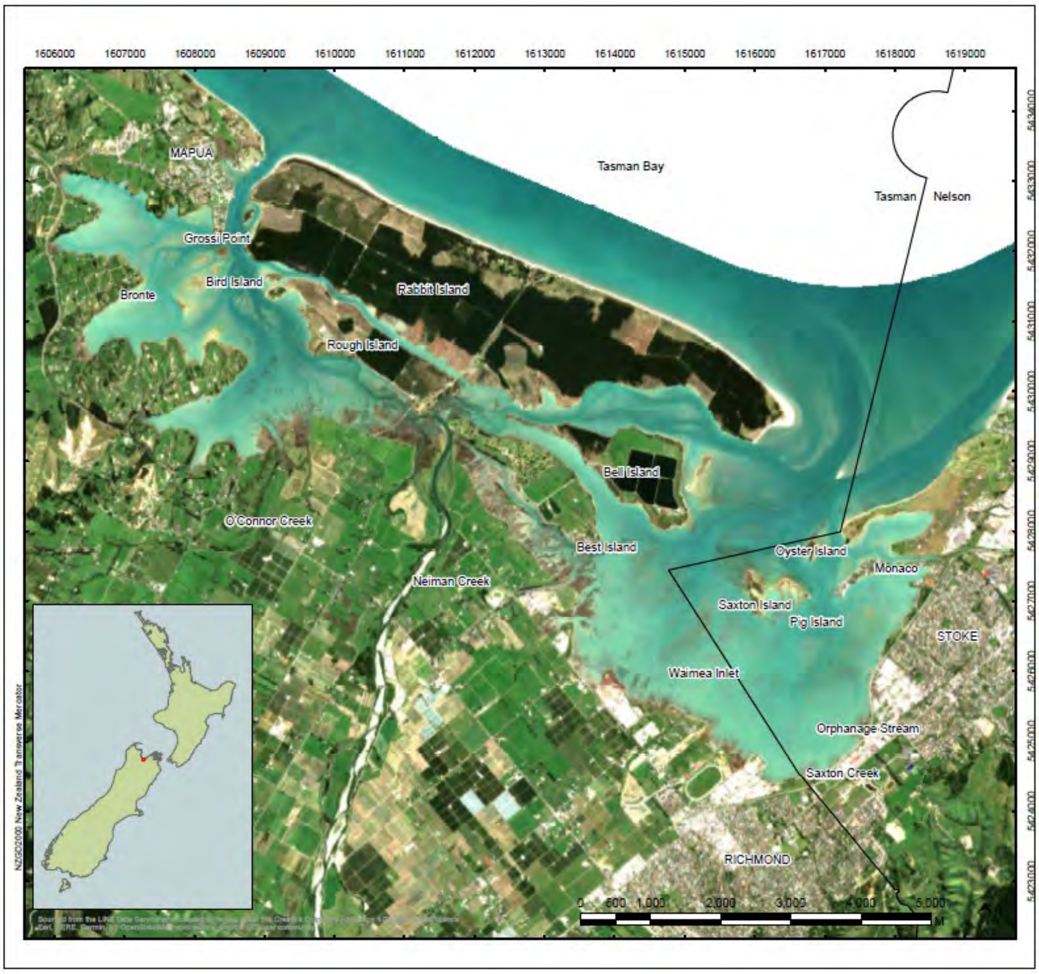


Fig. 1 Location of Waimea Inlet and places names referred to in text.

- NEMP fine scale surveys in 2001 (Robertson et. al 2002), 2006 (Gillespie et al. 2007), and 2014 (Robertson & Robertson 2014). Additional fine scale data were collected from three sites in 2015 and 2016, which is scheduled to be reported in 2021.

In addition, TDC have commissioned a variety of supporting studies, including targeted ecological surveys of intertidal sponge gardens (Asher et al. 2008), ecological vulnerability assessments of the estuary and wider coastline (Stevens & Robertson 2010; Robertson & Stevens 2012, Stevens & Rayes 2018), historical sediment coring using radioactive isotopes (Stevens & Robertson 2011), and an assessment of sediment sources by land use (Gibbs & Woodward 2018). In addition, TDC have initiated and undertaken near-annual sedimentation rate monitoring at 13 sites throughout the estuary since 2008,. Estuarine fish and coastal bird surveys are scheduled in the Waimea Inlet in the summer of 2021.

Salt Ecology was contracted to undertake a repeat NEMP broad scale intertidal mapping survey in the Inlet in May 2020. This report describes the methods and results of the survey, compares findings with earlier intertidal NEMP broad scale surveys (1999, 2006, 2014) and earlier survey data where appropriate, and discusses the current status and trends in estuary health. Recommendations for future monitoring and assessment are also made.

1.2 DESCRIPTION OF WAIMEA INLET

Background information on Waimea Inlet was detailed in the 2014 broad scale report (Stevens & Robertson 2014) and is summarised below.

Waimea Inlet is a large (3462ha), shallow, well-flushed tidal lagoon type estuary fed by the Waimea River and a number of small streams. The estuary comprises two main intertidal basins, each with side arms and embayments, some separated by causeways, and numerous islands. It discharges to Tasman Bay via two tidal entrances at either end of Rabbit Island. Residence time in the estuary is less than 1 day, with the estuary almost completely draining at low tide.

The estuary has high human use and high ecological values. It is recognised as a valuable nursery area for marine and freshwater fish, is an extensive shellfish resource, and is very important for birdlife. While dominated by intertidal sand and mudflats, the well flushed and often steeply incised estuary channels are deep and, particularly near the entrances, support a variety of cobble, gravel, sand, and biogenic (oyster, tubeworm) habitats.

However, the estuary has been extensively modified over the years leading to historical loss of seagrass and salt marsh habitat. Catchment land use (Table 1, Fig. 2) is dominated by indigenous and exotic forestry, and high producing exotic grassland, while much of the estuary margin is directly bordered by developed urban and rural land, roads, cycleways/walkways, causeways, and seawalls.

The last broad scale survey showed that while large sections of the estuary remain in good condition, a decline in many of the estuary condition indicators had occurred since early surveys. Various reports have identified excessive muddiness as a major problem in the estuary basins and sheltered arms and, to a lesser extent, localised areas of nuisance opportunistic macroalgal growth (Clark et al. 2008; Stevens & Robertson 2014).

Table 1. Summary of catchment land cover (LCDB5 2018) for Waimea Inlet.

LCDB5 (2018) Class and Name		Ha	%
1	Built-up Area (settlement)	2356.7	2.5
2	Urban Parkland/Open Space	602.6	0.6
5	Transport Infrastructure	115.1	0.1
6	Surface Mine or Dump	77.3	0.1
10	Sand or Gravel	28.3	0.03
15	Alpine Grass/Herbfield	396.9	0.4
16	Gravel or Rock	592.7	0.6
20	Lake or Pond	112.1	0.1
21	River	15.8	0.02
22	Estuarine Open Water	133.5	0.1
30	Short-rotation Cropland	888.1	0.9
33	Orchard, Vineyard Other Perennial Crop	2689.9	2.8
40	High Producing Exotic Grassland	18357.0	19.4
41	Low Producing Grassland	501.1	0.5
43	Tall Tussock Grassland	1934.1	2.0
45	Herbaceous Freshwater Vegetation	6.2	0.01
46	Herbaceous Saline Vegetation	91.7	0.1
50	Fernland	67.1	0.1
51	Gorse and/or Broom	959.6	1.0
52	Manuka and/or Kanuka	2769.7	2.9
54	Broadleaved Indigenous Hardwoods	2171.9	2.3
55	Sub Alpine Shrubland	494.4	0.5
56	Mixed Exotic Shrubland	107.9	0.1
64	Forest - Harvested	4681.5	5.0
68	Deciduous Hardwoods	198.6	0.2
69	Indigenous Forest	28614.2	30.3
71	Exotic Forest	25491.0	27.0
	Total	**94455**	**100**

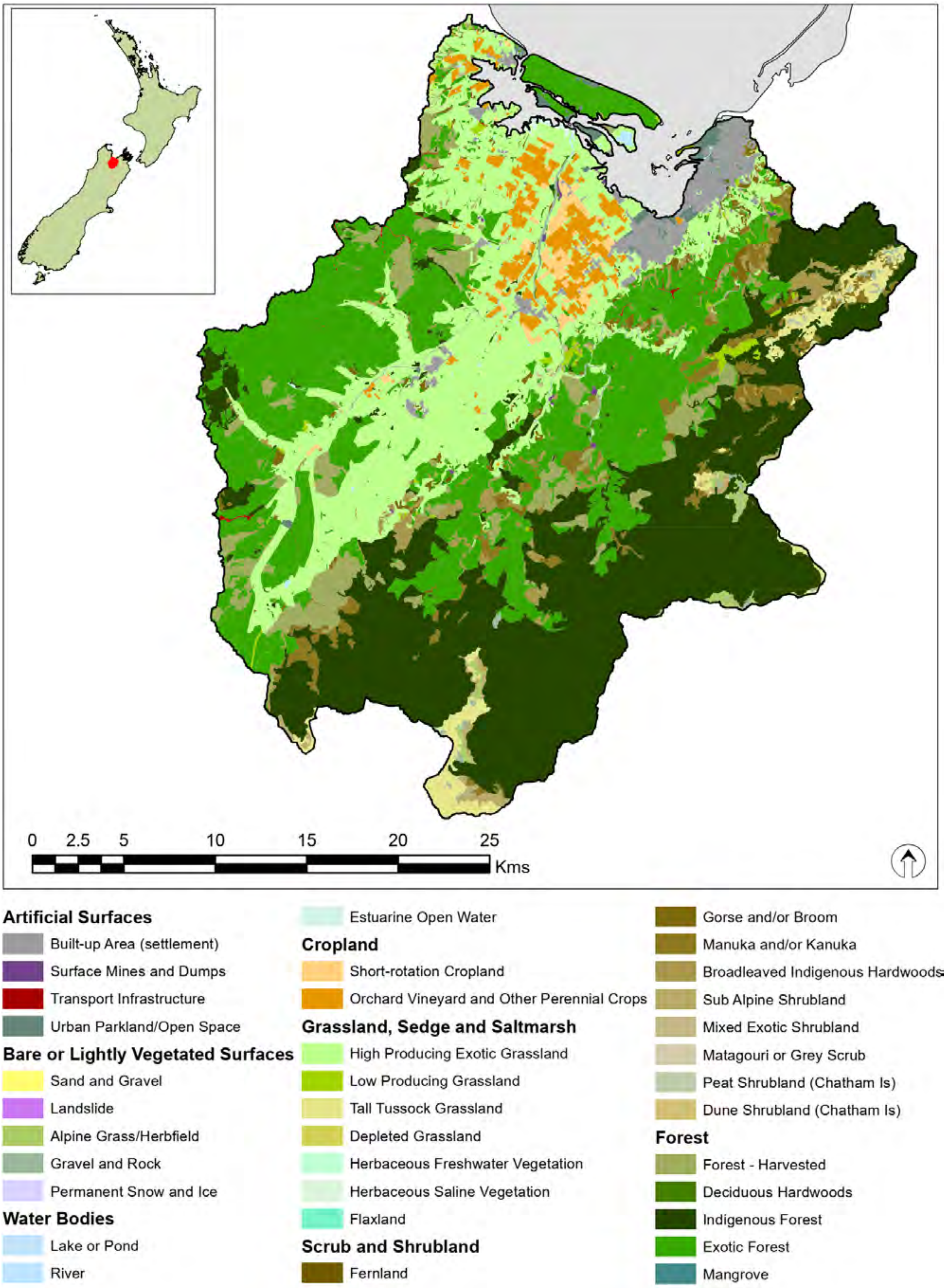


Fig. 2 Waimea Inlet and surrounding catchment.

2. BROAD SCALE METHODS

2.1 OVERVIEW OF MAPPING

Broad-scale surveys involve describing and mapping estuaries according to dominant surface habitat features (substrate and vegetation). This procedure combines 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 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 over time.

Broad scale mapping of the Waimea Inlet in 2020 used colour aerial photographs sourced from the LINZ data service and accessed through ESRI online. The online imagery comprised Tasman 0.3m Rural Aerial Photos (2019), Nelson 0.3m Rural Aerial Photos (2018-2019), Tasman 0.1m Urban Aerial Photos (2017-2018), and Nelson City 0.075m Urban Aerial Photos (2017-2018)

Ground truthing was undertaken in May 2020 to map the spatial extent of dominant substrate and vegetation. Ground truthing tracks are shown in Appendix 1. A particular focus was to characterise the spatial extent of mud-elevated (i.e. 25-50% mud content) and mud-dominated (i.e. >50% mud content) sediment, opportunistic nuisance macroalgae (as an indicator of nutrient enrichment status), and ecologically important vegetated habitats. The latter were estuarine seagrass (Zostera muelleri) and salt marsh, as well as vegetation of the terrestrial margin bordering the estuary. Background information on the ecological significance of opportunistic macroalgae and the different vegetation features is provided in Table 2.

In the field the habitat features were drawn onto laminated aerial photographs at a scale of 1:3000. The 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 substrate, macroalgae, seagrass and salt marsh features, and the vegetation and dominant land cover of the 200m terrestrial margin.

Estuary boundaries for mapping purposes were based on the definition used in the New Zealand 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 <150o. This is consistent with the New Zealand coastal hydrosystems boundaries (Hume et al. 2016) developed in support of NIWAs CLUEs estuary model.

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 sulfides).

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.

2.2 SUBSTRATE ASSESSMENT

2.2.1 Substrate mapping

The NEMP approach to substrate classification has 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, Appendix 1).

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 classes 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.

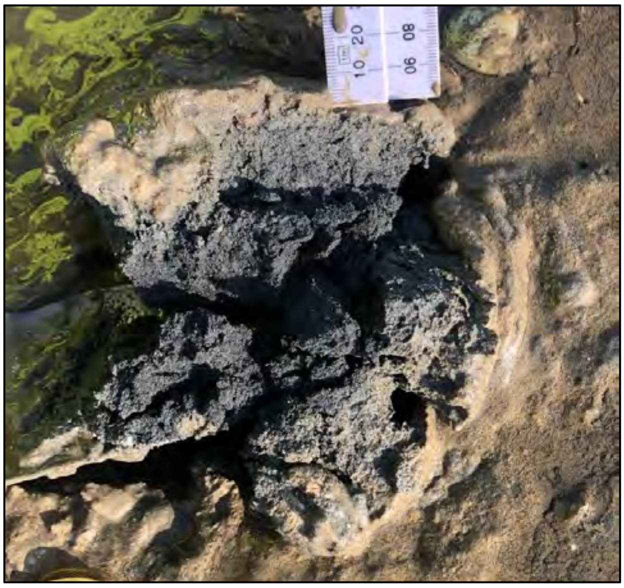
2.2.2 Sediment mud content and trophic status

Sediment mud content

A focus of substrate mapping is on documenting changes in the area (horizontal extent) of intertidal muddy sediment. As a supporting indicator to this broad scale measure, and to validate the subjective sediment classifications used as part of the mapping method, mud content in representative sediment samples was also determined by laboratory analysis. Samples consisted of surface sediments (0-20mm deep) collected with a trowel from 12 sites across a range of substrate classes. Analytical methods are provided in Appendix 2.

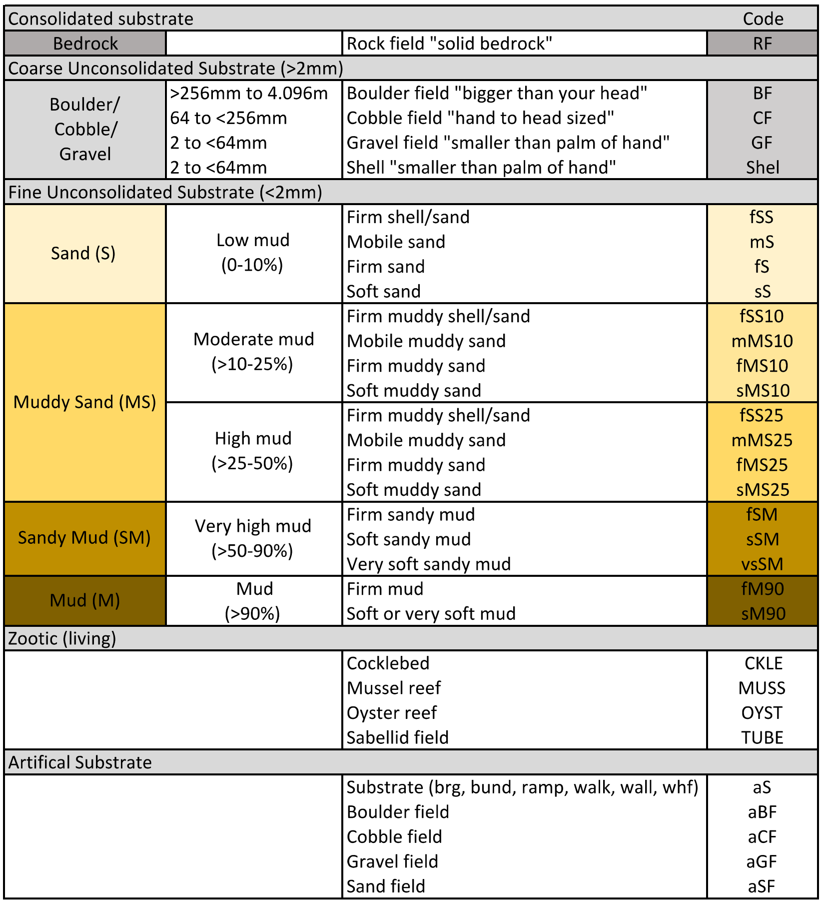
Sediment trophic status

A subjective indication of the trophic status (i.e. extent of excessive organic or nutrient enrichment) of soft sediment is provided by the depth of the visible transition between oxygenated surface sediments (typically brown in colour) and deeper less oxygenated sediments (typically dark grey or black in colour). This transition is referred to as the apparent Redox Potential Discontinuity (aRPD) depth, and provides an easily measured, time-integrated, and relatively stable indicator of sediment enrichment and oxygenation conditions.



Sediment trophic status is indicated by the depth of transition between oxygenated surface sediments (typically brown in colour) and deeper less oxygenated sediments (typically dark grey or black in colour

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%)	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

As a supporting indicator of trophic status in Waimea Inlet, 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 <10mm 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 approach was intended as a preliminary screening tool to determine the need for additional sampling effort.

2.3 OPPORTUNISTIC MACROALGAE ASSESSMENT

Because the occurrence of opportunistic macroalgae is a primary indicator of nutrient enrichment (see Table 2), 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 3, 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:

- *Percentage cover of opportunistic macroalgae*: The spatial extent and surface cover of algae present in intertidal soft sediment habitat in an estuary provides an early warning of potential eutrophication issues.
- *Macroalgal biomass*: biomass provides a direct measure of macroalgal growth. Estimates of mean biomass are made within areas affected by macroalgal growth, as well across the total estuary intertidal area.

- *Extent of algal entrainment into the sediment matrix*: Macroalgae is defined as entrained when growing >30mm deep within sediments, which indicates that persistent macroalgal growths have established.

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

Using this approach in Waimea Inlet, macroalgae patches were mapped to the nearest 10% using a 6-category rating scale (modified from FGDC 2012) 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. When sufficient representative patches had been measured to enable biomass to be reliably estimated, additional subjective biomass estimates were made following the OMBT method. Using the macroalgal cover and biomass data, macroalgal OMBT scores were calculated using the WFD-UKTAG Excel template. The scores were then categorised on the five-point scale adopted by the method that was noted above.

2.4 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.

2.5 SALT MARSH ASSESSMENT

Salt marsh was mapped and classified using an interpretation of the Atkinson (1985) system defined in the NEMP (Appendix 1), 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 brackets, 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).

As well as generating summaries (e.g. maps, tables) of salt marsh type and extent in 2020 relative to other years, two additional measures were used to assess salt marsh condition: i) Intertidal extent (percent cover), and ii) Current extent compared to estimated historical extent, noting the latter is a nominal value as it has not been formally determined.

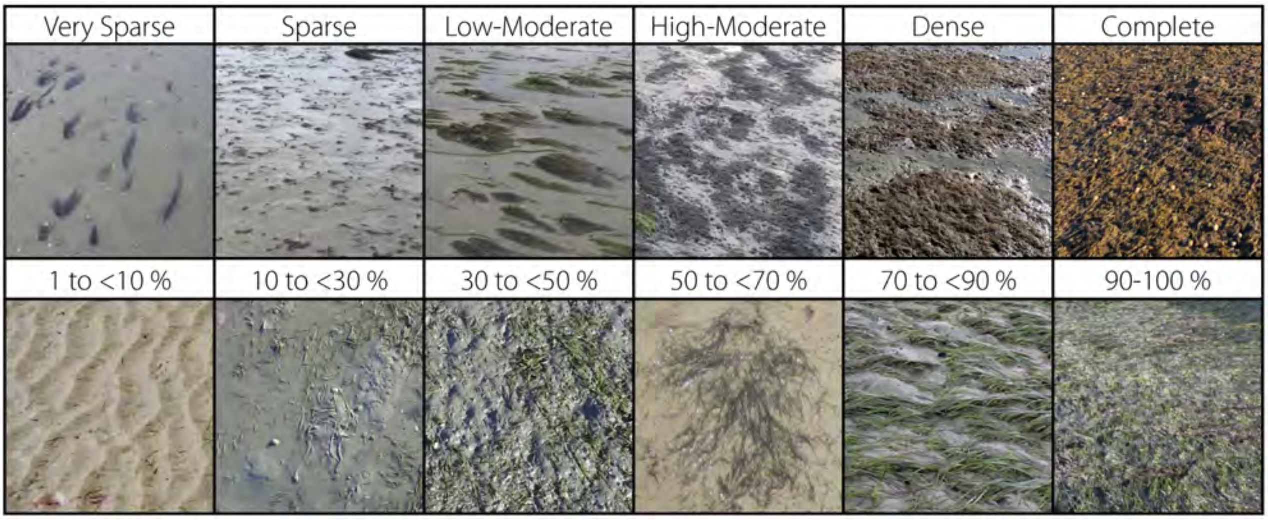


Fig. 3 Visual rating scale for percentage cover estimates. Macroalgae (top), seagrass (bottom). Modified from FGDC (2012).

2.6 TERRESTRIAL MARGIN ASSESSMENT

The 200m terrestrial margin surrounding the estuary was mapped and classified using the dominant land cover classification codes described in the Landcare Research Land Cover Data Base (LCDB5 2018). Classes are shown in Fig. 2 and detailed in Appendix 1.

2.7 DATA RECORDING, QA/QC AND ANALYSIS

Broad scale mapping is intended to provide a rapid overview of estuary condition. The ability to correctly identify and map features is primarily determined by the resolution of available aerial photos, the extent of ground truthing undertaken to validate features visible on photographs, 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 photographs alone.

In 2020, following digitising of habitat features, 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 1946, 1985, 1999, 2006 and 2014 GIS data layers were similarly checked for any errors in basic geometry (e.g. overlapping polygons), and updated to fix any identified issues (note, the 1990 data were hard copy only). Corrections to overlapping polygons were made by assessing features in the original photographs used for mapping. Other than addressing gaps in coverage within the supplied GIS files, no attempt was made to modify earlier data. However, 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 and NCC.

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. As noted above, macroalgal OMBT scores were calculated using the WFD-UKTAG Excel template.

2.8 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 New Zealand 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 4. Note that the condition rating descriptors used in the four-point rating scale in the ETI (i.e. between 'very good' and 'poor') differ from the five-point scale for macroalgal OMBT EQR scores (i.e. which range from 'high' to 'bad').

As a supporting measure for the broad scale indicator of mud-dominated sediment extent (areas >50% mud), we also consider the 'mud-elevated' (>25% mud) sediment component, as this is the threshold above which ecological communities can become degraded (hence the sediment quality rating of 'poor' in Table 4). To assess temporal changes in estuary seagrass, 2020 data were compared to data from previous broad scale reports (Stevens & Robertson 2008, 2013) 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 (it was assumed this was for cover >50%), and it is difficult to clearly distinguish seagrass cover of <50% when assessing features off historical aerial photographs in the absence of ground truthing.

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 referred to alternatively as 'Gross Eutrophic Zones' (GEZs) in the ETI (Zeldis et al. 2017). For our purposes HECs were defined as mud-dominated sediments (>50% mud content) with macroalgal cover >50% that is entrained (growing >30mm deep) within the sediment. HECs can also be present in non-algal areas where sediments have an elevated organic content (>1% total organic carbon) and low sediment oxygenation (aRPD <10mm). These latter sediment profile measures are not often used as part of the HEC assessment, as it is seldom feasible to routinely assess them over an entire estuary (especially one the size of Waimea).

In addition to the Table 4 indicators, the percent change from the first measured (or estimated) 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 and condition rating criteria 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.*

3. RESULTS AND DISCUSSION

The 2020 broad scale results are summarised in the following sections, with the supporting GIS files (supplied as a separate electronic output) providing a more detailed data set designed for easy interrogation, and to address specific monitoring and management questions.

3.1 INTERTIDAL SUBSTRATE

Photographs of representative substrates are provided on the following pages. Results from the 2020 survey (Table 5 and Fig. 4) show that although intertidal substrate in the inlet was relatively heterogeneous, it was dominated by soft/very soft mud (33%) and sandy mud (14%). A total of 1546ha (~55% of the intertidal zone) was classified as having an elevated mud content (i.e. a sediment mud content >25%), much of which (911ha) was assessed as having a mud content >90%.

Muddy sediments were concentrated in deposition zones in the mid-upper intertidal basins and embayments, with the muddiest areas being in the western arm of the estuary located near the Hoddy and Bronte Peninsulas. Extensive mud habitats were also present throughout most of the upper intertidal reaches of the main eastern basin (Fig 5).

Table 5. Summary of dominant intertidal substrates, with examples of dominant substrate types.

Subclass	Dominant feature	Ha	%
Artificial	Substrate	0.9	0.03
	Boulder field	4.0	0.1
	Gravel field	0.04	0.001
	Cobble field	8.6	0.3
Boulder/Cobble/ Gravel	Cobble field	230.2	8.2
	Gravel field	90.2	3.2
Sand (0-10% mud)	Mobile sand	345.2	12.3
	Firm sand	333.0	11.9
Muddy Sand (>10-25% mud)	Firm muddy sand	214.0	7.6
	Soft muddy sand	8.3	0.3
Muddy Sand (>25-50% mud)	Firm muddy sand	102.0	3.6
	Soft muddy sand	130.3	4.6
Sandy Mud (>50-90% mud)	Firm sandy mud	1.0	0.04
	Soft sandy mud	401.3	14.3
Mud (>90% mud)	Firm mud	95.1	3.4
	Soft/very soft mud	816.3	29.1
Zootic	Shell bank	9.1	0.3
	Cocklebed	12.1	0.4
	Oyster reef	5.4	0.2
	Tubeworm reef	1.2	0.04
Total		**2808.4**	**100**

There was often no clearly demarcated colour change in sediments, suggesting a relatively low organic content. However, where the aRPD depth was visible, synoptic sampling revealed it to be 1-10mm deep in most locations (Appendix 5). The shallow aRPD depth is considered primarily due to the infilling of interstitial spaces by fine surficial muddy sediment (sometimes with sandier sediments beneath), thereby reducing oxygenation by restricting tidal flushing and atmospheric exchange.

In the lower (i.e. seaward) estuary, where channels and entrances are well-flushed by tidal exchange, muddy sand (16%) and sand (14%) habitats dominated (Fig. 4). The Tahunanui back beach estuary was also sand-dominated, with wind-blown sand from Tahunanui Beach and sand washing in from the main channel being the key sources.

In addition to the sand or mud dominated sediments, other ecologically important habitats present included cobble and gravel fields (11%) and 'zootic' features (cockle beds, shell banks, oyster and tubeworm reefs). Zootic reef features were most common near both estuary entrances and around lower estuary channels that have a high degree of flushing. Although relatively scarce, these areas create valuable biogenic habitat for a variety of other organisms.

Laboratory validation of 12 sediment samples showed that the sediment grain size measurements in most instances aligned closely to the mud content classifications subjectively determined in the field (Appendix 5). As many of the validation samples were deliberately collected from sites at the transition between mud content classes, results were expected to fall either side of the thresholds used. Five classes were correctly allocated and four of the measured samples were within 5% of the estimated class boundary, indicating that the field classifications provide a reasonably accurate representation of surface sediments. At two of the remaining sites the offset is likely due to a thin layer of muddy sediment deposited on top of a relatively coarse sand/gravel base. Therefore, although the surface layer appears mud-dominated, the underlying sediments dilute this influence when sampled and analysed. The largest relative offset was where sand-dominated sediment was muddier than estimated.

A comparison of changes in the spatial extent of intertidal mud-dominated sediment (excluding salt marsh areas) over the five habitat mapping surveys conducted to date is presented in the Fig 5 inset graph.

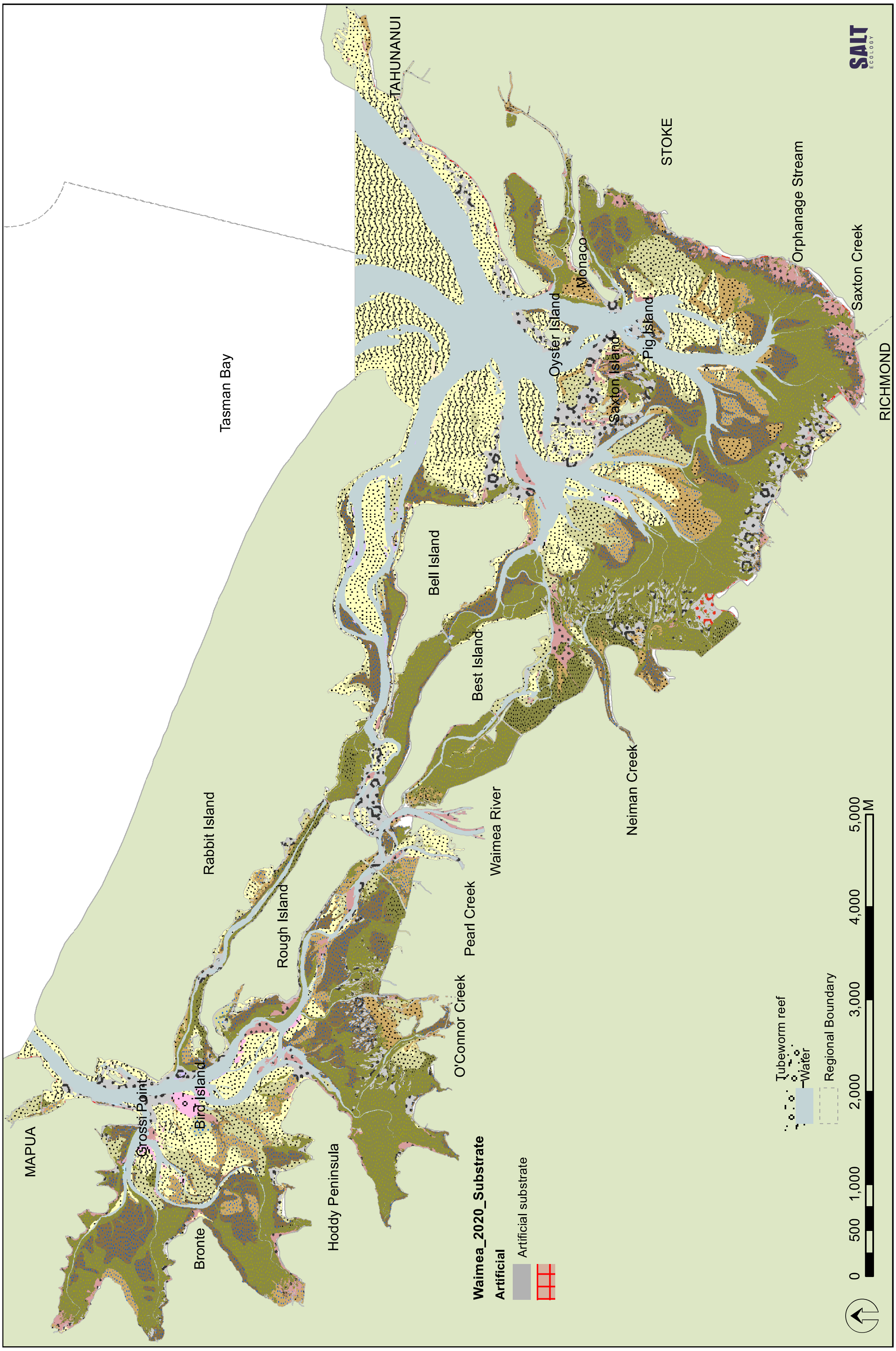


Fig. 4. Map of dominant intertidal substrate types, Waimea Inlet May 2020

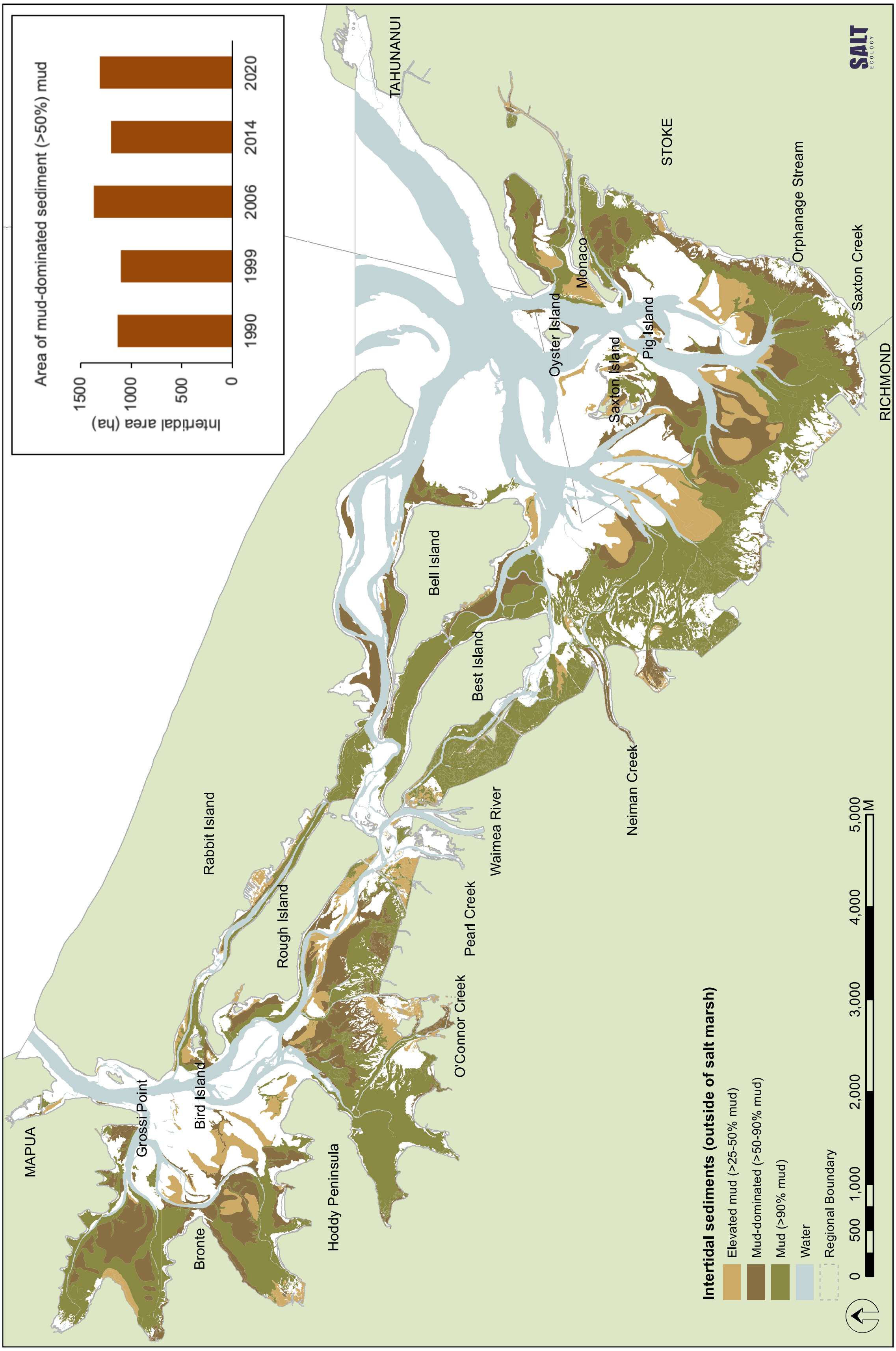


Fig. 5 Map of intertidal substrate types showing area of mud-elevated (>25-50% mud) and mud-dominated (>50% mud) sediment, Waimea Inlet May 2020. Inset bar graph shows change in mud-dominated sediments since 1990, not including areas within salt marsh (see text for explanation).


Very soft anoxic mud, Hoddy-Bronte arm


Firm sand and rip rap wall, Tahunanui back beach


Firm mud flats near Best Island


Scouring of soft muds exposing firm sands, Hoddy-Research Orchard arm (~10ha)

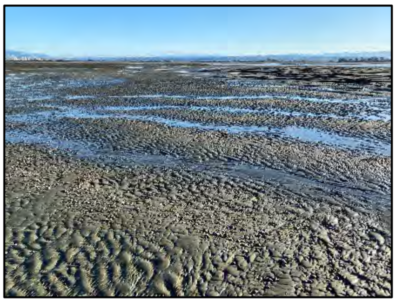

Shell bank north of Hoddy Peninsula


Expansive gravel field near Bell Island


Firm sand and residential seawalls, near Leisure Park in Mapua


Exposure of old shell banks, Hoddy-Research Orchard arm


Cobble fields and soft sandy muds near the MDF plant


Mobile sand flats near Saxton Island


Tube worm reef, Mapua wharf


Knee-deep mud (mud content >50%), southeast estuary


Modified margin of southeast estuary


Modified and eroding margin along Tahunanui golf course


Cobble field used as road, Monaco

Examples of substrate features photographed in May 2020

Due to variable approaches used in assessing and classifying sediment types over time, assumptions were made to standardise the data as much as possible with the revised (2020) classifications being used. It was assumed that the original NEMP classifications used in 1999, 2006 and 2014 for firm muddy sand represented sediments with mud contents of 10-25%. Soft mud and very soft mud classifications were assumed to represent mud-elevated (>25–50% mud content), and mud-dominated (>50% mud content) sediments. The latter classes have been combined and are referred to as 'mud-dominated' sediments for the purposes of making temporal comparisons. Sediments underlying seagrass and macroalgae in 1999 and 2006 were not reported, but were assumed to be the same as in 2014. Note that for the 1990 data, it was assumed that areas described as 'mudflats' were equivalent to areas >50% mud.

The Fig. 5 inset graph shows mud-dominated sediment has been relatively high and reasonably consistent since it was first mapped in 1990 (by Davidson & Moffat), noting that significant inputs of mud-dominated sediment had occurred prior to the 1990 survey, with the estuary historically dominated by sand and shell/gravel substrate that had little mud and a plentiful population of large shellfish (Stevens & Robertson 2011).

Although there is uncertainty associated with the past mapping estimates, results over the 30 year period suggest there has been a net increase of ~30ha of mud-dominated sediment from 1990 to 2020, although within this net change there is considerable temporal variability in the deposition and erosion or redistribution of fine sediment deposits. This variability was evident in the most recent survey with the central flats of the eastern arm showing ~20mm of muddy sediment deposition on top of coarser substrate, and extensive mud deposits in parts of the Bronte Road arm. The latter deposits currently appear to be eroding, as do deposits in parts of the western arm of Rough Island (see photos this page). There has also been significant erosion and redistribution of sand at the western end of Tahunanui Beach and within the back beach estuary.

The temporal variability is also evident in historical coring in the estuary, which indicated large mud inputs in the 1950's - 1960's that were consistent with anecdotal reports of sediment runoff during orchard land development (Stevens & Robertson 2011). With regard to overall changes in sediment deposition, sedimentation rate monitoring undertaken by TDC shows virtually no significant net change in sediment accumulation at 12 monitoring sites in the estuary over the past decade (Appendix 6). Such results suggest that either sediment loads to the estuary over the past decade have been relatively low, or sediment inputs have not been retained (i.e. flushed from the system into Tasman Bay). While these findings are positive for the estuary (but less so for Tasman Bay), the episodic nature of sediment inputs from catchment land disturbances means that it is important to maintain ongoing monitoring of land use and management of fine sediment inputs to the estuary.

10-20mm layer of muddy sediment on top of firm sands, central eastern tidal flats

Soft mud eastern tidal flats

Extensive deposits of soft muds in Bronte-Hoddy arm showing signs of recent erosion over ~15-20ha

Scouring of soft muds on the north side of Rough Island (~4ha)

3.2 OPPORTUNISTIC MACROALGAE

Table 6 summarises macroalgal percentage cover classes for the estuary in 2020, with the mapped cover and biomass shown in Fig. 6 and Fig. 7, respectively. Data from 124 measurements of macroalgal biomass are presented in Appendix 3.

The vast majority (~95%) of the estuary had very little intertidal macroalgal growth (<1% cover), with a further 4.3% classified as having a 'very sparse' (1-<10%) or 'sparse' (10-<30%) cover.

Table 6. Summary of intertidal macroalgae cover classes.

Macroalgal Percent Cover	Ha	%
Trace (<1%)	2655.6	94.6
Very sparse (1 to <10%)	80.9	2.9
Sparse (10 to <30%)	38.1	1.4
Moderate (30 to <70%)	21.9	0.8
Dense (70 to <90%)	10.0	0.4
Complete (>90%)	2.0	0.1
Total	**2808.4**	**100**

Where macroalgae were present, the dominant species were the red seaweed *Gracilaria chilensis* and green seaweed *Ulva* (see photos).

The areas where macroalgal cover exceeded 30% cover were highly localised and were concentrated adjacent to the MDF plant/Bark Processor's sites, near Hoddy Peninsula and south of Rough Island. Additional areas of nuisance growth were located north of Best Island, Neimann Creek, in the upper extent of the Hoddy arms, and parts of the southeast estuary near Richmond (Fig. 6) where many streams have consistently high nutrient concentrations.

The key features of these areas were as follows:

- MDF plant/Bark Processor's sites in the eastern arm had the most extensive cover (up to 100%) and the greatest biomass (12kg/m^2) of entrained macroalgae, consisting primarily of *Gracilaria chilensis*.
- In Hoddy Peninsula, entrained *Gracilaria* was found in numerous small patches of dense (70 to <90%) cover, predominantly east of the peninsula.
- South of Rough Island, one of the conspicuous features was extensive mats of *Ulva* containing smaller areas of sediment-entrained *Gracilaria*.

Where macroalgal mats had an extensive cover or high biomass they had a smothering effect, creating a black anoxic sediment (i.e. aRPD at the sediment surface). An extreme example of this was observed adjacent to the MDF plant where sediment conditions appear to have been degraded to a point where remaining macroalgae could no longer survive. Extensive microbial mats were observed in these areas (see photo below) with underlying sediments having a high organic content and strong hydrogen sulphide odours.

Microbial mats near the MDF plant

The OMBT input metrics and overall macroalgal EQR for 2020 are provided in Table 7. The OMBT EQR was 0.73, which equates to a rating of 'good' according to the Table 4 criteria.

Table 7. Summary of OMBT input metrics and calculation of overall macroalgal ecological quality rating, Waimea Inlet 2020.

Metric	Face Value	FEDS	Environmental Quality Status
% cover in AIH	0.5	0.98	High
Biomass per m^2 AIH	13.3	0.97	High
Biomass per m^2 AA	869	0.45	Moderate
% entrained in AA	5.9	0.59	Moderate
Worst of AA (ha) and AA (% of AIH)		0.66	Good
AA (ha)	37.5	0.66	Good
AA (% of AIH)	1.5	0.94	High
Survey EQR		**0.73**	**Good**

AIH = Available Intertidal Habitat, AA = Affected Area, FEDS = Final Equidistant Score, EQR = Ecological Quality Rating

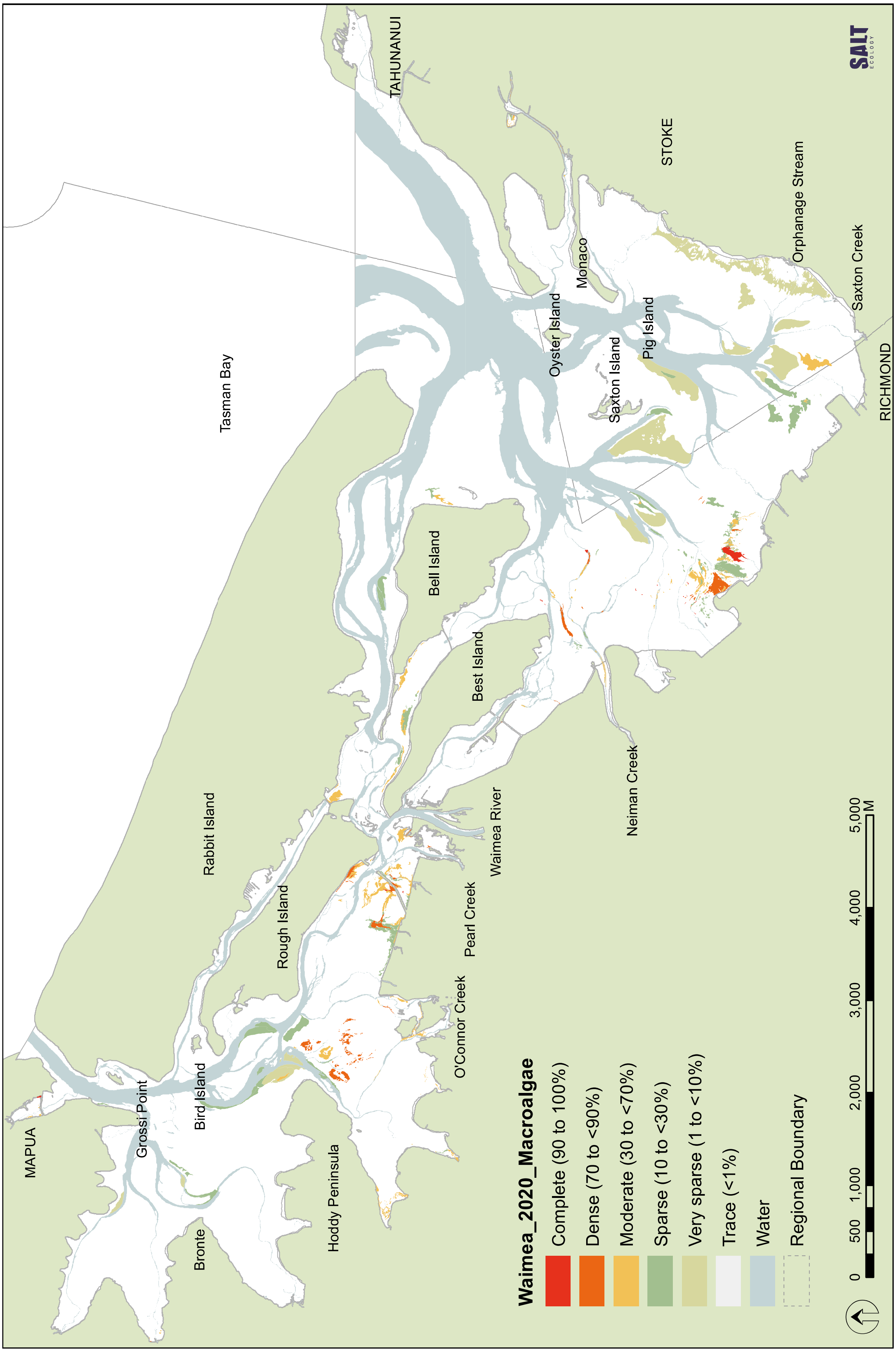


Fig. 6 Distribution and percentage cover classes of opportunistic macroalgae, Waimea Inlet May 2020.

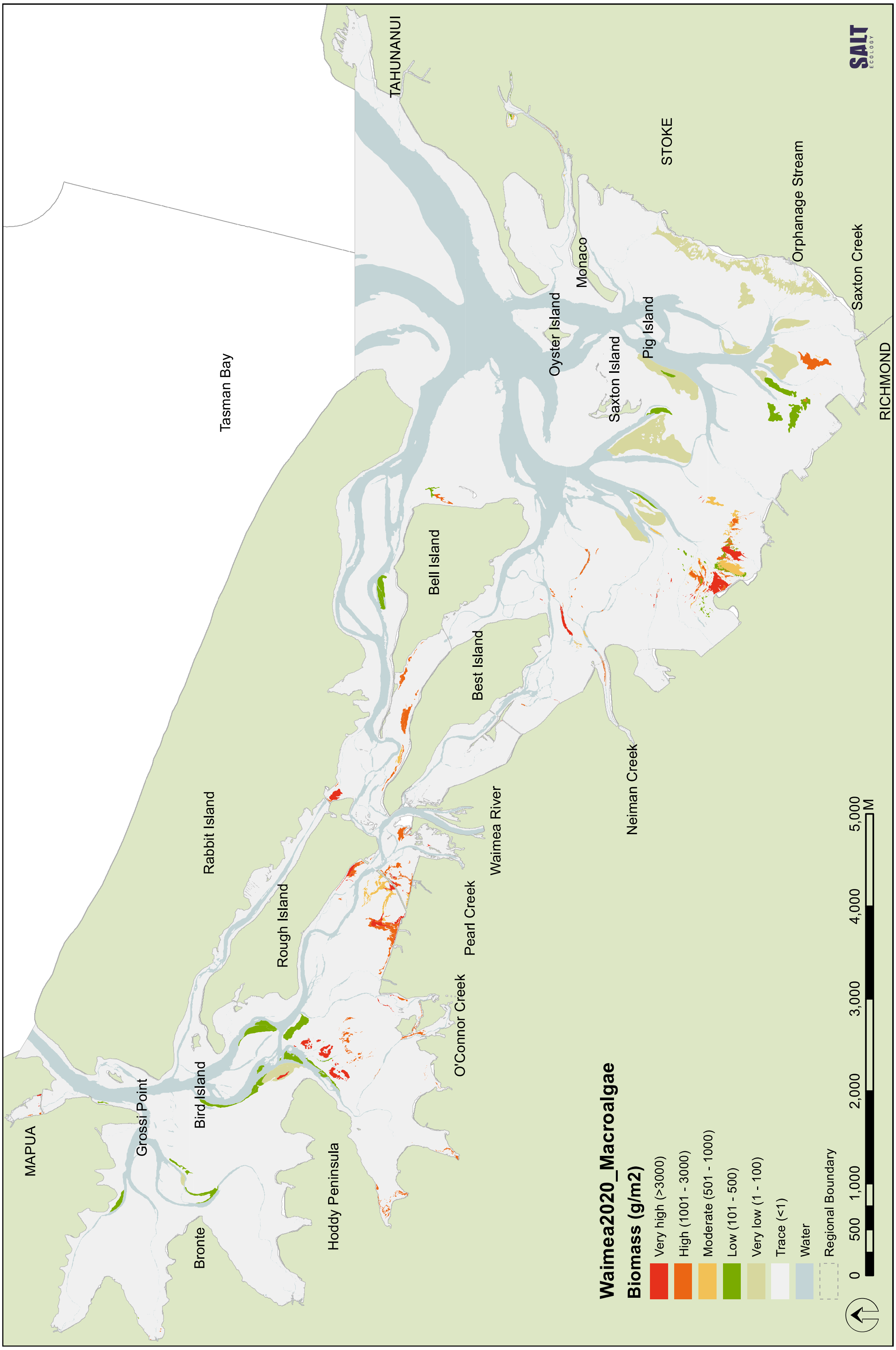


Fig. 7 Biomass (wet weight g/m^2) classes of opportunistic macroalgae, Waimea Inlet May 2020.

Data from a previous macroalgal survey in 2014 gave an EQR score of ' 'moderate' (Table 8). Stevens and Robertson (2014) reported that the majority of the intertidal area had <5% macroalgal percent cover but significant areas of high-very high (>50%) nuisance macroalgal cover (59ha) were present at various locations throughout the estuary in 2014.

The 2020 macroalgae survey confirms some of these beds are growing in size and density, namely near the MDF plant and Hoddy Peninsula. However, in other areas such as the western airport embayment near Monaco where macroalgae has previously been recorded, a significant reduction in extent is evident. This change appears to have been due to a die-off of macroalgae similar to what has been observed recently in Moutere Estuary (Stevens et al. 2020). Local flood events during early 2018 (Cyclones Gita and Fehi) may also have directly scoured macroalgae or aided in flushing already-decaying macroalgae out of some parts of the estuary.

Table 8. Summary of EQR scores for broadscale monitoring in Waimea Inlet, 2014 and 2020.

Year	EQR	Rating
2014	0.55	Moderate
2020	0.73	Good

Scouring evident near *Gracilaria chilensis* beds, Hoddy Peninsula.

The only patch of *Gracilaria* evident within the western airport embayment

The areas of Waimea Inlet where persistent High Enrichment Conditions (HECs) were established in 2020 are shown in Fig. 9 and Table 9. The HEC extent in 2020 (20.3ha, 0.6%) was rated as 'poor' using the criteria in Table 4. As expected, HEC areas were predominantly found in locations with high biomass macroalgal growths (Fig. 7). These parts of the estuary are highly enriched with consistently poor sediment quality, comprising low oxygenation, high organic matter, and sulphide-rich sediments. Most of the problem areas identified in 2014 are still present, and include Hoddy -Bronte arm and in particular the upper intertidal flats near the Bark Processors/MDF plant. At the latter site there was a discharge of milky sulphurous water at the Penny-Farthing Creek mouth, and several enriched seeps along the edge of the seawall.

Since 2014 there has been a decrease in HEC areas of ~8ha. The key areas of improvement include:

- The embayments to the west, and to a lesser degree, east of Nelson airport
- The area north of the Best Island golf course
- South of Rough Island, near Redwood Road
- Rabbit Island, east of Ken Beck Drive

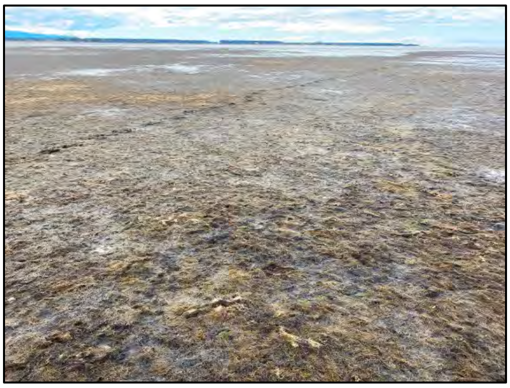
The decreases are a result of a decline in dense macroalgal cover in these areas, which appears to have in turn released muddy sediments, which have been either redistributed within the estuary or flushed out to sea. As mentioned above, this process could have been facilitated by local flood events. Regardless of the mechanism, the HEC decrease is a positive outcome, although there are several moderate density macroalgal areas showing signs of expansion (e.g. upper Hoddy arms) which have a potential to become HECs in the future if they continue to develop.

Table 9. Summary of HEC extent, Waimea Inlet 2014 and 2020.

Year	Ha	% of Estuary
2014	28.0	0.7
2020	20.3	0.6

Overall, the reduction of nuisance macroalgal cover since 2014 has likely resulted in a slight improvement in some areas in the habitat conditions for sediment-dwelling biota. However, >20ha of the estuary remains significantly degraded as a consequence of sediment nutrient enrichment, hence continued monitoring of macroalgal status is desirable.

Gracilaria chilensis was the most widespread macroalgae. Example shown here on the banks of Neimann Creek



Nuisance growths of *Gracilaria* near the MDF plant, southeast estuary

Dense *Ulva* growing on poorly-flushed very soft mud near Redwood Rd. Groundwater seeps are likely to be present.

Nuisance *Gracilaria* beds between Best Island and Bell Island

Broad-bladed *Ulva* spp. (aka 'sea lettuce') was prevalent in the lower intertidal reaches of the western arm

Ulva spp. with anoxic sediments beneath, eastern airport embayment

High biomass beds of *Gracilaria* were found entrained within sediment in the Hoddy-Bronte arm

Moderate cover of *Gracilaria*, upper extent of Hoddy-Bronte arm

Examples of macroalgal growths photographed in May 2020

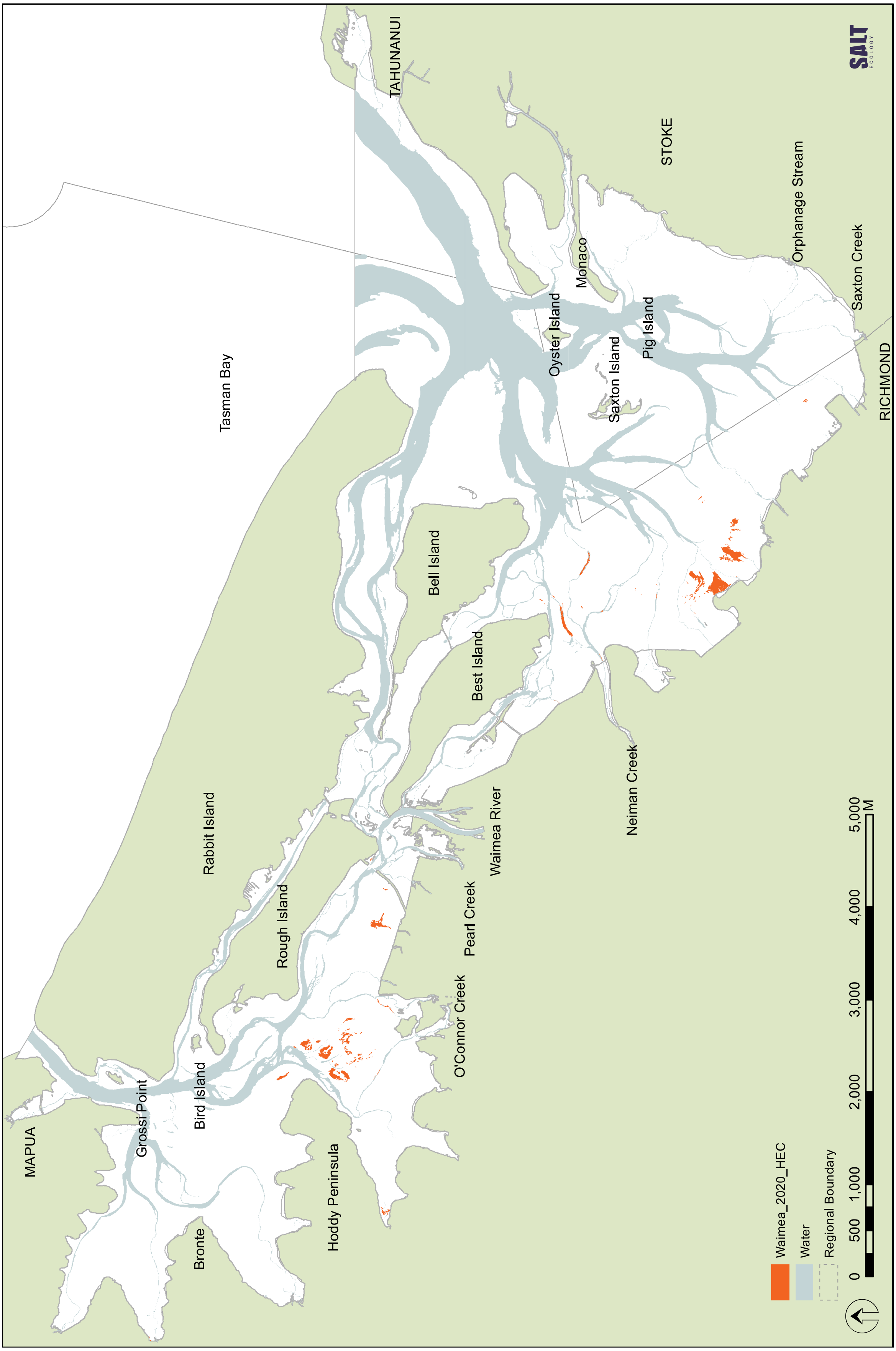


Fig. 8 Areas of High Enrichment Conditions (HECs), Waimea Inlet May 2020

3.3 SEAGRASS

Table 10 summarises intertidal seagrass (*Zostera muelleri*) cover in 2020, with the distribution shown in Fig. 9, and additional detail of the most extensive areas shown in Fig. 10.

Seagrass beds are sparse across the estuary, occurring almost exclusively in the eastern arm primarily near the well-flushed entrance and channel and central basin. One very small patch of seagrass was recorded in the western arm near Grossi Point. In 2020, the total mapped area of seagrass was 63.7ha (2.2% of the intertidal area). Of this, 36.1ha was categorised as being at least 'moderate' density (≥30% cover), mainly located west of Saxton Island, east of Bells Island and west of the airport. Within these areas, 8.9ha (0.3% of intertidal) was categorised as dense (70-<90%). A notable feature of the seagrass beds east of Bell Island was an extensive area inundated with muddy sediment (see photo this page), which was also reported by Stevens and Robertson (2014).

Table 10. Summary of intertidal seagrass cover classes, Waimea Inlet May 2020.

Percent cover category	Ha	%
Trace (<1%)/Absent	2744.3	97.7
Very sparse (1 to <10%)	4.5	0.2
Sparse (10 to <30%)	23.1	0.8
Low-Moderate (30 to <50%)	14.6	0.5
High-Moderate (50 to <70%)	12.7	0.5
Dense (70 to <90%)	8.9	0.3
Total	**2808.1**	**100**

Seagrass was first mapped in 1990, with repeat surveys in 1999, 2006 and 2014. These records are presented with the 2020 data in Table 11, for areas with measured or assumed seagrass cover of >50%. The 2006 data from Clark et al. (2008) was subject to QA/QC checks as part of the current work (see Methods), and updated following the correction of typology errors. Based on these long-term records, the following patterns are evident:

- The total seagrass area >50% cover is low, with 58ha in 1990 being the maximum recorded.
- There appears to have been a 63% reduction in seagrass extent from 1990 to 2020. Since 1999, there has been relatively little change in overall extent, with reported differences likely to be within the margin of error for mapping accuracy.
- In 2020, previously unreported seagrass beds were mapped. These beds are not considered likely to be newly established, but to reflect more accurate mapping. They include a 'sparse' extension running northeast from the existing Saxton Island seagrass beds, and smaller areas west of Oyster Island (see Fig. 9 & 10).
- Between Saxton and Bell Islands, seagrass lost during installation of a sewage pipe in 2011 has partially re-established in the north-west where seagrass beds were dense. However, the majority of the disturbed area remains dominated by bare cobble and gravel despite the presence of adjacent seagrass beds. The failure of seagrass to re-establish is likely due to the loss of fine sediment and highlights the sensitivity of seagrass to disturbance, and its slow recovery.


Seagrass beds near Saxton Island (left) and Bell Island flats (right)


Sediment covering seagrass east of Bell Island

Table 11. Summary of changes in seagrass area (ha) from baseline measures in 1990 based on areas where % cover exceeded 50%.

Year	Ha	% Reduction from baseline
1990	58	NA
1999	35	39.7
2006	30.2*	47.9
2014	30.5	47.4
2020	21.6	62.8

* Revised from Clark et al (2008) Originally reported as 21ha.

Historically, the estuary had been significantly modified by 1990, and it is likely seagrass beds were far more extensive in their natural state. By way of comparison, estimates of the natural state cover of seagrass in Nelson Haven indicate ~15% of the estuary would have historically supported seagrass beds with >50% cover (Stevens & Forrest 2019).

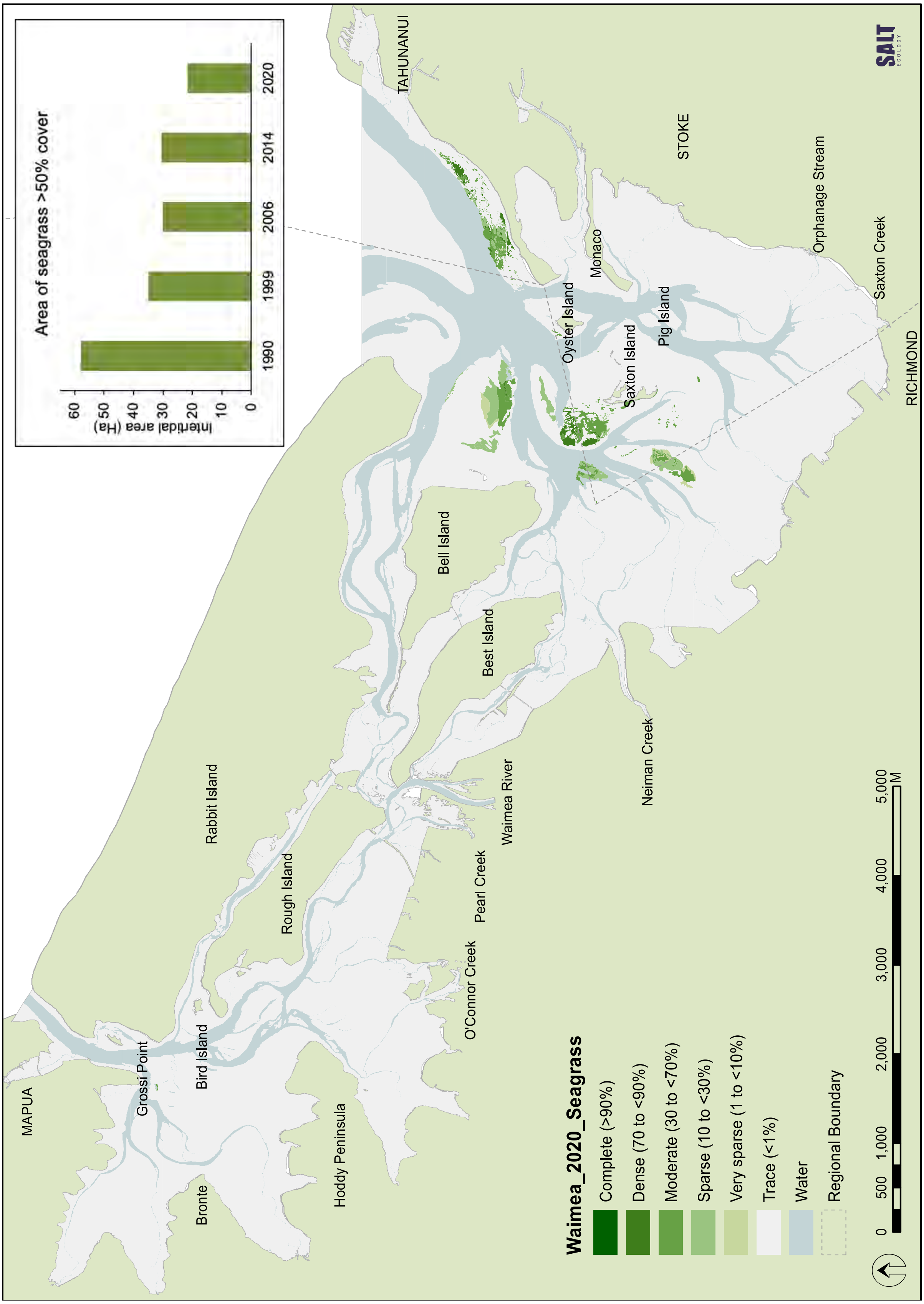


Fig. 9 Distribution and percentage cover classes of seagrass, Waimea Inlet 2020. Inset bar graph shows change in seagrass cover (areas >50% cover) from a 1990 baseline of 58ha.

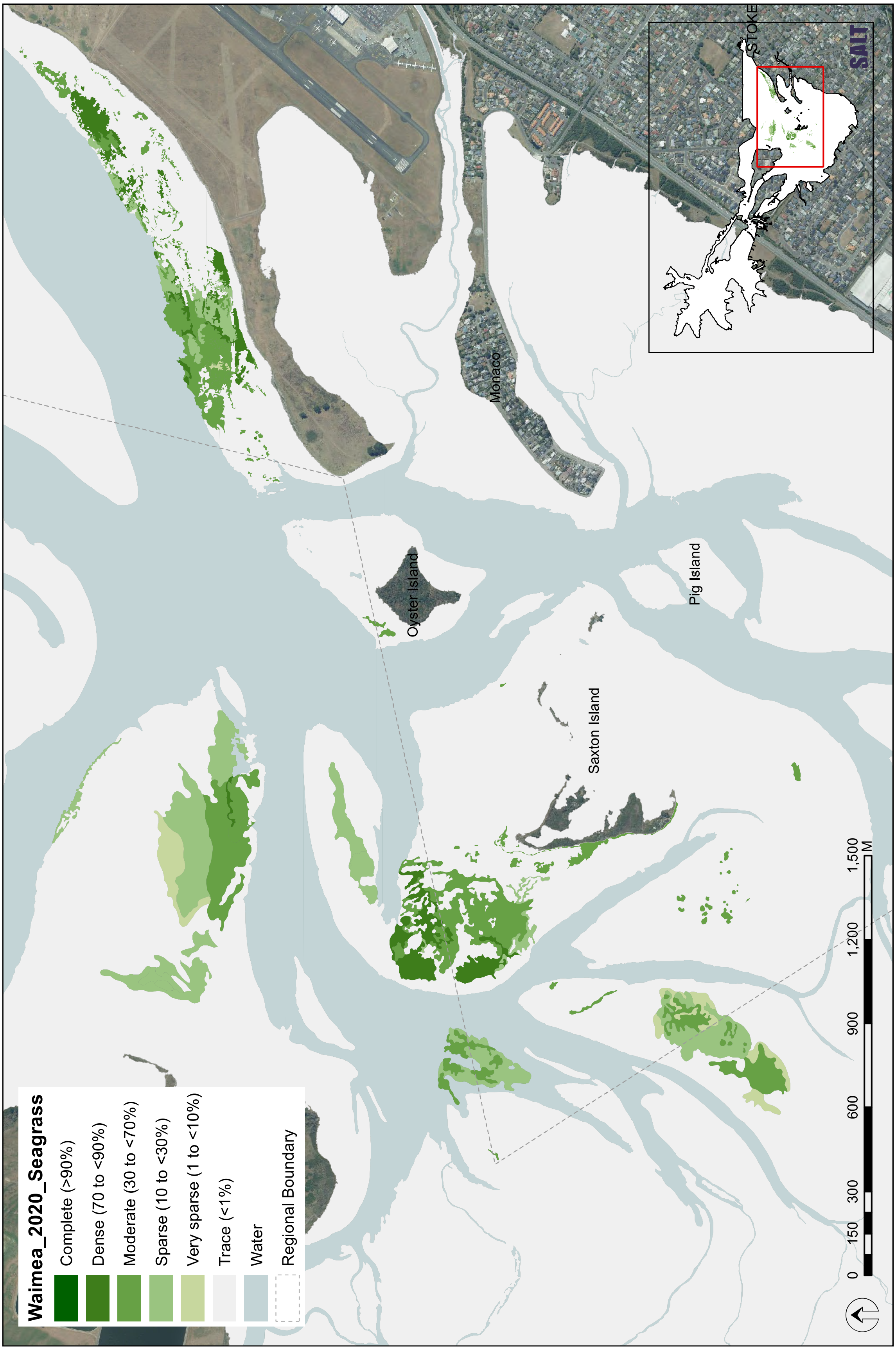


Fig. 10 Detailed distribution and percentage cover classes of seagrass, east arm of Waimea Inlet May 2020.

3.4 SALT MARSH

Table 12 summarises intertidal salt marsh subclasses and cover for historical data from 1946, 1985, and 1990 (sourced from Tuckey & Robertson 2003, and Davidson & Moffat 1990), and the four ground truthed NEMP broad scale surveys. The salt marsh mapped in 2020 is shown in Fig. 11. Detail regarding the dominant and subdominant species recorded in 2020 is provided in Appendix 7.

A total of 278.2ha of salt marsh was recorded from the estuary in 2020, comprising 9.9% of the intertidal area. The most extensive areas were located either side of the Waimea River in relatively narrow embayments, and at the head of the arms in the western side of the estuary. Salt marsh was dominated by herbfield (162.1ha, 5.8% of the intertidal area) and rushland (87.2ha, 3.1%), with less extensive areas of tussockland (15.9, 0.6%), estuarine shrubs (11.4ha, 0.4%), sedgeland (1.4ha, 0.05%) and reedland (0.2ha, 0.01%).

Herbfield comprised primarily glasswort (*Sarcocornia quinqueflora*) followed by sea blite (*Suaeda novaeuzelandiae*). Rushland comprised mainly searush (*Juncus kraussii*) and jointed wire rush (*Apodasmia similis*). Tussockland was dominated by shore tussock (*Stipa stipoides*) often found at the top of the tidal range. Saltmarsh ribbonwood (*Plagianthus divaricatus*) was the dominant estuarine shrub, generally forming a narrow boundary to the upper estuary margins. Small, localised areas of grey saltbush (*Atriplex cinerea*) were present at Tahunanui back beach, Oyster Island the Monaco embayment, and near Bark Processors.

The remaining extent of salt marsh in the inlet reflects historic and ongoing modification of the estuary. Data from 1946 is the first available measured baseline, however significant modification to the once extensive coastal forest, wetland and salt marsh is known to have already occurred prior to this time (Davidson & Moffat 1990). Historical estuary drainage, reclamation, margin development and channelisation are the primary reasons for salt marsh decline. Compared to the 1946 baseline, the 2020 results show a 74ha (21%) reduction in salt marsh (Table 12, Fig. 11 inset, Appendix 8). In the intervening years, the lower extents mapped in 1985 and 1990 are likely to reflect differences in mapping accuracy or coverage.

Mapping undertaken in 2006 incorrectly classified extensive areas of terrestrial tall fescue and salt marsh ribbonwood as salt marsh, and mis-classified some gravel beds near Grossi Point as rushland. Therefore, when changes between 2006 and 2020 are compared, there is an apparent 36ha decline in salt marsh cover (Table 12). This primarily reflects more accurate classification in 2020 rather than a recent loss of salt marsh, with most salt marsh losses occurring prior to 2006 as a result of margin development. The spatial location of changes between 2006 and 2020 are shown in Appendix 9. Many differences represent a slight offset in the underlying spatial imagery used in the different years and do not indicate meaningful change. While a detailed analysis was outside the current scope of work, the biggest actual change appears to be a reduction in herbfield cover on the southern side of the estuary near Richmond, although this could also be due in part to more accurate mapping in 2020. The biggest gains were in the Nelson back beach area where herbfield has expanded.

More recently there have been offsets to past losses through the active replanting of salt marsh and terrestrial margin habitat. This aspect is discussed further in subsequent sections.

Table 12. Summary of composition and temporal change in saltmarsh area (ha), showing % reduction since 1946 baseline.

Subclass	1946	1985	1990	1999[1]	2006[2]	2014[2]	2020
Estuarine shrub	16	3.2		11.9	22.3	11.3	11.4
Tussockland	6.9	7	4.8	10.4	12.8	15.5	15.9
Sedgeland				0.4	0.2	0.1	1.4
Rushland	126	96	75	83.8	104.0	103.5	87.2
Reedland		43.5	29	0.01		0.01	0.2
Herbfield	165	120	93	120.3	174.8	169.8	162.1
Grassland						3.3	
Unspecified	38.5						
Total area (ha)	**352**	**270**	**202**	**300[1]**	**314**	**304**	**278**
% Reduction (from 1946 baseline)		**-23**	**-56**	**-61.4**	**-16.6**	**-15.4**	**-24.3**

[1] Updated to approx. 300ha by Stevens & Robertson (2014) following a review of original 1999 data.

[2] Updated by current authors following QA of original 2006 & 2014 data. Note, 1946 and 1985 data do not include Tahunanui back beach.

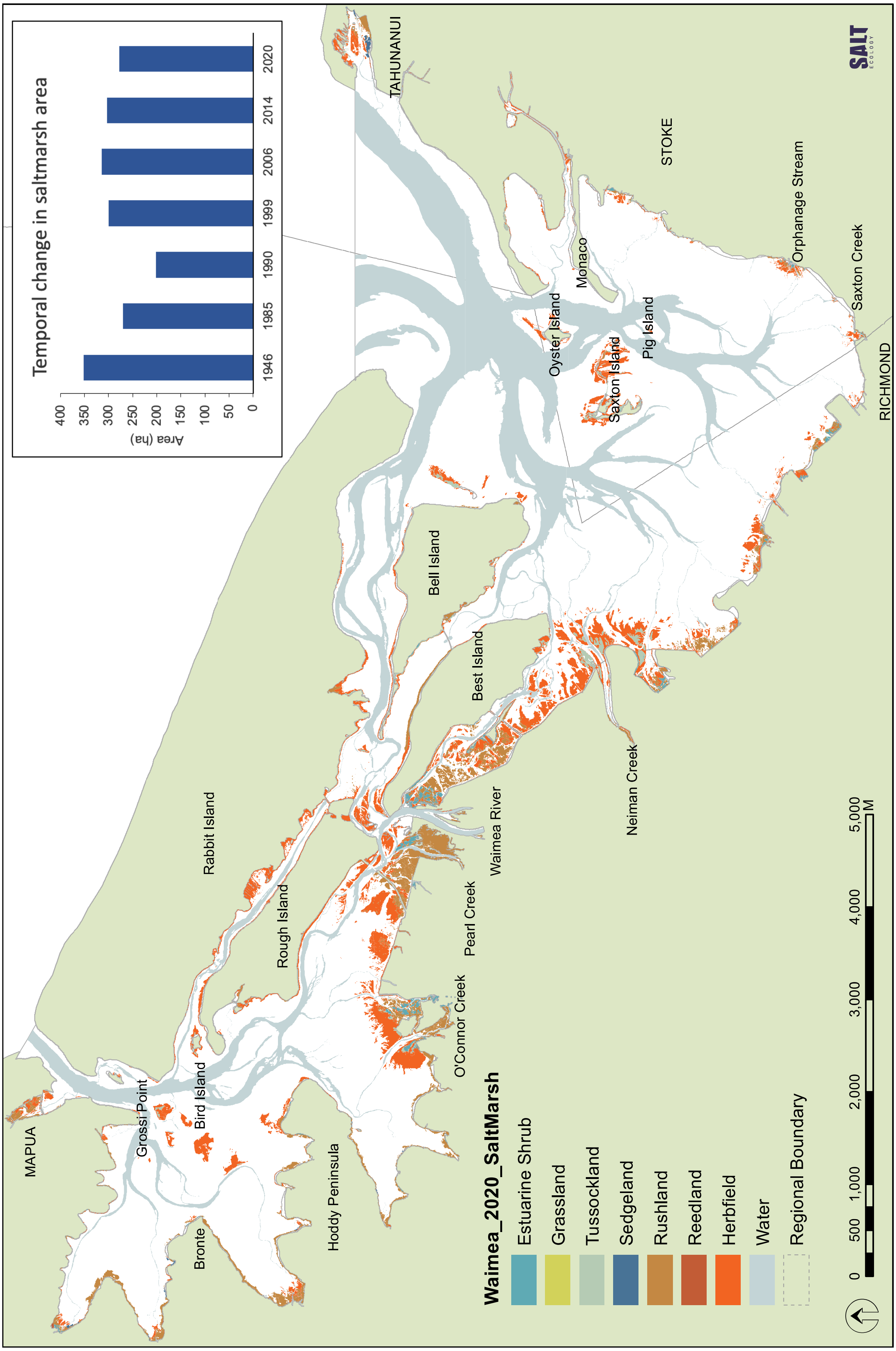


Fig. 11 Distribution and type of saltmarsh, Waimea Inlet May 2020. Inset bar graph shows temporal change in salt marsh extent.

Narrow band of glasswort and searush growing within the artificial boulder wall near Nelson airport

Restoration plantings at the Tahunanui back beach. Note, impact of non-designated walking tracks through the glassport fields.

Great Taste Trail track inhibiting saltmarsh expansion, southeast estuary

Rushland was the second most dominant salt marsh class, consisting mainly of searush. Note minor wave erosion of the seaward rushes.

Small area of saltmarsh and residential seawalls in Mapua

Seawall, Hoddy arm

A small patch of glasswort adjacent to timber jetties and walls, Monaco

Herbfield growing within low-lying land separated from the estuary by earth bunds near Richmond

Examples of salt marsh features photographed in May 2020

3.5 TERRESTRIAL MARGIN

Mapping of the 200m wide terrestrial margin (Table 13, Fig. 12) in 2020, as in previous surveys, showed the margin was dominated by grassland (43.2%), built-up areas (21.9%), exotic forest (12.7%) and urban parkland/open space (12.6%).

Approximately 18% of the margin was classified as densely vegetated, the majority of which is exotic forestry located on Rabbit and Rough Islands (12.7%). The low extent of the densely vegetated terrestrial buffer fits the condition rating of 'poor', with a small decrease of 4% since 2014. This decrease can be attributed to recently harvested pine trees (*Pinus radiata*) on Rabbit Island.

The extensive presence of shoreline armouring for roads, seawalls, reclamations and causeways estuary breaks the natural sequence of estuarine to terrestrial vegetation, and is likely to impinges upon the aesthetic and natural value of the estuary. Furthermore, these developments compromise the natural capacity of the estuary to respond to climate change related sea level rise, and to catchment derived inputs of sediment and nutrients. This issue is most pronounced in the eastern arm due to extensive shoreline hardening (e.g. SH6), drainage of wetland areas for pasture, earth bunding and channelisation of streams.

Sections of the western arm (e.g. Bronte and Hoddy arms) remain relatively undeveloped comprising rural lifestyle blocks, with a few pockets of scrub/forest. Grassland adjacent to the estuary generally contained a range of introduced weeds and grasses. Overall, the terrestrial margin is dominated by artificial structures, grazed pasture and industrial and residential development. While largely historical, the consequence of this significant development is that the Waimea Inlet margin retains relatively very few habitat features that are unmodified and in their natural state.

One of the more visible changes occurring in the estuary margin recently has been effort put into salt marsh and fringing habitat restoration by TDC, NCC, the Department of Conservation, Tasman Environment Trust, 'Plant Right Now, and the wider community through initiatives under the Waimea Inlet Restoration Project. These include restorative planting at numerous sites such as Pearl Creek, Neimans Creek, Estuary Place and Dominion Flats., as well as smaller plantings in many other locations. In 2020, government grants were allocated to plant trees around the Waimea Inlet as part of the One Billion Trees programme which will further support these restoration initiatives.

Table 13. Terrestrial margin features in Waimea Inlet 2020.

LCDB5 Class and name		Ha	%
1	Built-up Area (settlement)	401.2	21.9
2	Urban Parkland/Open Space	229.9	12.6
5	Transport Infrastructure	19.5	1.1
10	Sand and Gravel	1.5	0.1
20	Lake or Pond	2.3	0.1
21	River	1.8	0.1
33	Orchard/Vineyard	56.3	3.1
40	High Producing Exotic Grassland	357.9	19.6
41	Low Producing Grassland	431.2	23.6
45	Herbaceous Freshwater Vegetation	0.0003	0.00002
46	Herbaceous Saline Vegetation	13.7	0.7
51	Gorse and/or Broom	1.3	0.1
52	Manuka and/or Kanuka	7.3	0.4
54	Broadleaved Indigenous Hardwoods	69.3	3.8
56	Mixed Exotic Shrubland	0.7	0.04
58	Matagouri or Grey Scrub	4.3	0.2
71	Exotic Forest	232.1	12.7
	Total	1830.2	100
Total dense vegetated margin (LCDB classes 45-71)		**328.7**	**18.0**

Because of the large loss of salt marsh compared to its historical extent, even small areas of restoration have the potential to substantially increase the extent and quality of salt marsh in the estuary. However, it is emphasised that the results of tidal inundation modelling should be utilised when planning restorative planting to maximise the future sustainability of plantings in light of ongoing impacts of predicted climate change and sea level rise.

Estuary Place restoration with newly created channel and plantings


Industrial area bordering the estuary near Beach Road


SH6 near Monaco


Rip rap seawall, southeast estuary


Earth bund and cycleway track near Pearl Creek


Erosion near Saxton Creek


Rip rap Rough Island


Artificial cobble field running alongside cycleway and SH6


Plantings in Hoddy arm

Examples of terrestrial margin features photographed in May 2020

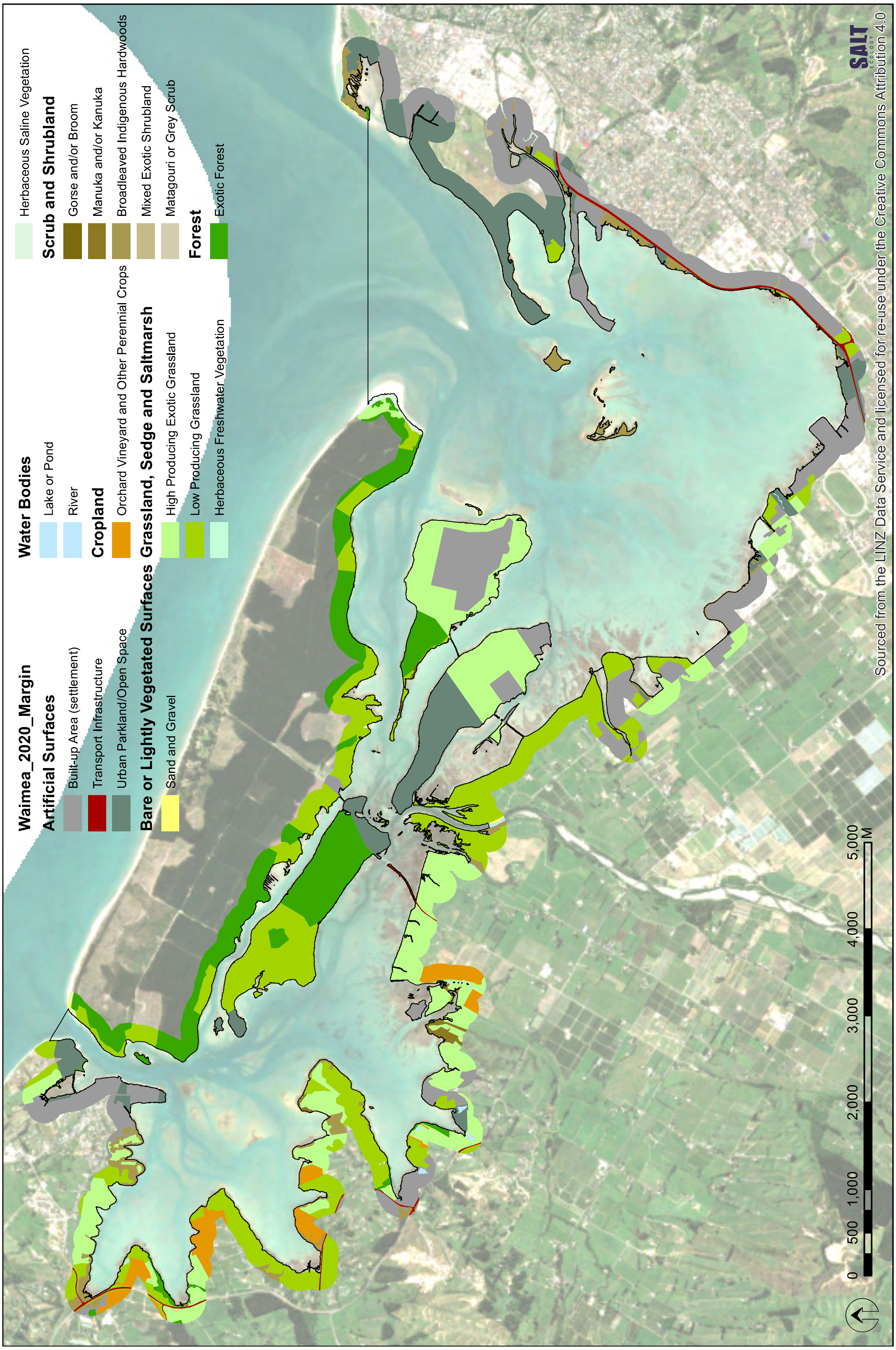


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Fig. 12 Distribution and classes (LCDB5 2018) of vegetation in the 200m terrestrial margin, Waimea Inlet May 2020.

4. SYNTHESIS OF KEY FINDINGS

This report has described a broad scale habitat mapping and assessment survey of Waimea Inlet, largely following the broad scale survey methods described in New Zealand's NEMP.

A summary of key broad scale features measured in 2020 is provided in Table 14. with additional supporting data used to assess estuary condition presented in Table 15. In

Table 16 indicators are assessed in relation to condition rating criteria (presented in Table 4), and compared with previous years.

For the comparison, earlier GIS data (1946, 1985, 1999, 2006, 2014) were QA checked and clipped or adjusted to provide a standardised extent across surveys. For 1946 and 1985, only salt marsh was mapped and the data summaries in the hard copy report were found to be significantly different to the coverages obtained from the GIS files that the report was based on. As it could not be determined which was the more reliable source, the reported data were used. Because the historical coverage also excluded the Tahunanui back beach estuary, an estimate of the back beach saltmarsh (10ha) was added to the 1946 extent for assessing change from baseline. For all other years, where discrepancies occurred between GIS data and reported values, the underlying GIS data were used.

The 2020 survey revealed the estuary is very much intertidally dominated (81%) with a large proportion of the intertidal flats being perched high in the tidal range such that they are exposed for long parts of the tidal cycle. Over the summer, this facilitates the drying and hardening of sediments. This effect is particularly evident where mud-dominated sediments are present, with the resultant conditions too harsh for many plants and animals to inhabit. Such habitats are widespread due to 46.8% of the intertidal area having >50% mud content, most of which is located in deposition zones in the mid-upper intertidal basins and embayments of both arms.

However, the source of the mud-dominated sediment appears to be largely historical. The first comprehensive survey of the estuary in 1990 (Davidson & Moffatt 1990) reported that 1282ha (48%) of the estuary comprised mudflats and high

Table 14. Summary of broad scale indicators, Waimea Inlet May 2020.

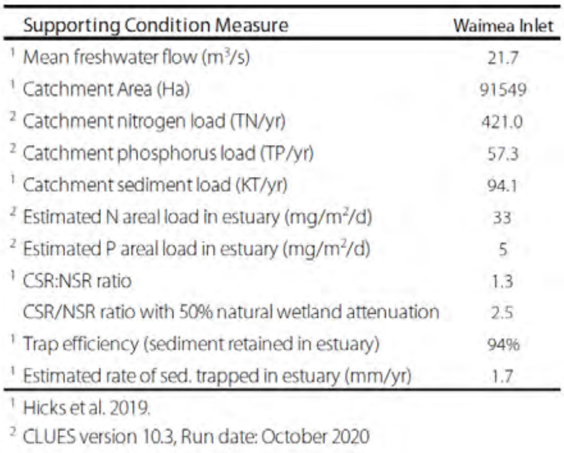
Component	Ha	%Estuary	%Intertidal	%Salt marsh	%Margin
Area					
Intertidal area	2808.1	81.1			
Subtidal area	654.3	18.9			
Total estuary area	**3462.4**	**100**			
Substrate					
Mud-elevated sediment (25-50% mud)	232.4		8.3		
Mud-dominated sediment (>50% mud)	1313.6		46.8		
Total mud elevated sediment (>25% mud)	**1545.9**		**55.1**		
Macroalgae and seagrass					
Macroalgal beds (≥50% cover)	20.3		0.7		
Seagrass (≥50% cover)	21.6		0.8		
Salt marsh					
Estuarine Shrub	11.4	0.3	0.4	4.1	
Tussockland	15.9	0.5	0.6	5.7	
Sedgeland	1.4	0.0	0.0	0.5	
Reedland	0.2	0.0	0.0	0.1	
Rushland	87.2	2.5	3.1	31.4	
Herbfield	162.1	4.7	5.8	58.3	
Salt marsh total	**278.2**	**8.0**	**9.9**	**100**	
200m Terrestrial margin					
% Densely vegetated (LCDB classes 45-71)	328.7				18.0

shore flats, very similar to the 1313ha (46.8%) reported in 2020. Monitoring of sediment deposition over the past decade by TDC has indicated very low net rates of sediment accumulation (average 0.1mm/yr), well below the 2mm/yr guideline value proposed for New Zealand estuaries.

Historical coring and dating of sediments undertaken at two sites in deposition zones also showed low rates of sediment deposition (1.3mm to 1.5mm/year) since ~1964, but with a period of high input (12.7mm/year) between ~1953 and 1964 consistent with anecdotal reports of sediment inputs during development of orchard land in the 1950's and 1960's (Stevens & Robertson 2011). Underlying these mud-dominated sediments, derived largely from post glacial deposits in the catchment, were sand-dominated sediments containing many intact shells, indicating that prior to catchment development the estuary would have been very different to its current state.

Part of the reason for the change in state over time is that the estuary is predicted to trap and retain 94% of the sediment that enters it (Table 15, Hicks et al. 2019), making it relatively susceptible to sediment inputs. Although this retention rate may be relatively accurate for the numerous smaller sub-catchment inputs that enter the main deposition basins and smaller side arms of the estuary, it is likely significantly overestimate sediment retention from the Waimea River which is the primary source of sediment to the estuary. This is because the Waimea River discharges relatively close to the estuary entrance, and significant volumes of sediment are clearly discharged directly to Tasman Bay during elevated river flows.

Table 15. Supporting data used to assess estuary ecological condition.



Supporting Condition Measure	Waimea Inlet
[1] Mean freshwater flow (m^3/s)	21.7
[1] Catchment Area (Ha)	91549
[2] Catchment nitrogen load (TN/yr)	421.0
[2] Catchment phosphorus load (TP/yr)	57.3
[1] Catchment sediment load (KT/yr)	94.1
[2] Estimated N areal load in estuary (mg/m^2/d)	33
[2] Estimated P areal load in estuary (mg/m^2/d)	5
[1] CSR:NSR ratio	1.3
CSR/NSR ratio with 50% natural wetland attenuation	2.5
[1] Trap efficiency (sediment retained in estuary)	94%
[1] Estimated rate of sed. trapped in estuary (mm/yr)	1.7

[1] Hicks et al. 2019.

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

The current sources of sediment to the estuary were recently assessed using forensic methods (Gibbs & Woodward 2018) who, not unexpectedly, found sediment entered the estuary from multiple land uses. Because of the large catchment size, much of the sediment at the point that it enters the estuary reflects a mix of contributing land uses with no clear source able to be attributed to it. Gibbs and Woodward (2018) classified this component as *legacy sediment from bank 'erosion'*. However, further up the

Table 16. Summary of broad scale condition rating scores based on the key indicators and criteria in Table 4. Baseline data and survey year shown in Appendix 8.

Indicator	Unit	1946	1985	1990	1999	2006	2014	2020
Mud-dominated substrate[1]	% of intertidal area >50% mud	na	na	33	70	40	35	38
Macroalgae (OMBT)	Ecological Quality Rating (EQR)	na	na	na	na	0.6	0.55	0.73
Seagrass (>50%)[2]	% decrease from baseline	na	na	na	51.3	47.8	47.4	62.8
Salt marsh extent (current)	% of intertidal area	12.5	9.6	7.2	8.1	11.2	10.8	9.9
Historical salt marsh extent[3]	% of historical remaining[3]	<40	<40	<40	<40	<40	<40	<40
200m terrestrial margin	% densely vegetated	na	na	na	na	na	22	18
High Enrichment Conditions	ha	na	na	na	na	na	28	20.3
High Enrichment Conditions	% of estuary	na	na	na	na	na	0.7	0.6

[1] To enable comparison across years, mud dominated substrate assessed as percentage of intertidal area excluding salt marsh.

[2] Seagrass change rated for total seagrass cover (>50%).

[3] Historic salt marsh extent not formally assessed, but assumed to have been >900ha.

Condition rating key:

Very Good	Good	Fair	Poor

catchment, their results clearly show that inputs are proportionally higher from harvested pine forest than pasture and native forest sources. The results indicate that forest harvesting has the greatest potential to significantly increase sediment loads to the estuary, but that management of sediment losses from all land disturbance activities is important.

This need was highlighted by localised fine sediment deposits (~20mm) over otherwise firm muddy sand, which was observed on the tidal flats in the eastern arm in 2020, and with many of the small stream deltas in the eastern arm also showing signs of recent fine sediment deposition from the catchment. These results indicate pulsed inputs of fine sediment, possibly as a response to recent weather events (e.g. cyclones Gita, and Fehi are examples where catchment inputs occurred), or from the redistribution of previously deposited sediment within the estuary due to wave or current action. The transitional nature of fine sediment deposits in the estuary is evident in the scouring of some previously mud-dominated areas, in particular near Hoddy and Bronte peninsulas, and Rough Island.

Overall, based on preliminary criteria for assessing estuary health in Table 4, the extent of mud-dominated sediment is rated as 'poor' in

Table 16.

Seagrass beds were sparse across the estuary. The remaining cover (~2% of the intertidal area), is considerably less than ~15% expected for an estuary of this type, e.g. Nelson Haven had a seagrass cover in 2019 of 15% (Stevens & Forrest 2019). The primary reason for the low seagrass presence is likely to be a combination of low clarity water in the estuary, and perched tidal flats that remain exposed for long periods of the tidal cycle, resulting in stress from heating and drying of the estuary sediments. The low clarity water forces seagrass into shallower areas where it is able to photosynthesise, but the greater exposure to drying in the shallower areas, particularly over the summer, creates stressful conditions for plant growth. Consequently, the seagrass beds in the estuary are almost exclusively located near the well-flushed entrance channel and central basin of the eastern arm.

There has been a reported decrease in >50% cover seagrass beds since 2014. This is considered primarily attributable to increased mapping accuracy rather than a significant change in the location or condition of the seagrass present. Overall, in recent years seagrass appears to have been relatively stable, although there are indications that some beds are being impacted by fine sediment deposition. Other losses due to physical disturbance, i.e. from the installation of a sewage pipe in 2011 Between Saxton and Bell Islands, remain evident and highlight the sensitivity of seagrass, and its slow recovery from disturbance. By comparison with the assumed baseline status of seagrass, the current condition rating is 'poor'.

In terms of other indicators, nuisance opportunistic algal growths were uncommon, with 94.5% of the estuary rated as having macroalgae either absent or present as a trace (<1%) cover. At an estuary-wide scale, the macroalgal ecological quality rating was 0.73, giving a rating of 'good' according to both the ETI (see Table 16) and OMBT (see Table 8) criteria. This result is consistent with NIWA's CLUES model estimates, which indicate relatively low average nutrient loads to the estuary of 33mgN/m^2/d (see Table 15). This overall loading is below the threshold of ~100mgN/m^2/d where nuisance growths are commonly encountered in intertidally-dominated estuaries like the Waimea, although localised areas with elevated point source inputs may express problems.

This was evident with localised hotspots of persistent opportunistic macroalgae growth in 2020, in particular adjacent to the MDF plant, the Hoddy-Bronte arm and south of Rough Island. These areas had dense, high biomass growths of sediment-entrained *Gracilaria*, which are contributing to sediment degradation expressed through the presence of HECs. HECS are likely to cause significant adverse ecological impacts to sediment-dwelling animals and, once established, are generally slow to recover. While only covering a small proportion of the total estuary (0.6%), the extent of HEC areas (20.3ha) was rated 'poor' in Table 16. The extent of HECs has slightly reduced since 2014, primarily due to the reduction in dense macroalgal cover in the Hoddy-Bronte arm.

Salt marsh remains a significant feature of the estuary (9.9% of the intertidal) with a minor change in extent from 2014 (10.8%) to 2020 (9.9%). This reflects multiple small localised changes in the condition of salt marsh habitat with terrestrial grasses and weeds starting to dominate over salt marsh in parts of the estuary only infrequently inundated by the tide. There have also been small losses of salt marsh as a result of shoreline erosion, in particular between Vercoes Drain (near Beach Road) and Saxton Creek near Richmond.

Other notable changes in salt marsh include the Tahunanui back beach, where there has been an expansion in tussockland and herbfield over the past 6 years in response to increasing sand inputs to this part of the estuary. The sand is largely sourced from the western end of Tahunanui Beach where the coastal dunes have been eroding. The released sand has been trapped in the estuary and led to a change from mud-dominated to sand-dominated surface substrates and the expansion of existing salt marsh.

The earliest mapped estimate of salt marsh cover in the estuary is ~362ha in 1946, although the natural extent of salt marsh is likely to have been significantly greater due to large scale land clearance and drainage prior to 1946. Compared to the 1946 baseline there has been a net reduction of ~24% in 2020, and a small but steady decline since 2006. Virtually all of the past losses relate to development of the estuary margin for roading, pasture and residential or industrial development.

The 200m wide terrestrial margin bordering the estuary was also highly modified and comprises very few habitat features that are in their natural state. This indicator is rated as 'poor' in 2020, with no significant change in the percentage of densely vegetated margin since 2014. This is likely to change in the next decade or so as the recent plantings become a 'densely vegetated margin'.

The modification of the estuary margin severely restricts the area available for salt marsh growth and disrupts the natural connectivity between the land and the estuary, preventing the migration of estuarine species 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.

The cost of this reduction is high. 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 enabling its natural expansion.

To that end, there are many areas surrounding the estuary margin that are very well suited to salt marsh restoration, and a number of initiatives are underway to increase the extent and diversity of salt marsh and fringing terrestrial margin habitat.

Overall, despite extensive historical habitat modification, significantly reduced habitat diversity, and large areas of mud-dominated sediments, Waimea Inlet retains many areas of very significant ecological value. However, the prevalence of mud-dominated substrate, the persistence of localised dense macroalgal beds and HEC's, and pressures on salt marsh near the estuary margin are key broad scale habitat stressors that threaten these values. Salt marsh losses are likely to increase in future in response to sea level rise due to the current limited capacity for migration, while reductions in sediment loads, and targeted management of localised nutrient inputs, will be required to improve estuary condition.

5. RECOMMENDATIONS

Waimea Inlet has been identified by TDC and NCC as a priority for monitoring because of its high ecological and human use values, and because it is vulnerable to elevated sedimentation and localised eutrophication issues. Based on the 2020 results, the following recommendations are proposed for consideration:

Monitoring

Broad Scale Habitat

In order to track changes in the dominant features of the estuary, undertake broad scale habitat mapping at 5-10 yearly intervals. In light of the potential for rapid changes to nuisance macroalgal beds, the extent and state of established and persistent macroalgal beds should be synoptically assessed annually to determine the need for further or more frequent monitoring. This involves a quick visual assessment of whether there has been a significant change in macroalgal cover or biomass over the previous year.

Sedimentation Rate

Given the consistency of sedimentation rate monitoring results over the past 10 years it is recommended that sedimentation be monitored biennially.

Catchment Influences

Where localised opportunistic nuisance macroalgal growths are present, it is recommended that the potential source of nutrients to these parts of the estuary be investigated and managed as appropriate.

In addition to field-based monitoring and assessment, it would also be helpful if the councils maintained records on the location and scale of known catchment disturbances or land use changes (e.g. forest harvesting, 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. The use of forensic methods such as compound specific stable isotopes (CSSI) to trace the source of wider catchment sediment and nutrient inputs is also recommended.

Management and Restoration

There is significant potential for the ecological restoration of Waimea Inlet. To that end, both NCC and TDC are currently developing strategies to identify and prioritise areas for ecological enhancement and protection, including recommending specific restoration options, e.g. replanting salt marsh, improving tidal flushing, recontouring shorelines, and removing barriers to salt marsh expansion. This work would ideally contribute to a region-wide planning approach facilitated to assist community and stakeholder initiatives.

A key component of the strategy should be to delineate low-lying areas landward of seawalls but which were previously within the estuary, or areas likely to be impacted by sea level rise, using GIS-based mapping techniques and existing coastal LIDAR data. These outputs could be used to encourage the protection or expansion of salt marsh on land adjacent to the estuary, and to facilitate planning for the managed retreat of salt marsh in response to predicted sea level rise.

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

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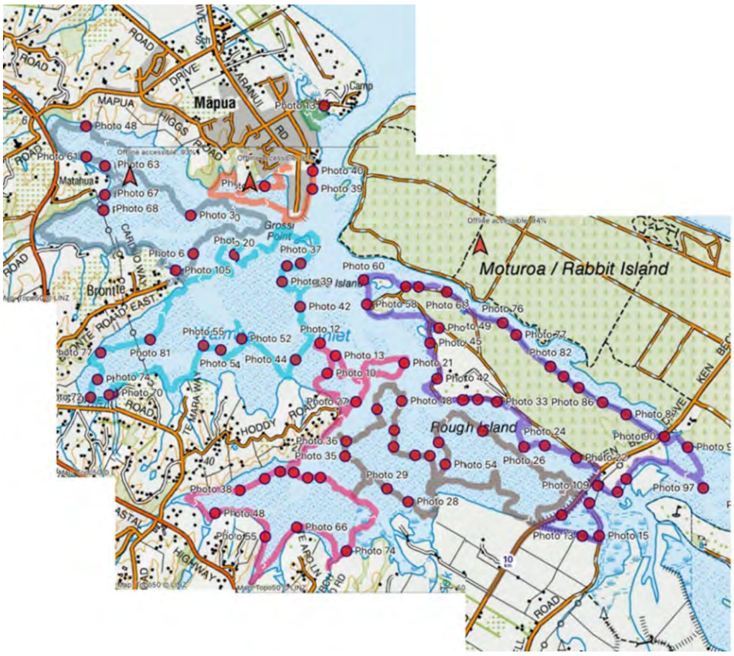
APPENDICES

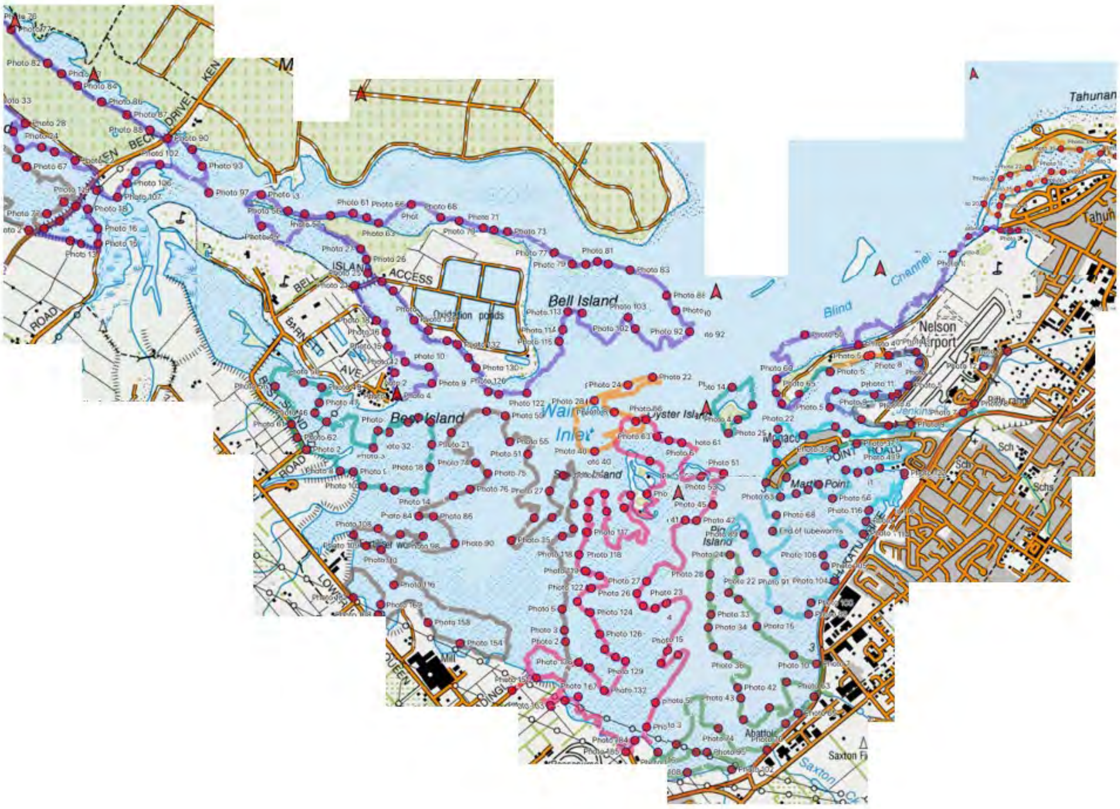
APPENDIX 1. GROUND TRUTHING TRACKS AND BROADSCALE HABITAT CLASSIFICATION DEFINITIONS

Field tracks and photos were recorded using an Iphone 11 and the Topo GPS App V6.3.2.

A. Western arm, Waimea Inlet.



B. Eastern arm, Waimea Inlet



Habitat classification

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).

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: 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 or Tubeworm field: Area that is dominated by raised beds of 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

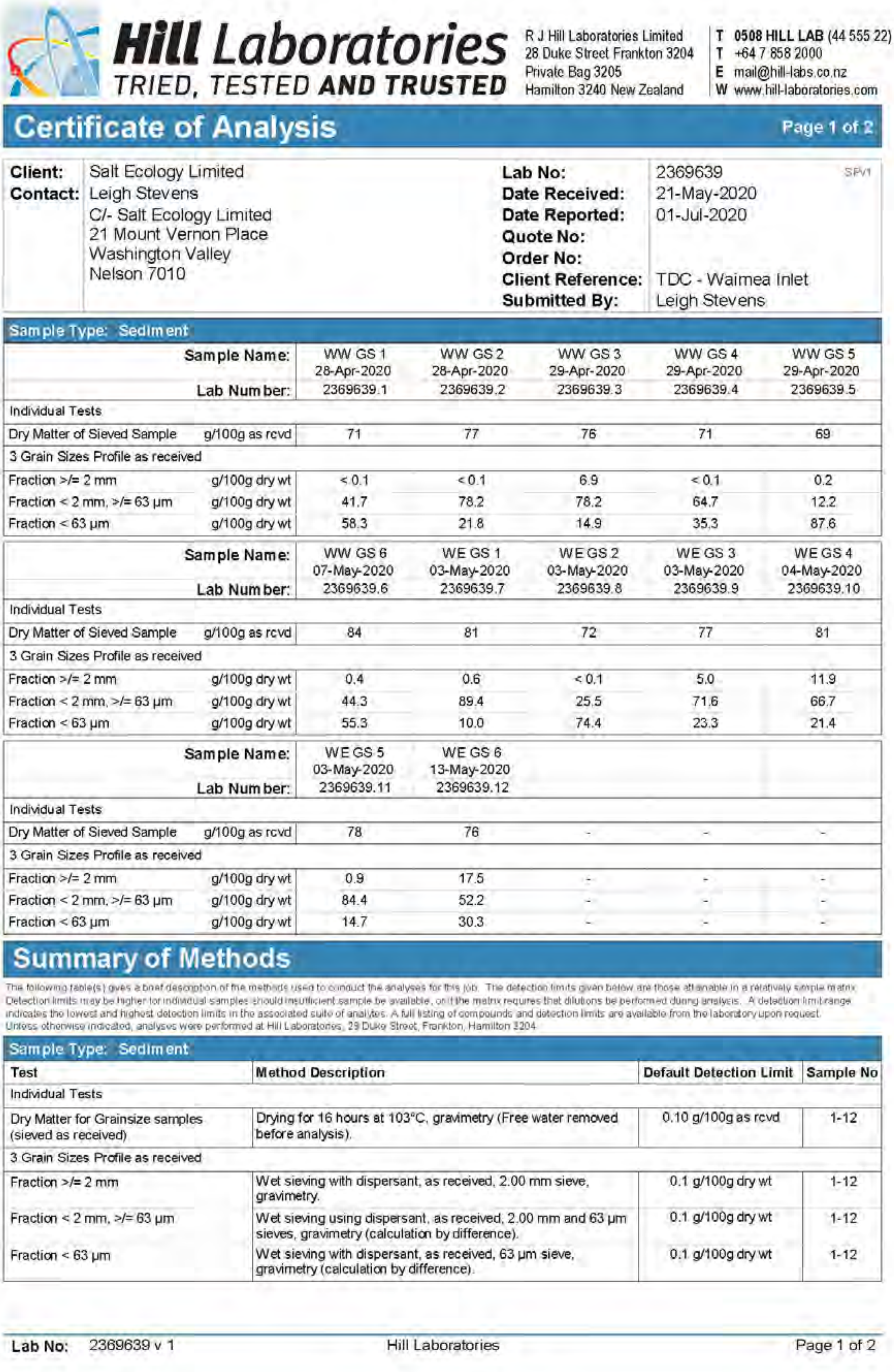
Artificial Surfaces	
1	Built-up Area (settlement)
2	Urban ParklandOpen Space
5	Transport Infrastructure
6	Surface Mines and Dumps
Bare or Lightly Vegetated Surfaces	
10	Sand and Gravel
12	Landslide
14	Permanent Snow and Ice
15	Alpine Grass/Herbfield
16	Gravel and Rock
Water Bodies	
20	Lake or Pond
21	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. ANALYTICAL METHODS FOR SEDIMENT SAMPLES (RJ HILL LABORATORIES)



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Certificate of Analysis

Page 1 of 2

Client:	Salt Ecology Limited	**Lab No:**	2369639 SPv1
Contact:	Leigh Stevens C/- Salt Ecology Limited 21 Mount Vernon Place Washington Valley Nelson 7010	**Date Received:**	21-May-2020
		Date Reported:	01-Jul-2020
		Quote No:	
		Order No:	
		Client Reference:	TDC - Waimea Inlet
		Submitted By:	Leigh Stevens

Sample Type: Sediment

Sample Name:		WW GS 1 28-Apr-2020	WW GS 2 28-Apr-2020	WW GS 3 29-Apr-2020	WW GS 4 29-Apr-2020	WW GS 5 29-Apr-2020
Lab Number:		2369639.1	2369639.2	2369639.3	2369639.4	2369639.5
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	71	77	76	71	69
3 Grain Sizes Profile as received						
Fraction >/= 2 mm	g/100g dry wt	< 0.1	< 0.1	6.9	< 0.1	0.2
Fraction < 2 mm, >/= 63 µm	g/100g dry wt	41.7	78.2	78.2	64.7	12.2
Fraction < 63 µm	g/100g dry wt	58.3	21.8	14.9	35.3	87.6

Sample Name:		WW GS 6 07-May-2020	WE GS 1 03-May-2020	WE GS 2 03-May-2020	WE GS 3 03-May-2020	WE GS 4 04-May-2020
Lab Number:		2369639.6	2369639.7	2369639.8	2369639.9	2369639.10
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	84	81	72	77	81
3 Grain Sizes Profile as received						
Fraction >/= 2 mm	g/100g dry wt	0.4	0.6	< 0.1	5.0	11.9
Fraction < 2 mm, >/= 63 µm	g/100g dry wt	44.3	89.4	25.5	71.6	66.7
Fraction < 63 µm	g/100g dry wt	55.3	10.0	74.4	23.3	21.4

Sample Name:		WE GS 5 03-May-2020	WE GS 6 13-May-2020			
Lab Number:		2369639.11	2369639.12			
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	78	76	-	-	-
3 Grain Sizes Profile as received						
Fraction >/= 2 mm	g/100g dry wt	0.9	17.5	-	-	-
Fraction < 2 mm, >/= 63 µm	g/100g dry wt	84.4	52.2	-	-	-
Fraction < 63 µm	g/100g dry wt	14.7	30.3	-	-	-

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 simple 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. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. 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	1-12
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	1-12
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	1-12
Fraction < 63 µm	Wet sieving with dispersant, as received, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12

Lab No: 2369639 v 1 Hill Laboratories Page 1 of 2

APPENDIX 3. 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 (% 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).

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.					

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.

EQR calculation

Each metric in the OMBT has equal weighting and is combined to produce the **Ecological Quality Rating** 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.

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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.

Waimea Inlet 2020 OMBT Patch ID and biomass data

Ent. 0= not entrained, 1=entrained

PatchID	FieldCode	%	Biomass (gm2)	Ent.	Species
1	Grch	50	3200	0	Gracilaria
1	Grch	50	3200	0	Gracilaria
1	Grch Ulsp	40 5	1360	0	Gracilaria, Ulva
1	Grch Ulsp	40 5	1360	0	Gracilaria, Ulva
2	Ulsp	100	3000	0	Ulva
3	Grch	25	1040	0	Gracilaria
4	Ulsp	10	160	0	Ulva
5	Ulsp	5	120	0	Ulva
6	Grch	15	400	0	Gracilaria
7	Grch	50	1600	0	Gracilaria
7	Grch	75	3000	0	Gracilaria
7	Grch	75	3000	0	Gracilaria
8	Grch	30	1100	0	Gracilaria
8	Grch	35	1200	0	Gracilaria
9	Ulsp Grch	5 1	100	0	Ulva, Gracilaria
9	Ulsp	5	80	0	Ulva
10	Grch	15	200	0	Gracilaria
10	Grch	15	200	0	Gracilaria
11	Ulsp	15	160	0	Ulva
11	Ulsp	15	180	0	Ulva
12	Grch Ulsp	5 5	200	0	Gracilaria, Ulva
12	Grch Ulsp	5 5	240	0	Gracilaria, Ulva
12	Ulsp	10	120	0	Ulva
12	Ulsp	10	140	0	Ulva
12	Ulsp	5	115	0	Ulva
12	Ulsp	5	120	0	Ulva
12	Ulsp Grch	10 5	140	0	Ulva, Gracilaria
12	Ulsp Grch	5 1	110	0	Ulva, Gracilaria
13	Grch	60	4000	1	Gracilaria
14	Grch Ulsp	60 5	3840	0	Gracilaria, Ulva
15	Ulsp Grch	10 5	150	0	Ulva, Gracilaria
15	Ulsp Grch	20 5	260	0	Ulva, Gracilaria
16	Grch Ulsp	5 5	240	0	Gracilaria, Ulva
17	Grch	70	4320	0	Gracilaria
17	Grch	85	4320	0	Gracilaria
17	Grch	85	4320	0	Gracilaria
17	Grch	85	4320	0	Gracilaria
18	Grch	60	3680	1	Gracilaria
19	Grch Ulsp	10 10	400	0	Gracilaria, Ulva
19	Grch Ulsp	10 10	400	0	Gracilaria, Ulva
20	Grch Ulsp	75 1	3840	1	Gracilaria, Ulva
20	Grch Ulsp	75 1	3840	1	Gracilaria, Ulva
20	Grch Ulsp	75 5	4240	1	Gracilaria, Ulva
21	Grch Ulsp	75 1	2560	0	Gracilaria, Ulva
21	Grch Ulsp	75 1	2560	0	Gracilaria, Ulva
21	Grch Ulsp	75 1	2560	0	Gracilaria, Ulva
21	Grch Ulsp	75 1	2560	0	Gracilaria, Ulva
21	Grch Ulsp	75 1	2560	0	Gracilaria, Ulva
22	Grch	50	1800	0	Gracilaria
23	Grch Ulsp	30 20	1600	0	Gracilaria, Ulva
23	Ulsp Grch	20 20	1600	0	Ulva, Gracilaria
23	Ulsp Grch	30 20	1600	0	Ulva, Gracilaria
24	Grch	60	3600	1	Gracilaria
24	Grch	80	4960	1	Gracilaria
25	Ulsp Grch	40 20	3200	1	Ulva, Gracilaria
26	Grch Ulsp	25 10	1400	0	Gracilaria, Ulva
27	Grch	30	1100	0	Gracilaria
27	Grch	40	1250	0	Gracilaria
27	Grch	60	1460	0	Gracilaria
27	Grch	60	1480	0	Gracilaria
27	Grch Ulsp	30 2	1100	0	Gracilaria, Ulva
27	Grch Ulsp	40 1	1240	0	Gracilaria, Ulva
27	Grch Ulsp	40 1	1240	0	Gracilaria, Ulva
27	Grch Ulsp	40 1	1240	0	Gracilaria, Ulva
27	Grch Ulsp	45 1	1300	0	Gracilaria, Ulva
28	Grch	10	300	0	Gracilaria
29	Grch Ulsp	45 1	1340	0	Gracilaria, Ulva
30	Grch	20	900	0	Gracilaria
30	Grch	25	1200	0	Gracilaria
30	Grch Ulsp	40 1	1840	0	Gracilaria, Ulva
30	Ulsp Grch	25 25	2120	0	Ulva, Gracilaria
30	Ulsp Grch	30 20	2040	0	Ulva, Gracilaria
30	Grch Ulsp	25 25	2120	0	Gracilaria, Ulva
31	Grch	40	1650	0	Gracilaria
31	Grch	40	1880	0	Gracilaria
31	Grch Ulsp	45 1	1840	0	Gracilaria, Ulva
31	Grch Ulsp	45 1	1840	0	Gracilaria, Ulva
32	Grch Ulsp	10 10	1200	0	Gracilaria, Ulva
32	Grch Ulsp	10 10	2400	0	Gracilaria, Ulva
32	Ulsp Grch	20 5	2700	0	Ulva, Gracilaria
32	Ulsp Grch	25 5	3360	0	Ulva, Gracilaria
33	Ulsp	50	3500	0	Ulva
34	Grch Ulsp	75 5	5120	0	Gracilaria, Ulva
34	Grch Ulsp	75 5	5120	0	Gracilaria, Ulva
35	Ulsp	15	800	0	Ulva
36	Grch	10	600	0	Gracilaria
37	Ulsp	40	600	0	Ulva
37	Ulsp Grch	40 10	750	0	Ulva, Gracilaria
37	Ulsp Grch	40 10	640	0	Ulva, Gracilaria
37	Ulsp Grch	40 20	750	0	Ulva, Gracilaria
37	Ulsp Grch	40 20	750	0	Ulva, Gracilaria
37	Ulsp Grch	45 20	780	0	Ulva, Gracilaria
38	Grch	90	6080	0	Gracilaria
39	Ulsp	70	3200	0	Ulva
39	Ulsp	70	3360	0	Ulva
40	Grch Ulsp	30 10	2400	0	Gracilaria, Ulva
41	Ulsp Grch	40 10	2500	0	Ulva, Gracilaria
41	Ulsp Grch	60 10	3200	0	Ulva, Gracilaria
41	Ulsp Grch	60 10	3200	0	Ulva, Gracilaria
42	Grch Ulsp	50 5	2000	0	Gracilaria, Ulva
42	Grch Ulsp	50 5	2000	0	Gracilaria, Ulva
43	Ulsp	90	4500	0	Ulva
44	Ulsp	30	1400	0	Ulva
44	Ulsp	40	1700	0	Ulva
45	Grch Ulsp	25 45	3500	0	Gracilaria, Ulva
46	Grch	25	1500	0	Gracilaria
47	Grch Ulsp	30 30	2560	0	Gracilaria, Ulva
48	Ulsp	15	700	0	Ulva
49	Grch	40	1350	0	Gracilaria
50	Ulsp	75	3400	0	Ulva
51	Ulsp	55	2880	0	Ulva
52	Grch	45	3440	0	Gracilaria
53	Grch	30	1600	0	Gracilaria
54	Grch	20	800	0	Gracilaria
55	Grch	30	2000	1	Gracilaria
56	Grch	20	900	0	Gracilaria
56	Grch	30	1160	0	Gracilaria
56	Grch	35	1300	0	Gracilaria
57	Grch	35	2100	1	Gracilaria
57	Grch	35	2100	1	Gracilaria
58	Grch	15	1100	0	Gracilaria
59	Grch	30	2000	1	Gracilaria
60	Ulsp	40	1200	0	Ulva
61	Grch	30	2040	0	Gracilaria
62	Ulsp	40	1500	0	Ulva
62	Ulsp	60	2000	0	Ulva
63	Grch	30	1880	1	Gracilaria
63	Grch	30	1880	1	Gracilaria
64	Ulsp	10	160	0	Ulva
65	Grch	10	300	0	Gracilaria
65	Grch	35	1200	1	Gracilaria
66	Grch	70	4160	0	Gracilaria
67	Grch	30	1100	0	Gracilaria
68	Grch	75	6240	0	Gracilaria
69	Grch	30	1600	1	Gracilaria
69	Grch	40	2460	1	Gracilaria
69	Grch	30	1600	1	Gracilaria
69	Grch	50	2740	1	Gracilaria
70	Grch	50	3440	0	Gracilaria
71	Grch	25	800	1	Gracilaria
72	Grch	20	680	1	Gracilaria
73	Grch	50	2720	1	Gracilaria
74	Grch	70	5240	1	Gracilaria
74	Grch	80	2560	0	Gracilaria
75	Grch	60	2640	1	Gracilaria
76	Grch	100	4000	0	Gracilaria
77	Grch	80	2200	0	Gracilaria
78	Grch	60	1440	0	Gracilaria
78	Grch	50	2040	1	Gracilaria
78	Grch Ulsp	15 75	2400	0	Gracilaria, Ulva
78	Grch	35	1520	1	Gracilaria
79	Grch	30	1300	0	Gracilaria
80	Grch	20	1280	1	Gracilaria
81	Grch	70	2800	0	Gracilaria
82	Grch	100	2240	0	Gracilaria
83	Grch	30	3040	1	Gracilaria
83	Grch	30	1380	0	Gracilaria
83	Grch	50	3400	1	Gracilaria
83	Grch	30	3040	1	Gracilaria
83	Grch	31	1380	0	Gracilaria
84	Grch	10	300	0	Gracilaria
85	Ulsp	2	20	0	Ulva
85	Ulsp Grch	10 2	60	0	Ulva, Gracilaria
85	Grch Ulsp	2 2	40	0	Gracilaria, Ulva
86	Grch	30	800	0	Gracilaria
87	Grch Ulsp	35 5	400	0	Gracilaria, Ulva
88	Grch	20	580	0	Gracilaria
89	Grch	15	400	0	Gracilaria
90	Grch Ulsp	90 1	12000	1	Gracilaria, Ulva
91	Grch	95	10000	1	Gracilaria
91	Grch	20	1000	1	Gracilaria
91	Grch	75	6400	1	Gracilaria
92	Grch	95	8000	1	Gracilaria
92	Grch Ulsp	50 1	3200	1	Gracilaria, Ulva
93	Grch Ulsp	50 1	4960	1	Gracilaria, Ulva
93	Grch	80	6000	1	Gracilaria
93	Grch	75	5600	1	Gracilaria
93	Grch Ulsp	50 1	2400	0	Gracilaria, Ulva
93	Grch	75	6400	1	Gracilaria
94	Grch	10	300	0	Gracilaria
94	Grch	20	800	0	Gracilaria
94	Grch	30	1000	0	Gracilaria
95	Grch	80	2000	0	Gracilaria
95	Grch Ulsp	90 1	2240	0	Gracilaria, Ulva
96	Grch	10	300	0	Gracilaria
96	Grch	96	2880	0	Gracilaria
96	Grch	20	800	0	Gracilaria
96	Grch	30	1500	1	Gracilaria
96	Grch	70	3220	0	Gracilaria
96	Grch	50	1500	0	Gracilaria
96	Grch	50	1840	0	Gracilaria
97	Grch	10	300	0	Gracilaria
97	Grch	20	800	0	Gracilaria
97	Grch	40	1600	0	Gracilaria
98	Grch	30	1500	0	Gracilaria
99	Grch	10	300	0	Gracilaria
99	Grch	20	700	0	Gracilaria
99	Grch	30	1450	0	Gracilaria
99	Grch	35	1550	0	Gracilaria
99	Grch	55	2260	0	Gracilaria
99	Grch	55	2350	0	Gracilaria
99	Grch	50	2080	0	Gracilaria
100	Grch	30	1600	0	Gracilaria
101	Grch	98	6960	0	Gracilaria
102	Grch Ulsp	80 1	2480	0	Gracilaria, Ulva
103	Grch Ulsp	50 1	2240	0	Gracilaria, Ulva
104	Grch	25	680	0	Gracilaria
105	Grch	20	700	0	Gracilaria
106	Grch	80	3500	0	Gracilaria
107	Ulsp	10	160	0	Ulva
107	Ulsp	5	80	0	Ulva
108	Ulsp	20	300	0	Ulva
108	Ulsp	5	80	0	Ulva
109	Ulsp	5	80	0	Ulva
110	Grch	10	250	0	Gracilaria
110	Grch	2	30	0	Gracilaria
111	Grch	50	1500	0	Gracilaria
112	Grch	25	1000	0	Gracilaria
113	Grch	2	30	0	Gracilaria
114	Grch Ulsp	35 5	1280	1	Gracilaria, Ulva
114	Grch	20	1000	1	Gracilaria
115	Grch	2	30	0	Gracilaria
116	Grch	2	30	0	Gracilaria
117	Grch	2	30	0	Gracilaria
117	Grch	60	1700	1	Gracilaria
118	Grch	30	800	0	Gracilaria
118	Grch	30	760	0	Gracilaria
119	Grch Ulsp	30 1	920	1	Gracilaria, Ulva
119	Grch Ulsp	30 1	1040	1	Gracilaria, Ulva
120	Ulsp	50	1250	0	Ulva
121	Ulsp	20	480	0	Ulva
121	Ulsp	70	1520	0	Ulva
121	Ulsp Grch	25 10	520	0	Ulva, Gracilaria
122	Grch	20	1040	0	Gracilaria
122	Grch	20	1040	0	Gracilaria
123	Ulsp	20	300	0	Ulva
123	Ulsp	30	430	0	Ulva
124	Ulsp	70	1700	0	Ulva

APPENDIX 4. INFORMATION SUPPORTING RATINGS IN REPORT TABLE 4

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.

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APPENDIX 5. SEDIMENT SAMPLING VALIDATION DATA

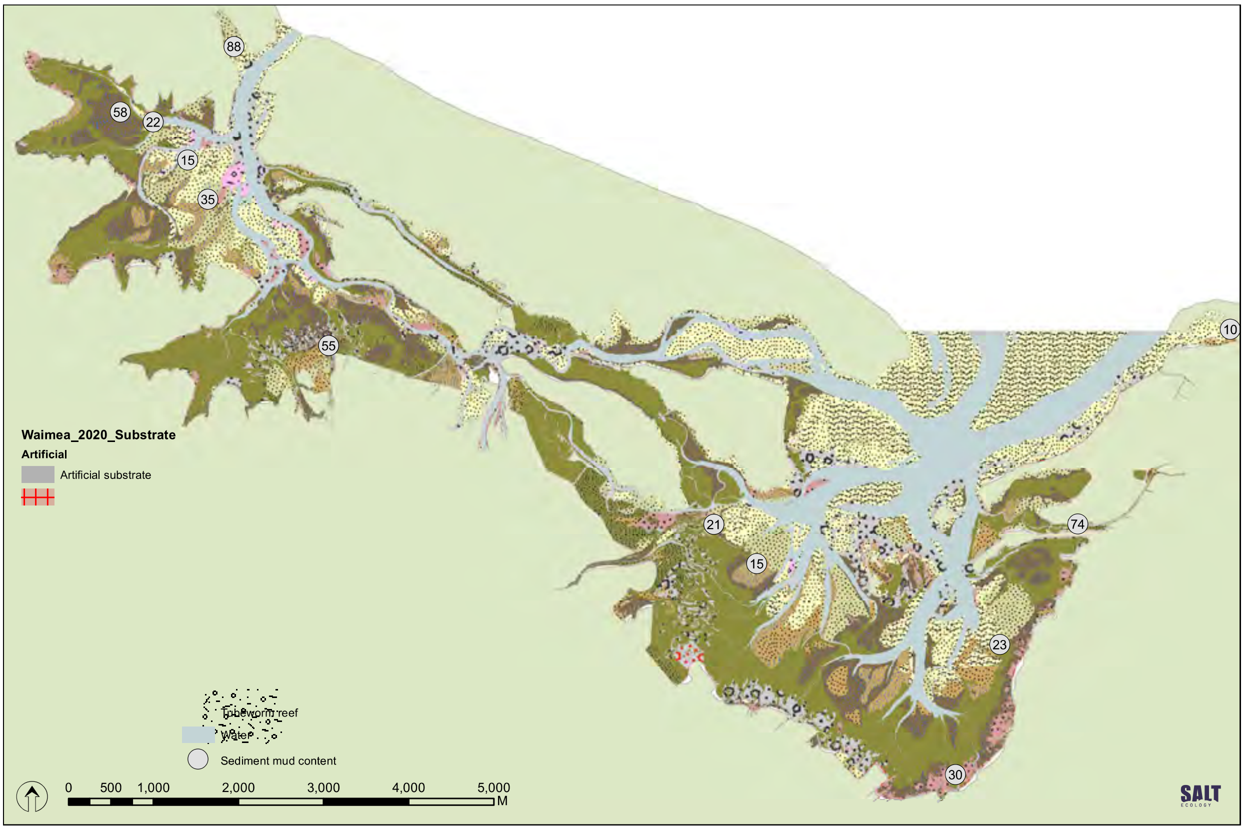
Comparison of field sediment type classifications against laboratory analysis of grain size (see Appendix 2 for grain size analytical results). Depth of apparent redox potential discontinuity (aRPD) also shown.

Discrepancies are highlighted with grey shading, which reflect locations where the field classification differed from the actual mud content. Four of the discrepancies are within ~5% of the class threshold. As many of the samples were collected specifically to evaluate class boundaries, these results are not unexpected. At two of the sites (WWGS4 and WEGS2) the offset is likely due to a thin layer of muddy sediment deposited on top of a relatively coarse sand/gravel base. The largest relative offset was for WWGS2 where sand-dominated sediment was muddier than estimated.

A. Comparative data. See Table in Appendix 1 for field classification codes.

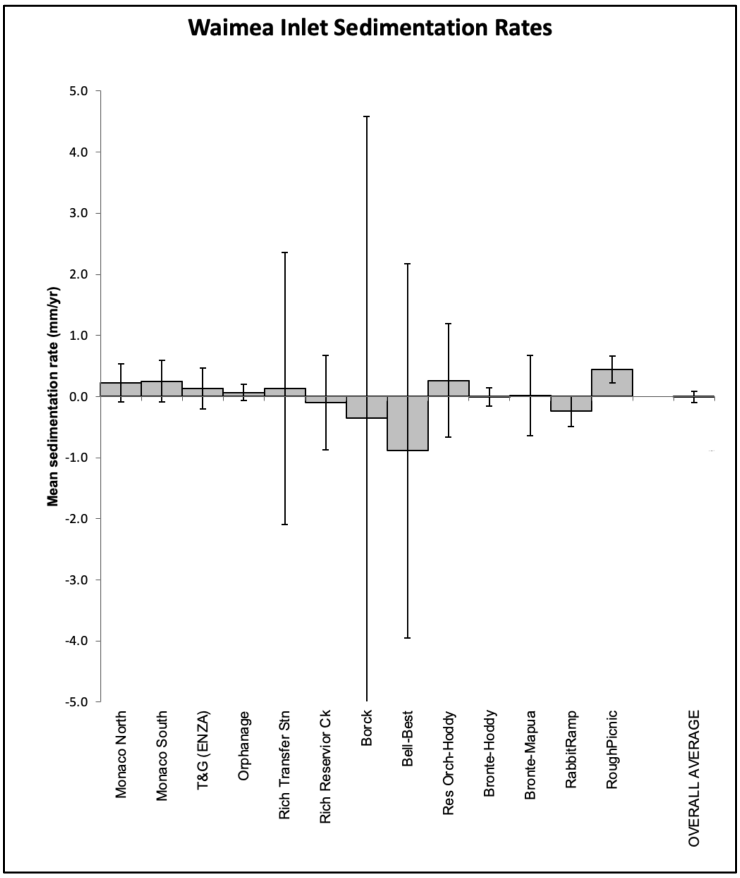
				Assessed	Measured			
Arm	Name	Latitude/longitude	Field code	Class	%mud (<63um)	%sand (63um-2mm)	%gravel (>2mm)	aRPD depth (mm)
West	WWGS1	41.259256,173.085304	ssm	>50-90	58.3	41.7	< 0.1	5
West	WWGS2	41.260282,173.089946	fs	<10	21.8	78.2	< 0.1	10
West	WWGS3	41.264311,173.094754	fms10	>10-25	14.9	78.2	6.9	5
West	WWGS4	41.267403,173.098627	ssm	>50-90	35.3	64.7	< 0.1	10
West	WWGS5	41.252301,173.101239	fm90	>90-100	87.6	12.2	0.2	5
West	WWGS6	41.283919,73.114573	fms25	>25-50	55.3	44.3	0.4	100
East	WEGS1	41.281996,173.241114	fs	<10	10	89.4	0.6	10
East	WEGS2	41.302639,173.219789	fm90	>90-100	74.4	25.5	< 0.1	1
East	WEGS3	41.315391,173.208879	sms25	>25-50	23.3	71.6	5	10
East	WEGS4	41.302763,173.168711	fms25	>25-50	21.4	66.7	11.9	2
East	WEGS5	41.306909,173.174728	fs10	>10-25	14.7	84.4	0.9	5
East	WEGS6	41.329720,173.201758	sms25	>25-50	30.3	52.2	17.5	4

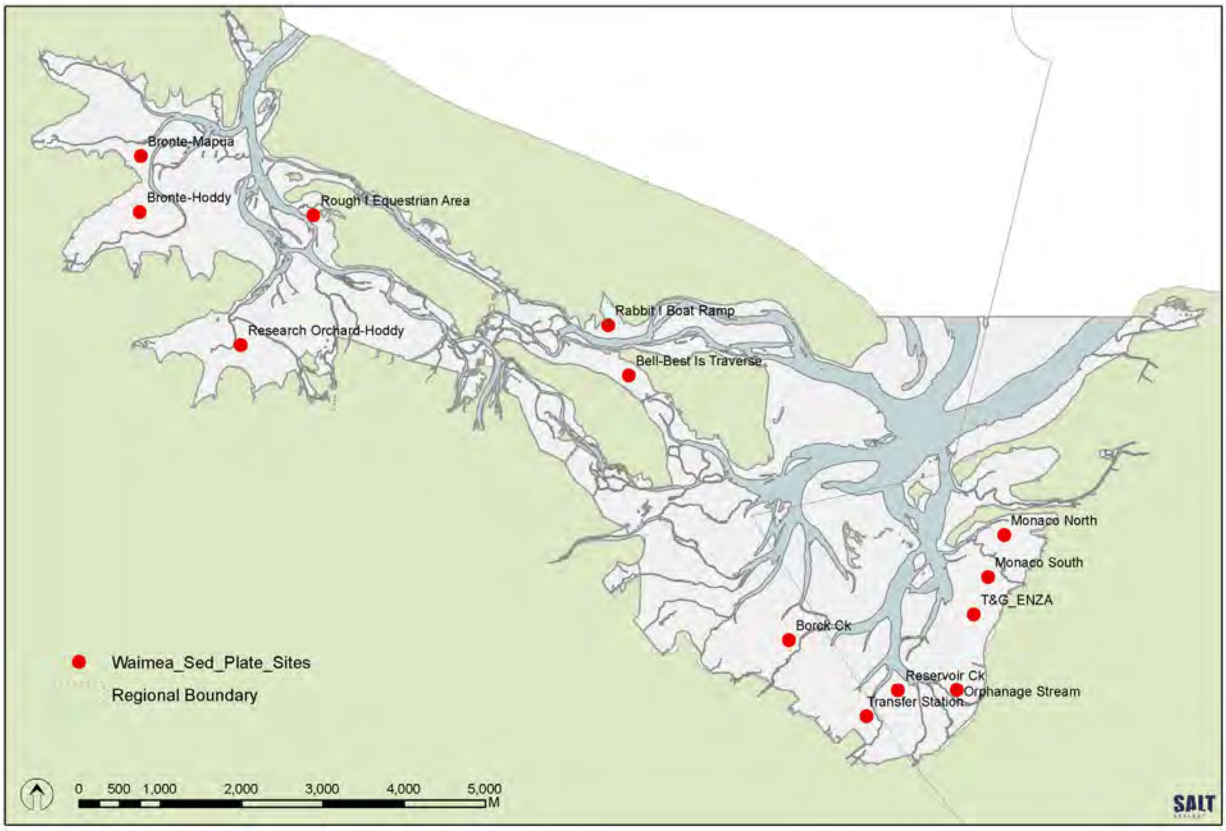
B. Map of sediment sampling stations and mud content (rounded to nearest whole number).



APPENDIX 6. SEDIMENT PLATE MONITORING SUMMARY

Summarised from data provided by TDC.





APPENDIX 7. SALT MARSH VEGETATION DETAIL

Subclass	Dominant species	SubDom1	SubDom2	SubDom3	Ha	%
Estuarine Shrub	*Atriplex cinerea (Grey saltbush)*	*Juncus kraussii (Searush)*			0.01	0.00
	Atriplex cinerea (Grey saltbush)				0.08	0.03
	Plagianthus divaricatus (Salt marsh ribbonwood)	*Apodasmia similis (Jointed wirerush)*			0.14	0.05
	Plagianthus divaricatus (Salt marsh ribbonwood)	*Juncus kraussii (Searush)*	*Apodasmia similis (Jointed wirerush)*		1.08	0.39
	Plagianthus divaricatus (Salt marsh ribbonwood)	*Juncus kraussii (Searush)*			0.18	0.07
	Plagianthus divaricatus (Salt marsh ribbonwood)				9.69	3.48
	Plagianthus divaricatus (Salt marsh ribbonwood)	*Stipa stipoides*	*Festuca arundinacea (Tall fescue)*		0.07	0.02
	Plagianthus divaricatus (Salt marsh ribbonwood)	*Stipa stipoides*	*Festuca arundinacea (Tall fescue)*	*Ulex europaeus (Gorse)*	0.04	0.01
	Plagianthus divaricatus (Salt marsh ribbonwood)	*Stipa stipoides*			0.15	0.05
Tussockland	*Stipa stipoides*	*Festuca arundinacea (Tall fescue)*	*Plagianthus divaricatus (Salt marsh ribbonwood)*		0.01	0.00
	Stipa stipoides	*Juncus kraussii (Searush)*	*Apodasmia similis (Jointed wirerush)*		0.02	0.01
	Stipa stipoides	*Juncus kraussii (Searush)*			0.51	0.18
	Stipa stipoides	*Juncus kraussii (Searush)*	*Sarcocornia quinqueflora (Glasswort)*		0.52	0.19
	Stipa stipoides				12.45	4.48
	Stipa stipoides	*Plagianthus divaricatus (Salt marsh ribbonwood)*			0.28	0.10
	Stipa stipoides	*Plagianthus divaricatus (Salt marsh ribbonwood)*	*Sarcocornia quinqueflora (Glasswort)*		0.03	0.01
	Stipa stipoides	*Sarcocornia quinqueflora (Glasswort)*			0.29	0.10
	Stipa stipoides	*Sarcocornia quinqueflora (Glasswort)*	*Selliera radicans (Remuremu)*		0.37	0.13
	Stipa stipoides	*Sarcocornia quinqueflora (Glasswort)*	*Suaeda novaezelandiae (Sea blite)*		1.42	0.51
Sedgeland	*Schoenoplectus pungens (Three square)*	*Apodasmia similis (Jointed wirerush)*			0.07	0.03
	Schoenoplectus pungens (Three square)	*Juncus kraussii (Searush)*			0.08	0.03
	Schoenoplectus pungens (Three square)				1.25	0.45
Reedland	*Typha orientalis (Raupo)*				0.15	0.06
Rushland	*Apodasmia similis (Jointed wirerush)*	*Festuca arundinacea (Tall fescue)*			0.01	0.00
	Apodasmia similis (Jointed wirerush)	*Juncus kraussii (Searush)*			0.22	0.08
	Apodasmia similis (Jointed wirerush)				11.27	4.05
	Apodasmia similis (Jointed wirerush)	*Plagianthus divaricatus (Salt marsh ribbonwood)*			8.62	3.10
	Apodasmia similis (Jointed wirerush)	*Sarcocornia quinqueflora (Glasswort)*			0.20	0.07
	Ficinia (Isolepis) nodosa (Knobby clubrush)	*Stipa stipoides*	*Plagianthus divaricatus (Salt marsh ribbonwood)*		0.03	0.01
	Juncus kraussii (Searush)	*Apodasmia similis (Jointed wirerush)*			0.12	0.04
	Juncus kraussii (Searush)	*Apodasmia similis (Jointed wirerush)*	*Sarcocornia quinqueflora (Glasswort)*		0.32	0.11
	Juncus kraussii (Searush)	*Apodasmia similis (Jointed wirerush)*	*Schoenoplectus pungens (Three square)*		0.03	0.01
	Juncus kraussii (Searush)	*Atriplex cinerea (Grey saltbush)*			0.01	0.00
	Juncus kraussii (Searush)	*Festuca arundinacea (Tall fescue)*			0.01	0.00
	Juncus kraussii (Searush)	*Festuca arundinacea (Tall fescue)*	*Sarcocornia quinqueflora (Glasswort)*		0.01	0.00
	Juncus kraussii (Searush)	*Festuca arundinacea (Tall fescue)*	*Stipa stipoides*		0.02	0.01
	Juncus kraussii (Searush)	*Isolepis cernua (Slender clubrush)*			0.03	0.01
	Juncus kraussii (Searush)	*Isolepis cernua (Slender clubrush)*	*Samolus repens (Primrose)*		0.01	0.00
	Juncus kraussii (Searush)				58.96	21.19
	Juncus kraussii (Searush)	*Plagianthus divaricatus (Salt marsh ribbonwood)*			0.57	0.21
	Juncus kraussii (Searush)	*Samolus repens (Primrose)*	*Sarcocornia quinqueflora (Glasswort)*		0.31	0.11
	Juncus kraussii (Searush)	*Sarcocornia quinqueflora (Glasswort)*	*Apodasmia similis (Jointed wirerush)*	*Plagianthus divaricatus (Salt marsh ribbonwood)*	0.01	0.00
	Juncus kraussii (Searush)	*Sarcocornia quinqueflora (Glasswort)*	*Isolepis cernua (Slender clubrush)*	*Samolus repens (Primrose)*	0.03	0.01
	Juncus kraussii (Searush)	*Sarcocornia quinqueflora (Glasswort)*			3.72	1.34
	Juncus kraussii (Searush)	*Sarcocornia quinqueflora (Glasswort)*	*Samolus repens (Primrose)*		0.23	0.08
	Juncus kraussii (Searush)	*Sarcocornia quinqueflora (Glasswort)*	*Stipa stipoides*		1.62	0.58
	Juncus kraussii (Searush)	*Sarcocornia quinqueflora (Glasswort)*	*Suaeda novaezelandiae (Sea blite)*		0.03	0.01
	Juncus kraussii (Searush)	*Schoenoplectus pungens (Three square)*			0.03	0.01
	Juncus kraussii (Searush)	*Schoenoplectus pungens (Three square)*	*Sarcocornia quinqueflora (Glasswort)*		0.12	0.04
	Juncus kraussii (Searush)	*Stipa stipoides*			0.62	0.22
	Juncus kraussii (Searush)	*Stipa stipoides*	*Sarcocornia quinqueflora (Glasswort)*		0.09	0.03
Herbfield	*Samolus repens (Primrose)*				0.15	0.05
	Samolus repens (Primrose)	*Sarcocornia quinqueflora (Glasswort)*			0.01	0.00
	Sarcocornia quinqueflora (Glasswort)	*Apodasmia similis (Jointed wirerush)*			0.14	0.05
	Sarcocornia quinqueflora (Glasswort)	*Atriplex cinerea (Grey saltbush)*			0.04	0.01
	Sarcocornia quinqueflora (Glasswort)	*Cotula coronopifolia (Bachelor's button)*	*Isolepis cernua (Slender clubrush)*		0.03	0.01
	Sarcocornia quinqueflora (Glasswort)	*Festuca arundinacea (Tall fescue)*			0.02	0.01
	Sarcocornia quinqueflora (Glasswort)	*Juncus kraussii (Searush)*			2.72	0.98
	Sarcocornia quinqueflora (Glasswort)	*Muehlenbeckia complexa (Wire vine)*			0.04	0.01
	Sarcocornia quinqueflora (Glasswort)				122.13	43.90
	Sarcocornia quinqueflora (Glasswort)	*Samolus repens (Primrose)*	*Juncus kraussii (Searush)*		0.16	0.06
	Sarcocornia quinqueflora (Glasswort)	*Samolus repens (Primrose)*			9.03	3.25
	Sarcocornia quinqueflora (Glasswort)	*Samolus repens (Primrose)*	*Selliera radicans (Remuremu)*		2.02	0.73
	Sarcocornia quinqueflora (Glasswort)	*Samolus repens (Primrose)*	*Stipa stipoides*		0.20	0.07
	Sarcocornia quinqueflora (Glasswort)	*Samolus repens (Primrose)*	*Suaeda novaezelandiae (Sea blite)*		0.05	0.02
	Sarcocornia quinqueflora (Glasswort)	*Schoenoplectus pungens (Three square)*	*Juncus kraussii (Searush)*	*Isolepis cernua (Slender clubrush)*	0.03	0.01
	Sarcocornia quinqueflora (Glasswort)	*Selliera radicans (Remuremu)*			0.90	0.32
	Sarcocornia quinqueflora (Glasswort)	*Selliera radicans (Remuremu)*	*Samolus repens (Primrose)*		0.27	0.10
	Sarcocornia quinqueflora (Glasswort)	*Stipa stipoides*	*Festuca arundinacea (Tall fescue)*		0.01	0.00
	Sarcocornia quinqueflora (Glasswort)	*Stipa stipoides*	*Juncus kraussii (Searush)*		0.01	0.00
	Sarcocornia quinqueflora (Glasswort)	*Stipa stipoides*			0.31	0.11
	Sarcocornia quinqueflora (Glasswort)	*Stipa stipoides*	*Plagianthus divaricatus (Salt marsh ribbonwood)*		0.01	0.01
	Sarcocornia quinqueflora (Glasswort)	*Suaeda novaezelandiae (Sea blite)*	*Carpobrotus edulis (Ice Plant)*	*Festuca arundinacea (Tall fescue)*	0.24	0.09
	Sarcocornia quinqueflora (Glasswort)	*Suaeda novaezelandiae (Sea blite)*	*Carpobrotus edulis (Ice Plant)*		0.05	0.02
	Sarcocornia quinqueflora (Glasswort)	*Suaeda novaezelandiae (Sea blite)*			20.70	7.44
	Sarcocornia quinqueflora (Glasswort)	*Suaeda novaezelandiae (Sea blite)*	*Samolus repens (Primrose)*		0.02	0.01
	Sarcocornia quinqueflora (Glasswort)	*Suaeda novaezelandiae (Sea blite)*	*Stipa stipoides*		2.02	0.73
	Selliera radicans (Remuremu)	*Isolepis cernua (Slender clubrush)*			0.00	0.00
	Selliera radicans (Remuremu)				0.05	0.02
	Selliera radicans (Remuremu)	*Samolus repens (Primrose)*			0.06	0.02
	Selliera radicans (Remuremu)	*Samolus repens (Primrose)*	*Sarcocornia quinqueflora (Glasswort)*		0.35	0.13
	Selliera radicans (Remuremu)	*Samolus repens (Primrose)*	*Schoenoplectus pungens (Three square)*		0.01	0.00
	Selliera radicans (Remuremu)	*Sarcocornia quinqueflora (Glasswort)*	*Samolus repens (Primrose)*		0.05	0.02
	Suaeda novaezelandiae (Sea blite)	*Carpobrotus edulis (Ice Plant)*	*Samolus repens (Primrose)*	*Stipa stipoides*	0.19	0.07
	Suaeda novaezelandiae (Sea blite)				0.01	0.00
	Suaeda novaezelandiae (Sea blite)	*Sarcocornia quinqueflora (Glasswort)*	*Carpobrotus edulis (Ice Plant)*		0.04	0.02
Grand Total					**278.2**	**100**

APPENDIX 8. BASELINE DATA

Indicator	Unit	Baseline value	Baseline year	Reference report
Mud-dominated substrate[1]	% of intertidal area >50% mud	37.1%	1990	Davidson & Moffat (1990)
Macroalgae (OMBT)	Ecological Quality Rating (EQR)	0.55	2014	Stevens & Robertson (2014)
Seagrass[2]	% decrease from baseline	58ha	1990	Davidson & Moffat (1990)
Salt marsh extent (current)	% of intertidal area	13%	1946	Tuckey & Robertson (2003)
200m terrestrial margin	% densely vegetated	22%	2014	Stevens & Robertson (2014)
High Enrichment Conditions	ha	28%	2014	Stevens & Robertson (2014)
High Enrichment Conditions	% of estuary	0.7%	2014	Stevens & Robertson (2014)

[1] Comprises substrate defined in 1990 as 'mudflats' and 'highshore flats' outside of salt marsh

[2] Seagrass cover assumed to be >50%

Key Estuary Features (Ha)	1946	1985	1990	1999	2006	2014	2020
Intertidal area	2876	2876	2869	2876	2916	2962	2808
Subtidal area	482	482	587	482	530	487	654
Estuary area	3358	3358	3456	3358	3446	3449	3462
Salt marsh area	352	270	202	228	314	304	278
Seagrass (≥50% cover)	na	na	58	28	30	30	22
Macroalgal beds (≥50% cover)	na	na	15	67	60	54	20
Mud-dominated sediment (≥50%)	na	na	1282	2342	1369	1197	1314
200m densely vegetated terrestrial margin*	na	na	na	na	na	404	329

*(LCDB classes 45-71)

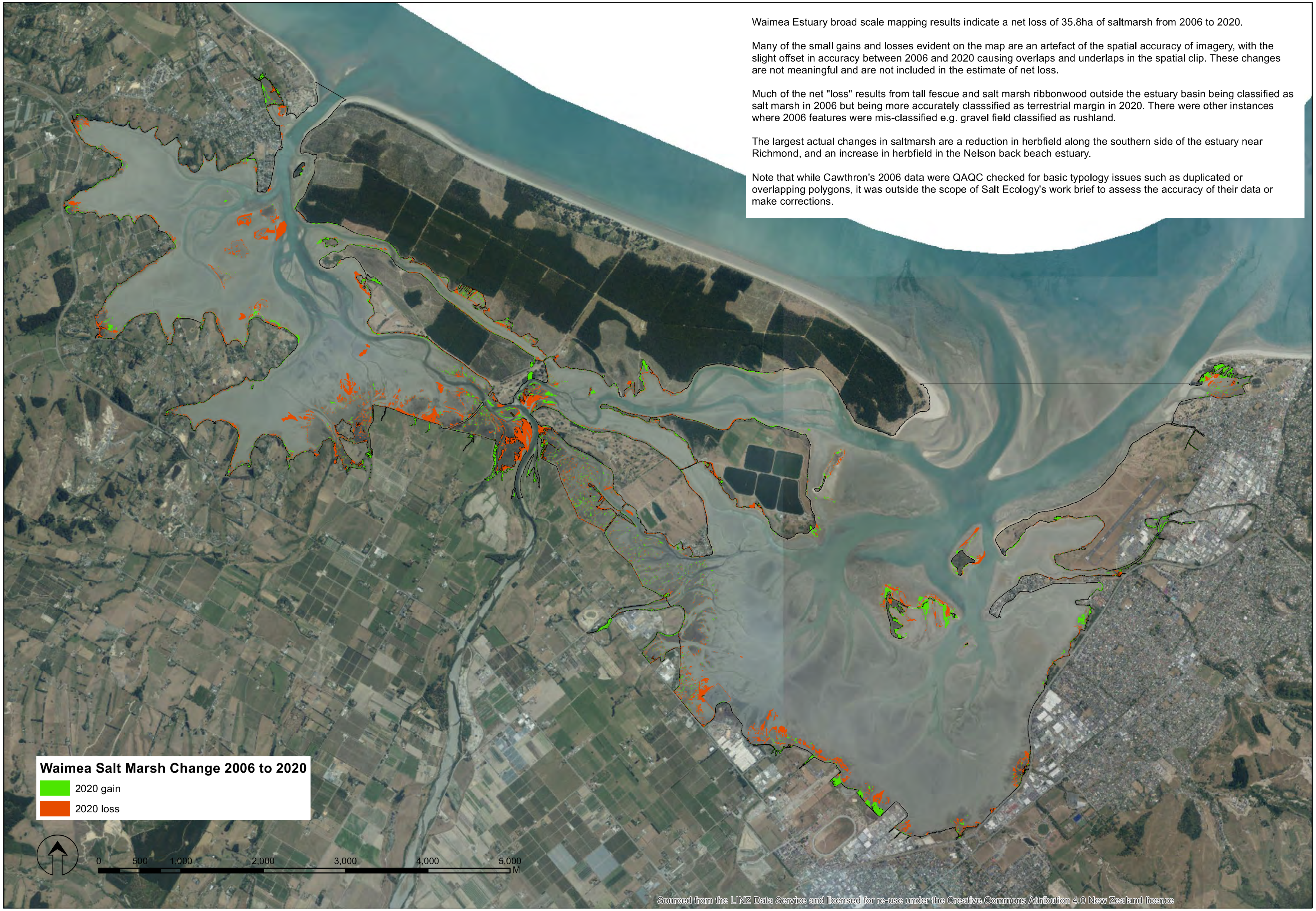
Key Estuary Features (% of Estuary)	1946	1985	1990	1999	2006	2014	2020
Intertidal area	85.6	85.6	83.0	85.6	84.6	85.9	81.1
Subtidal area	14.4	14.4	17.0	14.4	15.4	14.1	18.9
Estuary area	100	100	100	100	100	100	100
Salt marsh area	12.5	9.6	7.2	8.1	11.2	10.8	9.9
Seagrass (≥50% cover)	na	na	1.7	0.8	0.9	0.9	0.6
Macroalgal beds (≥50% cover)	na	na	0.4	2.0	1.7	1.6	0.6
Mud-dominated sediment (≥50%)	na	na	37.1	69.7	39.7	34.7	37.9
200m densely vegetated terrestrial margin*	na	na	na	na	na	22.0	18.0

*(LCDB classes 45-71)

Salt marsh (Ha)	1946	1985	1990	1999	2006	2014	2020
Estuarine Shrub	15.9	3.2		11.9	22.3	11.3	11.4
Tussockland	6.9	7.0	4.8	10.4	12.8	15.5	15.9
Sedgeland		0.03		0.4	0.2	0.1	1.4
Grassland		0.01		1.1		3.3	
Reedland	0.0	43.5	29.0	0.1		0.0	0.2
Rushland	125.8	96.0	75.0	83.8	104.0	103.5	87.2
Herbfield	164.7	120.3	93.0	120.3	174.8	169.8	162.1
Unknown	38.5	1.1					
TOTAL (Ha)	**352**	**271**	**202**	**228**	**314**	**304**	**278**

Salt marsh (%)	1946	1985	1990	1999	2006	2014	2020
Estuarine Shrub	0.5	0.1		0.4	0.6	0.3	0.3
Tussockland	0.2	0.2	0.1	0.3	0.4	0.4	0.5
Sedgeland		0.001		0.01	0.004	0.004	0.04
Grassland		0.0003		0.03		0.1	
Reedland	0.0	1.3	0.8	0.004		0.0003	0.004
Rushland	3.7	2.9	2.2	2.5	3.0	3.0	2.5
Herbfield	4.9	3.6	2.7	3.6	5.1	4.9	4.7
Unknown	1.1	0.03					
TOTAL (%)	**10.5**	**8.1**	**5.8**	**6.8**	**9.1**	**8.8**	**8.0**

APPENDIX 9. SPATIAL CHANGES IN SALTMARSH 2006-2020



Waimea Estuary broad scale mapping results indicate a net loss of 35.8ha of saltmarsh from 2006 to 2020.

Many of the small gains and losses evident on the map are an artefact of the spatial accuracy of imagery, with the slight offset in accuracy between 2006 and 2020 causing overlaps and underlaps in the spatial clip. These changes are not meaningful and are not included in the estimate of net loss.

Much of the net "loss" results from tall fescue and salt marsh ribbonwood outside the estuary basin being classified as salt marsh in 2006 but being more accurately classsified as terrestrial margin in 2020. There were other instances where 2006 features were mis-classified e.g. gravel field classified as rushland.

The largest actual changes in saltmarsh are a reduction in herbfield along the southern side of the estuary near Richmond, and an increase in herbfield in the Nelson back beach estuary.

Note that while Cawthron's 2006 data were QAQC checked for basic typology issues such as duplicated or overlapping polygons, it was outside the scope of Salt Ecology's work brief to assess the accuracy of their data or make corrections.

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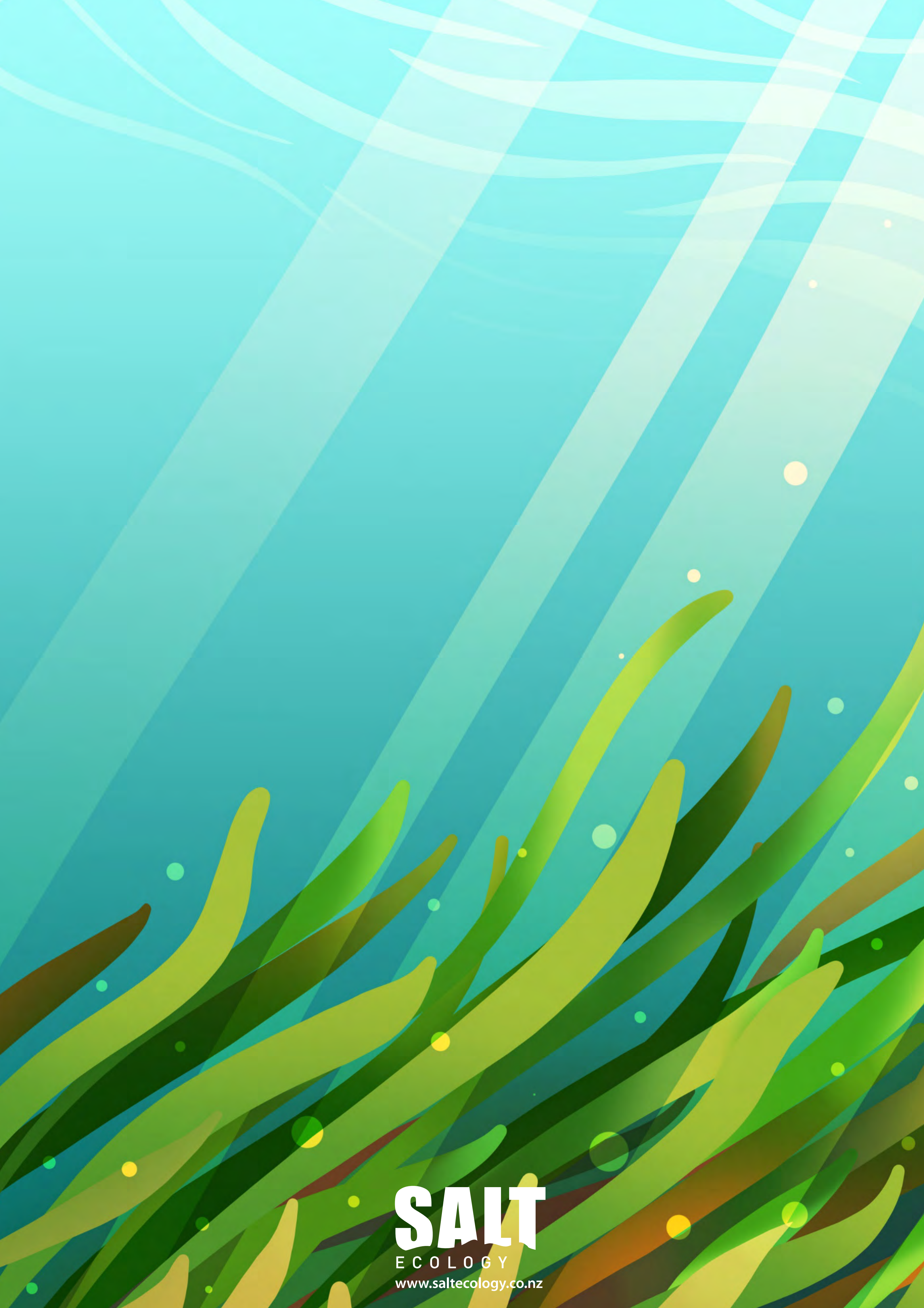

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