SALT ECOLOGY

Macroalgal and Seagrass Monitoring of New River Estuary

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For the People
Mō ngā tāngata

Macroalgal Monitoring of New River Estuary

Prepared by

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for

Environment Southland

November 2020

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For the environment
Mō te taiao

SALT ECOLOGY

GLOSSARY

AA	Affected Area
AIH	Available Intertidal Habitat
aRPD	Apparent Redox Potential Discontinuity
EQR	Ecological Quality Rating
ES	Environment Southland
ETI	Estuary Trophic Index
GEZ	Gross Eutrophic Zones
GIS	Geographic Information System
HEC	High Enrichment Conditions (eutrophic area)
NEMP	National Estuary Monitoring Protocol
OMBT	Opportunistic Macroalgal Blooming Tool
SOE	State of the Environment (monitoring)

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BACKGROUND

As part of its State of the Environment programme, Environment Southland (ES) undertakes monitoring and assessment of estuaries and other coastal environments. New River Estuary has been identified by ES as a priority for monitoring, as significant beds of opportunistic nuisance macroalgal (seaweed) growths have previously been identified during broad scale habitat mapping and more targeted assessments. This report describes a survey of nuisance macroalgae and seagrass (a high value habitat) conducted in the estuary in February 2020, and compares findings with monitoring conducted in 2019 by Salt Ecology and in earlier surveys over 2001-2018. Results are discussed in terms of the current status and trends in estuary health, and recommendations for future monitoring and management are made.

KEY FINDINGS

The following bullet points summarise key monitoring results, and the table below rates them using preliminary criteria for assessing estuary health.

- The latest survey revealed persistent and extensive beds of the opportunistic nuisance seaweed *Gracilaria chilensis* in the Waihopai arm, near the Oreti River mouth, in Daffodil Bay and in the east of the estuary near Woodend. The opportunistic species *Ulva* spp. covers a far less extensive area and does not cause significant nuisance conditions.
- Across 14% (399ha) of the estuary, high biomass *Gracilaria* beds form eutrophic 'High Enrichment Conditions' (HECs), whereby extensive (>50% cover) growths are entrained into soft, anoxic mud-dominated sediments. These HEC beds trap muddy sediments and build raised mounds 5-10cm high.
- The HEC area has generally increased steadily since 2001, with a slight decline the HEC area in 2019 and 2020, and an improvement in another macroalgal condition index, reflecting erosion of the *Gracilaria* beds. This was attributed to physical scouring due to recent flood flows in the Waihopai and Oreti Rivers and does not reflect a significant improvement in estuary health.
- Some of the HEC areas are exhibiting symptoms of extreme anoxia, including sulphide production and growth of surface bacterial mats. The overall severity and scale of enrichment is unprecedented in New Zealand.
- Seagrass is a minor feature of the estuary. It has been steadily declining since 2001 with a 97% reduction in seagrass in the Waihopai arm. Further seagrass loss between 2019 and 2020 was attributed to smothering by overgrowth of *Gracilaria*, in particular near the Oreti River mouth.

Overall, the entrained macroalgal growths, widespread persistence of *Gracilaria*, extreme sediment anoxia and seagrass losses, serve as clear indicators that the assimilative capacity of the estuary is being dramatically exceeded. This situation is consistent with modelled nutrient loads, which greatly exceed thresholds for nuisance growths. These high loads reflect the extensively modified nature of the catchment, of which about three quarters is in pasture.

Broad scale indicator (unit)	2001	2007	2012	2016	2018	2019	2020
Macroalgal OMBT[1] (Ecological Quality Rating (EQR)	0.616	0.532	0.398	0.303	0.284	0.234	0.481
High Enrichment Conditions (Ha)	23	49	240	351	428	417	399
High Enrichment Conditions (% of estuary)	0.8	1.7	8.6	12.6	15.3	14.93	14.3
Seagrass[2] (% decrease from baseline)	na	na	44	55	61	61	67

1 OMBT = Opportunistic Macroalgal Blooming Tool. 2 Data for 2001 used as baseline for seagrass. Na not applicable or not available.

Condition rating key:

Very Good	Good	Fair	Poor

RECOMMENDATIONS

New River Estuary has been identified by ES as a priority for monitoring and management, and is a key part of the programme being undertaken throughout the region. Based on the 2020 survey and evaluation of trends since 2001, our recommendations are as follows:

- Given the persistent eutrophic state indicated by areas expressing High Enrichment Conditions (HECs), continue annual monitoring during summer to track long term changes.
- Given that HECs are likely a reflection of very high nutrient inputs, and associated inputs of muddy sediments, ES should continue with planned work to determine limits on nutrient and sediment mass loads that would be expected to mitigate effects, or at least prevent further degradation.
- As part of the mass load assessment, determine catchment nutrient and sediment sources, and evaluate whether there are any effective and feasible management practices that could be undertaken to achieve ES's desired condition for the estuary.

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. Environment Southland (ES) has undertaken monitoring of selected estuaries in the Southland region for over a decade, much of which has been based on methods outlined in New Zealand's National Estuary Monitoring Protocol (NEMP, Robertson et al. 2002), or extensions of that approach.

The focus of SOE monitoring efforts by ES has been on estuaries at risk from problems relating to catchment land use. Of particular concern are muddy sediment inputs that alter estuary habitats, and excessive nutrient loads that lead to symptoms of eutrophication such as prolific macroalgal (seaweed) growth. Although macroalgae is an important feature of estuaries that contributes to their high productivity and biodiversity, when high nutrient inputs combine with suitable growing conditions, nuisance blooms of rapidly growing species can occur. These are typically referred to as 'opportunistic' species, of which the most significant in Southland are the red seaweed *Gracilaria chilensis* and the bright green *Ulva* spp. (often called 'sea lettuce').

At nuisance levels such growths can smother and deprive ecologically valuable seagrass (*Zostera muelleri*) of light, causing its eventual decline. Decaying macroalgae can also accumulate on shorelines causing localised depletion of sediment oxygen, and nuisance odours. When high macroalgal cover is associated with soft, muddy sediments, conditions for animal life in the sediments are generally very poor due to elevated organic matter, depleted oxygen and an accumulation of toxic sulphides.

New River Estuary (Fig. 1) is one of the key estuaries in Southland where nuisance macroalgal growths have previously been identified during long-term SOE monitoring. Broad scale habitat mapping in 2007 highlighted an increase in localised areas where opportunistic macroalgal growth was causing nuisance conditions, and recommended annual monitoring of macroalgae to assess change (Robertson & Stevens 2007). As a result, targeted macroalgal monitoring was undertaken each summer from 2008-2013 and again in 2016 and 2018. The results of this work documented a steady expansion in the cover and biomass of nuisance macroalgae in the estuary, with 15% of the estuary's intertidal area classified as eutrophic (referred to at that time as Gross Eutrophic Zones; GEZs) in February 2018 (Stevens 2018).

Salt Ecology was contracted to carry out a further assessment of macroalgal status in February 2019

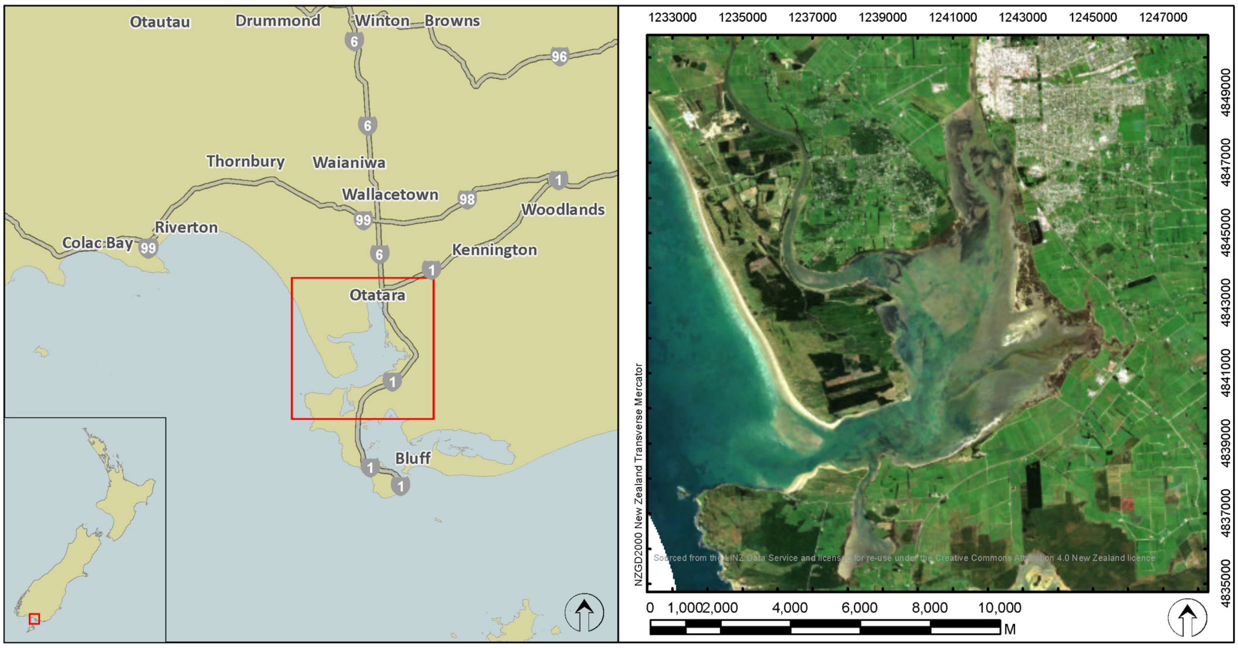


Fig. 1 Location of New River Estuary.

and 2020, and to map changes in the areas of seagrass previously described. This report details the latest surveys, and compares findings with monitoring conducted in 2019 and previously (2001-2018). Results are discussed in terms of the current status and trends in estuary health, and recommendations for future monitoring and assessment are made.

1.2 DESCRIPTION OF NEW RIVER ESTUARY

New River Estuary is a relatively large (4,600ha) system situated at the confluence of the Oreti and Waihopai Rivers near Invercargill, which discharges to the sea at the eastern end of Oreti Beach. It is categorised as a shallow (mean depth ~2m) intertidal-dominated, 'tidal lagoon' type estuary, commonly referred to as a 'SIDE'.

The estuary drains a large 4,314km^2 catchment comprising ~60% intensive pasture, 17% low producing pasture, 13% native forest, and 8% exotic forest (Stevens 2018). The immediate terrestrial margin of the estuary has a mix of vegetation and land uses (urban, bush and grazed pasture). Within the estuary are a wide range of habitats including extensive mud and sand flats, and ecologically important cockle beds, seagrass beds (*Zostera muelleri*) and extensive salt marsh areas.

Historically large areas of the estuary have been lost through drainage and reclamation. The Waihopai arm in the northern estuary is the most modified area, with around 1,200ha (75%) of the arm reclaimed historically. Such changes have greatly reduced the capacity of the estuary to filter, dilute, and assimilate nutrient and sediment inputs. In addition to nutrient enrichment and nuisance blooms of *Gracilaria* and *Ulva*, environmental issues facing the estuary include excessive sedimentation and muddiness, discharges of leachate, stormwater and wastewater, and the frequent exceedance of bathing and shellfish faecal indicator bacteria guidelines (lawa.org.nz). Nonetheless, ecological values and human use of large parts of the estuary are high.

Upper Waihopai Arm

2. MONITORING METHODS

2.1 OVERVIEW OF MAPPING

Mapping was undertaken according to NEMP methods used previously, to delimit the spatial extent of macroalgae. This procedure combined aerial photography, detailed ground truthing, and digital mapping using Geographic Information System (GIS) technology.

Broad scale mapping of New River Estuary in 2019 and 2020 used 1:3000 colour satellite imagery supplied to ES by Apollo Mapping (Colorado). The imagery was captured on 1 Jan 2018 and 17 Jan 2020 respectively. During field ground truthing, macroalgae and seagrass areas were drawn onto laminated aerial photographs, and percent cover and biomass were estimated or measured as described below. The features were subsequently digitised into ArcMap 10.6 shapefiles using a Wacom Cintiq21UX drawing tablet, and combined with field measurements and georeferenced photographs. From this information, maps were produced showing the spatial extent and density of macroalgae.

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

2.2 MACROALGAE ASSESSMENT

The United Kingdom Water Framework Directive (WFD-UKTAG 2014) Opportunistic Macroalgal Blooming Tool (OMBT) approach was a key part of the macroalgal assessment. The OMBT, described in detail in Appendix 1, 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 five 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 in total 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 New River Estuary, opportunistic macroalgae patches were mapped to the nearest 10% during field ground truthing, using a 6-category rating scale (modified from FGDC 2012) as a guide to describe percentage cover (Fig. 2). 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, 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 as noted above.

In addition to macroalgal proliferation, 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 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. Hence, as a supporting indicator, 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.

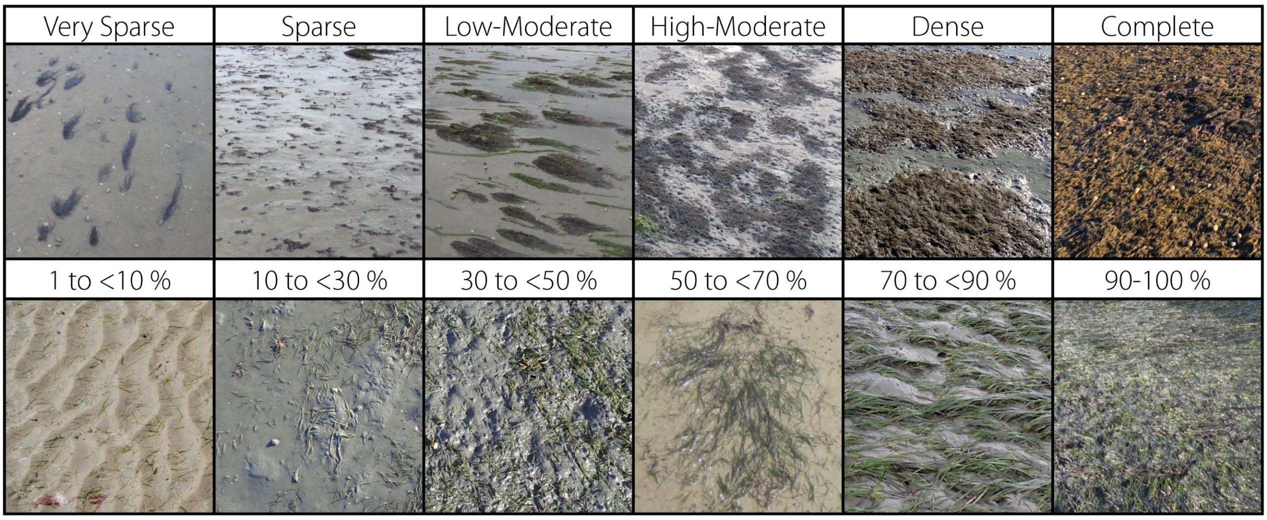


Fig. 2 Visual rating scale for percentage cover estimates. Macroalgae (top), seagrass (bottom). Modified from FGDC (2012).

Sampling macroalgal biomass and rinsing sample bags, Waihopai Arm west side.

2.3 SEAGRASS ASSESSMENT

Although not the primary focus of the work, seagrass cover was assessed in the Waihopai arm and on the banks of the Oreti River where there has been a steady decline in cover over the past decade due to smothering by nuisance macroalgae. As for macroalgae, the percent cover of discrete seagrass patches was visually estimated to the nearest 10% during macroalgal ground truthing, based on the 6-category percent cover scale in Fig. 2.

2.4 DATA RECORDING AND QA/QC

Broad scale mapping was intended to provide a rapid overview of estuary macroalgal 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 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. Extensive mapping experience has shown that transitional boundaries can be mapped to within ±10m where they have been thoroughly ground truthed, but when relying on photographs alone, accuracy is unlikely to be better than ±20-50m, and generally limited to features with a percent cover >50%.

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 2001-2019 GIS layers were similarly checked for any errors in basic geometry (e.g. overlapping polygons), and updated to fix any identified issues.

As well as annotation of field information onto aerial photographs during the field ground truthing, point estimate macroalgal data (i.e. biomass and cover measurements, entrainment), along with supporting measures of sediment aRPD, texture and sediment type 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.

2.5 MACROALGAE AND SEAGRASS CONDITION AND ASSESSMENT OF TEMPORAL CHANGE

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 1). These metrics assign different indicators to one of four colour-coded 'health status' bands, as shown in Table 1. The condition ratings are primarily sourced from the NZ ETI (Robertson et al. 2016b). Additional supporting information on the ratings is provided in Appendix 2. 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 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 have been referred to as 'Gross Eutrophic Zones' (GEZs) in the ETI (Zeldis et al. 2017) and the 2018 monitoring report (Stevens 2018). For our purposes, HECs are defined as mud-dominated sediments (≥50% mud content, based on expert judgement) with >50% macroalgal cover and with macroalgae entrained (growing >30mm deep) within the sediment. These areas typically also have an aRPD depth shallower than 10mm due to sediment anoxia.

As many of the scoring categories in Table 1 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).

Note that the assessment of temporal change in macroalgae and seagrass between 2001 and 2020 used a threshold cover of >50%. A cover of <50% cannot be reliably distinguished from aerial photographs alone, and in the earliest surveys these features were only mapped when they were dominant or conspicuous, which we assume to equate to >50% cover. Also, note that biomass data for calculation of OMBT scores have been collected only for the four surveys undertaken since 2016, although retrospective values have been previously estimated for 2001, 2007 and 2012 (Stevens 2018).

Sunset over New River estuary, 2019.

Table 1. Indicators and condition rating criteria used to assess results in the current report.

Indicator	Unit	Very Good	Good	Fair	Poor
Broad scale indicators					
Macroalgae (OMBT)[1]	Ecological Quality Rating (EQR)	≥ 0.8 - 1.0	≥ 0.6 - < 0.8	≥ 0.4 - < 0.6	0.0 - < 0.4
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%
Seagrass[2]	% decrease from baseline	< 5	≥ 5-10	≥ 10-20	≥ 20
Sediment quality					
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 2 for further explanation of the origin or derivation of the different metrics.

[2] Subjective indicator threshold for seagrass derived from previous broad scale mapping assessments.

3. RESULTS AND DISCUSSION

Data summaries are provided below. Supporting GIS files (supplied to ES as a separate electronic output) provide a more detailed dataset designed for easy interrogation and to address specific monitoring and management questions.

3.1 OPPORTUNISTIC MACROALGAE

Table 2 summarises macroalgal percentage cover and biomass classes for the estuary in 2020, with the mapped cover and biomass shown in Fig. 3 and Fig. 4, respectively. Macroalgal sampling stations and raw wet weights for biomass measurements are provided in Appendix 3. Key results were as follows:

- Across ~64.7% of the 1944ha intertidal area macroalgae cover was classified as absent or trace (i.e. < 1% cover), and classified as 'very sparse' (1-<10%) across a further 4.2% of the mapped area. Macroalgae cover was conspicuous (≥10% cover) across 21.9% of the intertidal area, and exceeded 50% cover across 486ha (16.5% of the intertidal). By far the most extensive species was *Gracilaria*, with only small patches of *Ulva* present.
- *Gracilaria* was most extensive (>50% cover) in the Waihopai arm on both sides of the river channel, in parts of the lower Oreti arm, and in Daffodil Bay. Much of the coverage in these areas was categorised as 'dense' (>70-90%) or 'complete' (>90%). *Gracilaria* biomass in the areas of greatest cover was typically categorised as 'high' (1-3kg/m^2) to 'very high' (>3kg/m^2), and in most places consisted of mounds of the seaweed (5-10cm high) deeply entrained into anoxic muddy sediment. The greatest biomass recorded was 41.5kg/m^2 (~14x the EQR 'bad' threshold), with >10kg/m^2 present across 79ha.
- Some of the most anoxic zones were evident along the western margins of the Waihopai arm, Daffodil Bay and the Oreti River. These include areas where there was a 'slurry' of anoxic decaying material covered in a white bacterial mat, overlying jet-black anoxic sediments that had a very strong odour of hydrogen sulfide. In some hot spots, surface *Gracilaria* had completely decayed, leaving a barren anoxic sediment with a thin surface veneer of mud covered with a green microalgal film (see photos on pages 7 and 10).
- Despite the areas of extreme anoxia, much of the outer tidal flats of Daffodil Bay consisted of firm muddy sand with only a low macroalgal cover. By contrast, in the Waihopai and Oreti arms, *Gracilaria* extended almost to the river channel although there was considerable erosion of the beds closer to the channel margins.

Waihopai Arm north of Stead St bridge showing *Gracilaria* and *Ulva* (top), and prolific *Gracilaria* south of Stead St bridge on east side of river channel

Table 2. Summary of intertidal macroalgal cover (A) and biomass (B), New River Estuary February 2020.

A. Cover

Percent cover category	Ha	%
Complete (>90%)	223.8	7.6
Dense (70 to <90%)	171.5	5.8
High-Moderate (50 to <70%)	90.8	3.1
Low-Moderate (30 to <50%)	34.4	1.2
Sparse (10 to <30%)	123.5	4.2
Very sparse (1 to <10%)	393.6	13.4
Absent or trace	1906.0	64.7
Grand Total	2944	100

B. Biomass

Biomass category (g/m^2)	Ha	%
Very high (>3000)	280.7	9.5
High (1001 - 3000)	243.6	8.3
Moderate (501 - 1000)	12.5	0.4
Low (101 - 500)	89.4	3.0
Very low (1 - 100)	411.5	14.0
Absent or trace	1906.2	64.8
Grand Total	2944	100



Waihopai Arm south of Stead St bridge on west side with prolific *Gracilaria* (top) and illustrating scouring of beds next to river channel



Oreti Arm lower section showing *Gracilaria* mounds (top), and luxuriant *Gracilaria* around Bushy Point on north side (bottom)



Oreti Arm, with *Gracilaria* and Ulva amongst seagrass next to three-square sedge in upper north side (top), and extensive patches of *Gracilaria* next to river channel on south side (bottom).



Daffodil Bay, inner area with extensive *Gracilaria* (top) and outer bay area of clean sediments next to river channel (bottom)

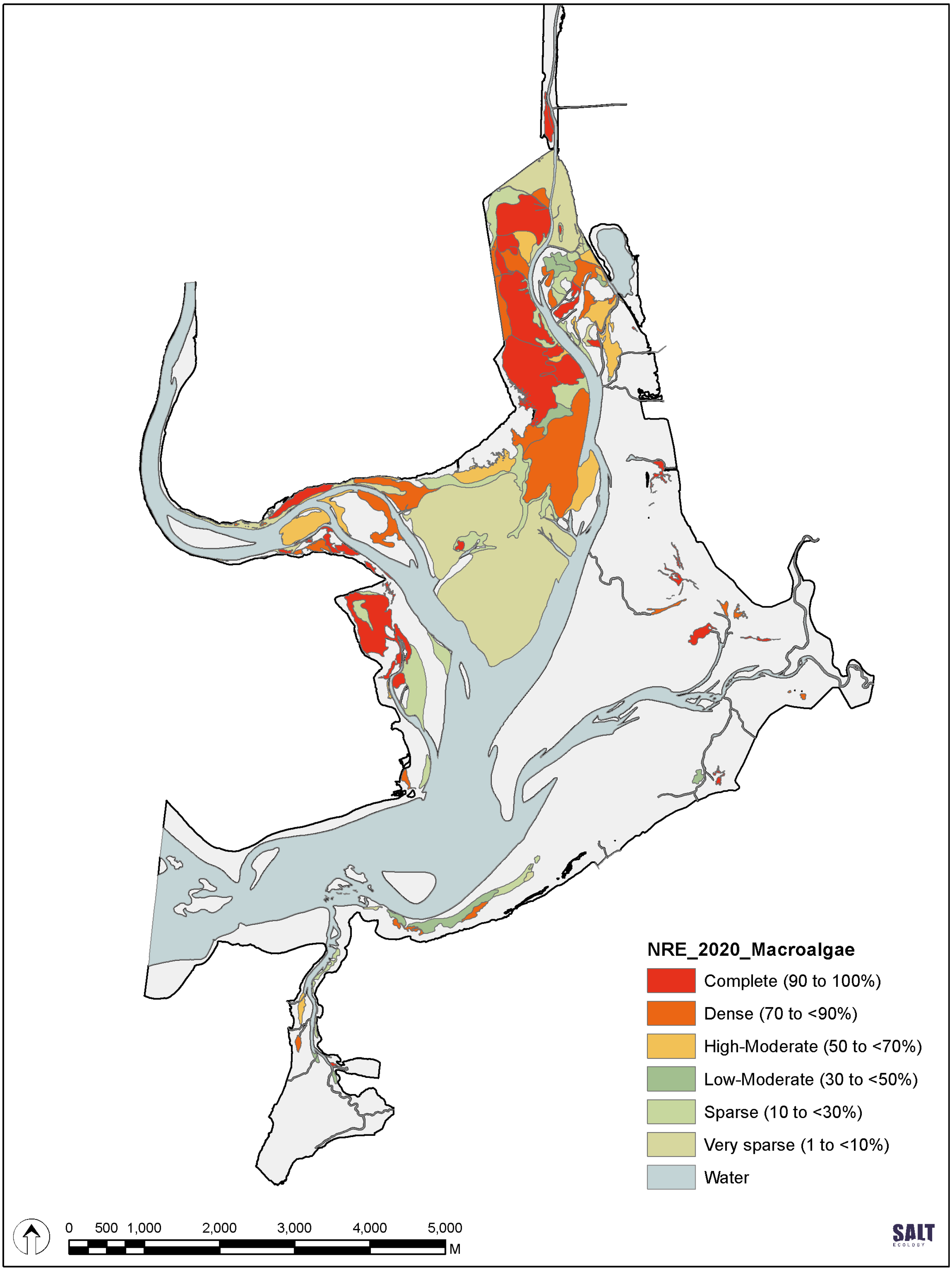


Fig. 3 Distribution and percentage cover classes of macroalgae, New River Estuary February 2020.

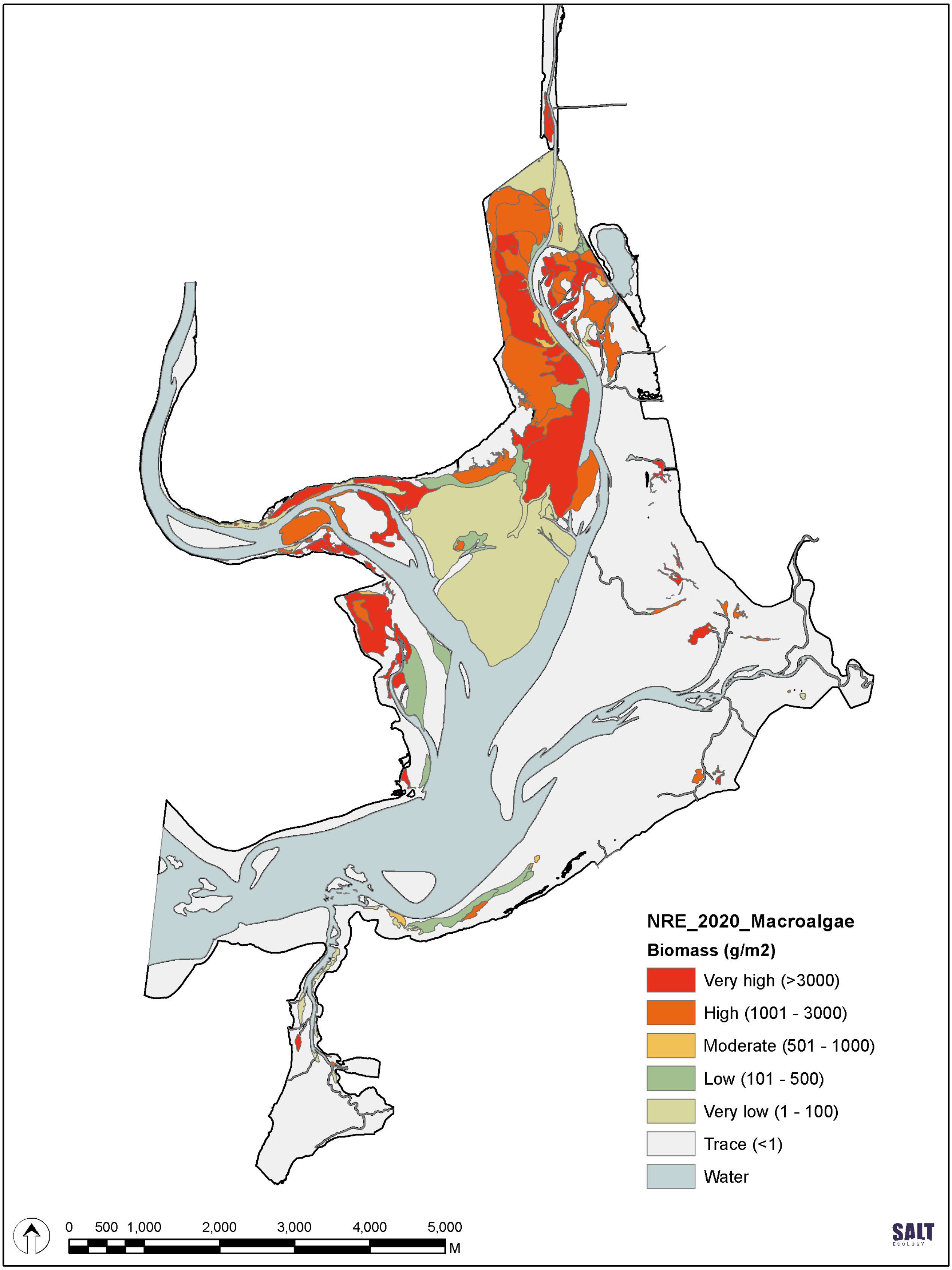


Fig. 4 Biomass (wet weight g/m^2) classes of macroalgae, New River Estuary February 2020.

- Compared to *Gracilaria*, the green seaweed *Ulva* covered a less extensive area of the estuary in 2020 (as in other years), being most prominent in the upper Waihopai arm north of Stead Street bridge, and along the banks of the Oreti River.
- Moving south towards the seaward end of the estuary, macroalgal cover was generally sparse, except for a few high cover patches in the eastern mid-estuary around Woodend.
- Mokomoko Inlet at the far south end of the estuary had a low macroalgal cover for the most part, with a localised hot spot in the lower section of the central basin near the channel connecting the inlet to the main estuary.

Daffodil Bay, anoxic slurry of decaying *Gracilaria* at south end (top), and anoxic mud in inner bay location where *Gracilaria* has decayed and not re-established (bottom)

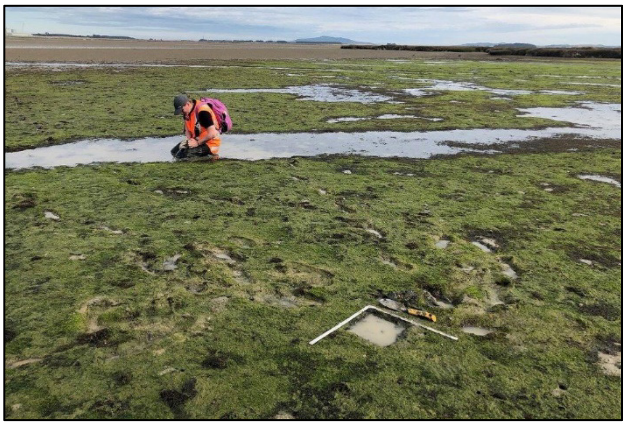
Entrained *Gracilaria* is very effective at trapping muddy sediment

Rotting sulphide covered *Gracilaria* near the Oreti mouth in 2019

25cm thick deposits of macroalgae in Daffodil Bay

Highly eutrophic and anoxic microalgal covered sediment

Jet black anoxic sediments and white sulphide bacteria between Daffodil Bay and Oreti River mouth



Ulva and *Gracilaria* on the east side in the mid reaches of the estuary

Mid-NRE eastern inlet by Woodend

Mid-southern NRE south of Woodend on east side

Fig. 5a shows the temporal change in macroalgal cover exceeding high-moderate (i.e. >50% cover, the most reliable threshold for comparison to baseline measurements; see Methods). Map layers for all years are in Appendix 4. Results indicate a steady increase in cover until 2018, with small declines in 2019 and 2020. The 2020 cover was ~21% less than the maximum cover measured in 2018. Nonetheless, the *Gracilaria* beds in the upper estuary areas are in the same location as previously and are clearly persistent.

The OMBT input metrics and overall macroalgal EQR are shown for all surveys in Table 3. The EQR calculated using the OMBT method was 0.481 in 2020, which is categorised as 'fair' according to the OMBT criteria. This score is an improvement on the scores calculated over 2001 to 2019 (Fig. 5a). The 2020 results primarily reflect an order of magnitude reduction in biomass since the worst-case score measured in 2019, as the overall percentage cover has not appreciably decreased (Table 3, Fig. 5a, Appendix 5). This reduction is likely attributable to considerable erosion of the beds observed in 2020 relative to 2019 (see photos below), presumably reflecting scouring during recent flood events.

Despite the slightly improved condition in 2020 the estuary is still clearly expressing significant widespread symptoms of eutrophication. This situation is highlighted by the temporal change in HECs in Table 4 and Fig. 5c, showing the pronounced increase in HEC area between 2007 and 2012, the peak in 2018, and small declines in 2019 and 2020 associated with erosion of beds noted above. The HEC map for 2020 highlights the particularly extensive eutrophic zone in the Waihopai arm (Fig. 6). In a healthy state, an estuary like New River would be expected to have less than 5ha of the estuary classified as having HEC present. In 2020, 399ha of HEC was present covering 14% of the estuary intertidal area.

Oreti arm north side showing extensive *Gracilaria* in 2019 (left) which was been scoured out in 2020 (right)

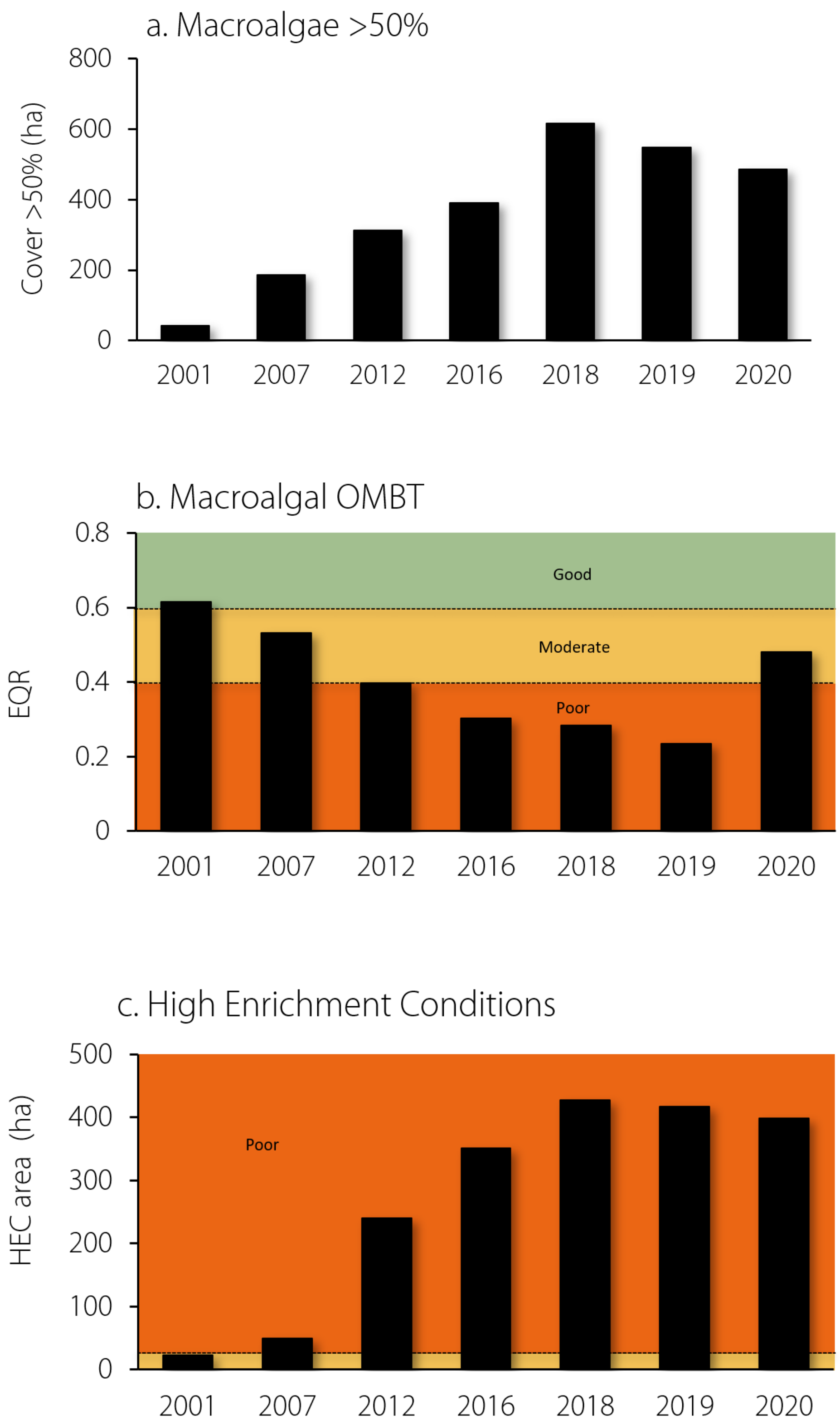


Fig. 5 Temporal change in macroalgal, New River Estuary 2001-2020: a) areas >50% cover; b) OMBT EQR scores; c) HEC extent.

Table 3. Summary of OMBT input metrics and calculation of overall macroalgal ecological quality rating, New River Estuary 2001 to 2020.

2020 Metric	Face Value	FEDS	Environmental Quality Status
%cover in AIH	15.2	0.596	Moderate
Biomass per m^2 AIH	124.6	0.751	Good
Biomass per m^2 AA	353.5	0.498	Moderate
%entrained in AA	18.5	0.420	Moderate
Worst of AA (ha) and AA (% of AIH)		0.143	Bad
AA (ha)	1037.8	0.143	Bad
AA (% of AIH)	35.2	0.484	Moderate
Survey EQR		0.481	Moderate

2019 Metric	Face Value	FEDS	Environmental Quality Status
%cover in AIH	21.4	0.472	Moderate
Biomass per m^2 AIH	1327.6	0.226	Poor
Biomass per m^2 AA	3445.5	0.190	Bad
%entrained in AA	63.2	0.147	Bad
Worst of AA (ha) and AA (% of AIH)		0.136	Bad
AA (ha)	1134.4	0.136	Bad
AA (% of AIH)	38.5	0.466	Moderate
Survey EQR		0.234	Poor

2018 Metric	Face Value	FEDS	Environmental Quality Status
%cover in AIH	17.8	0.543	Moderate
Biomass per m^2 AIH	1204.8	0.252	Poor
Biomass per m^2 AA	3159.9	0.191	Bad
%entrained in AA	35.3	0.298	Poor
Worst of AA (ha) and AA (% of AIH)		0.137	Bad
AA (ha)	1122.5	0.137	Bad
AA (% of AIH)	38.1	0.468	Moderate
Survey EQR		0.284	Poor

2016	Face Value	FEDS	Environmental Quality Status
%cover in AIH	14.2	0.616	Good
Biomass per m^2 AIH	793.1	0.338	Poor
Biomass per m^2 AA	2005.1	0.197	Bad
%entrained in AA	37.2	0.285	Poor
Worst of AA (ha) and AA (% of AIH)		0.133	Bad
AA (ha)	1164.4	0.133	Bad
AA (% of AIH)	39.6	0.460	Moderate
Survey EQR		0.314	Poor

2013	Face Value	FEDS	Environmental Quality Status
%cover in AIH	10.2	0.695	Good
Biomass per m2 AIH	291.5	0.539	Moderate
Biomass per m2 AA	1679.1	0.199	Bad
%entrained in AA	30.2	0.332	Poor
Worst of AA (ha) and AA (% of AIH)		0.181	Bad
AA (ha)	511.1	0.181	Bad
AA (% of AIH)	17.4	0.587	Moderate
Survey EQR		0.389	Poor

Notes: AA = Affected Area, AIH = Available Intertidal Habitat, FEDS = Final Equidistant Score (Appendix 1)

Table 3. (cont.) Summary of OMBT input metrics and calculation of overall macroalgal ecological quality rating, New River Estuary 2001 to 2020.

2007 Metric	Face Value	FEDS	Environmental Quality Status
%cover in AIH	6.8	0.764	Good
Biomass per m^2 AIH	83.5	0.833	High
Biomass per m^2 AA	537.8	0.392	Poor
%entrained in AA	13.9	0.482	Moderate
Worst of AA (ha) and AA (% of AIH)		0.185	Bad
AA (ha)	457.3	0.185	Bad
AA (% of AIH)	15.5	0.597	Moderate
Survey EQR		0.531	Moderate

2001 Metric	Face Value	FEDS	Environmental Quality Status
%cover in AIH	1.4	0.944	High
Biomass per m^2 AIH	20.2	0.960	High
Biomass per m^2 AA	1437.8	0.203	Poor
%entrained in AA	37.6	0.283	Poor
Worst of AA (ha) and AA (% of AIH)		0.644	Good
AA (ha)	41.3	0.644	Good
AA (% of AIH)	1.4	0.944	High
Survey EQR		0.606	Good

Notes: AA = Affected Area, AIH = Available Intertidal Habitat, FEDS = Final Equidistant Score (Appendix 1)

Table 4. Summary of area classified as expressing High Enrichment Conditions, New River Estuary 2001-2020.

Year	Ha
2001	23
2007	49
2012	240
2016	351
2018	428
2019	417
2020	399

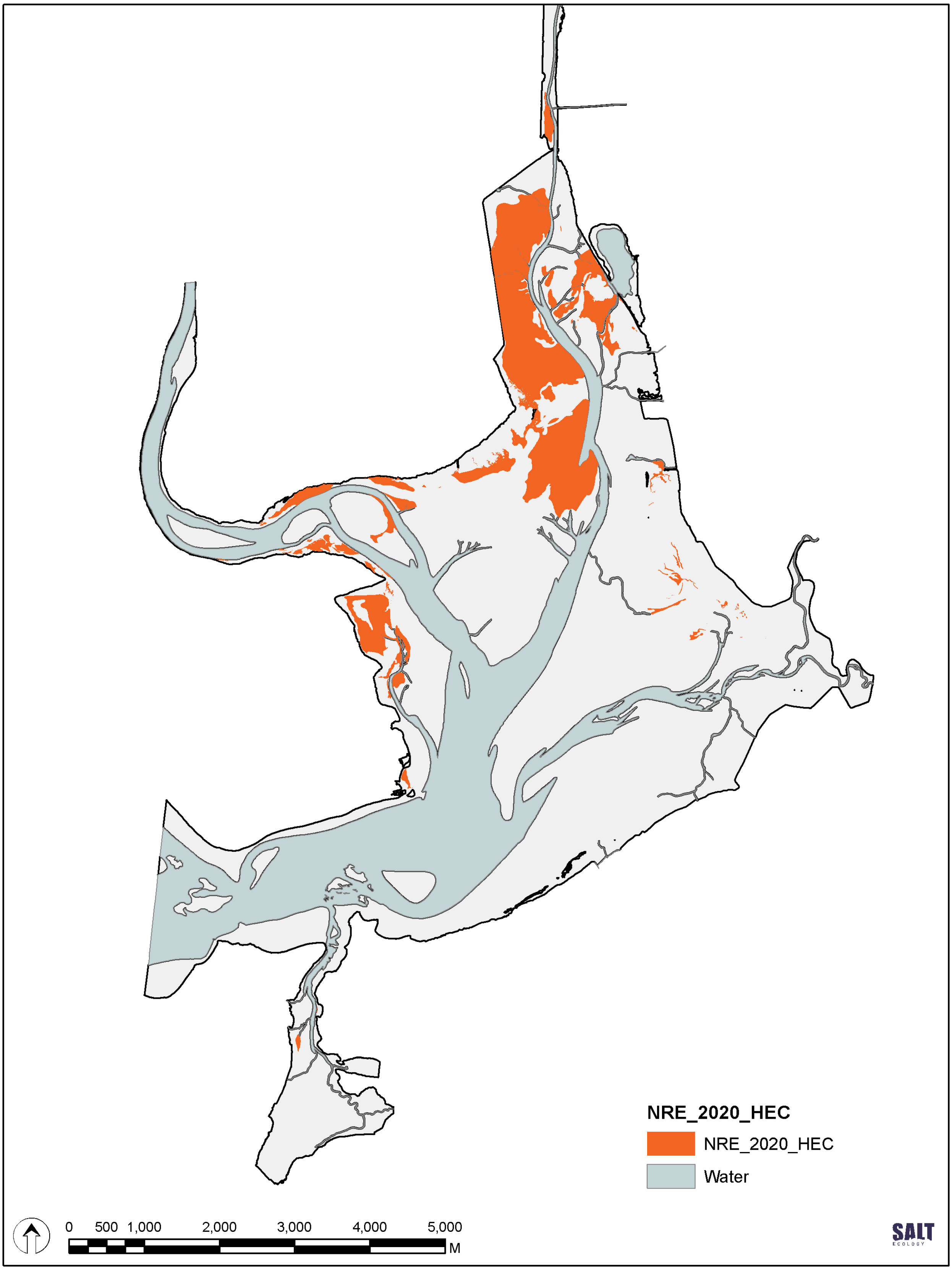


Fig. 6 Area categorised as showing High Enrichment Conditions (HECs), New River Estuary February 2020.

3.2 SEAGRASS

Intertidal seagrass (*Zostera muelleri*) cover in 2020 was limited in extent, with a total area of 41.9ha (2% of the intertidal area) consisting mainly of moderate density patches of >30-70% cover (Table 6, Fig. 7). These areas were located in the south side of the Oreti River and the eastern arm of the estuary. Based on a cover threshold of >50%, the maximum area recorded in previous surveys was 94ha in 2001 (Table 7). Although seagrass occupies a relatively small proportion of estuary area compared to many other estuaries in New Zealand, there has been a steady decline at New River from 2001-2020 (Table 5). Much of this decline has occurred in the Waihopai arm, which is attributable to displacement by the proliferation of *Gracilaria*. Map layers in Appendix 6 show detail of the main areas of decline in the Waihopai Arm which has reduced by 97% from 58ha in 2001 to just 1.8ha in 2020.

Only a few small patches of seagrass (*Zostera muelleri*) remain in the estuary. This patch was in the Oreti arm in 2019, but was smothered by *Gracilaria* in 2020.

Table 5. Summary of seagrass percent cover categories, New River Estuary 2020.

Percent cover category	Ha	%
Complete (>90%)	1.1	0.04
Dense (70 to <90%)	4.6	11.1
High-Moderate (50 to <70%)	25.3	0.9
Low-Moderate (30 to <50%)	8.0	0.3
Sparse (10 to <30%)	2.8	0.1
Very Sparse (1 to <10%)	0.0	0.0
Trace (<1%) or absent	2902	98.6
Grand Total	2944	100

Dense patch of seagrass at the high tide edge of the east Waihopai arm

Table 6. Temporal change in area of seagrass >50% cover, New River Estuary 2001-2020.

Year	Ha	Change (ha)	% Reduction
2001	94	na	na
2007	na	na	na
2012	53.0	41.0	44
2016	42.6	51.4	55
2018	36.9	57.1	61
2019	36.4	57.6	61
2020	31.1	62.9	67

Sparse seagrass in the east of the estuary near Woodend

Single patch of seagrass in the upper west Waihopai arm near the main channel

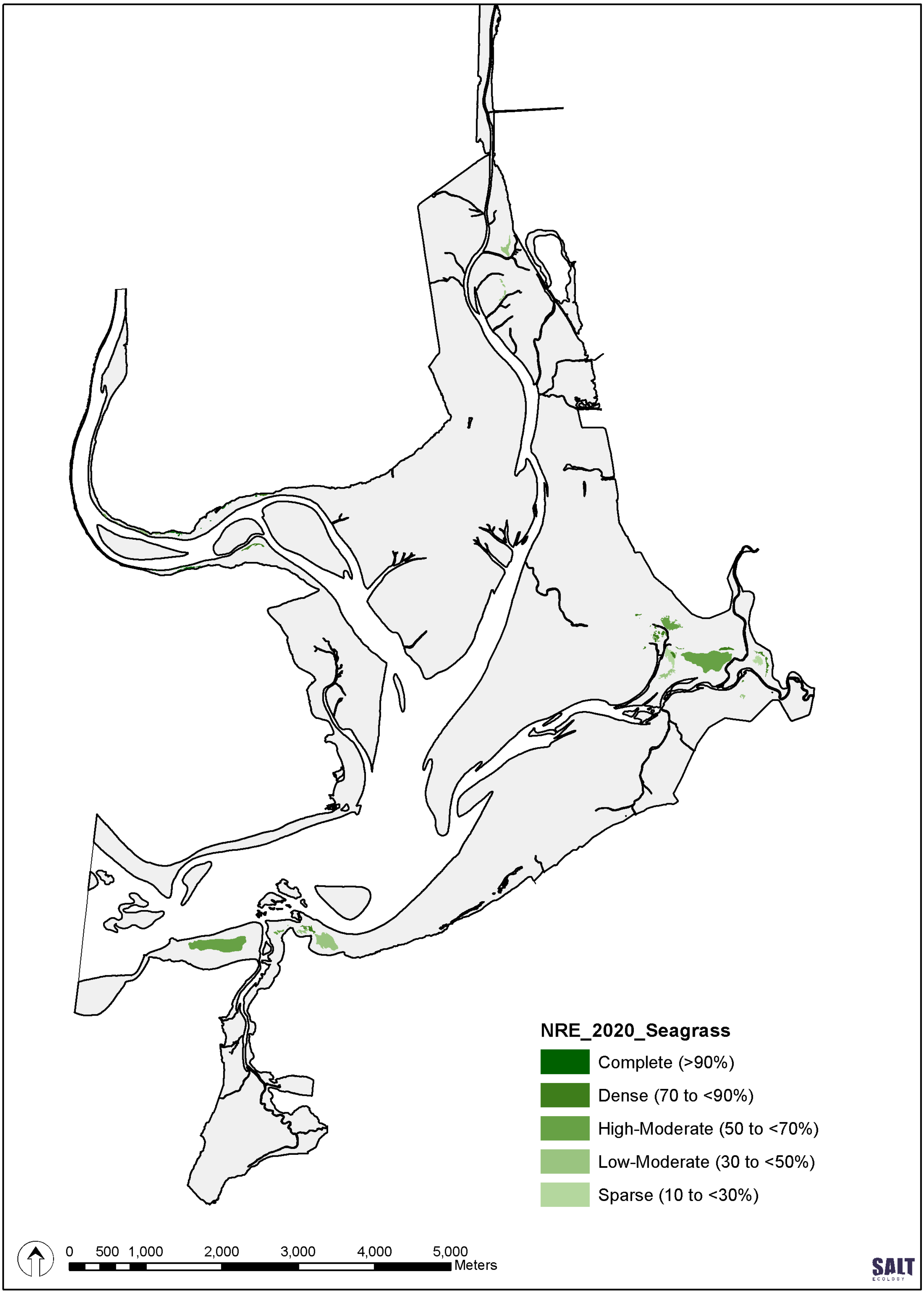


Fig. 7 Seagrass distribution, New River Estuary February 2020.

4. SYNTHESIS AND RECOMMENDATIONS

4.1 Synthesis of key findings

This report has described results of a broad scale macroalgae and seagrass survey of New River Estuary in 2020 and compared findings with earlier surveys conducted since 2001. In summary, the estuary is exhibiting significant and widespread problems associated with excessive enrichment and the proliferation of nuisance macroalgae, and represents the largest impact of this type that we are aware of. Eutrophication and sedimentation have been identified as major issues in New River Estuary since at least 1973, with significantly worsening conditions reported since 2007-2008 (see Stevens 2018 and references therein). Unless nutrient inputs to the estuary are reduced significantly, it is expected that there will be a continuation of the difficult-to-reverse adverse impacts that the estuary currently exhibits. Key points and discussion from the synthesis of data are described below.

Seagrass is a minor feature of the estuary, but has been steadily declining since 2001. The latest seagrass loss from 2019 and 2020 is attributable to smothering by *Gracilaria* overgrowth. *Gracilaria* growth was prolific in 2020, with symptoms of High Enrichment Conditions (HECs) described for 14% of the 2944ha intertidal area. Hence, despite macroalgal biomass being less in 2020 than in the previous two surveys, the estuary remains in a poor state.

The HEC areas are characterised by high biomass beds of entrained *Gracilaria*. These beds trap fine muddy sediments and form raised mounds 5-10cm high, which typically have anoxic sediments beneath the surface growth. The area with the most persistent prolific *Gracilaria* is the Waihopai arm in the northern estuary. Since 2018 there has been a significant expansion in macroalgal growth on the eastern side of the arm, and in the lower Waihopai River above Stead Street Bridge. *Gracilaria*, is also well established in parts of the Oreti arm and in Daffodil Bay and to the east near Woodend. Elsewhere in the estuary, beds are less prolific, with the green seaweed *Ulva* spp. present in some areas, but not at nuisance levels.

The reduction in biomass in 2020 compared with the few years prior primarily reflects erosion of the *Gracilaria*, and is presumably due to physical removal by flood scour from the Waihopai and Oreti Rivers. In some areas along the western margins of the Waihopai arm and Daffodil Bay, *Gracilaria* has also declined due to what appears to be 'self-pollution'. Decay of previously excessive *Gracilaria* biomass has led to barren and anoxic sediments covered in surface bacterial mats and/or microalgal films. It is unclear whether recovery from enrichment in these areas will occur, and over what time frame. Given the persistent nature of the problem, it is more likely that if these areas recover from extreme enrichment, *Gracilaria* will simply re-establish once conditions become suitable.

To our knowledge, the severity of impacts described in New River Estuary, which is also evident regionally in Jacobs River Estuary, and to a lesser extent in Fortrose/Toetoes estuary, has not been described at this scale anywhere else in New Zealand. The only examples of such extreme enrichment that we have encountered occur at a very localised scale on the seabed beneath finfish cages in sheltered low-flow environments (e.g. Forrest et al. 2007; Keeley et al. 2012). However, the spatial extent of the enrichment problem in New River (and Jacobs River) Estuary is

Table 7. Summary of OMBT input metrics and calculation of overall macroalgal ecological quality rating, New River Estuary 2001 and 2020.

Broad scale indicator (unit)	2001	2007	2012	2016	2018	2019	2020
Macroalgal OMBT[1] (Ecological Quality Rating (EQR)	0.616	0.532	0.398	0.303	0.284	0.234	0.481
High Enrichment Conditions (Ha)	23	49	240	351	428	417	399
High Enrichment Conditions (% of estuary)	0.8	1.7	8.6	12.6	15.3	14.93	14.3
Seagrass[2] (% decrease from baseline)	na	na	44	55	61	61	67

1 OMBT = Opportunistic Macroalgal Blooming Tool. 2 Data for 2001 used as baseline for seagrass. Na not applicable or not available.

Condition rating key:

Very Good	Good	Fair	Poor

unprecedented. The entrained conditions, the persistence of the *Gracilaria* mounds, and the development of enrichment to a level that not even *Gracilaria* appears to be able to survive, serves as a clear indicator that the assimilative capacity of the estuary has been dramatically exceeded.

This current situation is consistent with expectations from NIWA's CLUES model from which the estimated nutrient load to the estuary (235mgN/m^2/d) is well above the threshold (>50-100mgN/m^2/d) beyond which nuisance growths are expected in intertidally-dominated systems. Such high loads (which likely significantly underestimate both catchment and point-source inputs), reflect the extensively modified nature of the catchment, of which about three quarters is in pasture and about 60% intensively farmed (see Section 1.2). The loads are clearly well above natural inputs and highlight that excessive nutrient inputs are fuelling algal growth in the estuary.

Interestingly, despite the high nutrient loads and extensive areas of eutrophic sediment, the overall macroalgal EQR score was rated as 'moderate' according to the OMBT method (Appendix 1), and 'fair' according to the ETI (see Table 1). This result reflects the generally good conditions present across much of the well flushed lower (seaward) section of the estuary, and the expected short-term impact of flood scouring of macroalgae from the estuary. It therefore does not provide a particularly accurate representation of the true scale and magnitude of the problem present, and does not represent a meaningful improvement in estuary condition.

4.2 Recommendations

New River Estuary has been identified by ES as a priority for monitoring and management, and is a key part of the programme being undertaken throughout the region. Based on the 2020 survey and evaluation of trends since 2001, our recommendations are as follows:

- Given the persistent eutrophic state indicated by areas expressing High Enrichment Conditions (HECs), continue annual monitoring during summer to track long term changes.
- Given that HECs are likely a reflection of very high nutrient inputs, and associated inputs of muddy sediments, ES should continue with planned work to determine limits on nutrient and sediment mass loads that would be expected to mitigate effects, or at least prevent further degradation.
- As part of the mass load assessment, determine catchment nutrient and sediment sources, and evaluate whether there are any effective and feasible management practices that could be undertaken to achieve ES's desired condition for the estuary.

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APPENDICES

APPENDIX 1. 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 opportunistic 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.

APPENDIX 2. INFORMATION SUPPORTING RATINGS IN REPORT

Sediment 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. Such conditions indicate changes in land management may be needed

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 & 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.

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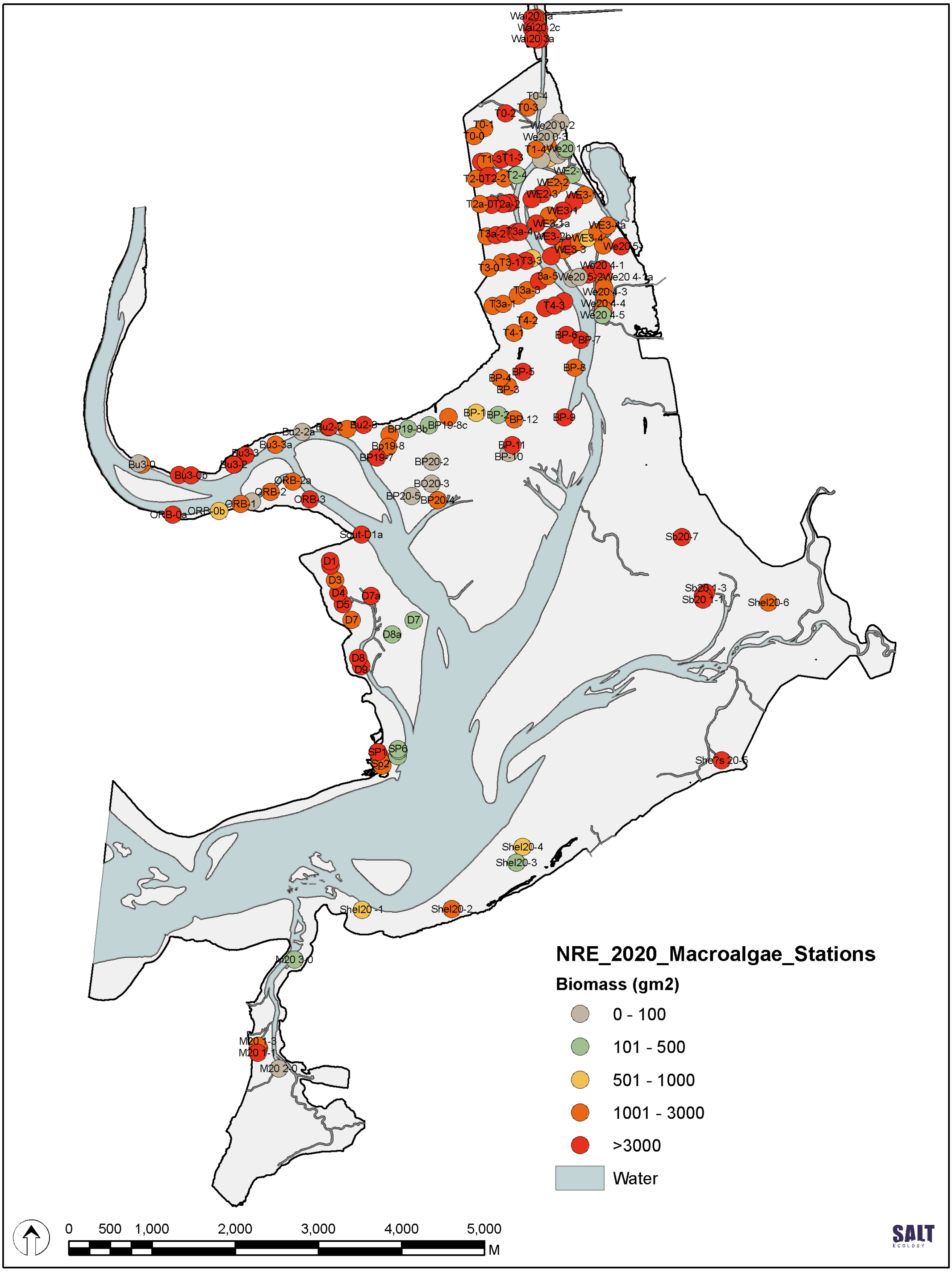
Zeldis J, Whitehead A, Plew D, Madarasz-Smith, A, Oliver M, Stevens L, Robertson B, Storey R, Burge O, Dudley B. 2017. The New Zealand Estuary Trophic Index (ETI) Tools: Tool 2 - Assessing Estuary Trophic State using Measured Trophic Indicators. Ministry of Business, Innovation and Employment Envirolink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

APPENDIX 3. 2019 AND 2020 MACROALGAL BIOMASS SAMPLING STATIONS AND PATCH DATA



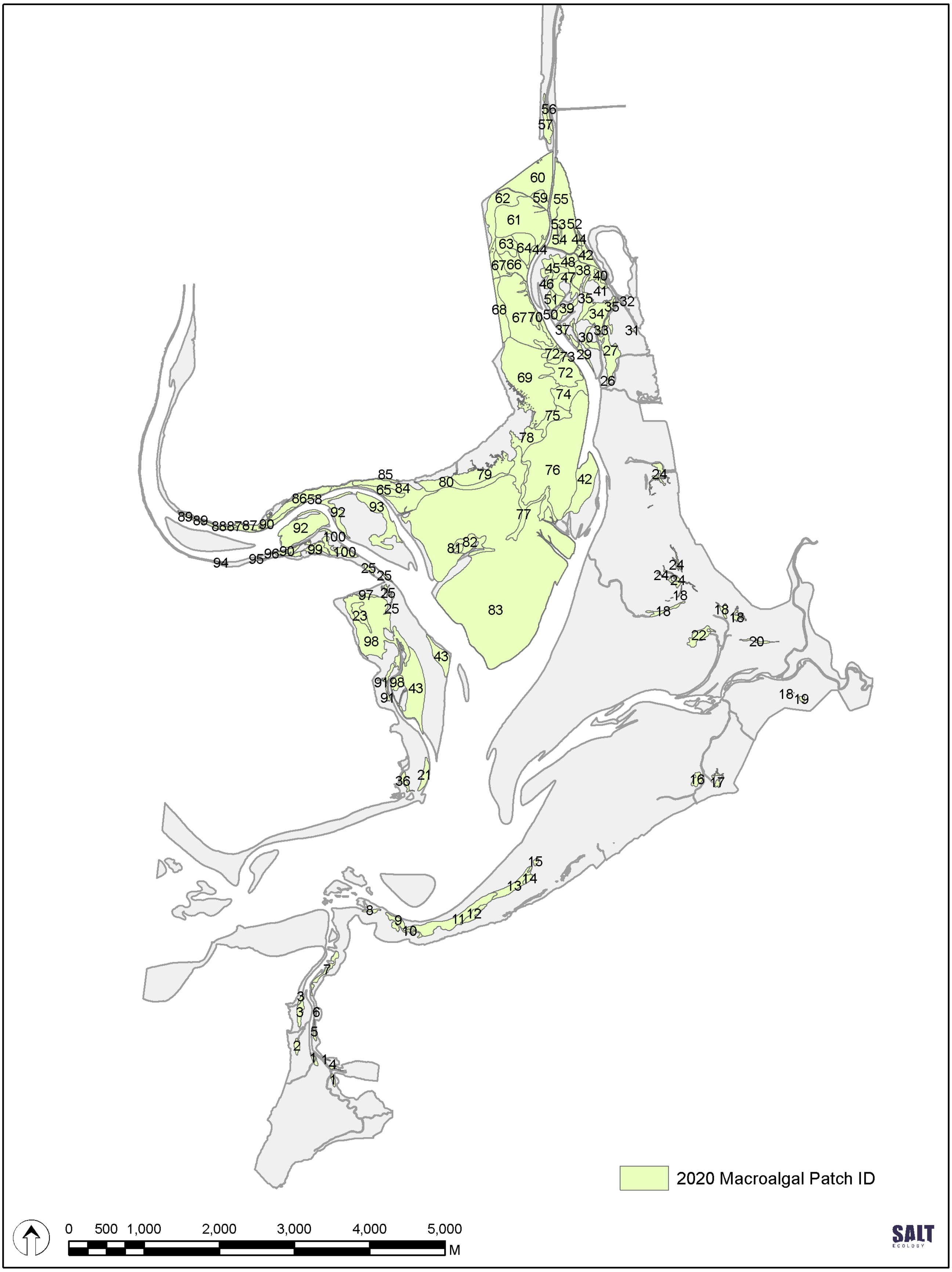
2020 Station data:

Entrained (>30mm in sediment) 0=no, 1=yes

Count	Station	FieldCode	%Cover	Tot%Cov	Biomass (gm$^{2)}$	Entrained	aRPD (mm)	NZTM_N	NZTM_E
1	WE2-1a	grch SM50_90	5	5	120	0	20	4847478	1242012
2	WE3-1b	grch SM50_90	25	25	1760	1	20	4846987	1241730
3	WE3-1a	grch ulva SM50_90	75 1	76	4400	1	35	4846891	1241578
4	WE3-2	grch SM50_90	50	50	1340	1	25	4846572	1241903
5	WE3-3	grch SM50_90	75	75	3120	1	15	4846626	1241985
6	WE3-3a	grch SM50_90	50	50	1040	1	25	4846675	1242096
7	WE3-4	grch SM50_90	50	50	800	1	25	4846716	1242194
8	We20 0-4	grch SM50_90	90	90	2480	1	10	4847829	1241712
9	We20 1-5	grch SM50_90	20	20	700	1	5	4847678	1241729
10	We20 1-4	grch SM50_90	1	1	10	0	15	4847712	1241835
11	We20 5-	grch ulva SM50_90	60 40	100	5200	1	4	4846617	1242597
12	We20 4-1a	grch SM50_90	60	60	2240	1	2	4846251	1242386
13	We20 4-2	grch SM50_90	60	60	1280	1	2	4846119	1242392
14	We20 4-3	grch SM50_90	65	65	1760	1	30	4846007	1242402
15	We20 5-1	grch SM50_90	100	100	8080	1	10	4846281	1242202
16	We20 4-1	grch SM50_90	100	100	3760	1	5	4846345	1242372
17	We20 4-0	grch SM50_90	60	60	1840	1	10	4846630	1242384
18	WE3-4b	grch MS25_50	60	60	2480	1	20	4846790	1242312
19	WE3-4a	grch MS25_50	70	70	2320	1	10	4846870	1242431
20	We20 0-1	grch MS25_50	1	1	5	0	20	4848109	1241864
21	We20 0-2	grch MS25_50	1	1	5	0	10	4848034	1241773
22	We20 1-6	grch MS25_50	1	1	5	0	10	4847657	1241637
23	WE3-2a	grch MS10_25	20	20	4240	1	50	4846501	1241758
24	We20 0-3	grch MS10_25	1	1	5	0	30	4847916	1241685
25	We20 1-3	grch MS10_25	2	2	5	0	30	4847762	1241918
26	We20 1-2	grch MS10_25	10	10	20	0	30	4847785	1241928
27	We20 4-4	grch MS10_25	60	60	1680	1	30	4845865	1242383
28	We20 4-5	grch MS10_25	30	30	220	1	25	4845794	1242373
29	We20 5-2	grch ulva MS10_25	5 8	13	60	0	40	4846229	1242011
30	We20 5-2	grch MS10_25	1	1	5	0	40	4846252	1242092
31	Wai20 1c	grch M90_100	100	100	2880	1	1	4849363	1241583
32	Wai20 1b	grch ulva M90_100	50 50	100	4720	1	1	4849359	1241560
33	Wai20 1a	grch ulva M90_100	40 60	100	4080	1	1	4849357	1241521
34	WE2-1	grch M90_100	15	15	1200	1	15	4847381	1241865
35	WE2-2	grch ulva M90_100	40 1	41	2000	1	15	4847328	1241779
36	WE2-3	grch M90_100	40	40	3040	1	15	4847245	1241647
37	WE2-4	grch ulva M90_100	70 5	75	3040	1	25	4847185	1241522
38	Wai20 2a	grch ulva M90_100	10 90	100	3760	1	1	4849233	1241530
39	Wai20 2b	grch ulva M90_100	10 90	100	5040	1	1	4849228	1241567
40	Wai20 2c	grch M90_100	100	100	3280	1	1	4849226	1241614
41	Wai20 3c	grch ulva M90_100	99 1	100	12000	1	1	4849106	1241625
42	Wai20 3b	grch ulva M90_100	50 50	100	5520	1	2	4849101	1241591
43	Wai20 3a	grch ulva M90_100	5 95	100	3040	1	3	4849109	1241536
44	WE3-1d	grch M90_100	70	70	2240	1	10	4847234	1242158
45	WE3-1c	grch M90_100	100	100	8640	1	5	4847155	1242029
46	WE3-1	grch ulva M90_100	99 1	100	7760	1	15	4847047	1241897
47	WE3-2b	grch ulva M90_100	90 1	91	8800	1	15	4846739	1241773
48	We20 1-0	grch M90_100	20	20	280	1	7	4847792	1241935
49	Sb20-7	grch ulva SM50_90	60 40	100	7920	1	2	4843129	1243327
50	Sb20 1-3	grch ulva SM50_90	99 1	100	7600	1	4	4842459	1243615
51	Sb20 1-2	grch ulva SM50_90	99 1	100	3680	1	1	4842425	1243583
52	M20 1-2	grch ulva SM50_90	80 5	85	4520	1	1	4836988	1238243
53	M20 1-3	grch ulva SM50_90	80 10	90	2400	1	1	4837018	1238233
54	M20 1-1	grch ulva SM50_90	70 5	75	4320	1	1	4836934	1238231
55	D9	grch SM50_90	60	60	3280	1	2	4841572	1239475
56	D7	grch SM50_90	90	90	1920	1	3	4842130	1239356
57	Sout-D1a	grch SM50_90	95	95	4320	1	2	4843157	1239480

58	ORB-2a	grch SM50_90	90	90	2880	1	25	4843793	1238652
59	ORB-2	grch SM50_90	90	90	2960	1	5	4843668	1238385
60	Shel20-4	grch ulva S0_10	20 5	25	640	1	>150	4839406	1241416
61	Shel20-3	grch ulva S0_10	5 1	6	300	1	>150	4839218	1241340
62	Shel20-2	grch ulva S0_10	80 5	85	1920	1	90	4838657	1240560
63	Shel20 -1	grch ulva S0_10	25 5	30	900	1	10	4838651	1239481
64	Shels 20-5	grch ulva MS25_50	90 5	95	3200	1	25	4840447	1243807
65	ORB-1b	grch MS25_50	2	2	5	0	15	4843552	1238160
66	Shel20-6	grch ulva MS10_25	90 1	91	1500	1	10	4842341	1244369
67	M20 3-0	grch ulva MS10_25	1 70	71	440	0	5	4838052	1238672
68	M20 2-0	grch ulva MS10_25	30 10	40	60	0	10	4836741	1238483
69	D8a	grch MS10_25	15	15	270	0	40	4841959	1239844
70	D7	grch MS10_25	15	15	440	0	50	4842129	1240105
71	SP4	grch ulva MS10_25	10 5	15	160	0	25	4840494	1239910
72	SP5	grch ulva MS10_25	20 5	25	440	0	30	4840561	1239921
73	SP6	grch ulva MS10_25	10 5	15	250	0	35	4840581	1239917
74	Sb20 1-1	grch ulva M90_100	99 1	100	3680	1	2	4842376	1243582
75	D7a	grch M90_100	100	100	8160	1	5	4842420	1239594
76	Sp7	grch ulva M90_100	99 1	100	1620	1	0	4840380	1239727
77	Sp1 -a	grch ulva M90_100	70 30	100	7440	0	0	4840492	1239699
78	Sp2	grch ulva M90_100	10 10	20	2320	0	0	4840440	1239701
79	SP1	grch ulva M90_100	70 30	100	4080	0	0	4840544	1239671
80	D8	grch M90_100	60	60	3040	1	1	4841675	1239437
81	D5	grch M90_100	100	100	6960	1	0	4842323	1239255
82	D4	grch ulva M90_100	99 1	100	3440	0	1	4842455	1239201
83	D3	grch M90_100	25	25	1120	0	2	4842611	1239162
84	D2	grch M90_100	100	100	3280	0	1	4842783	1239105
85	D1	grch M90_100	30	30	3520	0	1	4842840	1239100
86	ORB-3	grch M90_100	100	100	7760	1	2	4843581	1238856
87	ORB-1	grch M90_100	100	100	1580	1	5	4843526	1238025
88	ORB-0a	grch M90_100	60	60	4080	1	5	4843395	1237210
89	ORB-0b	ulva GF	50	50	640	0	indet	4843439	1237764
90	Bu2-3	grch SM50_90	60	60	6400	1	25	4844473	1239501
91	Bu2-1	grch SM50_90	60	60	1360	1	20	4844447	1239079
92	Bu2-2	grch SM50_90	60	60	3280	1	15	4844450	1239090
93	Bu3-0a	grch SM50_90	50	50	3440	1	20	4843872	1237282
94	BP-8	grch SM50_90	90	90	2640	1	5	4845161	1242042
95	BP-3	grch SM50_90	75	75	2360	1	2	4844937	1241240
96	BO20-3	grch S0_10	1	1	20	0	80	4843768	1240321
97	BP20-5	grch S0_10	1	1	40	0	100	4843617	1240078
98	BP20-4	grch S0_10	90	90	2480	1	65	4843567	1240395
99	BP-10	grch ulva S0_10	24 1	25	100	0	35	4844137	1241248
100	BP19-8a	grch MS25_50	60	60	1380	0	15	4844355	1239818
101	Bp19-8	grch MS25_50	70	70	2880	0	15	4844210	1239797
102	Bu2-3a	grch MS25_50	75	75	2560	0	15	4844425	1239303
103	Bu3-3a	grch MS25_50	50	50	1120	1	20	4844235	1238442
104	BP-9	grch MS25_50	50	50	4240	1	5	4844566	1241916
105	BP-7	grch MS25_50	100	100	41520	1	1	4845493	1242111
106	BP-1	grch MS25_50	50	50	560	1	20	4844620	1240855
107	BP20-2	grch MS10_25	1	1	50	0	indet	4844030	1240325
108	BP-12	grch MS10_25	90	90	2240	1	90	4844537	1241315
109	BP19-1a	grch MS10_25	70	70	2400	1	25	4844569	1240524
110	BP19-8c	grch MS10_25	20	20	240	0	10	4844469	1240287
111	BP19-8b	grch MS10_25	40	40	400	0	10	4844425	1240033
112	Bu2-2a	grch MS10_25	2	2	5	0	20	4844389	1238765
113	BP-11	grch MS10_25	80	80	6480	1	20	4844232	1241289
114	BP-2	grch MS10_25	10	10	140	0	60	4844595	1241118
115	BP19-7	grch M90_100	100	100	7280	1	3	4844080	1239663
116	Bu3-3	grch ulva M90_100	95 5	100	7360	1	4	4844108	1238080
117	Bu3-1	grch M90_100	100	100	8160	1	2	4843995	1237947
118	Bu3-2	grch M90_100	100	100	11280	1	3	4843997	1237942
119	Bu3-0b	grch ulva M90_100	60 20	80	4640	1	5	4843867	1237429
120	Bu3-0	grch M90_100	50	50	1600	1	8	4843997	1236835

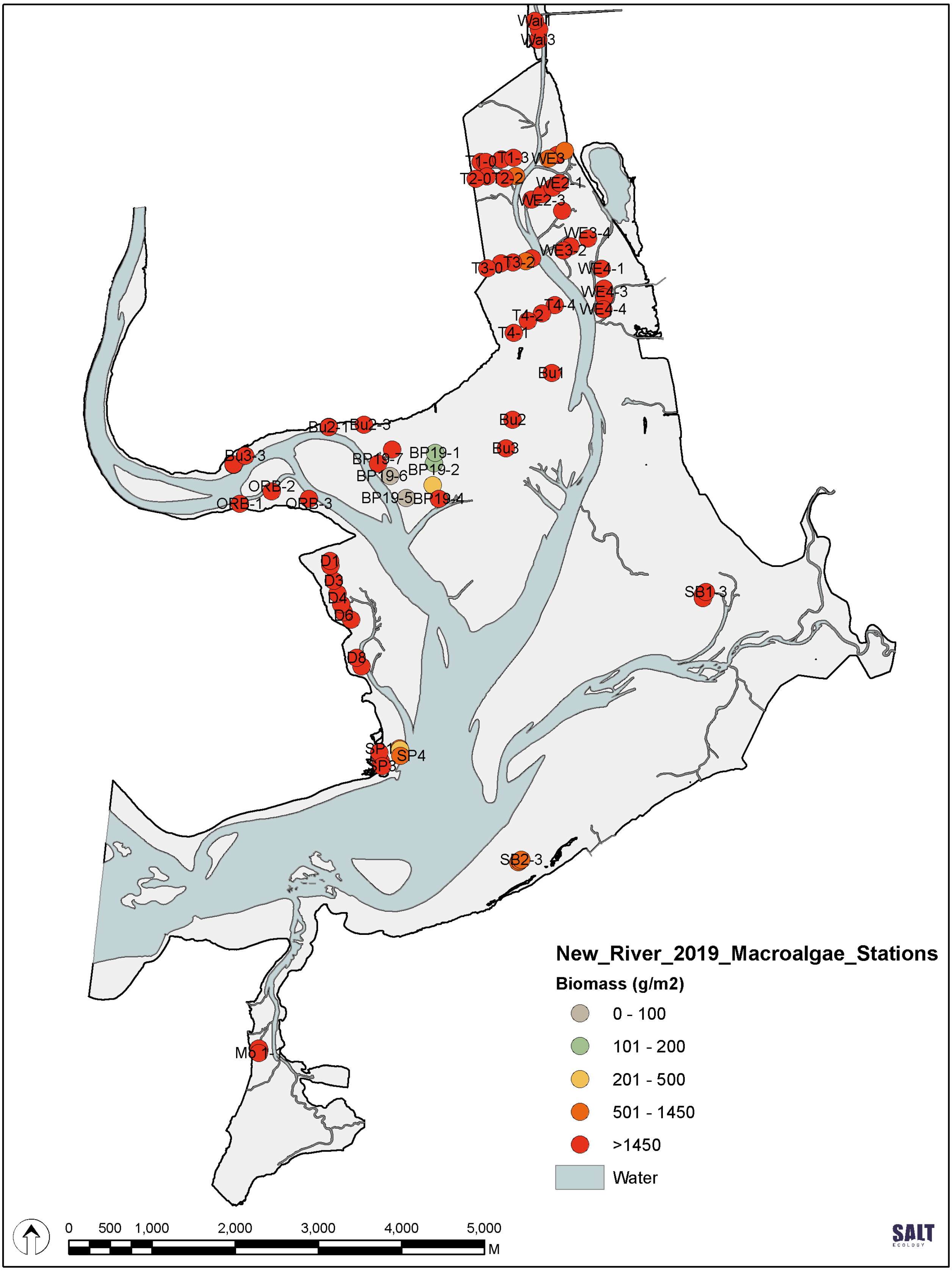
121	Bu3-1a	grch M90_100	1	1	5	0	1	4844012	1236798
122	BP-6	grch M90_100	100	100	4880	1	2	4845553	1241943
123	BP-5	grch M90_100	80	80	5920	1	5	4845113	1241421
124	BP-4	grch ulva M90_100	80 20	100	2240	1	1	4845038	1241146
125	T4-2	grch ulva SM50_90	95 5	100	2880	1	1	4845727	1241474
126	T4-3	grch SM50_90	100	100	3600	1	5	4845877	1241686
127	T2-3	grch SM50_90	50	50	1280	1	30	4847475	1241332
128	T0-4	grch SM50_90	1	1	60	1	10	4848360	1241595
129	T3a-0	grch M90_100	100	100	2880	1	1	4845903	1241057
130	T3a-1	grch M90_100	100	100	2560	1	1	4845929	1241178
131	T3a-2	grch ulva M90_100	98 2	100	2960	1	2	4846025	1241358
132	T3a-3	grch ulva M90_100	95 5	100	2800	1	2	4846092	1241467
133	T3a-4	grch ulva M90_100	95 5	100	9760	1	5	4846202	1241611
134	T3a-0	grch ulva M90_100	10 1	11	2080	1	1	4846740	1240981
135	T3a-1	grch ulva M90_100	99 1	100	3760	1	1	4846752	1241096
136	T3a-2	grch ulva M90_100	99 1	100	4560	1	1	4846769	1241200
137	T3a-3	grch ulva M90_100	99 1	100	4080	1	1	4846788	1241334
138	T3a-4	grch ulva M90_100	65 35	100	5280	1	3	4846795	1241377
139	T3-4	grch ulva M90_100	20 1	21	720	1	3	4846477	1241529
140	T3-3	grch ulva M90_100	65 35	100	6800	1	2	4846444	1241456
141	T3-2	grch ulva M90_100	99 1	100	3520	1	3	4846428	1241301
142	T3-1	grch M90_100	100	100	2400	1	4	4846426	1241163
143	T3-0	grch M90_100	100	100	2160	1	2	4846361	1241010
144	3a-5	grch ulva M90_100	50 1	51	2080	1	5	4846261	1241716
145	T4-5	grch M90_100	100	100	4720	1	5	4845955	1241913
146	T4-3	grch M90_100	100	100	9520	1	5	4845908	1241798
147	T4-1	grch ulva M90_100	95 5	100	1360	1	2	4845578	1241309
148	T1-0	grch M90_100	80	80	6080	1	2	4847632	1240913
149	T1-1	grch M90_100	100	100	2720	1	3	4847640	1240975
150	T1-3	grch ulva M90_100	80 10	90	3360	1	2	4847663	1241159
151	T1-3	grch ulva M90_100	70 1	71	3280	1	5	4847685	1241296
152	T1-4	grch M90_100	80	80	2160	1	5	4847784	1241574
153	T2-0	grch ulva M90_100	98 1	99	1920	1	1	4847432	1240854
154	T2-1	grch ulva M90_100	99 1	100	3760	1	5	4847465	1241001
155	T2-2	grch ulva M90_100	65 10	75	1600	1	7	4847435	1241193
156	T2-4	grch M90_100	5	5	120	0	6	4847476	1241344
157	T2a-4	grch ulva M90_100	50 1	51	3040	1	5	4847142	1241265
158	T2a-3	grch ulva M90_100	50 50	100	9760	1	5	4847138	1241234
159	T2a-2	grch M90_100	100	100	8560	1	5	4847127	1241179
160	T2a-1	grch ulva M90_100	99 1	100	3200	1	2	4847118	1241040
161	T2a-0	grch M90_100	100	100	2600	1	3	4847125	1240901
162	T0-3	grch M90_100	75	75	1920	1	1	4848287	1241477
163	T0-2	grch M90_100	100	100	3600	1	1	4848214	1241208
164	T0-1	grch M90_100	90	90	1840	1	1	4848035	1240951
165	T0-0	grch M90_100	15	15	1040	1	1	4847941	1240831


2020 Macroalgal Patch ID
0 500 1,000 2,000 3,000 4,000 5,000
M
SALT ECOLOGY

WaterbdyID	SurveyID	PatchID	ValidCode	Pct_Cover	TotPctCov	Pct Cover Category	Biomassgm2	Biomass Category	Entrained	DomHab	SubDom1	Area_ha
NREs-Sout	2020	1	Grch Ulva	30 10	40	Low-Moderate (30 to <50%)	60	Very low (1 - 100)	0	Gracilaria chilensis	Ulva (Sea lettuce)	1.42
NREs-Sout	2020	2	Grch Ulva	76 6	82	Dense (70 to <90%)	3747	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	1.16
NREs-Sout	2020	3	Ulsp	50	50	High-Moderate (50 to <70%)	100	Very low (1 - 100)	0	Ulva sp (Sea lettuce)		2.45
NREs-Sout	2020	4	Grch	100	100	Complete (>90%)	2000	High (1001 - 3000)	1	Gracilaria chilensis		0.34
NREs-Sout	2020	5	Ulsp	10	10	Sparse (10 to <30%)	10	Very low (1 - 100)	0	Ulva sp (Sea lettuce)		0.59
NREs-Sout	2020	6	Grch	50	50	High-Moderate (50 to <70%)	10	Very low (1 - 100)	1	Gracilaria chilensis		0.11
NREs-Sout	2020	7	Ulsp	20	20	Sparse (10 to <30%)	50	Very low (1 - 100)	0	Ulva sp (Sea lettuce)		2.52
NREs-Sout	2020	8	Ulsp	5	5	Very sparse (1 to <10%)	50	Very low (1 - 100)	0	Ulva sp (Sea lettuce)		0.65
NREs-Sout	2020	9	Grch Ulva	25 5	30	Low-Moderate (30 to <50%)	900	Moderate (501 - 1000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	1.93
NREs-Sout	2020	10	Ulsp Grch	80 5	85	Dense (70 to <90%)	100	Very low (1 - 100)	0	Ulva sp (Sea lettuce)	Gracilaria chilensis	1.88
NREs-Sout	2020	11	Grch Ulsp	30 10	40	Low-Moderate (30 to <50%)	250	Low (101 - 500)	1	Gracilaria chilensis	Ulva sp (Sea lettuce)	12.97
NREs-Sout	2020	12	Grch Ulva	80 5	85	Dense (70 to <90%)	1920	High (1001 - 3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	2.41
NREs-Sout	2020	13	Grch Ulsp	10 5	15	Sparse (10 to <30%)	150	Low (101 - 500)	0	Gracilaria chilensis	Ulva sp (Sea lettuce)	5.01
NREs-Sout	2020	14	Grch Ulva	5 1	6	Very sparse (1 to <10%)	300	Low (101 - 500)	1	Gracilaria chilensis	Ulva (Sea lettuce)	0.97
NREs-Sout	2020	15	Grch Ulva	20 5	25	Sparse (10 to <30%)	640	Moderate (501 - 1000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	0.69
NREs-Sout	2020	16	Grch	30	30	Low-Moderate (30 to <50%)	1500	High (1001 - 3000)	1	Gracilaria chilensis		1.74
NREs-Sout	2020	17	Grch Ulva	90 5	95	Complete (>90%)	3200	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	1.06
NREs-Sout	2020	18	Grch	80	80	Dense (70 to <90%)	2000	High (1001 - 3000)	1	Gracilaria chilensis		4.18
NREs-Sout	2020	19	Ulsp	80	80	Dense (70 to <90%)	5	Very low (1 - 100)	0	Ulva sp (Sea lettuce)		0.44
NREs-Sout	2020	20	Grch Ulva	90 1	91	Complete (>90%)	1500	High (1001 - 3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	0.83
NREs-Sout	2020	21	Grch Ulva	13 5	18	Sparse (10 to <30%)	283	Low (101 - 500)	0	Gracilaria chilensis	Ulva (Sea lettuce)	2.88
NREs-Sout	2020	22	Grch Ulva	99 1	100	Complete (>90%)	4987	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	4.01
NREs-Sout	2020	23	Grch	27	27	Sparse (10 to <30%)	2320	High (1001 - 3000)	1	Gracilaria chilensis		4.22
NREs-Sout	2020	24	Grch Ulva	60 40	100	Complete (>90%)	7920	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	5.31
NREs-Sout	2020	25	Grch	95	95	Complete (>90%)	4320	Very high (>3000)	1	Gracilaria chilensis		2.26
NREs-Sout	2020	26	Grch	30	30	Low-Moderate (30 to <50%)	220	Low (101 - 500)	1	Gracilaria chilensis		0.20
NREs-Sout	2020	27	Grch	67	67	High-Moderate (50 to <70%)	2093	High (1001 - 3000)	1	Gracilaria chilensis		9.65
NREs-Sout	2020	28	Grch	100	100	Complete (>90%)	8080	Very high (>3000)	1	Gracilaria chilensis		1.28
NREs-Sout	2020	29	Ulva Grch	8 5	13	Sparse (10 to <30%)	60	Very low (1 - 100)	0	Ulva (Sea lettuce)	Gracilaria chilensis	2.24
NREs-Sout	2020	30	Grch	1	1	Very sparse (1 to <10%)	5	Very low (1 - 100)	0	Gracilaria chilensis		1.86
NREs-Sout	2020	31	Grch Ulsp	60 40	100	Complete (>90%)	3000	High (1001 - 3000)	1	Gracilaria chilensis	Ulva sp (Sea lettuce)	0.12
NREs-Sout	2020	32	Grch	50	50	High-Moderate (50 to <70%)	5000	Very high (>3000)	1	Gracilaria chilensis		0.16
NREs-Sout	2020	33	Grch	75	75	Dense (70 to <90%)	1000	Moderate (501 - 1000)	1	Gracilaria chilensis		0.45
NREs-Sout	2020	34	Grch	52	52	High-Moderate (50 to <70%)	1415	High (1001 - 3000)	1	Gracilaria chilensis		9.44
NREs-Sout	2020	35	Grch	72	72	Dense (70 to <90%)	2720	High (1001 - 3000)	1	Gracilaria chilensis		4.19
NREs-Sout	2020	36	Grch Ulva	62 17	79	Dense (70 to <90%)	3865	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	1.51
NREs-Sout	2020	37	Grch	20	20	Sparse (10 to <30%)	4240	Very high (>3000)	1	Gracilaria chilensis		1.18
NREs-Sout	2020	38	Grch	85	85	Dense (70 to <90%)	5440	Very high (>3000)	1	Gracilaria chilensis		7.76
NREs-Sout	2020	39	Grch Ulva	94 1	95	Complete (>90%)	8280	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	5.33
NREs-Sout	2020	40	Grch	60	60	High-Moderate (50 to <70%)	2000	High (1001 - 3000)	1	Gracilaria chilensis		1.40
NREs-Sout	2020	41	Grch	30	30	Low-Moderate (30 to <50%)	1000	Moderate (501 - 1000)	1	Gracilaria chilensis		1.05
NREs-Sout	2020	42	Grch	50	50	High-Moderate (50 to <70%)	1500	High (1001 - 3000)	1	Gracilaria chilensis		18.22
NREs-Sout	2020	43	Grch	15	15	Sparse (10 to <30%)	355	Low (101 - 500)	1	Gracilaria chilensis		28.19
NREs-Sout	2020	44	Grch	5	5	Very sparse (1 to <10%)	120	Low (101 - 500)	1	Gracilaria chilensis		4.00
NREs-Sout	2020	45	Grch	40	40	Low-Moderate (30 to <50%)	3040	Very high (>3000)	1	Gracilaria chilensis		4.66
NREs-Sout	2020	46	Grch Ulva	70 5	75	Dense (70 to <90%)	3040	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	2.30
NREs-Sout	2020	47	Grch	25	25	Sparse (10 to <30%)	1760	High (1001 - 3000)	1	Gracilaria chilensis		4.89
NREs-Sout	2020	48	Grch Ulva	40 1	41	Low-Moderate (30 to <50%)	2000	High (1001 - 3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	3.85
NREs-Sout	2020	49	Grch	15	15	Sparse (10 to <30%)	1200	High (1001 - 3000)	1	Gracilaria chilensis		1.69
NREs-Sout	2020	50	Grch Ulva	75 1	76	Dense (70 to <90%)	4400	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	1.80
NREs-Sout	2020	51	Grch	25	25	Sparse (10 to <30%)	2000	High (1001 - 3000)	1	Gracilaria chilensis		1.80
NREs-Sout	2020	52	Grch	20	20	Sparse (10 to <30%)	280	Low (101 - 500)	1	Gracilaria chilensis		0.15
NREs-Sout	2020	53	Grch	90	90	Complete (>90%)	2480	High (1001 - 3000)	1	Gracilaria chilensis		0.33
NREs-Sout	2020	54	Grch	20	20	Sparse (10 to <30%)	700	Moderate (501 - 1000)	1	Gracilaria chilensis		0.83
NREs-Sout	2020	55	Grch	2	2	Very sparse (1 to <10%)	8	Very low (1 - 100)	1	Gracilaria chilensis		30.58
NREs-Sout	2020	56	Grch	100	100	Complete (>90%)	3080	Very high (>3000)	1	Gracilaria chilensis		1.08
NREs-Sout	2020	57	Ulva Grch	62 37	99	Complete (>90%)	5451	Very high (>3000)	1	Ulva (Sea lettuce)	Gracilaria chilensis	3.68
NREs-Sout	2020	58	Grch	50	50	High-Moderate (50 to <70%)	1120	High (1001 - 3000)	1	Gracilaria chilensis		0.98
NREs-Sout	2020	59	Grch	75	75	Dense (70 to <90%)	1920	High (1001 - 3000)	1	Gracilaria chilensis		3.39
NREs-Sout	2020	60	Grch	1	1	Very sparse (1 to <10%)	60	Very low (1 - 100)	1	Gracilaria chilensis		21.57
NREs-Sout	2020	61	Grch	90	90	Complete (>90%)	2533	High (1001 - 3000)	1	Gracilaria chilensis		31.23
NREs-Sout	2020	62	Grch	15	15	Sparse (10 to <30%)	1040	High (1001 - 3000)	1	Gracilaria chilensis		12.98
NREs-Sout	2020	63	Grch	90	90	Complete (>90%)	4400	Very high (>3000)	1	Gracilaria chilensis		6.15
NREs-Sout	2020	64	Grch Ulva	66 3	69	High-Moderate (50 to <70%)	2640	High (1001 - 3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	7.76
NREs-Sout	2020	65	Grch	2	2	Very sparse (1 to <10%)	5	Very low (1 - 100)	1	Gracilaria chilensis		5.53
NREs-Sout	2020	66	Grch Ulva	82 5	87	Dense (70 to <90%)	2680	High (1001 - 3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	7.78
NREs-Sout	2020	67	Grch Ulva	87 12	99	Complete (>90%)	5192	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	38.64
NREs-Sout	2020	68	Grch	77	77	Dense (70 to <90%)	2190	High (1001 - 3000)	1	Gracilaria chilensis		10.17
NREs-Sout	2020	69	Grch Ulva	97 2	99	Complete (>90%)	2573	High (1001 - 3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	51.40
NREs-Sout	2020	70	Grch Ulva	20 1	21	Sparse (10 to <30%)	720	Moderate (501 - 1000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	6.51
NREs-Sout	2020	72	Grch Ulva	98 1	99	Complete (>90%)	6900	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	15.18
NREs-Sout	2020	73	Grch Ulva	50 1	51	High-Moderate (50 to <70%)	2080	High (1001 - 3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	2.29
NREs-Sout	2020	74	Grch	10	10	Sparse (10 to <30%)	150	Low (101 - 500)	1	Gracilaria chilensis		9.91
NREs-Sout	2020	75	Grch	30	30	Low-Moderate (30 to <50%)	1500	High (1001 - 3000)	1	Gracilaria chilensis		6.63
NREs-Sout	2020	76	Grch	85	85	Dense (70 to <90%)	10333	Very high (>3000)	1	Gracilaria chilensis		79.24
NREs-Sout	2020	77	Grch Ulva	24 1	25	Sparse (10 to <30%)	100	Very low (1 - 100)	1	Gracilaria chilensis	Ulva (Sea lettuce)	11.18

WaterbdyID	SurveyID	PatchID	ValidCode	Pct_Cover	TotPctCov	Pct Cover Category	Biomassgm2	Biomass Category	Entrained	DomHab	SubDom1	Area_ha
NREs-Sout	2020	78	Grch Ulva	78 6	84	Dense (70 to <90%)	3507	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	8.02
NREs-Sout	2020	79	Grch	60	60	High-Moderate (50 to <70%)	1480	High (1001 - 3000)	1	Gracilaria chilensis		14.24
NREs-Sout	2020	80	Grch	23	23	Sparse (10 to <30%)	260	Low (101 - 500)	1	Gracilaria chilensis		17.83
NREs-Sout	2020	81	Grch	90	90	Complete (>90%)	2480	High (1001 - 3000)	1	Gracilaria chilensis		1.10
NREs-Sout	2020	82	Grch	20	20	Sparse (10 to <30%)	160	Low (101 - 500)	1	Gracilaria chilensis		7.29
NREs-Sout	2020	83	Grch	1	1	Very sparse (1 to <10%)	37	Very low (1 - 100)	0	Gracilaria chilensis		318.77
NREs-Sout	2020	84	Grch	70	70	Dense (70 to <90%)	3123	Very high (>3000)	1	Gracilaria chilensis		16.94
NREs-Sout	2020	85	Grch	60	60	High-Moderate (50 to <70%)	6400	Very high (>3000)	1	Gracilaria chilensis		0.78
NREs-Sout	2020	86	Grch Ulva	98 1	99	Complete (>90%)	8933	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	8.43
NREs-Sout	2020	87	Grch Ulva	60 20	80	Dense (70 to <90%)	4640	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	0.64
NREs-Sout	2020	88	Grch	50	50	High-Moderate (50 to <70%)	3440	Very high (>3000)	1	Gracilaria chilensis		0.03
NREs-Sout	2020	89	Grch	50	50	High-Moderate (50 to <70%)	1600	High (1001 - 3000)	1	Gracilaria chilensis		0.02
NREs-Sout	2020	90	Grch	1	1	Very sparse (1 to <10%)	5	Very low (1 - 100)	1	Gracilaria chilensis		9.72
NREs-Sout	2020	91	Grch	60	60	High-Moderate (50 to <70%)	3160	Very high (>3000)	1	Gracilaria chilensis		0.52
NREs-Sout	2020	92	Grch	50	50	High-Moderate (50 to <70%)	3000	High (1001 - 3000)	1	Gracilaria chilensis		22.53
NREs-Sout	2020	93	Grch	80	80	Dense (70 to <90%)	5000	Very high (>3000)	1	Gracilaria chilensis		13.35
NREs-Sout	2020	94	Grch	60	60	High-Moderate (50 to <70%)	4080	Very high (>3000)	1	Gracilaria chilensis		0.16
NREs-Sout	2020	95	Ulva	50	50	High-Moderate (50 to <70%)	640	Moderate (501 - 1000)	0	Ulva (Sea lettuce)		0.08
NREs-Sout	2020	96	Grch	93	93	Complete (>90%)	2473	High (1001 - 3000)	1	Gracilaria chilensis		1.83
NREs-Sout	2020	97	Grch	10	10	Sparse (10 to <30%)	1000	Moderate (501 - 1000)	1	Gracilaria chilensis		0.96
NREs-Sout	2020	98	Grch	97	97	Complete (>90%)	4752	Very high (>3000)	1	Gracilaria chilensis		39.84
NREs-Sout	2020	99	Grch Ulsp	75 5	80	Dense (70 to <90%)	5000	Very high (>3000)	1	Gracilaria chilensis	Ulva sp (Sea lettuce)	3.90
NREs-Sout	2020	100	Grch	100	100	Complete (>90%)	7760	Very high (>3000)	1	Gracilaria chilensis		4.39

entrained (>30mm in sediment) 0=no, 1=yes



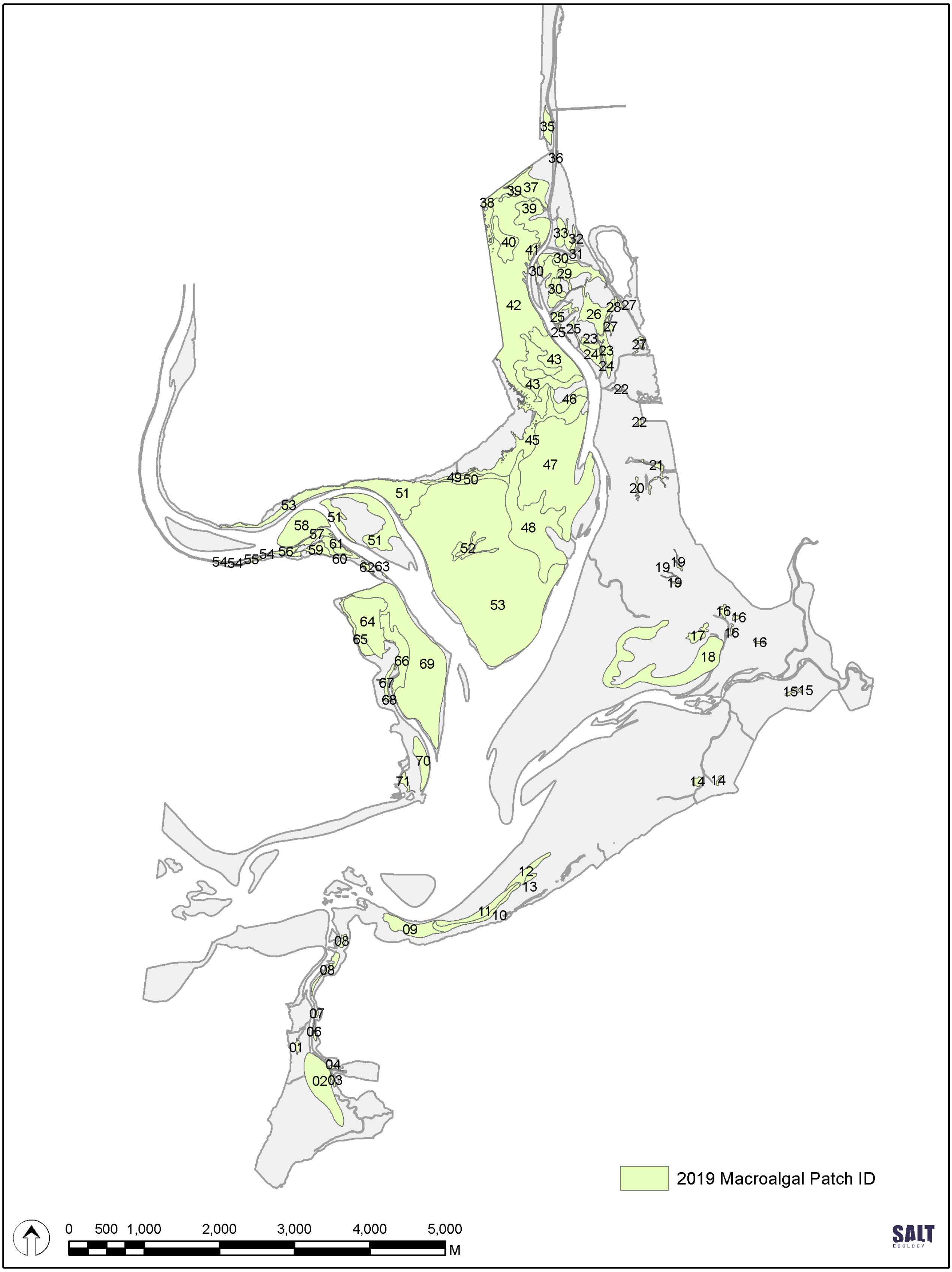
New_River_2019_Macroalgae_Stations
Biomass (g/m2)
0 - 100
101 - 200
201 - 500
501 - 1450
>1450
Water
0
500
1,000
2,000
3,000
4,000
5,000
M

2019 Station data:

Entrained = growing >30mm in sediment

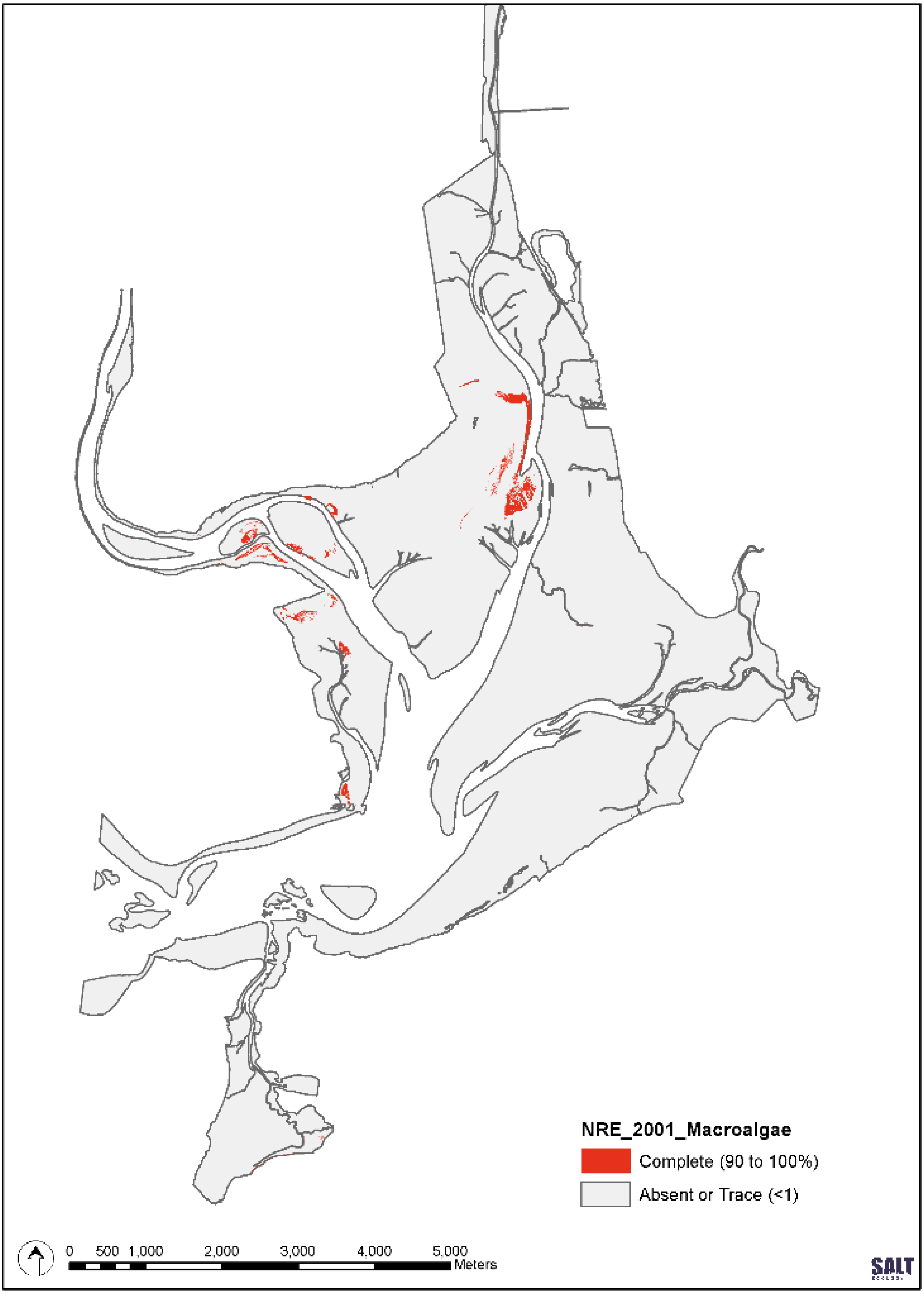
Count	Station	FieldCode	%Cover	Tot%Cov	Biomass (gm^2)	Entrained	aRPD (mm)	NZTM_N	NZTM_E
1	Wai3	grch ulva VSM	95 5	100	4000	yes	1	4849099	1241601
2	Wai2	grch ulva VSM	95 5	100	6800	yes	1	4849227	1241611
3	Wai1	grch ulva VSM	95 5	100	3200	yes	2	4849331	1241563
4	WE2	grch SM	25	25	1600	yes	5	4847721	1241833
5	WE1	grch FSM	10	10	960	yes	10	4847766	1241919
6	BP19-3	grch MS	10	10	320	no	45	4843748	1240333
7	T4-4	grch VSM	100	100	9440	yes	0	4845913	1241801
8	SB2-1	grch ulva MS	50 1	51	1168	yes	150	4839214	1241363
9	SB2-2	grch MS	50	50	800	yes	150	4839232	1241378
10	SB1-2	grch SM	100	100	5600	yes	5	4842432	1243583
11	SB1-1	grch SM	100	100	5520	yes	5	4842389	1243583
12	SB1-3	grch SM	100	100	6560	yes	5	4842463	1243617
13	SB2-3	grch ulva MS	50 1	51	680	yes	150	4839247	1241401
14	BP19-8	grch MS	50	50	3500	yes	20	4844178	1239844
15	BP19-7	grch MS	100	100	8080	yes	25	4844008	1239676
16	BP19-6	grch MS	1	1	40	no	38	4843855	1239819
17	BP19-5	grch MS	1	1	50	no	40	4843592	1240013
18	BP19-4	grch ulva other FSM	90 5 5	100	5760	yes	20	4843583	1240406
19	BP19-2	grch MS	5	5	175	no	28	4844014	1240349
20	BP19-1	grch MS	2	2	150	no	25	4844138	1240362
21	Bu3	grch FMS	100	100	3040	yes	55	4844192	1241213
22	Bu2	grch FMS	100	100	3760	yes	50	4844532	1241296
23	Bu1	grch VSM	100	100	9280	yes	0	4845095	1241765
24	T4-3	grch VSM	100	100	14320	yes	0	4845812	1241645
25	T4-2	grch VSM	100	100	8800	yes	0	4845723	1241478
26	T4-1	grch VSM	95	95	3520	yes	0	4845578	1241308
27	Bu2-3	grch SM	75	75	5760	yes	8	4844474	1239506
28	Bu2-2	grch VSM	90	90	6080	yes	1	4844447	1239086
29	Bu2-1	grch MS	90	90	6880	yes	5	4844446	1239084
30	Bu3-1	grch SM	90	90	5120	yes	5	4843993	1237942
31	Bu3-2	grch SM	90	90	6880	yes	1	4843996	1237940
32	Bu3-3	grch SM	65	65	12640	yes	5	4844103	1238081
33	T1-0	grch VSM	100	100	6160	yes	0	4847634	1240912
34	T1-1	grch VSM	100	100	5120	yes	1	4847635	1240972
35	T1-2	grch SM	90	90	4720	yes	15	4847661	1241159
36	T1-3	grch VSM	65	65	5280	yes	5	4847683	1241303
37	T2-3	grch FMS	25	25	1360	yes	35	4847467	1241334
38	T2-2	grch VSM	55	55	2160	yes	3	4847433	1241202
39	T2-1	grch VSM	95	95	2640	yes	1	4847457	1240984
40	T2-0	grch VSM	80	80	2880	yes	1	4847427	1240850
41	T3-4	grch VSM	95	95	4160	yes	10	4846475	1241526
42	T3-3	grch SM	50	50	1360	yes	3	4846441	1241454
43	T3-2	grch ulva VSM	85 15	100	5520	yes	10	4846424	1241300
44	T3-1	grch VSM	100	100	2560	yes	5	4846417	1241154
45	T3-0	grch VSM	75	75	2400	yes	1	4846354	1240990
46	D9	grch SSM	50	50	1760	yes	5	4841571	1239476
47	D8	grch SM	100	100	5920	yes	0	4841674	1239417
48	D7	grch SSM	90	90	2400	yes	3	4842129	1239352
49	D6	grch VSM	100	100	7200	yes	0	4842219	1239265
50	D5	grch VSM	100	100	5760	yes	0	4842316	1239236
51	D4	grch VSM	100	100	5760	yes	0	4842446	1239191
52	D3	grch VSM	100	100	7600	yes	0	4842600	1239142
53	D2	grch VSM	90	90	3200	yes	0	4842776	1239106
54	D1	grch VSM	70	70	6080	yes	0	4842839	1239099
55	SP2	grch ulva VSM	95 2	97	2600	yes	0	4840427	1239710
56	WE3	grch FSM	25	25	640	yes	15	4847674	1241727
57	WE3-1	grch SM	100	100	4400	yes	15	4847045	1241892

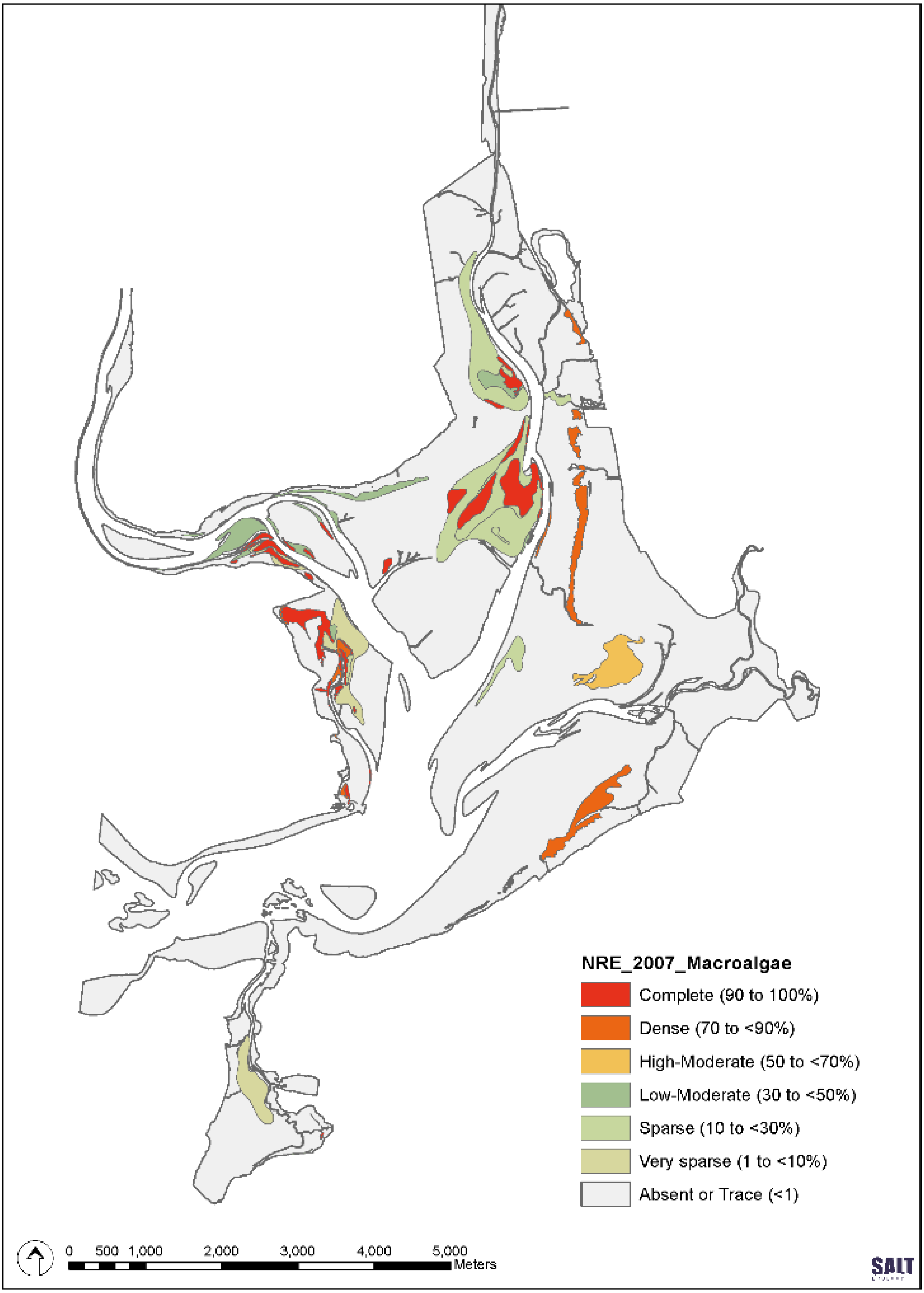
58	ORB-3	grch ulva VSM	99 1	101	10960	yes	2	4843586	1238848
59	ORB-2	grch VSM	100	100	4960	yes	2	4843671	1238398
60	WE3-3	grch BF	80	80	6240	yes	12	4846619	1241992
61	ORB-1	grch FSM	100	100	5760	yes	25	4843524	1238017
62	WE3-4	grch other SM	75 8	83	3360	yes	25	4846714	1242198
63	WE3-2	grch SM	75	75	2880	yes	5	4846569	1241904
64	WE4-1	grch VSM	100	100	6400	yes	10	4846349	1242364
65	WE4-2	grch SM	90	90	4640	yes	5	4846109	1242392
66	WE4-3	grch SM	75	75	1760	yes	25	4846007	1242399
67	WE4-4	grch FMS	80	80	2240	yes	30	4845862	1242384
68	WE2-4	grch ulva FSM	92 8	108	6560	yes	50	4847181	1241521
69	WE2-3	grch SM	100	100	3520	yes	2	4847245	1241649
70	WE2-2	grch FSM	60	60	4160	yes	15	4847328	1241774
71	WE2-1	grch FSM	50	50	3120	yes	15	4847378	1241863
72	Mo 1-2	grch VSM	90	90	10320	yes	0	4836955	1238248
73	Mo 1-3	grch ulva VSM	95 1	96	6080	yes	0	4836979	1238245
74	Mo 1-1	grch ulva VSM	90 1	91	11200	yes	1	4836923	1238244
75	SP6	grch ulva MS	15 1	16	600	no	150	4840584	1239936
76	SP5	grch ulva MS	10 15	25	480	no	150	4840567	1239942
77	SP4	grch ulva MS	10 35	45	920	no	120	4840492	1239944
78	SP1	grch VSM	100	100	3000	yes	0	4840533	1239693
79	SP3	grch ulva VSM	50 10	60	1884	yes	0	4840368	1239725

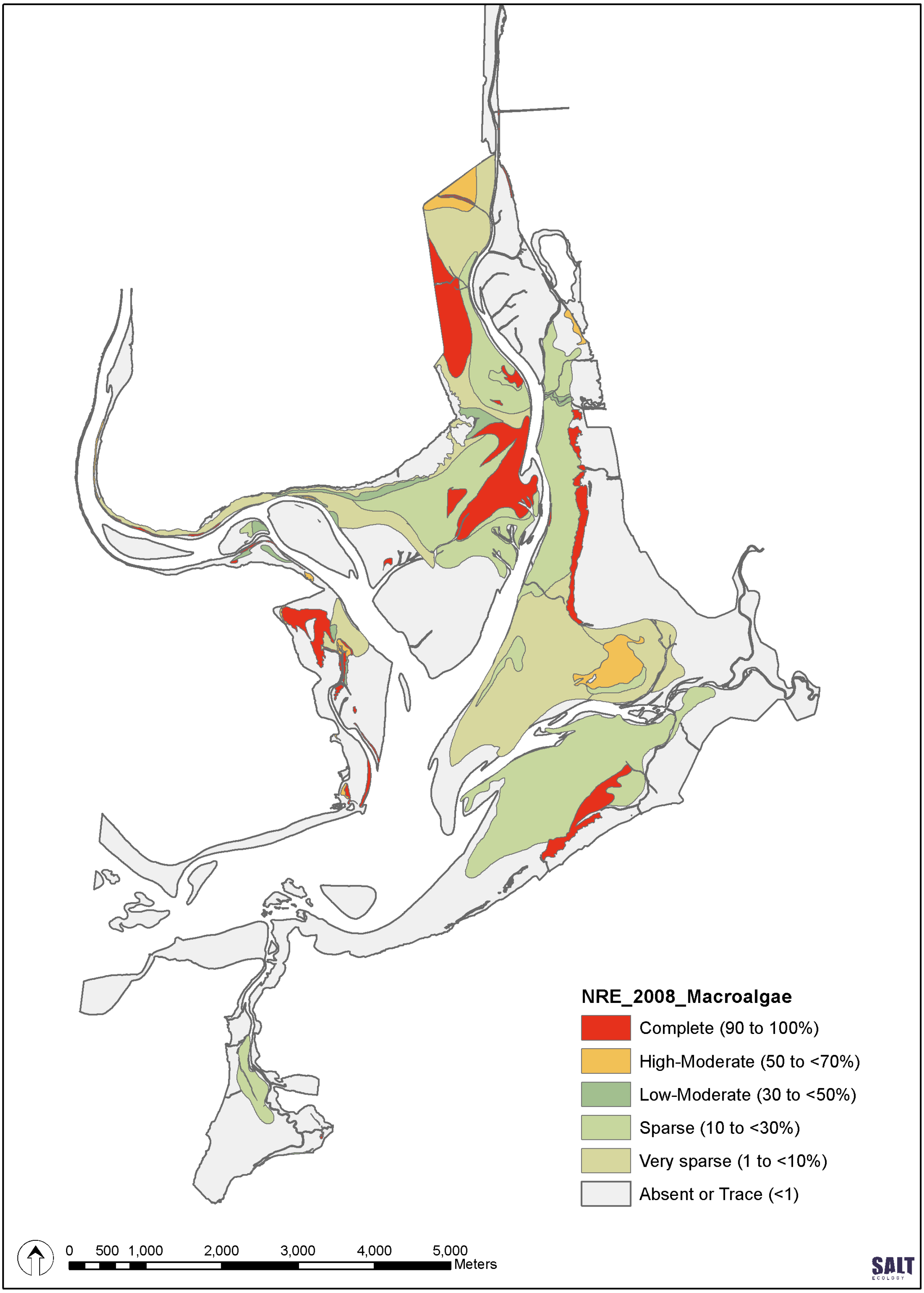

2019 Macroalgal Patch ID
0 500 1,000 2,000 3,000 4,000 5,000
M

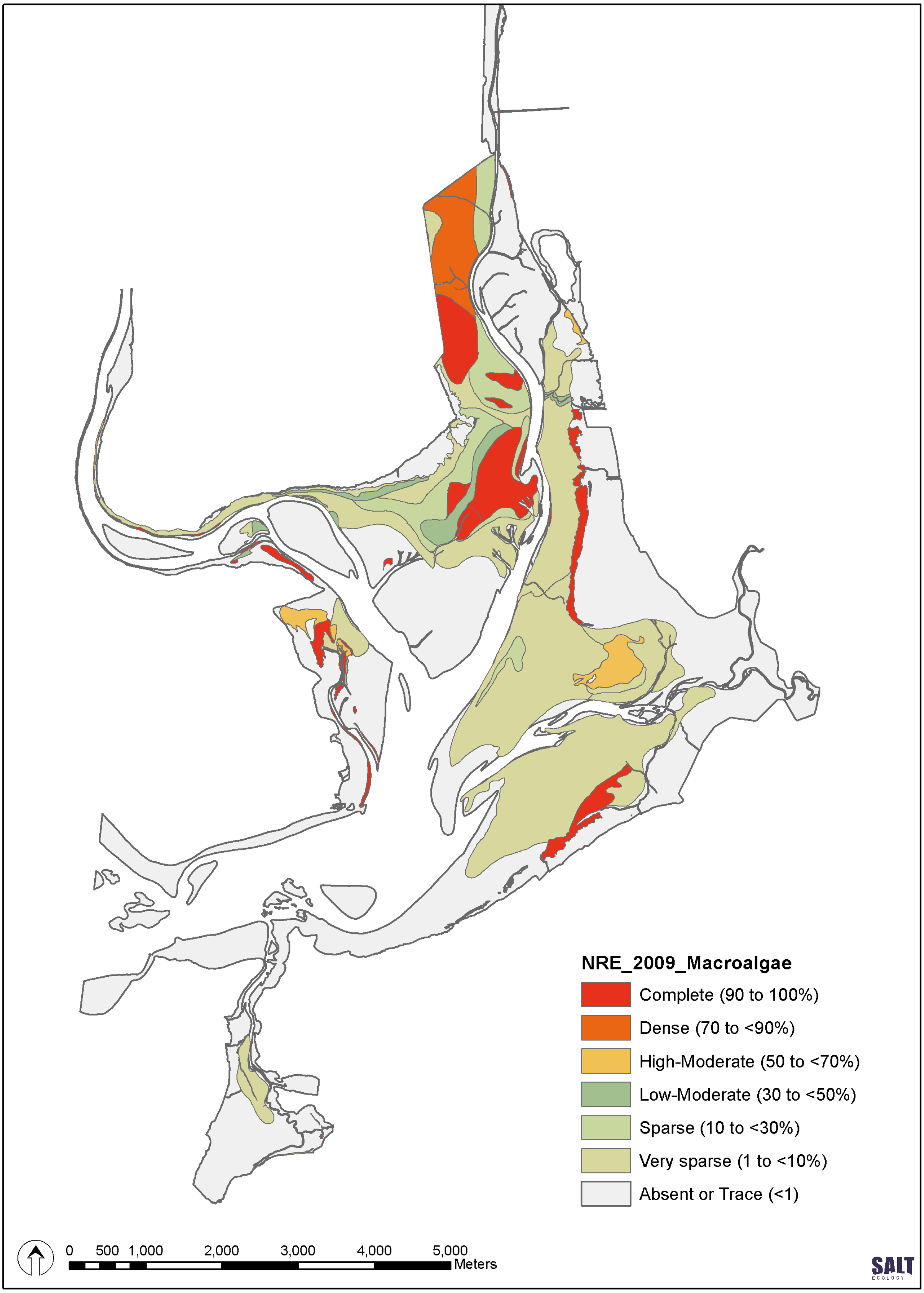
WaterbodyID	SurveyID	PatchID	ValidCode	Pct_Cover	TotPctCov	Pct Cover Category	Biomassgm2	Biomass Category	Entrained	DomHab	SubDom1	Area_ha
NREs-Sout	2019	1	Grch	91	91	Complete (>90%)	9200	Very high (>3000)	1	Gracilaria chilensis		0.8
NREs-Sout	2019	2	Grch Ulsp	1 1	2	Very sparse (1 to <10%)	15	Very low (1 - 100)	0	Gracilaria chilensis	Ulva sp (Sea lettuce)	22.2
NREs-Sout	2019	3	Grch Ulva	5 5	10	Sparse (10 to <30%)	25	Very low (1 - 100)	0	Gracilaria chilensis	Ulva (Sea lettuce)	0.6
NREs-Sout	2019	4	Grch	100	100	Complete (>90%)	2000	High (1001 - 3000)	1	Gracilaria chilensis		0.3
NREs-Sout	2019	5	Grch Ulva	25 5	30	Low-Moderate (30 to <50%)	30	Very low (1 - 100)	0	Gracilaria chilensis	Ulva (Sea lettuce)	0.1
NREs-Sout	2019	6	Ulsp	20	20	Sparse (10 to <30%)	20	Very low (1 - 100)	0	Ulva sp (Sea lettuce)		0.6
NREs-Sout	2019	7	Grch	20	20	Sparse (10 to <30%)	80	Very low (1 - 100)	1	Gracilaria chilensis		0.2
NREs-Sout	2019	8	Ulsp	20	20	Sparse (10 to <30%)	20	Very low (1 - 100)	0	Ulva sp (Sea lettuce)		4.3
NREs-Sout	2019	9	Ulsp Grch	10 10	20	Sparse (10 to <30%)	80	Very low (1 - 100)	0	Ulva sp (Sea lettuce)	Gracilaria chilensis	11.5
NREs-Sout	2019	10	Grch Ulsp	45 5	50	High-Moderate (50 to <70%)	3500	Very high (>3000)	1	Gracilaria chilensis	Ulva sp (Sea lettuce)	6.3
NREs-Sout	2019	11	Grch Ulsp	15 5	20	Sparse (10 to <30%)	150	Low (101 - 500)	0	Gracilaria chilensis	Ulva sp (Sea lettuce)	8.0
NREs-Sout	2019	12	Ulsp Grch	1 1	2	Very sparse (1 to <10%)	10	Very low (1 - 100)	0	Ulva sp (Sea lettuce)	Gracilaria chilensis	5.2
NREs-Sout	2019	13	Grch	50	50	High-Moderate (50 to <70%)	883	Moderate (501 - 1000)	1	Gracilaria chilensis		1.0
NREs-Sout	2019	14	Grch	20	20	Sparse (10 to <30%)	1000	Moderate (501 - 1000)	1	Gracilaria chilensis		1.6
NREs-Sout	2019	15	Grch	30	30	Low-Moderate (30 to <50%)	800	Moderate (501 - 1000)	1	Gracilaria chilensis		0.8
NREs-Sout	2019	16	Grch	80	80	Dense (70 to <90%)	1200	High (1001 - 3000)	1	Gracilaria chilensis		2.5
NREs-Sout	2019	17	Grch	100	100	Complete (>90%)	5893	Very high (>3000)	1	Gracilaria chilensis		3.3
NREs-Sout	2019	18	Ulsp	20	20	Sparse (10 to <30%)	15	Very low (1 - 100)	0	Ulva sp (Sea lettuce)		45.6
NREs-Sout	2019	19	Grch	50	50	High-Moderate (50 to <70%)	1200	High (1001 - 3000)	1	Gracilaria chilensis		1.6
NREs-Sout	2019	20	Ulsp	90	90	Complete (>90%)	50	Very low (1 - 100)	0	Ulva sp (Sea lettuce)		0.7
NREs-Sout	2019	21	Grch	90	90	Complete (>90%)	1700	High (1001 - 3000)	1	Gracilaria chilensis		2.3
NREs-Sout	2019	22	Grch	90	90	Complete (>90%)	1000	Moderate (501 - 1000)	1	Gracilaria chilensis		0.5
NREs-Sout	2019	28	Grch	80	80	Dense (70 to <90%)	10000	Very high (>3000)	1	Gracilaria chilensis		1.0
NREs-Sout	2019	24	Grch	75	75	Dense (70 to <90%)	2000	High (1001 - 3000)	1	Gracilaria chilensis		4.8
NREs-Sout	2019	23	Grch	86	86	Dense (70 to <90%)	3760	Very high (>3000)	1	Gracilaria chilensis		7.8
NREs-Sout	2019	27	Grch	50	50	High-Moderate (50 to <70%)	2000	High (1001 - 3000)	1	Gracilaria chilensis		2.3
NREs-Sout	2019	25	Grch	75	75	Dense (70 to <90%)	2880	High (1001 - 3000)	1	Gracilaria chilensis		5.0
NREs-Sout	2019	26	Grch Other	77 4	81	Dense (70 to <90%)	4800	Very high (>3000)	1	Gracilaria chilensis	Unspecified Macroalgae	12.2
NREs-Sout	2019	31	Grch	10	10	Sparse (10 to <30%)	960	Moderate (501 - 1000)	1	Gracilaria chilensis		1.3
NREs-Sout	2019	32	Grch	25	25	Sparse (10 to <30%)	1600	High (1001 - 3000)	1	Gracilaria chilensis		2.4
NREs-Sout	2019	33	Grch	25	25	Sparse (10 to <30%)	640	Moderate (501 - 1000)	1	Gracilaria chilensis		3.8
NREs-Sout	2019	30	Grch	55	55	High-Moderate (50 to <70%)	3640	Very high (>3000)	1	Gracilaria chilensis		9.8
NREs-Sout	2019	29	Grch Ulva	100 2	102	Complete (>90%)	4827	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	17.2
NREs-Sout	2019	35	Grch Ulva	95 5	100	Complete (>90%)	4667	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	4.3
NREs-Sout	2019	36	Grch	80	80	Dense (70 to <90%)	3000	High (1001 - 3000)	1	Gracilaria chilensis		0.2
NREs-Sout	2019	37	Grch	5	5	Very sparse (1 to <10%)	1200	High (1001 - 3000)	1	Gracilaria chilensis		12.6
NREs-Sout	2019	38	Ulsp	10	10	Sparse (10 to <30%)	20	Very low (1 - 100)	0	Ulva sp (Sea lettuce)		9.3
NREs-Sout	2019	39	Grch	80	80	Dense (70 to <90%)	10000	Very high (>3000)	1	Gracilaria chilensis		17.6
NREs-Sout	2019	40	Grch	95	95	Complete (>90%)	4160	Very high (>3000)	1	Gracilaria chilensis		9.6
NREs-Sout	2019	41	Grch	25	25	Sparse (10 to <30%)	1360	High (1001 - 3000)	1	Gracilaria chilensis		1.5
NREs-Sout	2019	43	Grch	100	100	Complete (>90%)	11560	Very high (>3000)	1	Gracilaria chilensis		23.4
NREs-Sout	2019	43	Grch	75	75	Dense (70 to <90%)	5400	Very high (>3000)	1	Gracilaria chilensis		23.3
NREs-Sout	2019	42	Grch Ulva	83 1	84	Dense (70 to <90%)	3849	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	104.6
NREs-Sout	2019	46	Grch	40	40	Low-Moderate (30 to <50%)	5000	Very high (>3000)	1	Gracilaria chilensis		6.5
NREs-Sout	2019	47	Grch	100	100	Complete (>90%)	5360	Very high (>3000)	1	Gracilaria chilensis		99.1
NREs-Sout	2019	48	Grch	25	25	Sparse (10 to <30%)	1200	High (1001 - 3000)	1	Gracilaria chilensis		54.8
NREs-Sout	2019	45	Grch	80	80	Dense (70 to <90%)	6000	Very high (>3000)	1	Gracilaria chilensis		29.1
NREs-Sout	2019	49	Grch	80	80	Dense (70 to <90%)	3000	High (1001 - 3000)	1	Gracilaria chilensis		3.4
NREs-Sout	2019	50	Grch	30	30	Low-Moderate (30 to <50%)	480	Low (101 - 500)	1	Gracilaria chilensis		5.8
NREs-Sout	2019	52	Grch Ulva Other	90 5 5	100	Complete (>90%)	5760	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	4.2
NREs-Sout	2019	53	Grch	3	3	Very sparse (1 to <10%)	147	Low (101 - 500)	0	Gracilaria chilensis		288.3
NREs-Sout	2019	51	Grch	81	81	Dense (70 to <90%)	6060	Very high (>3000)	1	Gracilaria chilensis		51.8
NREs-Sout	2019	53	Grch	81	81	Dense (70 to <90%)	8213	Very high (>3000)	1	Gracilaria chilensis		10.7
NREs-Sout	2019	55	Ulsp	50	50	High-Moderate (50 to <70%)	200	Low (101 - 500)	0	Ulva sp (Sea lettuce)		0.5
NREs-Sout	2019	54	Grch	80	80	Dense (70 to <90%)	5000	Very high (>3000)	1	Gracilaria chilensis		0.5
NREs-Sout	2019	56	Grch	100	100	Complete (>90%)	5760	Very high (>3000)	1	Gracilaria chilensis		2.2
NREs-Sout	2019	57	Grch	100	100	Complete (>90%)	4960	Very high (>3000)	1	Gracilaria chilensis		3.9
NREs-Sout	2019	58	Grch	50	50	High-Moderate (50 to <70%)	5000	Very high (>3000)	1	Gracilaria chilensis		19.7
NREs-Sout	2019	59	Grch	100	100	Complete (>90%)	3000	High (1001 - 3000)	1	Gracilaria chilensis		4.4
NREs-Sout	2019	60	Grch Ulva	100 1	101	Complete (>90%)	10960	Very high (>3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	1.9
NREs-Sout	2019	61	Grch	30	30	Low-Moderate (30 to <50%)	2000	High (1001 - 3000)	1	Gracilaria chilensis		4.8
NREs-Sout	2019	62	Grch	100	100	Complete (>90%)	6000	Very high (>3000)	1	Gracilaria chilensis		1.0
NREs-Sout	2019	63	Grch	80	80	Dense (70 to <90%)	3000	High (1001 - 3000)	1	Gracilaria chilensis		0.6
NREs-Sout	2019	65	Grch Ulsp	75 5	80	Dense (70 to <90%)	2500	High (1001 - 3000)	1	Gracilaria chilensis	Ulva sp (Sea lettuce)	5.5
NREs-Sout	2019	64	Grch	92	92	Complete (>90%)	5429	Very high (>3000)	1	Gracilaria chilensis		28.1
NREs-Sout	2019	66	Grch	80	80	Dense (70 to <90%)	2000	High (1001 - 3000)	1	Gracilaria chilensis		15.6
NREs-Sout	2019	67	Grch	100	100	Complete (>90%)	5920	Very high (>3000)	1	Gracilaria chilensis		2.4
NREs-Sout	2019	68	Grch	50	50	High-Moderate (50 to <70%)	1760	High (1001 - 3000)	1	Gracilaria chilensis		0.1
NREs-Sout	2019	69	Ulsp Grch	2 1	3	Very sparse (1 to <10%)	50	Very low (1 - 100)	0	Ulva sp (Sea lettuce)	Gracilaria chilensis	85.6
NREs-Sout	2019	70	Ulva Grch	17 11	28	Sparse (10 to <30%)	667	Moderate (501 - 1000)	1	Ulva (Sea lettuce)	Gracilaria chilensis	7.8
NREs-Sout	2019	71	Grch Ulva	81 4	85	Dense (70 to <90%)	2495	High (1001 - 3000)	1	Gracilaria chilensis	Ulva (Sea lettuce)	1.7

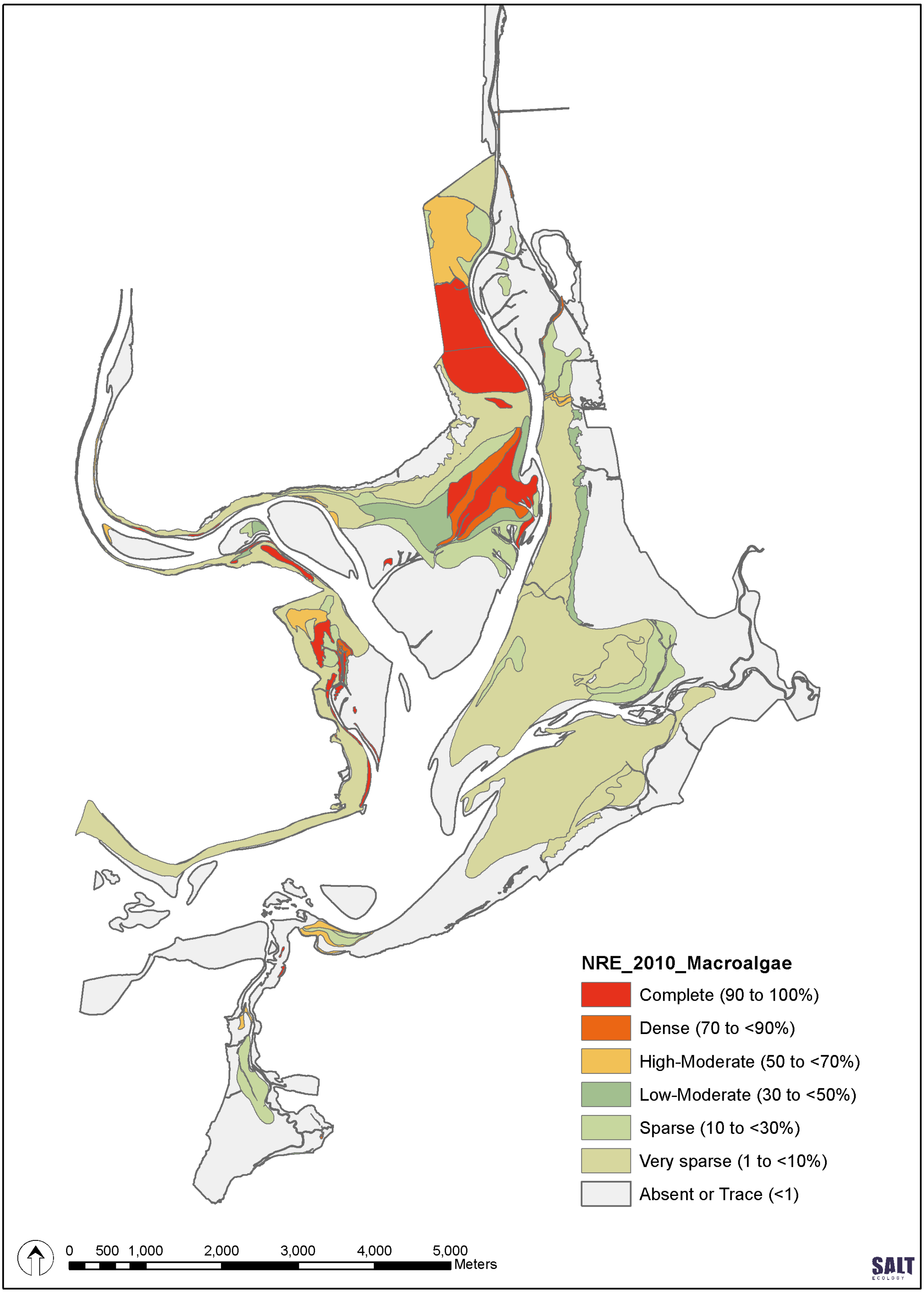
APPENDIX 4. MAP LAYERS FOR MACROALGAL COVER 2001 TO 2020

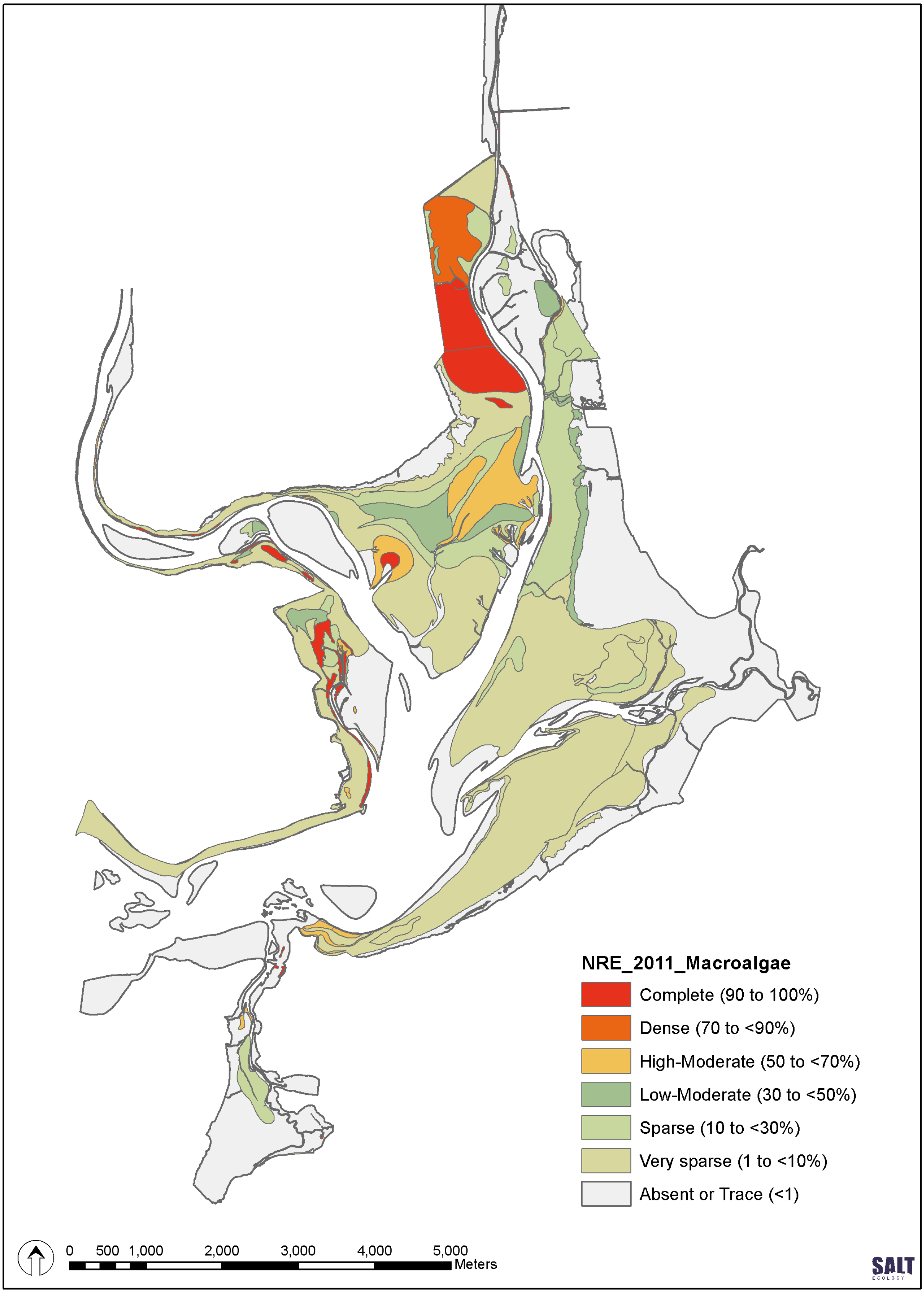


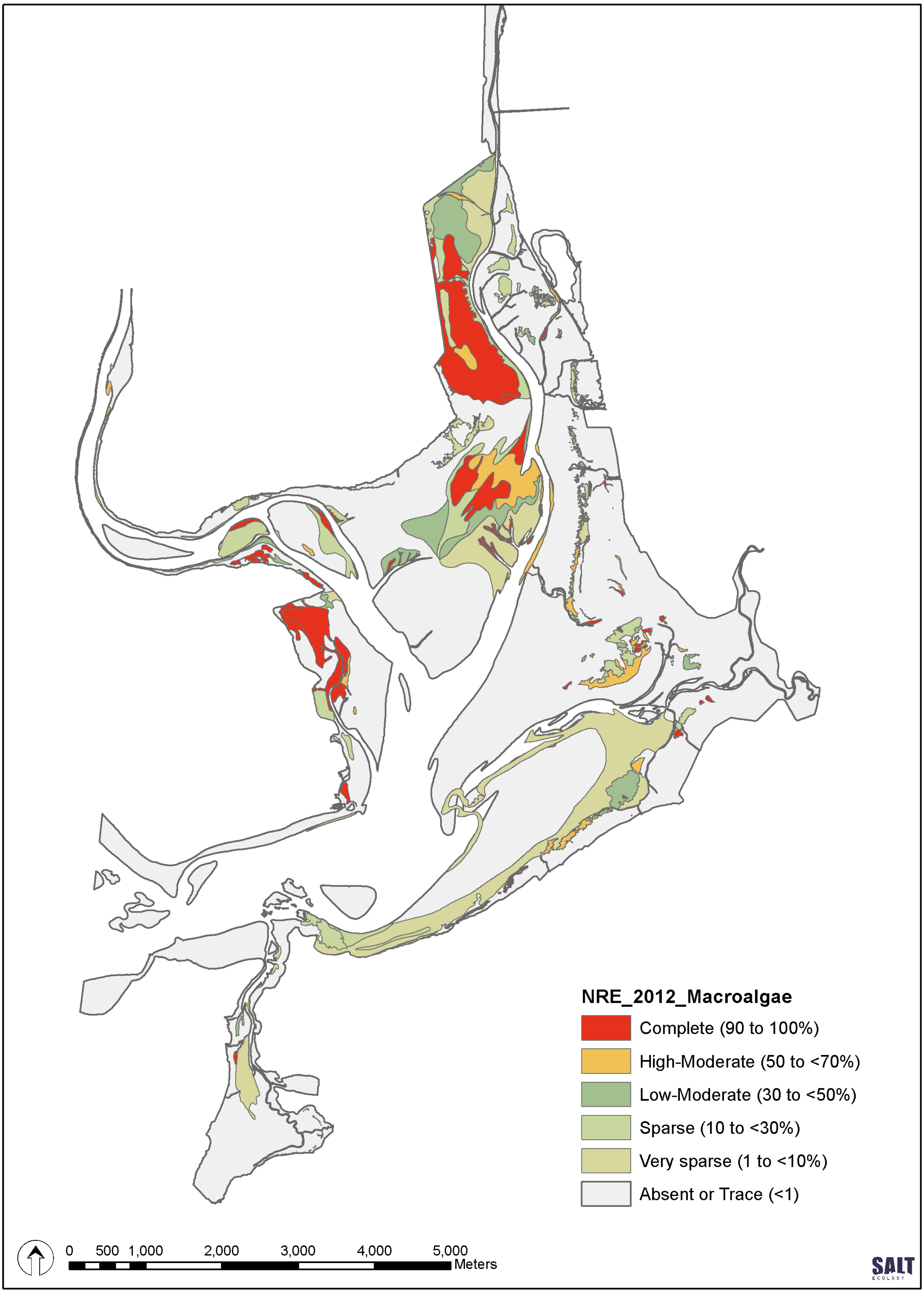

NRE_2007_Macroalgae
Complete (90 to 100%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Absent or Trace (<1)
0 500 1,000 2,000 3,000 4,000 5,000
Meters

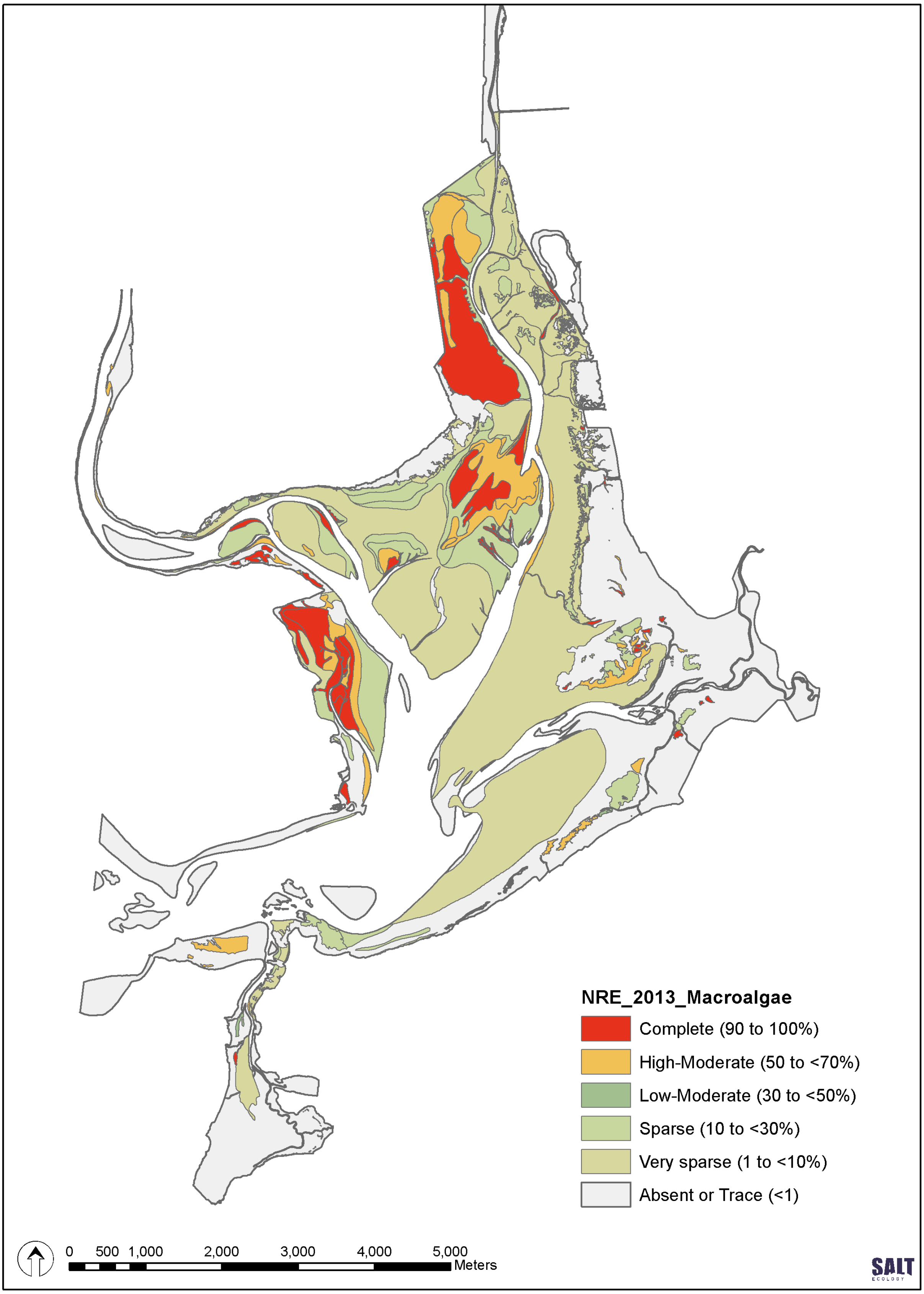

NRE_2008_Macroalgae
Complete (90 to 100%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Absent or Trace (<1)
0 500 1,000 2,000 3,000 4,000 5,000
Meters
SALT

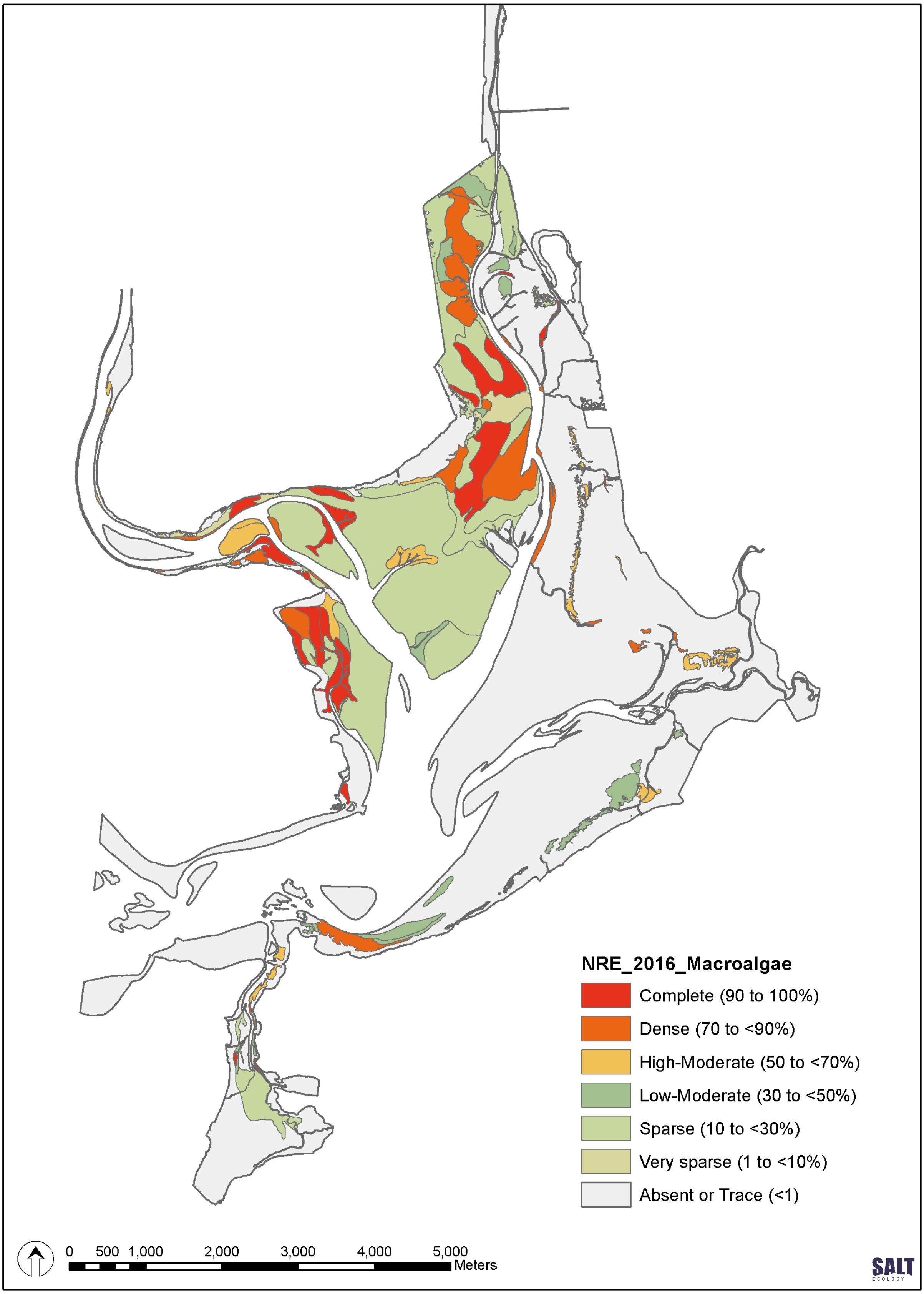

NRE_2009_Macroalgae
Complete (90 to 100%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Absent or Trace (<1)
0 500 1,000 2,000 3,000 4,000 5,000
Meters

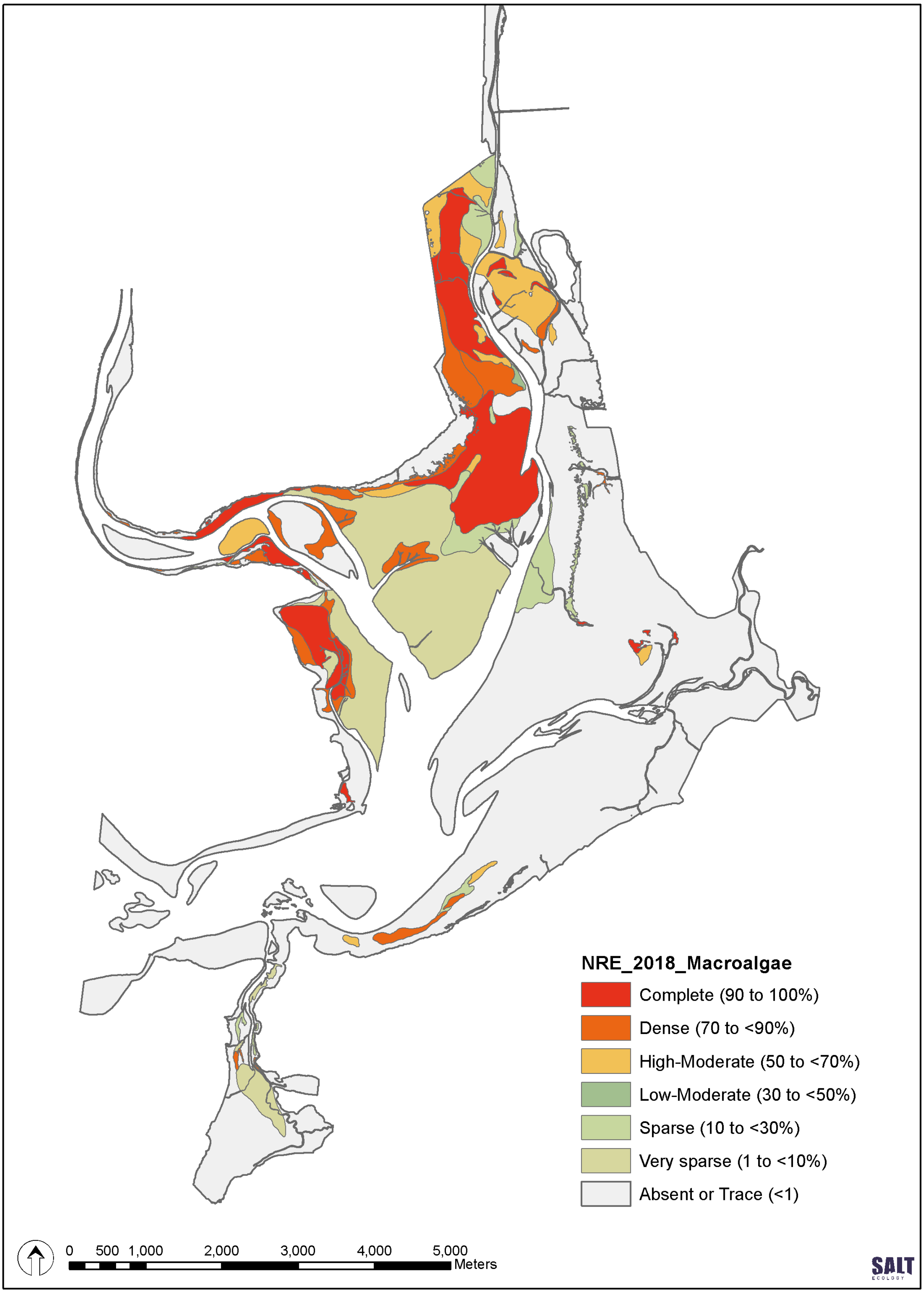

NRE_2010_Macroalgae
Complete (90 to 100%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Absent or Trace (<1)
0
500
1,000
2,000
3,000
4,000
5,000
Meters
SALT

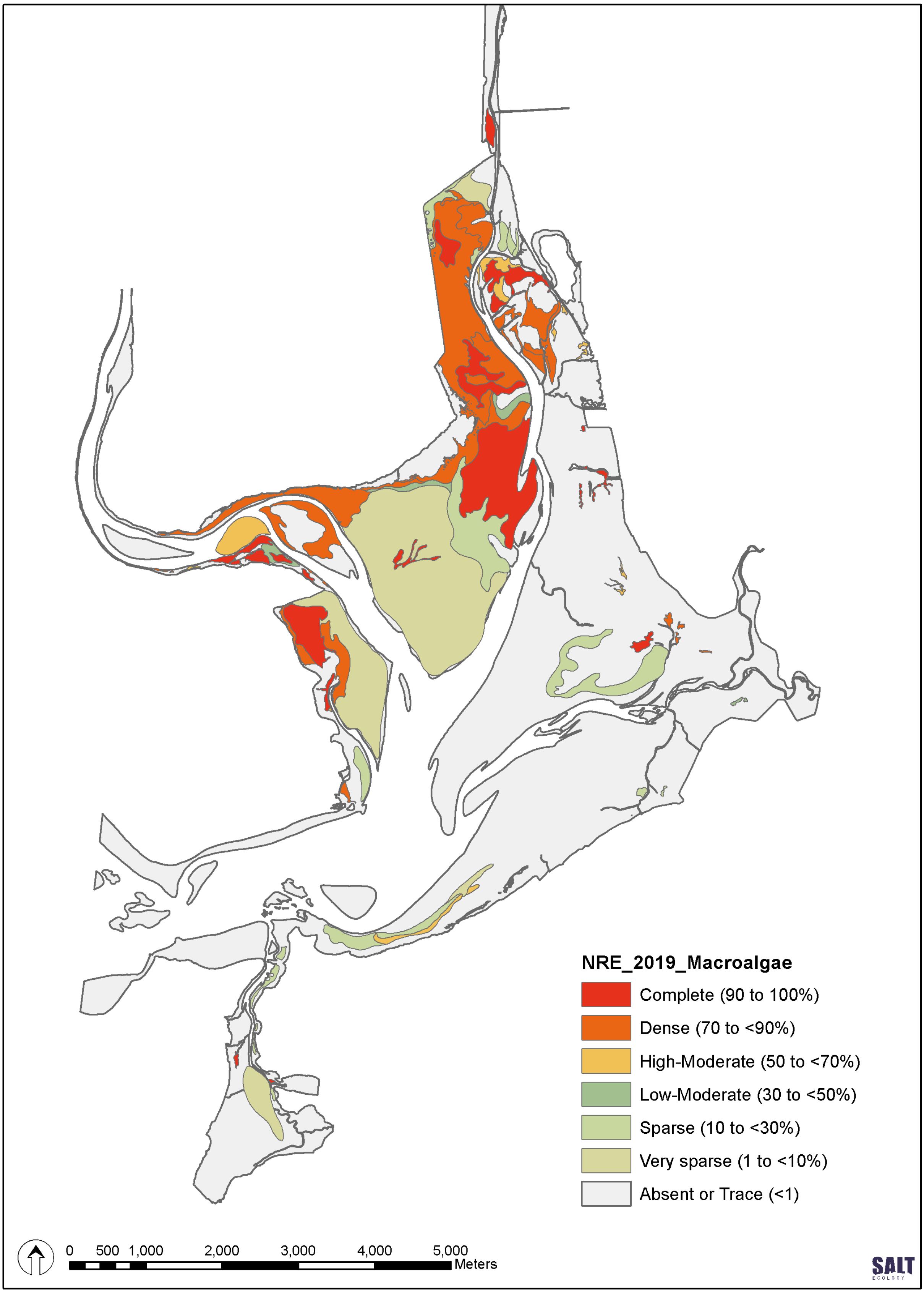

NRE_2011_Macroalgae
Complete (90 to 100%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Absent or Trace (<1)
0 500 1,000 2,000 3,000 4,000 5,000
Meters
SALT

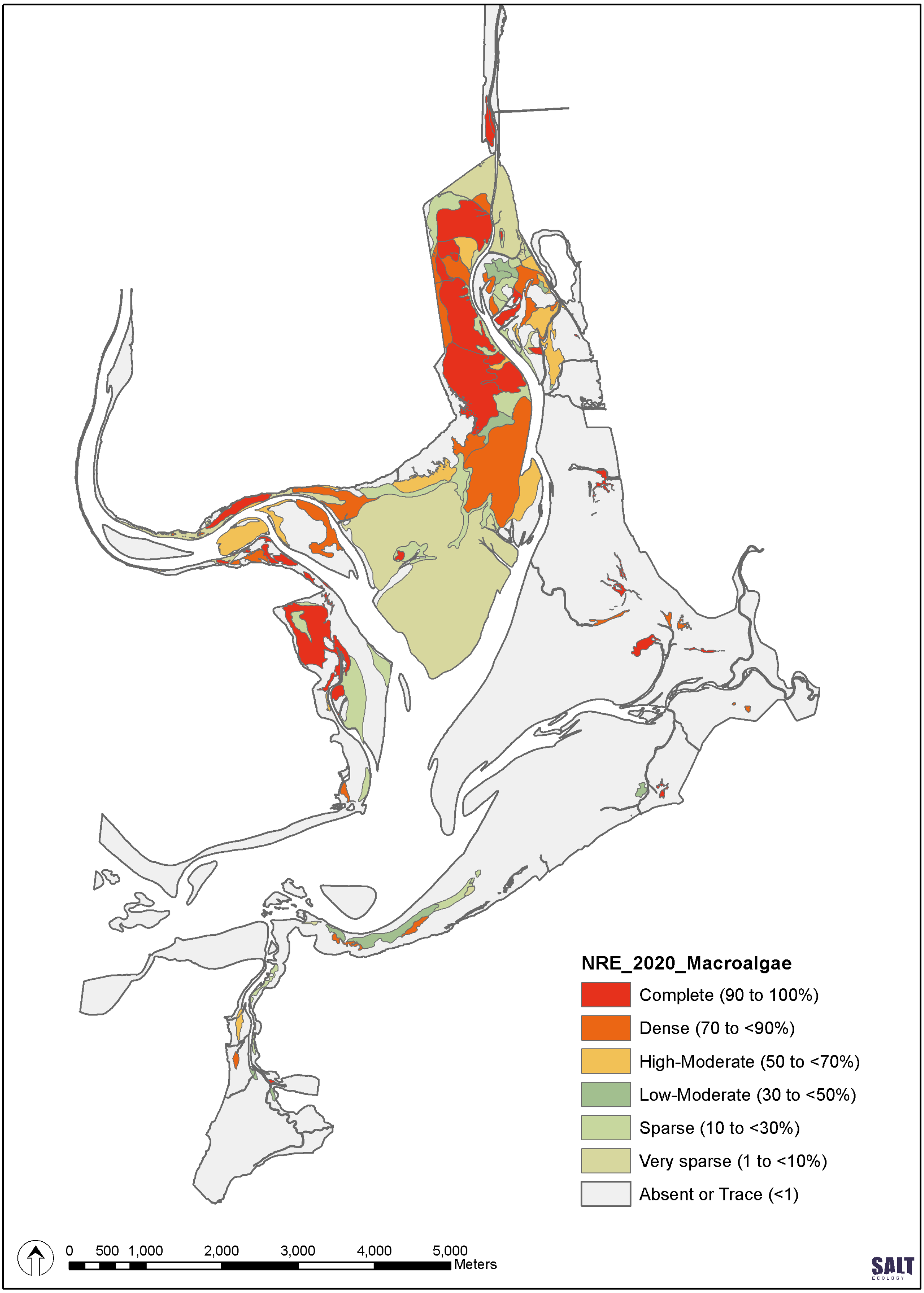

NRE_2012_Macroalgae
Complete (90 to 100%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Absent or Trace (<1)
0 500 1,000 2,000 3,000 4,000 5,000
Meters
SALT


NRE_2013_Macroalgae
Complete (90 to 100%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Absent or Trace (<1)
0 500 1,000 2,000 3,000 4,000 5,000
Meters
SALT

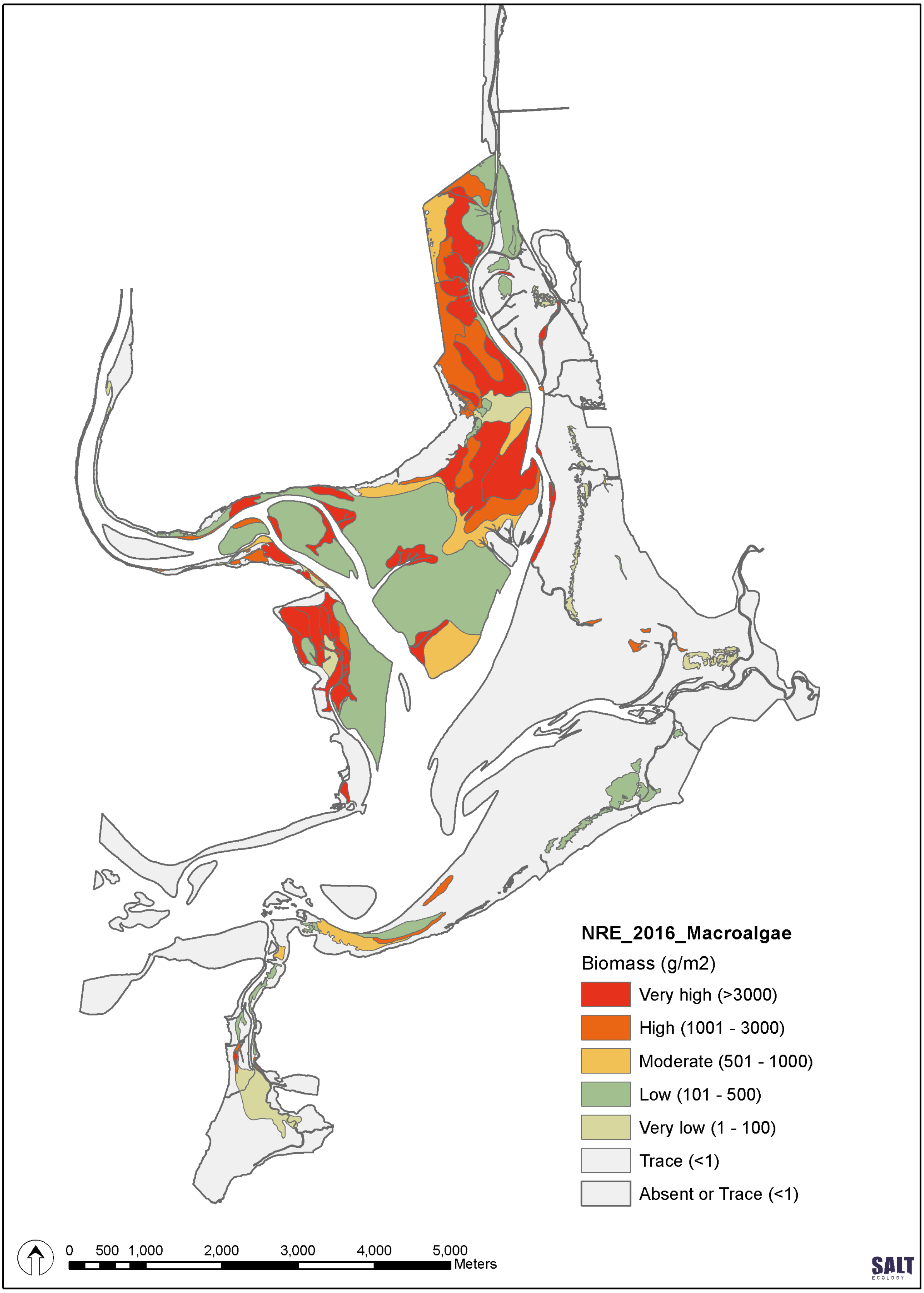

NRE_2016_Macroalgae
Complete (90 to 100%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Absent or Trace (<1)
0
500
1,000
2,000
3,000
4,000
5,000
Meters
SALT

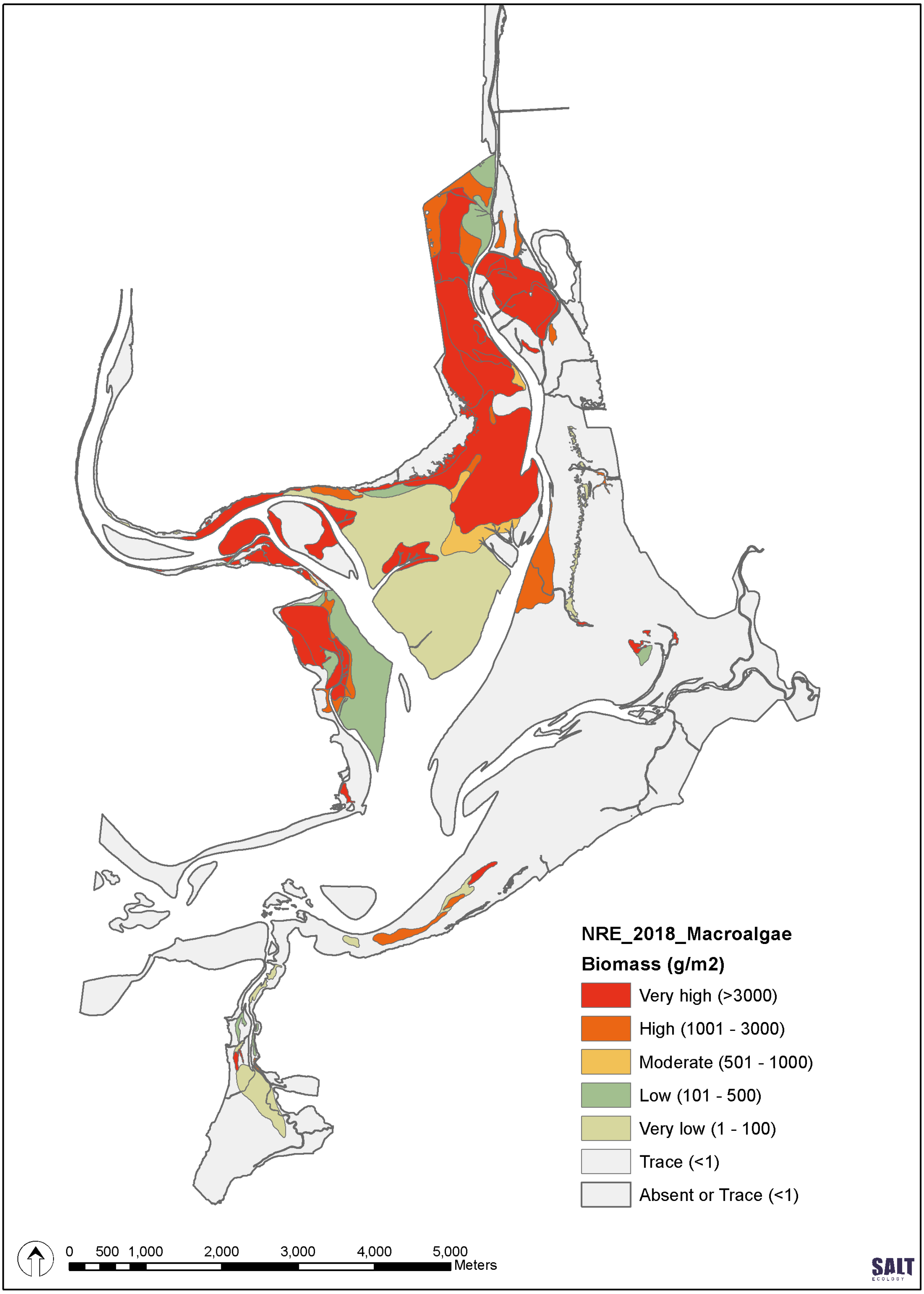

NRE_2018_Macroalgae
Complete (90 to 100%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Absent or Trace (<1)
0 500 1,000 2,000 3,000 4,000 5,000
Meters
SALT

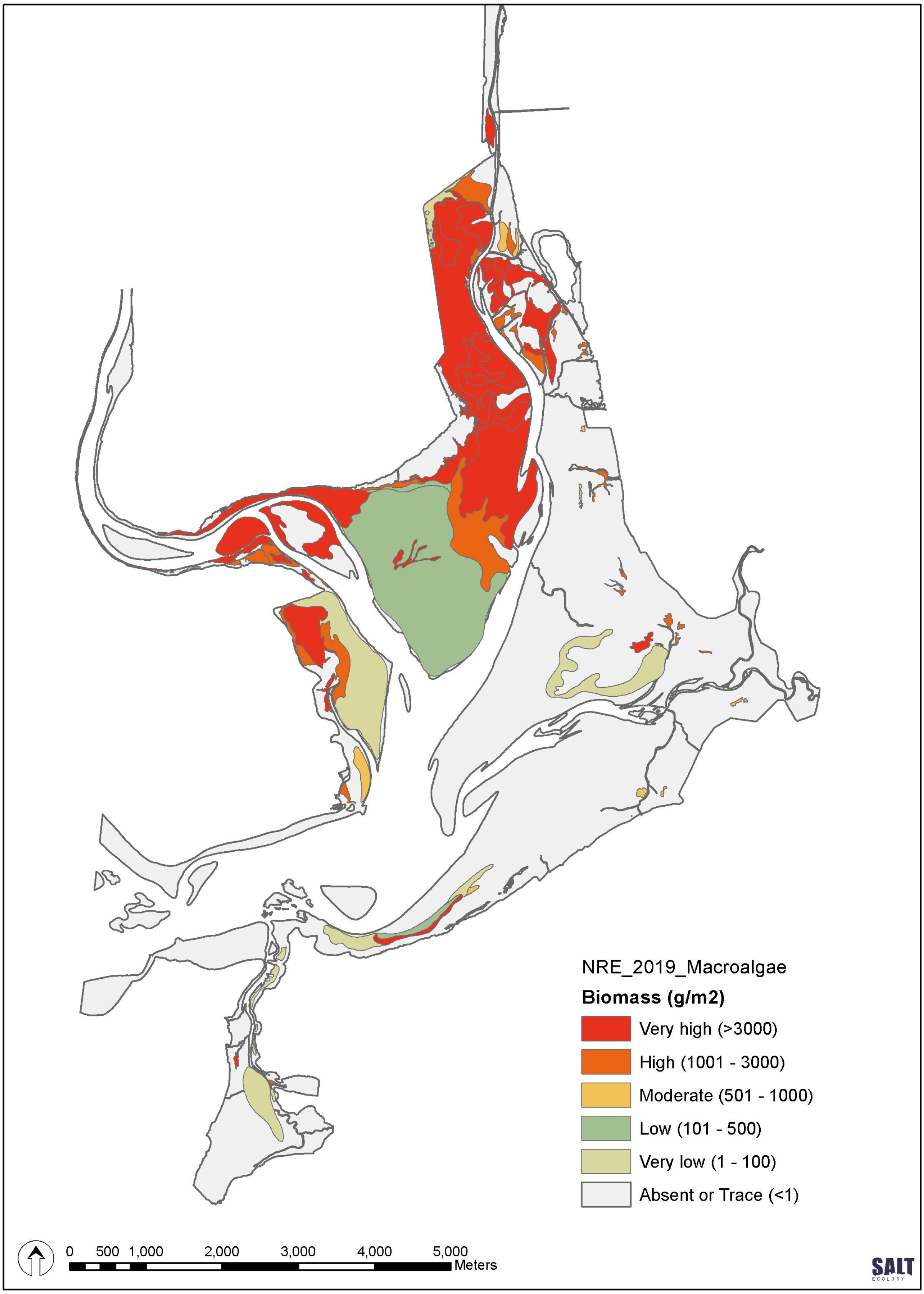

NRE_2019_Macroalgae
Complete (90 to 100%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Absent or Trace (<1)
0 500 1,000 2,000 3,000 4,000 5,000
Meters
SALT

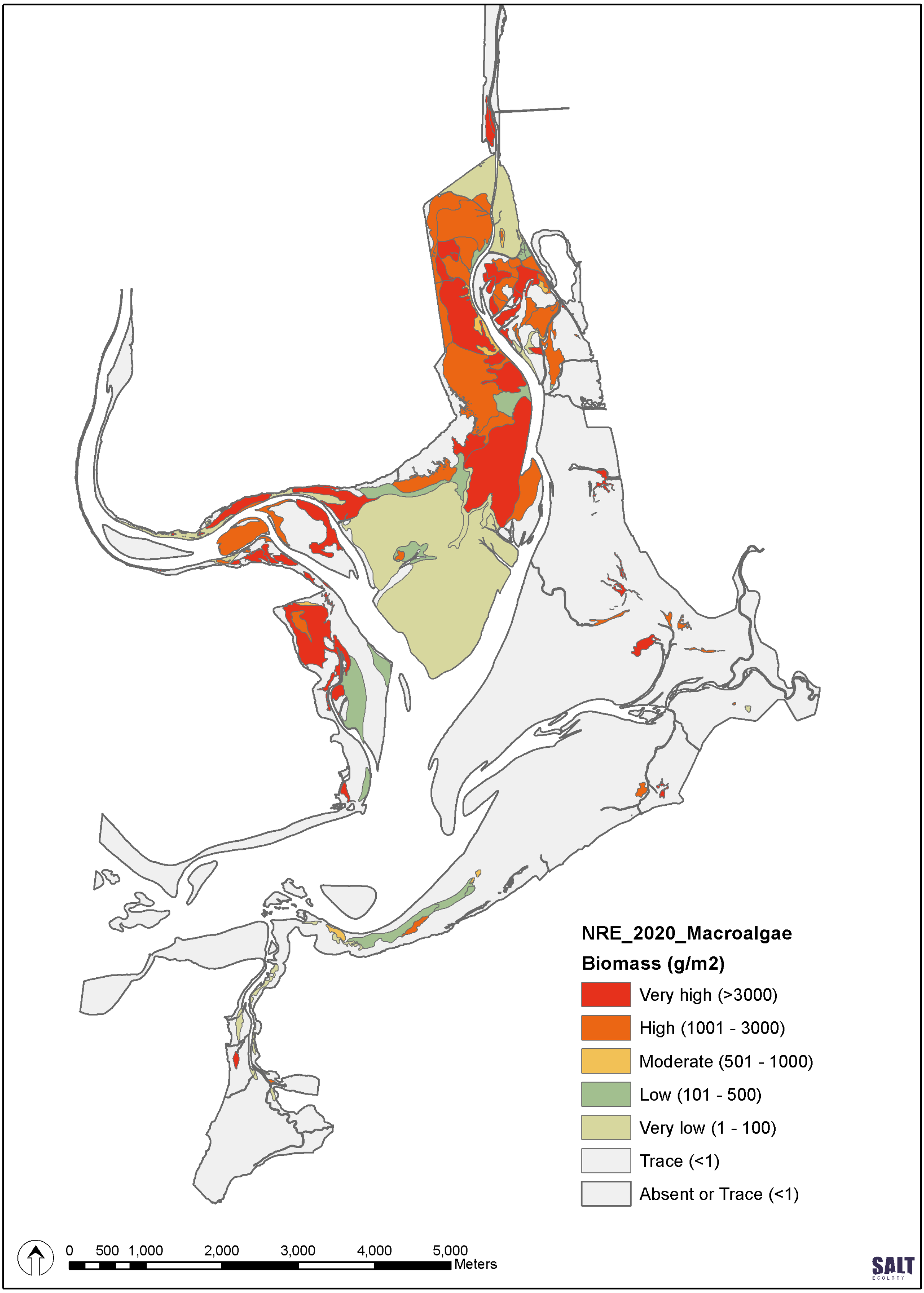

NRE_2020_Macroalgae
Complete (90 to 100%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Absent or Trace (<1)
0 500 1,000 2,000 3,000 4,000 5,000
Meters
SALT

APPENDIX 5. MAP LAYERS FOR MACROALGAL BIOMASS 2016 TO 2020



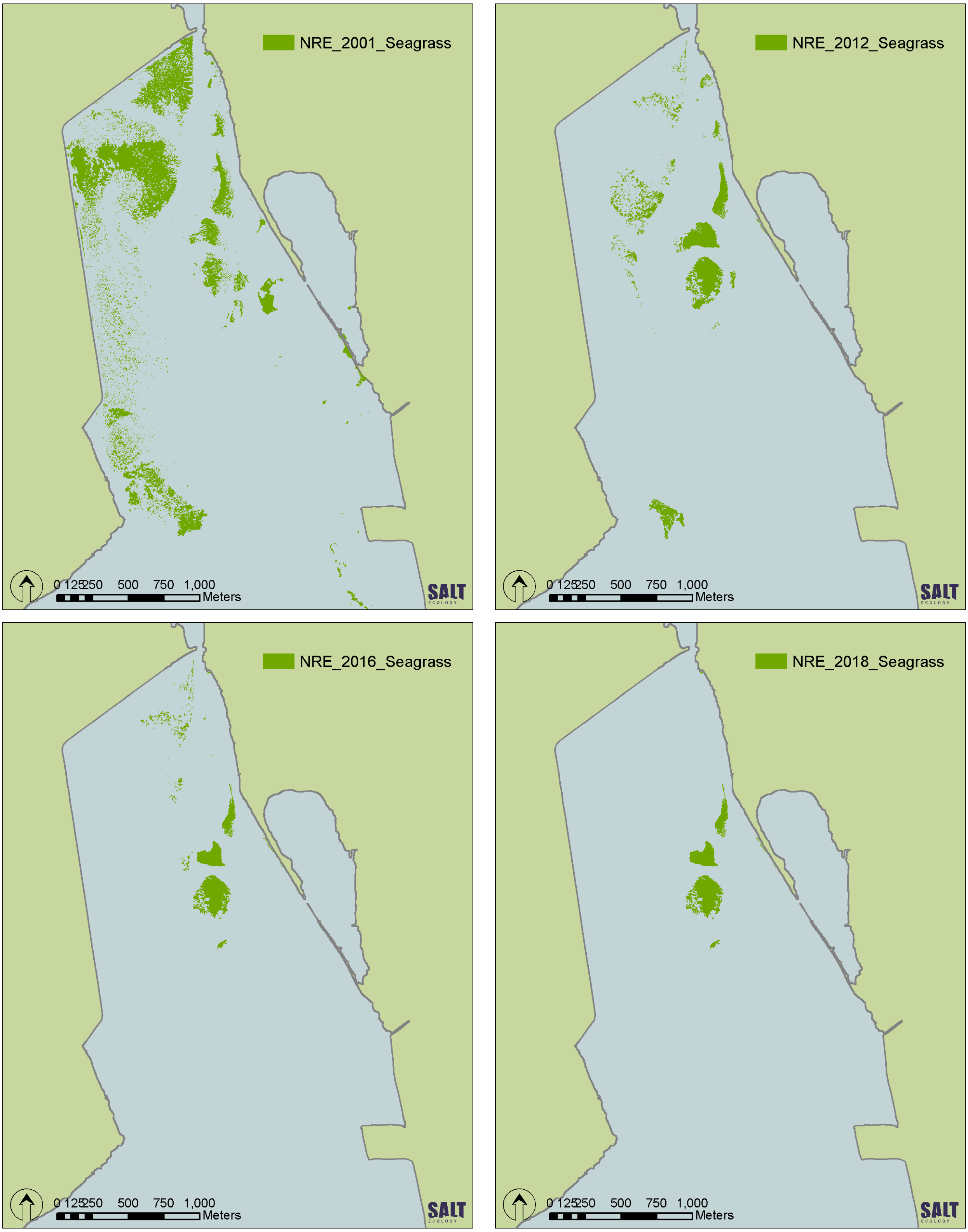

NRE_2018_Macroalgae
Biomass (g/m2)
Very high (>3000)
High (1001 - 3000)
Moderate (501 - 1000)
Low (101 - 500)
Very low (1 - 100)
Trace (<1)
Absent or Trace (<1)
0 500 1,000 2,000 3,000 4,000 5,000
Meters
SALT

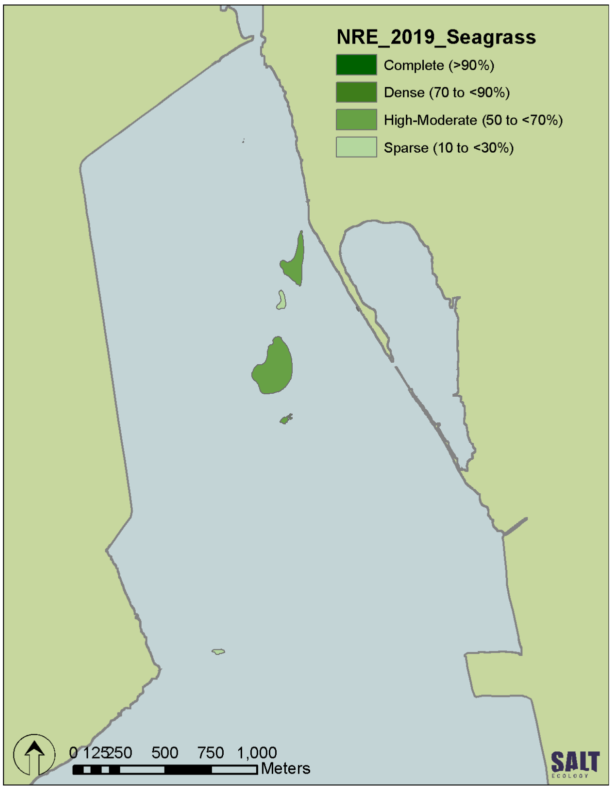

NRE_2019_Macroalgae
Biomass (g/m2)
Very high (>3000)
High (1001 - 3000)
Moderate (501 - 1000)
Low (101 - 500)
Very low (1 - 100)
Absent or Trace (<1)
0 500 1,000 2,000 3,000 4,000 5,000
Meters
SALT

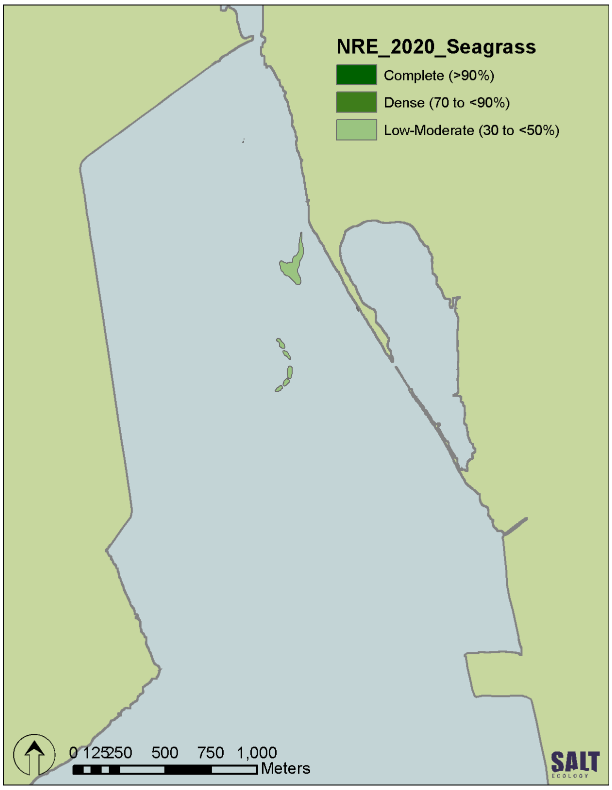

NRE_2020_Macroalgae
Biomass (g/m2)
Very high (>3000)
High (1001 - 3000)
Moderate (501 - 1000)
Low (101 - 500)
Very low (1 - 100)
Trace (<1)
Absent or Trace (<1)
0 500 1,000 2,000 3,000 4,000 5,000
Meters
SALT

APPENDIX 6. MAP LAYER DETAIL FOR SEAGRASS COVER IN WAIHOPAI ARM 2001 TO 2020

Note, for 2001-2018, cover of >50% is shown.




NRE_2019_Seagrass
Complete (>90%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Sparse (10 to <30%)
0 125 250 500 750 1,000
Meters
SALT


NRE_2020_Seagrass
Complete (>90%)
Dense (70 to <90%)
Low-Moderate (30 to <50%)
0 125 250 500 750 1,000
Meters
SALT

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