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Fortrose (Toetoes) Estuary 2016

Broad Scale Substrate, Macroalgae and Seagrass Mapping

Prepared for **Environment Southland**

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Cover Photo: Dense macroalgal growth in the central basin of the estuary, Feb. 2016.

Nuisance beds of *Gracilaria* establishing in front of rushland on the northern edge of the main basin, Feb. 2016.

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Prepared for
Environment Southland

By

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All photos by Wriggle except where noted otherwise.

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FORTROSE ESTUARY - EXECUTIVE SUMMARY

This report provides a brief summary of the results of the 2016 broad scale intertidal habitat mapping of substrate, macroalgae and seagrass in Fortrose (Toetoes) Estuary, a medium-sized (~500ha) "tidal lagoon" type estuary that discharges to Toetoes Beach at the mouth of the Mataura River and Titiroa Stream. It drains a large and primarily high productivity agricultural catchment, and has a large freshwater influence because the estuary is small in relation to the freshwater input. It is one of the key estuaries in Environment Southland's (ES's) long-term coastal monitoring programme. The following sections summarise broad scale monitoring results (from the current report and previous studies), condition ratings, estuary condition, and monitoring and management recommendations.

BROAD SCALE RESULTS

- Sandy substrate dominated the estuary (192ha, 79%) with sandiest areas primarily located in the central and lower estuary.
- Soft and very soft mud cover was 24ha (11%), mostly on the intertidal flats where Titiroa Stream and Mataura River discharge to the central basin of the estuary.
- Compared to the 2003 baseline, there was little significant change in the overall extent of mud-dominated sediment, although areas classified as very soft mud increased from 0.3ha in 2003 and 2013 to 7.1ha in 2016.
- Sediment oxygenation was generally good throughout most intertidal areas but there are significant areas (57ha, 23%) of the estuary with reduced oxygenation.
- Dense nuisance macroalgae (>50%) covered 8% (23ha) of the intertidal area, with highest densities on the eastern side of the estuary. Remaining intertidal areas supported widespread low density growths that have shown a trend of increase since 2003.
- Gross eutrophic conditions were not present in 2003 or 2013, but had established in 2016 over 8.3ha, 3% of the intertidal area.
- Dense seagrass cover (>50%) was very scarce (0.3ha, <1%) and a 40% loss in dense seagrass was recorded since 2013. Macroalgal smothering appears to be the probable cause of this loss.

ESTUARY CONDITION AND ISSUES

In relation to the key issues addressed by the broad scale monitoring undertaken (i.e. sediment, eutrophication, and habitat modification), the 2016 mapping results show that both sediment and eutrophication are ongoing issues within the estuary.

Large sections of the estuary remain in good condition, but the decline in estuary quality recorded from 2003 to 2013, specifically increased muddiness and macroalgal growth, has accelerated recently and is particularly evident in the increase in macroalgal biomass, lowered sediment oxygenation over a large area, the establishment of entrained stable *Gracilaria* beds, increased areas dominated by very soft muds, and particularly the establishment of 8.3ha of gross eutrophic zones in the estuary. While the reason the estuary does not support widespread growth of seagrass is uncertain it may relate to elevated nutrient inputs, the estimated nitrogen areal load to Fortrose Estuary of 2723mg.m^{-2}.d^{-1} being well above the 36.5mg.m^{-2}.d^{-1} threshold reported for the disappearance of seagrass in New England estuaries (Latimer and Rego 2010). Secondary stressors are also likely to be from elevated muddiness contributing to reduced sediment oxygenation and poor water clarity. Recent seagrass losses appear to be due to macroalgal smothering.

These symptoms show that current inputs of fine sediment and nutrients exceed the assimilative capacity of the estuary. Consequently, nutrient and sediment inputs would need to be reduced to levels the estuary can assimilate in order to achieve a more moderately enriched estuary and to protect it from further degradation.

RECOMMENDED MONITORING AND MANAGEMENT

To monitor the key issues of nutrient enrichment and sediment muddiness it is recommended that:

- Broad scale habitat mapping be repeated every 10 years (next due in 2023).
- Fine scale intertidal monitoring be repeated on a 5 yearly cycle (last undertaken in 2009).
- Sedimentation rate and macroalgal monitoring be undertaken annually, with additional sediment plates established in intertidal deposition areas where sediment is rapidly accumulating.
- Key changes in catchment landuse be tracked and mapped 5 yearly, particularly where activities have the potential to release sediments or increase nutrient loads to the estuary.

For management, the presence of increasing macroalgal growth in Fortrose Estuary (widespread throughout the central basin and eastern side of the estuary in 2009, 2010, 2013 and 2016) indicates catchment nutrient loads to the estuary exceed the ability of the estuary to assimilate these loads, as noted by Robertson and Stevens (2008). Previous recommendations (e.g. Robertson and Stevens 2009, Stevens and Robertson 2011, 2012, 2013) are reiterated, specifically the development of catchment nutrient and sediment guideline criteria for each estuary type in Southland to derive thresholds protecting against adverse sediment and nutrient impacts. Fortrose (Toetoes) Estuary has been identified as a priority for this work behind assessments for New River and Jacobs River estuaries and is included as a key component of the Estuary Health Programme (EHP) currently being developed by ES for the Southland region.

1. INTRODUCTION

In order to address issues of eutrophication and sedimentation identified though Environment Southland's (ES's) regular long term estuary monitoring programme, ES have committed to setting catchment load criteria (initially for nutrient/sediment loads) in each of four Freshwater Management Units (FMUs) to ensure freshwater and estuary environmental values are sustained at an acceptable ecological level which also meets community aspirations and expectations. The FMUs, each encompassing an entire catchment and estuarine receiving waters, are:

Mataura – includes Toetoes, Waituna, Waikawa, Haldane, Lake Brunton, The Reservoir, Lake Vincent and their catchments.

Aparima – Jacobs River Estuary, Waimatuku and their catchments.

Oreti – New River Estuary and its catchments including Waihopai.

Waiau – Te Waewae (Waiau) Lagoon and its catchment.

To help facilitate this process, ES have established an over-arching Estuary Health Programme (EHP) which will enable them to identify estuary condition, community values and expectations, and to establish the primary (scientific) factors determining the level of resource use (i.e. the nutrient/sediment load) needed to deliver these values so that stakeholders can make defensible and well-informed decisions regarding management. The initial approach being used in the EHP in Southland to explore the relationship between catchment nutrient and sediment loads and estuary ecological state/condition involves assessment of four main aspects:

1. Physical susceptibility of estuaries to eutrophication and fine sediment impacts.
2. Nutrient and sediment loads to estuaries (with additional recommendations on source tracking).
3. The broad scale expression of eutrophication and sedimentation symptoms (e.g. extent of, and changes in, soft mud, macroalgae, seagrass, sediment oxygenation).
4. Identification of load/existing condition relationships for nutrients (nitrogen and phosphorus) and recommendations for deriving sediment load/ecological condition relationships.

In combination, these outputs will define a continuum of ecological condition from "poor" to "healthy" that is matched to estimated nutrient and sediment loads i.e. an Ecological Condition Gradient (ECG).

In support of the first phase of the EHP initiative, and to provide up to date information for use in the ECG, Wriggle Coastal Management was contracted to undertake broad scale assessments in early 2016 of Jacobs River, New River, Toetoes, Haldane and Waikawa estuaries, five of Southland's largest and highest risk estuaries. The contracted work included the collection of specific data to better define the condition of vulnerable estuary habitats and the extent of problem areas, and a brief overview report of the main findings. The sampling approach was based on the methods described in the National Estuary Monitoring Protocol (NEMP) (Robertson et al. 2002), with several extensions including targeted broad scale habitat mapping of substrate, specific measures of macroalgal cover and biomass, and seagrass extent. To provide increased certainly of the location of mapped broad scale boundaries, areas between soft mud and sand dominated habitat, or areas expressing eutrophication symptoms (i.e. areas with combined high macroalgal biomass and cover, soft muds and poor sediment oxygenation) were targeted and direct measurements taken of sediment grain size and sediment oxygenation.

Other commonly used indicators that were not considered primary indicators of eutrophication or fine sediment symptom expression (such as the extent of saltmarsh and densely vegetated terrestrial margin cover, as well as disease risk measures) were not assessed in 2016.

The current report briefly describes the methods and results of sampling undertaken in Fortrose (Toetoes) Estuary in February 2016. A series of condition ratings described in Section 2 are used to help evaluate overall estuary condition, and results are briefly compared to data collected from ES's 2002-2013 long term estuary monitoring programme to assess changes in state over time. This includes broad scale habitat mapping of Fortrose (Toetoes) Estuary undertaken in 2003 (Robertson et al. 2003) and 2013 (Stevens and Robertson 2013), and fine scale monitoring of the main estuary basin in 2004, 2005, 2006 and 2009 (see Robertson and Stevens 2006, 2009, see also Figure 1). Ongoing fine scale monitoring on a 5 yearly cycle, as recommended in 2009, has not been undertaken. Macroalgal cover and sedimentation rates were monitored annually from 2009-2013 (e.g. Stevens and Robertson 2012, 2013, see also Figure 1).

Scheduled future work under the EHP includes predictions of likely natural estuary state conditions to place contemporary results into a broader context, and ongoing regular monitoring of estuary condition.

1. INTRODUCTION (CONTINUED)

Figure 1. Fortrose (Toetoes) Estuary showing the location of fine scale sites established in 2004 and buried sediment plates established in 2009.

Fortrose (Toetoes) Estuary is a medium-sized (500ha) "tidal lagoon" type estuary that discharges to Toetoes Beach at Fortrose. Situated at the mouth of the Mataura River and Titiroa Stream, it drains a large and primarily high productivity agricultural catchment. The shallow estuary (mean depth ~2m) has a large freshwater influence because the estuary is small in relation to the freshwater input. It has a wide range of habitats (extensive mudflats and saltmarsh areas, very small patches of seagrass) but has historically lost large areas of saltmarsh (estimated loss of ~75% (250ha), while virtually all the surrounding wetland has been lost through drainage and reclamation and conversion to pasture (see inset photo below and Figure 3). This has greatly reduced the estuary's ability to filter, dilute, and assimilate nutrient and sediment inputs.

In addition to these historical changes, the estuary has several ongoing issues:

- Water quality is moderately degraded (reduced clarity, elevated faecal coliforms, elevated nutrients), particularly in high river flows.
- Localised macroalgal blooms are common and are driven by elevated nutrient inputs.

A recent vulnerability assessment (Robertson and Stevens 2008) identified eutrophication, sedimentation and habitat loss as moderate vulnerabilities within the estuary and recommended ongoing monitoring and management to address these issues.

2. ESTUARY RISK INDICATOR RATINGS

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

In order to facilitate this assessment process, "risk indicator ratings" have also been proposed that assign a relative level of risk (e.g. very low, low, moderate, high) of specific indicators adversely affecting intertidal estuary condition (see Table 1 below). Each risk indicator rating is designed to be used in combination with relevant information and other risk indicator ratings, and under expert guidance, to assess overall estuarine condition in relation to key issues, and make monitoring and management recommendations. When interpreting risk indicator results we emphasise:

- The importance of taking into account other relevant information and/or indicator results before making management decisions regarding the presence or significance of any estuary issue e.g. community aspirations, cost/benefit analyses.
- That rating and ranking systems can easily mask or oversimplify results. For instance, large changes can occur within the same risk category, but small changes near the edge of one risk category may shift the rating to the next risk level.
- Most issues will have a mix of primary and supporting indicators, primary indicators being given more weight in assessing the significance of results. It is noted that many supporting estuary indicators will be monitored under other programmes and can be used if primary indicators reflect a significant risk exists, or if risk profiles have changed over time.
- Ratings have been established in many cases using statistical measures based on NZ estuary data and presented in the NZ estuary Trophic Index (NZ ETI; Robertson et al. 2016a and 2016b). However, where such data is lacking, or has yet to be processed, ratings have been established using professional judgement, based on our experience from monitoring numerous NZ estuaries. Our hope is that where a high level of risk is identified, the following steps are taken:
    1. Statistical measures be used to refine indicator ratings where information is lacking.
    2. Issues identified as having a high likelihood of causing a significant change in ecological condition (either positive or negative) trigger intensive, targeted investigations to appropriately characterise the extent of the issue.
    3. The outputs stimulate discussion regarding what an acceptable level of risk is, and how it should best be managed.

The indicators and interim risk ratings used for the Fortrose Estuary broad scale monitoring are summarised in Table 1, along with supporting notes explaining the use and justifications for each indicator. Detailed background notes for most indicators are also presented in the NZ ETI (Robertson et al. 2016b).

The basis underpinning most of the ratings is the observed correlation between an indicator and the presence of degraded estuary conditions from a range of tidal lagoon and tidal river estuaries throughout NZ. Work to refine and document these relationships is ongoing.

Table 1. Summary of estuary condition risk indicator ratings used in the present report.

RISK INDICATOR RATINGS / ETI BANDS (indicate risk of adverse ecological impacts)				
BROAD AND FINE SCALE INDICATORS	Very Low - Band A	Low - Band B	Moderate - Band C	High - Band D
Soft mud (% of unvegetated intertidal substrate)*	<1%	1-5%	>5-15%	>15%
Sediment Mud Content (%mud)*	<5%	5-10%	>10-25%	>25%
Apparent Redox Potential Discontinuity (aRPD)**	Unreliable	Unreliable	0.5-2cm	<0.5cm
Redox Potential (RP mV) upper 3cm***	>+100mV	+100 to -50mV	-50 to -150mV	>-150mV
Macroalgal Ecological Quality Rating (OMBT)*	≥0.8 - 1.0	≥0.6 - <0.8	≥0.4 - <0.6	0.0 - <0.4
NZ ETI Score*	0-0.25	0.25-0.50	0.50-0.75	0.75-1.0
Seagrass (% change from baseline - 1990 in this report)	<5% decrease	5%-10% decrease	>10-20% decrease	>20% decrease
Gross Eutrophic Conditions (ha or % of intertidal area)	<0.5ha or <1%	0.5-5ha or 1-5%	6-20ha or >5-10%	>20ha or >10%
Percent Change from Monitored Baseline	<5%	5-10%	>10-20%	>20%

* NZ ETI (Robertson et al. 2016b), ** Hargrave et al. (2008), ***Robertson (in prep.), Keeley et al. (2012),

See NOTES on following page for further information

2. ESTUARY RISK INDICATOR RATINGS (CONTINUED)

NOTES to Table 1: See Appendix 2, and Robertson et al. (2016a, 2016b) for further information supporting these ratings.

Soft Mud Percent Cover. Soft mud (>25% mud content) has been shown to result in a degraded macroinvertebrate community (Robertson et al. 2015, 2016), and excessive mud decreases water clarity, lowers biodiversity and affects aesthetics and access. Because estuaries are a sink for sediments, the presence of large areas of soft mud is likely to lead to major and detrimental ecological changes that could be very difficult to reverse. In particular, its presence indicates where changes in land management may be needed. If an estuary is suspected of being an outlier (e.g. has >25% mud content but substrate remains firm to walk on), it is recommended that the initial broad scale assessment be followed by particle grain size analyses of relevant areas to determine the extent of the estuary with sediment mud contents >25%.

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

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

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

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

Redox Potential (Eh). For meter approaches, Eh measurements represent a composite of multiple redox equilibria measured at the surface of a redox potential electrode coupled to a millivolt meter (Rosenberg et al. 2001) (often called an ORP meter) and reflects a system's tendency to receive or donate electrons. The electrode is inserted to different depths into the sediment and the extent of reducing conditions at each depth recorded (RPD is the depth at which the redox potential is ~0mV, Fenchel and Riedl 1970, Revsbech et al. 1980, Birchenough et al. 2012, Hunting et al. 2012). The Eh rating bands reflect the presence of healthy macrofauna communities in sediments below the aRPD depth.

Opportunistic Macroalgae. The presence of opportunistic macroalgae is a primary indicator of estuary eutrophication, and when combined with gross eutrophic conditions (see previous) can cause significant adverse ecological impacts that are very difficult to reverse. Thresholds used to assess this indicator are derived from the OMBT (see Section 3 and Appendix 2), 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 is likely to indicate an increase in these types of pressures.

As a baseline measure of seagrass presence, a continuous index (the seagrass coefficient - SC) has been developed to rate seagrass condition based on the percentage cover of seagrass in defined categories using the following equation: ***SC=((0 x %seagrass cover <1%)+(0.5 x %cover 1-5%)+(2 x %cover 6-10%)+(3.5 x %cover 11-20%)+(6 x %cover 21-50%)+(9 x %cover 51-80%)+(12 x %cover >80%))/100.*** Because estuaries are likely to support variable natural seagrass extents, the SC rating is intended to highlight estuaries with low seagrass cover for further evaluation (i.e. estimate natural seagrass cover to determine current state), and to provide an estuary specific metric against which future change can be assessed. It is not intended that the SC be used to directly compare different estuaries. The "early warning trigger" for initiating management action is a trend of decreasing SC.

Gross Eutrophic Conditions. Gross eutrophic conditions occur when sediments exhibit combined symptoms of: a high mud content, a shallow Redox Potential Discontinuity (RPD) depth, elevated nutrient and total organic carbon concentrations, displacement of invertebrates sensitive to organic enrichment, and high macroalgal growth (>50% cover). Persistent and extensive areas of gross nuisance conditions should not be present in short residence time estuaries, and their presence provides a clear signal that the assimilative capacity of the estuary is being exceeded. Consequently, the actual area exhibiting nuisance conditions, rather than the % of an estuary affected, is the primary condition indicator. Natural deposition and settlement areas, often in the upper estuary where flocculation at the freshwater/saltwater interface occurs, are commonly first affected. The gross eutrophic condition rating is based on the area affected by the combined presence of poorly oxygenated and muddy sediments, and a dense (>50%) macroalgal cover.

Change from Baseline Condition. Where natural state conditions for high value habitat of seagrass, saltmarsh, and densely vegetated terrestrial margin are unknown it is proposed that % change from the first measured baseline condition be used to determine trends in estuary condition. It is assumed that increases in such habitat are desirable (i.e. represent a Very Low risk rating), and decreases are undesirable. For decreases, the interim risk ratings proposed are: Very Low=<5%, Low=>5-10%, Moderate=>10-20%, and High=>20%. For indicators of degraded habitat e.g. extent of soft mud or gross eutrophic conditions, the same interim risk rating bands are proposed, but are applied to increases in extent.

3. METHODS

Broad-scale mapping is a method for describing habitat types based on the dominant surface features present (e.g. substrate: mud, sand, cobble, rock; or vegetation: macrophyte, macroalgae, rushland, etc). It follows the NEMP approach originally described for use in NZ estuaries by Robertson et al. (2002) with a combination of detailed ground-truthing of aerial photography, and GIS-based digital mapping from photography to record the primary habitat features present. Appendix 1 lists the definitions used to classify substrate and saltmarsh vegetation (although the latter was not assessed in the current study). Very simply, the method involves three key steps:

- Obtaining aerial photos of the estuary for recording dominant habitat features.
- Carrying out field identification and mapping (i.e. ground-truthing) using laminated aerial photos.
- Digitising ground-truthed features evident on aerial photographs into GIS layers (e.g. ArcMap).

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

Estuary boundaries were set seaward from an imaginary line closing the mouth to the upper extent of saline intrusion (i.e. where ocean derived salts during average annual low flow are <0.5ppt). For the current study, rectified ~0.4m/pixel resolution colour aerial photos flown by LINZ in 2014 were laminated (scale of 1:5,000) and used by experienced scientists who walked the area in Feb. 2016 (2 x 1 day) to ground-truth the spatial extent of dominant substrate types (Figure 3). The boundaries of substrates, seagrass and macroalgal cover represent the features observed on the ground in 2016 and are different to the underlying 2014 photos in many places. The "iGIS HD" ipad app. was used to show live position tracking (via an inbuilt GPS accurate to ~5m), and to log field notes. When present, macroalgae and seagrass patches were mapped to the nearest 5% using a 6 category percent cover rating scale as a guide to describe density (see Figure 2 below).

Broad scale habitat features were digitised into ArcMap 10.2 shapefiles using a Wacom Cintiq21UX drawing tablet, and combined with field notes and georeferenced photographs to produce habitat maps showing the dominant cover of: substrate, macroalgae (e.g. *Ulva, Gracilaria*), and seagrass. These broad scale results are summarised in Section 4, with the supporting GIS files (supplied as a separate electronic output) providing a much more detailed data set designed for easy interrogation to address specific monitoring and management questions. An example of the detail available on the GIS files is presented in Figure 3.

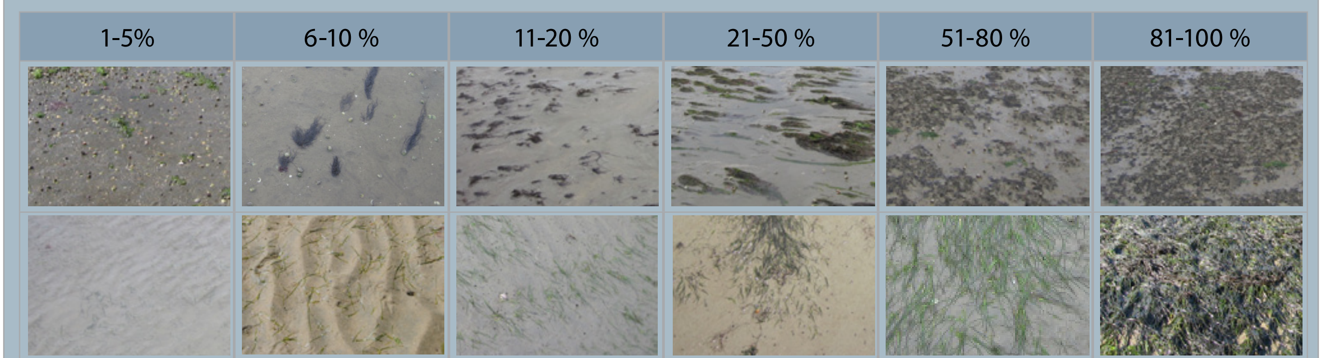
Macroalgae were further assessed by identifying patches of comparable growth, and enumerating each patch by measuring biomass and the degree of macroalgal entrainment within sediment. When macroalgae were present, the presence of soft muds and surface sediment anoxia was also noted to assess whether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

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

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

The georeferenced spatial habitat maps provide a robust baseline of key indicators and 2016 results have been compared to the previous broad scale survey results (2003, and 2013), noting in some instances since then, improvements have been made in the classification and mapping of key parameters like seagrass and macroalgae.

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



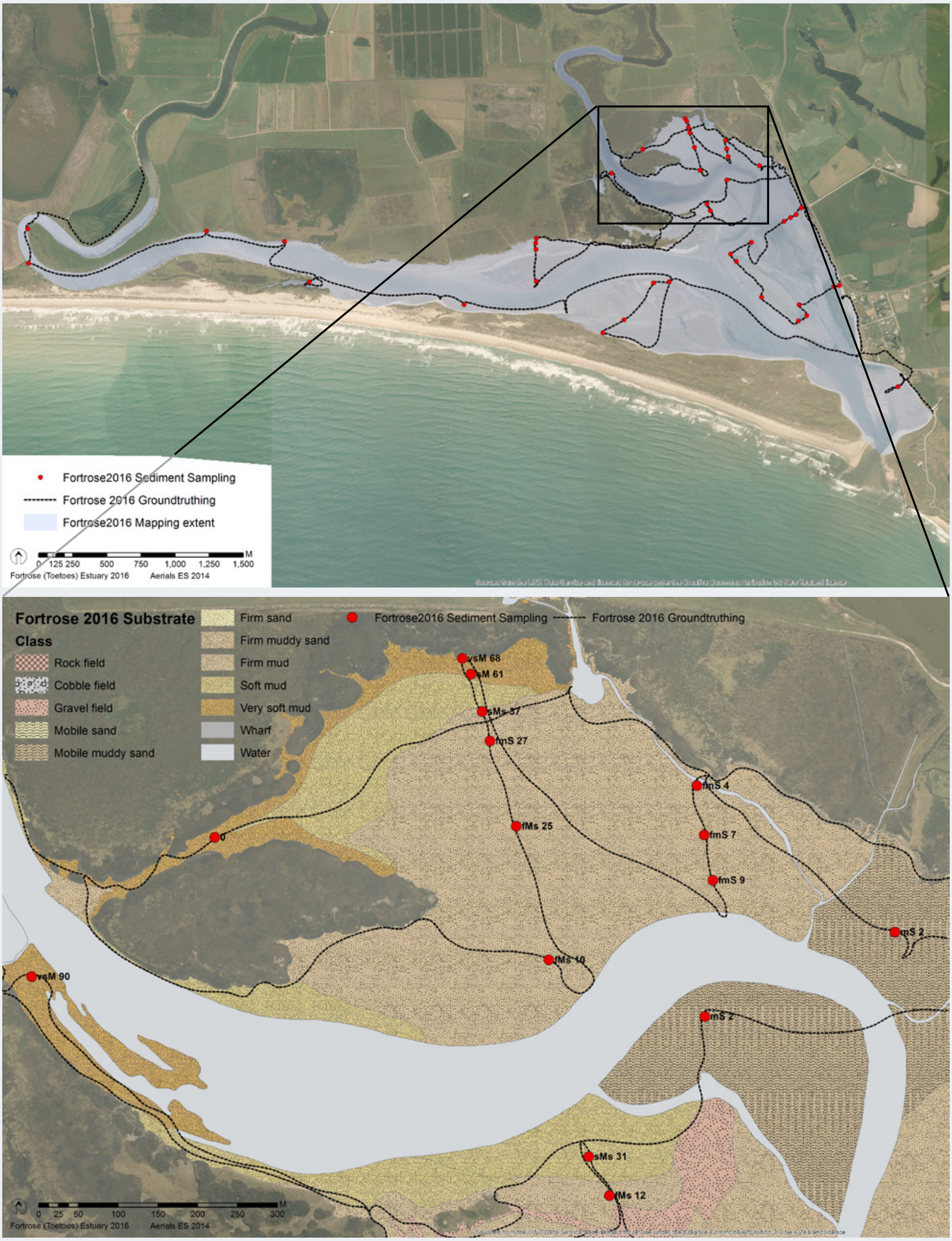


Figure 3. Mapped extent of Fortrose (Toetoes) Estuary showing 2016 groundtruthing coverage, location of grain size samples used to validate substrate classifications (top), and example of detailed map output across key soft mud and eutrophication boundaries in the northern settling basin (bottom).

Sediment sampling and analysis

Grain size samples were collected for analysis from 41 representative mud and sand habitats to validate substrate classifications and to provide increased resolution of the boundaries between these broad scale habitat types. A generalised transect based approach was used to position sites along the boundaries of problem areas in the estuary (Figure 3), and a stratified sampling approach applied to characterise representative broad scale features that took into account the availability of existing (very limited) sediment grain size sample results.

At sampling sites, photographs were taken to record the general site appearance, and a composite of the top 20mm of sediment (approx. 250gms in total) was collected using a plastic trowel and placed inside a numbered plastic bag. Samples were refrigerated within 4 hours of sample collection before being frozen and sent to R.J. Hill Laboratories for grain size analysis (% mud, sand, gravel). Details of lab methods and detection limits are presented in Appendix 1. Samples were tracked using standard Chain of Custody forms and results were checked and transferred electronically to avoid transcription errors.

In addition, at selected sampling sites redox potential (RP) was measured with an oxidation-reduction potential meter at 0, 1, 3, 6 and 10cm depths below the substrate surface, and the aRPD depth and substrate type recorded. These results have been used to generate broad scale maps showing areas where sediment oxygenation is depleted to the extent that adverse impacts to macrofauna (sediment and surface dwelling animals) are expected i.e. where RPD at 3cm <-150mV or aRPD <1cm (Robertson et al. 2016b).

Sampling resolution and accuracy

Estimates of error for different measurements have been made based on the field data collected to date. Initial broad scale mapping is intended to provide a rapid overview of estuary condition based on the mapping of features visible on aerial photographs, supported by ground-truthing to validate the visible features. The accuracy of mapping is therefore primarily determined by the resolution of the available photos, and secondarily by the extent of groundtruthing. In most instances features with readily defined edges such as saltmarsh beds, rockfields etc. can be accurately mapped to within 1-2m of their boundaries. The largest area for potential error is where boundaries are not readily visible on photographs e.g. where firm muddy sands transition to soft muds. These boundaries require field validation. Extensive mapping experience has shown that it is possible to define such boundaries to within ±10m where they have been thoroughly ground-truthed using NEMP classifications. Because broad scale mapping necessitates the grouping of variable and non-uniform patches (which introduces a certain amount of variation) overall broad scale accuracy is unlikely to exceed ±10% for boundaries not readily visible on photographs. Estimates of expected error for key summary statistics (e.g. soft mud area) are shown on plots in this report.

Where initial broad scale mapping results indicate a need for greater resolution of boundaries (e.g. to increase certainty about the extent of soft mud areas), or to define changes within NEMP categories (e.g. to define the mud content within firm muddy sand habitat), then issue-specific approaches are recommended. The former includes more widespread ground-truthing, and the latter uses transect or grid based grain size sampling. Both increased groundtruthing and targeted transect based grain size sampling have been undertaken as part of the 2016 Southland monitoring in Fortrose Estuary.

For specific broad scale seagrass and macroalgae features that are spatially and temporally variable, the overall spatial extent, and boundaries between different percentage cover and density areas, are considered accurate to within ±10m where they have been thoroughly ground-truthed using NEMP classifications. Accuracy declines when assessed remotely e.g. from aerial photographs, and particularly so when assessing lower density (<50%) cover which is commonly not visible on aerial coverages. As previously, the most accurate measures are obtained with increasing field time (and cost).

Within mapped boundaries, broad scale estimates of percentage cover and density, due to the grouping of variable and non-uniform patches, are considered accurate to ±10%. These however can be assessed to a much higher degree of accuracy using fine scale quadrat based approaches such as the OMBT which can be increased by applying fine scale approaches estuary-wide if a very high degree of accuracy is considered important.

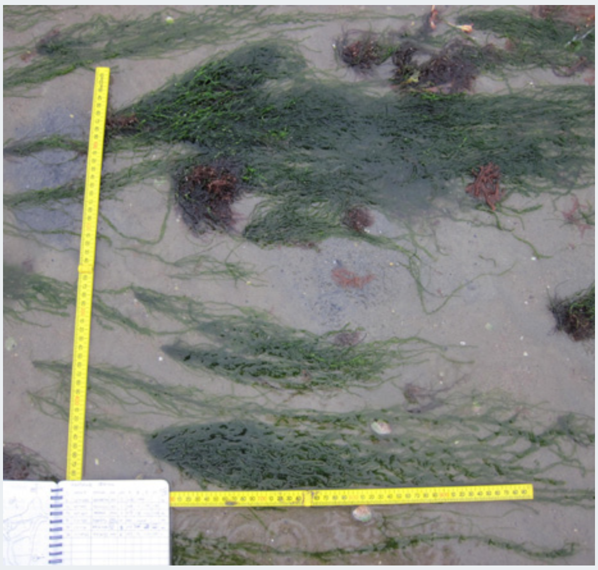
For the OMBT, a methodology for calculating a measure of the confidence of class (CofC), has been developed (Davey, 2009) that defines the specific accuracy of the measures undertaken. Called CAPTAIN ('Confidence And Precision Tool Aids aNalysis') it calculates CofC at three levels: i. metric, ii. survey (single sampling event), and iii. water body over the reporting period (potentially several surveys):

3. METHODS (CONTINUED)

- The CofC for each metric in each survey is based on the metric EQR and takes account of sampling error plus any error in the measurement. This aspect describes how each metric score is derived, and its corresponding standard error is calculated to give a metric CofC.
- The CofC for each survey is based on the Survey EQR and takes account of combined uncertainty in the five metrics. This part of the system considers how the metric scores are combined to yield an EQR and CofC for each survey.
- The CofC for the water body is based on the Final EQR and takes account of the temporal variation among the EQR results from replicate surveys. This part of the CofC assessment is performed for the water body as a whole.

For the CofC of each of the five metric scores and metric EQRs the level of standard error can be calculated incorporating all variables including measurement error. This can be converted to a CofC using a normal distribution approach. The CofC for the survey EQR is calculated using the average of the five metric EQRs. As the standard errors of the five metrics cannot be assumed to be independent because they are based on data from the same quadrats, they will share any errors in the measurement of patch area and AIH. Therefore the system calculates a further standard error of the whole survey EQR which is also converted to a confidence of class following the same normal distribution approach. When there is more than one patch, the sub-metrics are calculated by weighting the result for each patch by the area of each patch. The upper and lower 90% Confidence Intervals for the SE of the EQR are presented on OMBT plots in this report.

For comparison of changes in the estuary over time it is important that, as far as practicable, standardised extents and classifications are applied. To achieve this, the spatial extent of broad scale mapping was previously standardised across surveys by updating the 2003 extent to match that used in 2013 and, at the same time, retrospectively applying improvements in mapping classifications (see Stevens and Robertson 2013). For example, the substrate beneath macroalgal beds was not recorded in 2003 (and was therefore not included in estimates of mud extent), but has been subsequently added based on field notes, photographs and expert judgement. These changes have been recorded and included in updated GIS files prepared for the estuary. The 2016 mapped extent matched that assessed in 2013 as closely as practicable.



High cover low-moderate biomass macroalgal beds on firm sands in the north of the central basin.

High cover high biomass macroalgal beds causing sediment anoxia in the central basin of the estuary.

4. RESULTS AND DISCUSSION

The 2016 broad scale habitat mapping ground-truthed and mapped all intertidal substrate, macroalgae and seagrass, with the dominant estuary features summarised in Table 2.

Table 2. Summary of dominant broad scale features in Fortrose (Toetoes) Estuary, 2016.

Dominant Estuary Feature		Ha	% of Estuary
1.	Intertidal flats (excluding saltmarsh)	242.9	48.8
2.	Opportunistic macroalgal beds (>50% cover) [included in 1. above]	18.7	3.8
3.	Seagrass (>20% cover) [included in 1. above]	0.3	0.1
4.	Saltmarsh (with terrestrial boundary based on 2013 data)	83.7	16.8
5.	Subtidal waters	171.5	34.4
Total Estuary		**498**	**100**

In the following sections, various factors related to each of these habitats (e.g. area of soft mud) are used to apply risk ratings to assess key estuary issues of sedimentation, eutrophication, and habitat modification. Trends in broad scale features have been assessed based on the most relevant of either estimates of natural state cover or previous broad scale mapping results.

In addition, the supporting GIS files underlying this written report provide a detailed spatial record of the key features present throughout the estuary. These are intended as the primary supporting tool to help the Council address a wide suite of estuary issues and management needs, and to act as a baseline to assess future change.

4.1 INTERTIDAL SUBSTRATE

Table 3 and Figure 4 summarise the unvegetated intertidal substrate of Fortrose Estuary. Sand (comprising mobile-, mobile-muddy, firm-, and firm-muddy sand) was the dominant substrate type in the estuary (192ha, 79% of the unvegetated intertidal area), with muds (firm-, soft- and very-soft mud) comprising (30ha 12%) also prominent. The dominance of sands is likely to reflect the combined influence of high river flows, strong tidal flushing, and frequent wind driven waves all limiting the areas where deposits of fine mud accumulate in the estuary.

The primary indicator of sediment impacts is the area of the estuary dominated by soft muds with the 2016 soft mud percent cover condition (ecological impairment) band rated "MODERATE".

Table 3. Summary of dominant intertidal substrate, Fortrose (Toetoes) Estuary, Feb. 2016.

Dominant Substrate	Area Ha	Percentage	Comments
Rock field	0.1	0.0	Predominantly steep faced rock and earth margins of reclaimed land and roads.
Cobble field/Gravel field	5.2	2.1	Extensive bed near Fortrose township in the east of the central basin.
Gravel field	15.4	6.3	Extensive near estuary entrance and at the Titiroa Stream/Mataura River confluence.
Mobile sand	10.8	4.4	At the estuary entrance and in high flow areas near river/stream discharges.
Mobile muddy sand	46.1	19.0	High flushed central basin areas.
Firm sand	7.6	3.1	Most extensive near the estuary entrance, and along high tide shorelines.
Firm muddy sand	127.5	52.5	Most common as raised tidal flats in the central basin and among saltmarsh.
Firm Mud	2.4	1.0	Most common near rushland margins and along the edge of the Mataura River.
Soft mud	20.7	8.5	Most common near channel margins and along the eastern shoreline.
Very soft mud	7.1	2.9	Deposition zones in the upper central basin by channel margins near Titiroa Stream.
TOTAL	**243**	**100**	

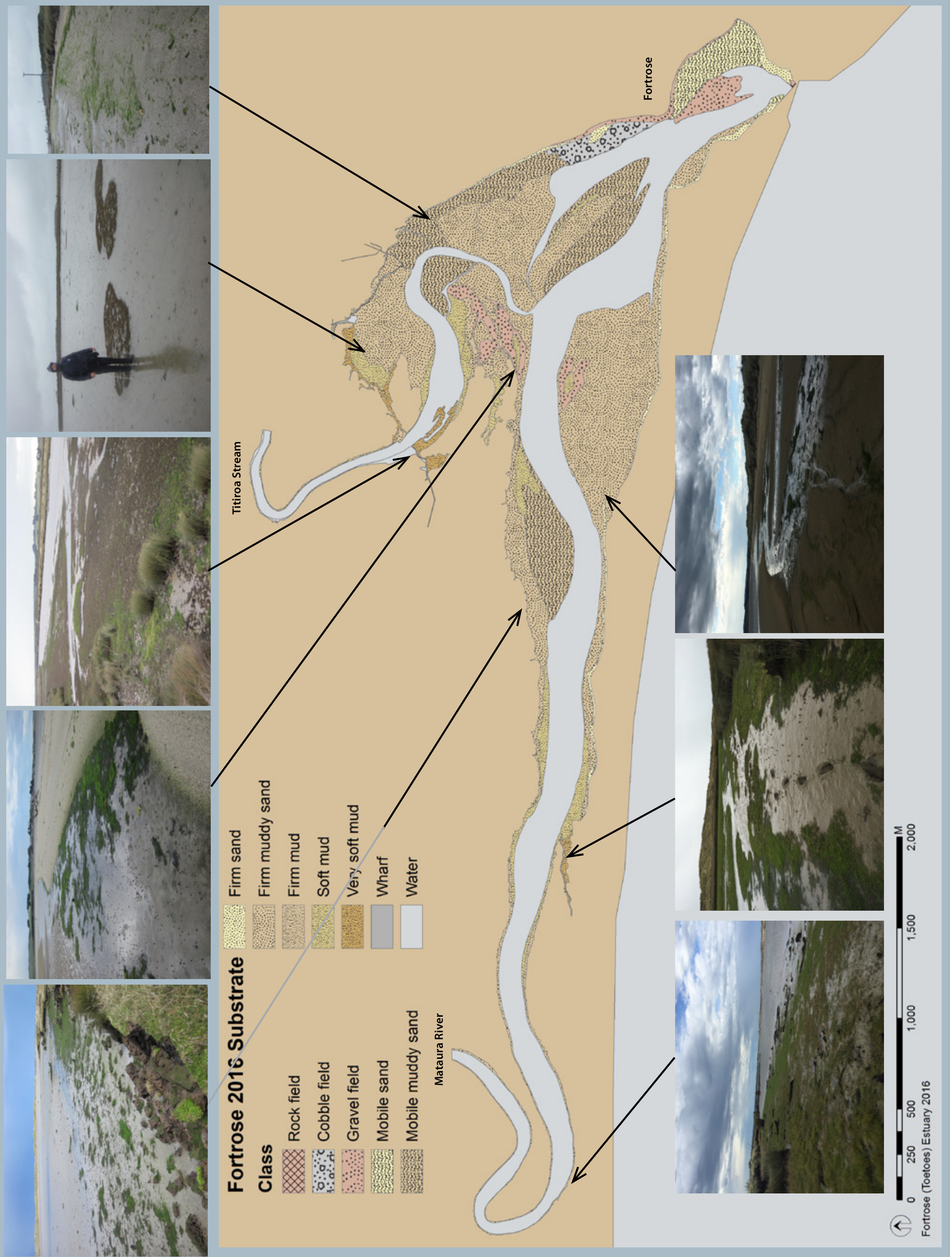


Figure 4. Map of dominant substrate types - Fortrose Estuary, Feb. 2016.

Examples of soft muds built up among macroalgal beds near Titiroa Stream.

CHANGES IN ESTUARY SOFT MUD 2003-2016

Observations over several years indicate that regular cycles of fine sediment deposition and erosion occur within the estuary, with stable deposition zones (e.g. where very soft muds consistently accumulate) remaining relatively confined in extent. The temporal variability is reflected in the monitoring results with the significant increase in soft muds from 2003 to 2013 primarily due to widespread deposition on intertidal flats in the lower Mataura River and eastern estuary flats. When remapped in 2016, these areas had largely been scoured free of deposited soft surface muds again, evident in a decline in overall mud cover (Table 4). Although such large temporal and spatial changes make detecting trends difficult, there has been a clear recent expansion in the area of stable soft mud accumulation in the estuary among nuisance macroalgal beds of *Gracilaria* that have become entrained in sediment and are now well established near Titiroa Stream (e.g. sidebar photos and discussed further in section 4.2).

Table 4. Intertidal soft mud extent (excluding saltmarsh areas), Fortrose (Toetoes) Estuary, 2003, 2013 and 2016.

Substrate Class	2003		2013		2016	
	Ha	%	Ha	%	Ha	%
Soft mud	24.4	10.0	60.3	24.8	20.7	8.5
Very soft mud	0.3	0.1	0.3	0.1	7.1	2.9
% of intertidal	**24.7**	**10.2**	**60.6**	**24.9**	**27.8**	**11.4**

Using the 2003 data as a baseline, there was a 13% increase in the total area of soft mud from 2001 to 2016, comprising a 145% increase from 2003 to 2013, followed by a 54% decrease from 2013 to 2016. Within this, very soft mud showed no increase in area from 2003 to 2013, but a >2000% increase from 2013 to 2016, most associated with sediment entrained macroalgal (*Gracilaria*) beds that had established in the northern arm. The condition (ecological impairment) band for the change in soft mud extent measured from the 2003 baseline for the period 2003-2016 was "MODERATE" (5-15%).

SEDIMENT MUD CONTENT

Sediment grain size has a strong influence on sediment oxygenation, macrofaunal community composition, water clarity, and public amenity values, among other things. Grain size sampling (see Figures 3 and 5, data in Appendix 1) was used to define sediment mud contents and to validate the NEMP sediment classifications applied. Results showed sediments could be consistently classified into NEMP categories through visual field methods. Mobile sands had a mean mud fraction of 2% (range 1%-5%), firm muddy sands had a mean mud fraction of 15% (range 4%-29%), soft mud had a mean mud fraction of 36% (range 23%-61%), and very soft mud had a mean mud fraction of 84% (range 68%-90%). The elevated mud contents in these latter two classes indicate a high likelihood of adverse effects occurring to macroinvertebrate communities in these areas of the estuary (e.g. Robertson et al. 2016).

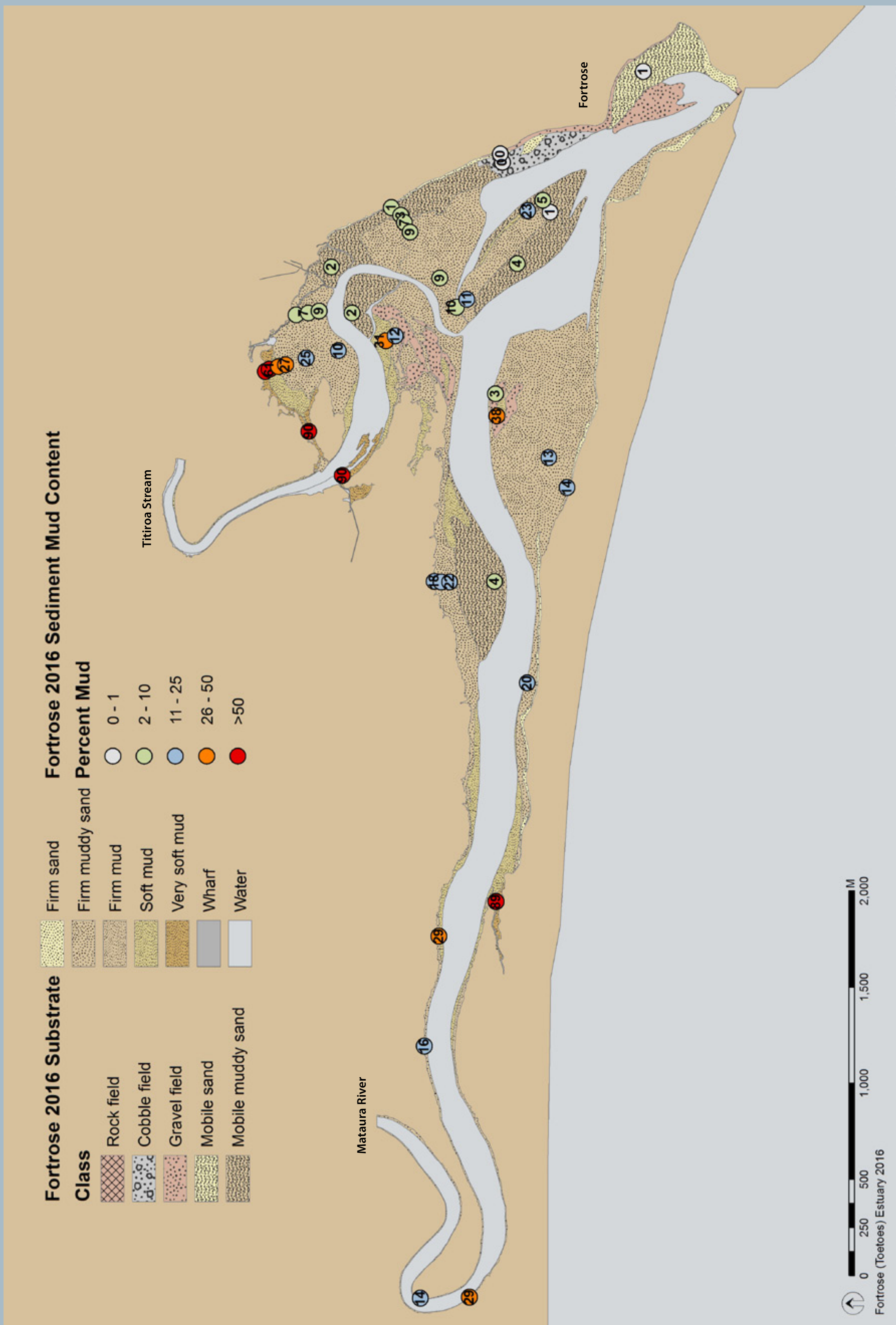
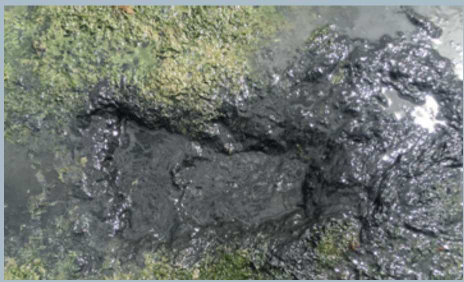


Figure 5. Sediment mud content - Fortrose Estuary, Feb. 2016.

4. RESULTS AND DISCUSSION (CONTINUED)

BROAD SCALE MAPPING (CONT.)



Examples of sediment oxygenation measures: aRPD at the surface among rotting macroalgae (top), @<0.5cm in firm sands in the southern flats (upper middle), @1cm in macroalgal covered sands in the central basin (lower middle), and measuring RP in the central basin (bottom).

SEDIMENT OXYGENATION

The primary indicators used to assess sediment oxygenation are aRPD depth and RP measured at 3cm. These indicators were measured at representative sites throughout the dominant sand and mud substrate types, and from a range of sites with variable macroalgal cover and biomass. From these measurements, broad boundaries have been drawn of estuary zones where sediment oxygen is depleted to the extent that adverse impacts to macrofauna (sediment and surface dwelling animals) are expected (Figure 6). Because macrofauna are used as an indicator of ecological impacts to other taxa, it is expected that these zones will also be exerting adverse impacts on associated higher trophic communities including birds and fish.

These results show that while the majority of the estuary sediments are well oxygenated, ~57ha (23%) of the intertidal area has substrate where sediment oxygen is depleted. The most extensive area of oxygen depletion was on the large sandy flats located on the southern side of the estuary in the lower Mataura River. Here the surface sediments showed no outward signs of oxygen depletion, but were highly anoxic immediately below the surface (see photo below). Most other sediments with depleted oxygen were directly attributable to the growth of excessive macroalgae within fine mud deposits.

Examples of highly anoxic sediments immediately below clean surface sands in the southern flats of the Mataura River.

Other sand dominated areas, along with gravel and cobble beds, were generally well oxygenated (aRPD >1cm deep, RP above -150mV at 3cm) and appeared in good (healthy) ecological condition.

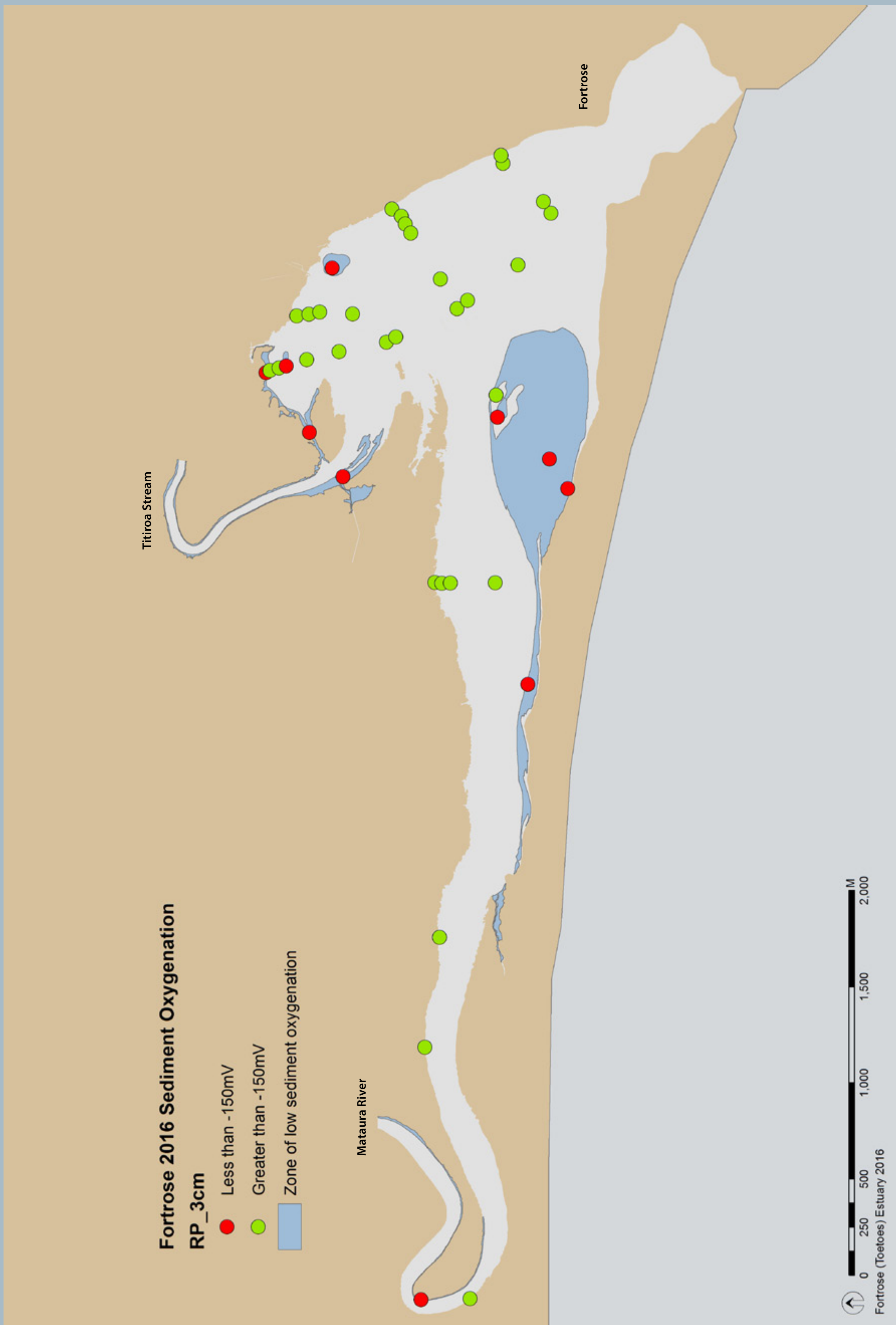


Figure 6. Map of areas with depleted sediment oxygenation - Fortrose Estuary, Feb. 2016.

4.2. OPPORTUNISTIC MACROALGAE

Opportunistic macroalgal growth was assessed by mapping the spatial spread and density of macroalgae in the Available Intertidal Habitat (AIH) (Figure 7), and calculating an "Ecological Quality Rating" (EQR) using the Opportunistic Macroalgal Blooming Tool (OMBT). For Fortrose, a conservative approach was taken of including all intertidal substrate excluding saltmarsh in the AIH.

The EQR score can range from zero (major disturbance) to one (reference/minimally disturbed) and relates to a quality status threshold band (i.e. bad, poor, good, moderate, high - Section 2, Table 1). The individual metrics that are used to calculate the EQR (spatial extent, density, biomass, and degree of sediment entrainment of macroalgae within the affected intertidal area), are also scored and have quality status threshold bands to guide key drivers of change.

The overall opportunistic macroalgal EQR for Fortrose Estuary in February 2016 was 0.447 (Table 5), a quality status of "MODERATE" and indicates that the estuary overall is expressing strong symptoms of eutrophication. This is apparent through the "Poor" Quality Status scores for the affected area of the estuary and the high biomass in affected areas, but mitigated by the overall low percentage cover of growth over much of the estuary. In other words, there is widespread macroalgal growth, most areas supporting a relatively low mean percentage cover and biomass (e.g. Figure 8), but with some areas becoming significantly impacted (e.g. Figures 9-11).

Most low biomass areas supported a mix of the red alga *Gracilaria chilensis* and the green alga *Ulva* and are located on the very strongly flushed and wave swept intertidal flats of the estuary. The regular flushing of these flats appears to limit the extent that macroalgae can establish dense beds in such areas. However one significant exception to this was apparent in the central basin where there was a 0.7ha area of very high biomass *Ulva* beds (average biomass of 34,000gm^{-2}). To place this biomass into context, the OMBT threshold between the "poor" and "bad" quality status bands is 1,450gm^{-2}. Sediments in this area were completely smothered by algae, anoxic and highly degraded (Figure 9).

The other area where high biomass beds were present was in soft mud depositional zones in sheltered parts of the upper estuary, and particularly in the northern arm where beds have only become established in the 3 years since the estuary was last monitored. In these areas *Gracilaria* was the dominant alga with high biomass (>2000gm^{-2}) beds trapping fine muds which are rapidly developing raised (5-10cm high) and stable beds supporting nuisance macroalgae. These conditions are the same as those that precipitated the rapid decline of estuary quality in New River Estuary and serve as a very significant warning that the assimilative capacity of the estuary is being exceeded. The strong relationship between soft mud deposition zones in the estuary, and the expression of macroalgal problems, was also clearly apparent with the most sediment degradation located where fine sediments had deposited.

Table 5. Summary of intertidal opportunistic macroalgal cover, Fortrose Estuary, Feb. 2016.

Metric	Face Value	Final Equidistant Score (FEDS)	Quality Status
AIH - Available Intertidal Habitat (ha)	243		
Percentage cover of AIH (%) = (Total % Cover / AIH) x 100 *where Total % cover = Sum of {(patch size) / 100} x average % cover for patch*	14.0	0.621	Good
Biomass of AIH (g.m^{-2}) = Total biomass / AIH *where Total biomass = Sum of (patch size x average patch biomass)*	487.1	0.409	Moderate
Biomass of Affected Area (g.m^{-2}) = Total biomass / AA *where Total biomass = Sum of (>5% cover patch size x average patch biomass)*	709.1	0.356	Poor
Presence of Entrained Algae = (No. quadrats or area (ha) with entrained algae / total no. of quadrats or area (ha)) x 100	5.1	0.599	Moderate
Affected Area (use the lowest of the following two metrics)		0.250	Poor
Affected Area, AA (ha) = Sum of all patch sizes (with macroalgal cover >5%)	166.9	0.311	Poor
Size of AA in relation to AIH (%) = (AA / AIH) x 100	68.7	0.250	Poor
OVERALL MACROALGAL ECOLOGICAL QUALITY RATING - EQR (AVERAGE OF FEDS)		**0.447**	Moderate

4. RESULTS AND DISCUSSION (CONTINUED)

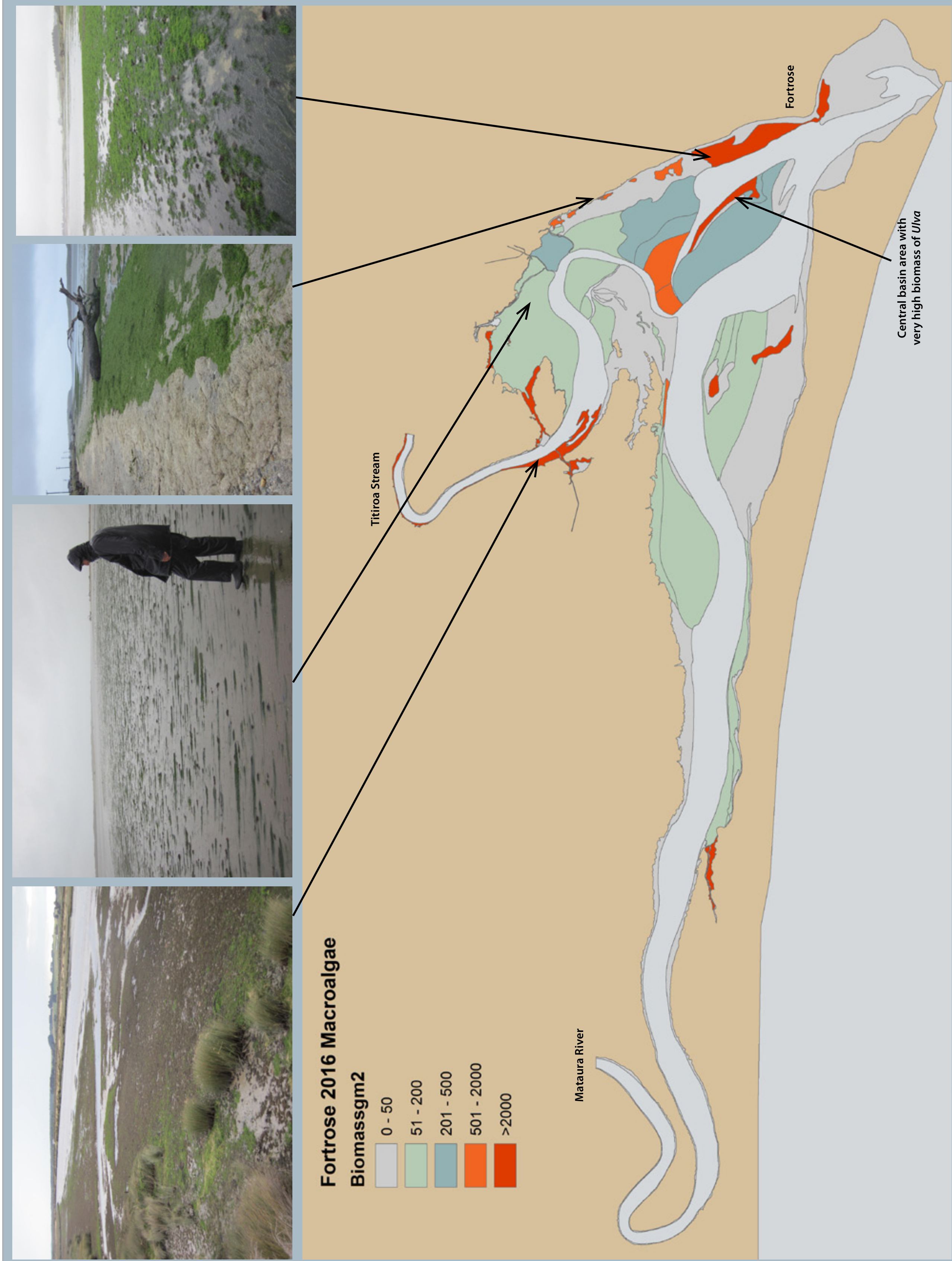


Figure 7. Map of Macroalgal Biomass (g.m²) and representative photos - Fortrose Estuary, Feb. 2016.

4. RESULTS AND DISCUSSION (CONTINUED)

Two other issues identified in the estuary not captured by the OMBT score are: 1. Significant deposits of drift beach-cast algae were rotting on the eastern shoreline of the estuary. 2. Very prolific subtidal growths were present throughout much of the shallow subtidal estuary, biomass in some areas exceeding 30,000gm^{-2} and completely smothering the estuary bed (see Figure 13).

As reported in Stevens and Robertson (2013), the extensive subtidal growth present in the estuary is driven by the very high nutrient loads entering the estuary (estimated N load based on NIWA's CLUES model with 2002 land cover is 2,450 tonnes N year^{-1}, therefore based on current land use is likely to be >4,000 tonnes N year^{-1}). Because the estuary is relatively small in comparison to the very large freshwater inflow (mean flow 76m^3.s^{-1}), most of the N inflow is rapidly flushed out to sea. However, the high N inputs support excessive growths of nuisance macroalgae in areas exposed to elevated nutrient concentrations and low salinity conditions. The nuisance macroalgae is usually *Ulva intestinalis,* which is very tolerant of low salinity, and these growths can break away and be transported to other areas of the estuary through wind and current action. However, prolific growths of *Gracilaria* are also widespread in the shallow subtidal channels of the estuary.

Consequently, setting limits on nutrient inputs, and the identification and management of nutrient sources, is considered a priority. It is therefore recommended that annual macroalgal monitoring be continued, that appropriate catchment nutrient guideline criteria be developed, and that the extent to which catchment loads meet these guidelines be assessed. The key steps in such an approach are a cornerstone to the ECG approach being undertaken by ES and includes::

- Assigning catchment nutrient load guideline criteria to the estuary based on available catchment load/estuary response data.
- Estimating catchment nutrient loads to the estuary using available catchment models and stream monitoring data.
- Determining the extent to which the estuary meets guideline catchment load criteria.
- Assessing requirements for detailed assessments of priority catchments (e.g. stream and tributary monitoring, load modelling).
- Developing plans for targeted management or restoration of priority catchments.

Because the estuary has shifted recently from a low to moderate state of enrichment, to a more enriched state with problems conditions developing, it is clearly becoming a priority for management. However, it still does not have the same high urgency as New River or Jacobs River estuaries.

CHANGES IN MACROALGAL COVER 2003-2016

Table 6 summarises the major changes in dense macroalgal cover since it was first assessed in 2003 (see Robertson et al. 2002, Stevens and Robertson 2009, 2010, 2011, 2012, 2013). Results show there was very little intertidal growth in 2003, but that by 2009, extensive areas were present. From 2009 to 2012 cover remained relatively consistent, anecdotal evidence suggesting variance was mostly due to flood related scouring of growths from the estuary. However in 2013 a significant increase in cover was evident that was accompanied by an increase in biomass (not measured). Most recently, sometime between 2013 and 2016, biomass has increased significantly, macroalgae has become entrained in sediment, and there has been a rapid deterioration of sediment quality in affected areas with the establishment of gross eutrophic zones not previously present in the estuary.

Table 6. Summary of intertidal opportunistic macroalgal cover, Fortrose Estuary, 2003-2016.

Year	% cover (Ha)		Result
	20-50%	>50%	
2003	<1	<1	Very little macroalgal growth present in the estuary.
2009	35	20	Widespread growth in central basin and eastern side of estuary. Little growth in the west and across the lower estuary, but localised concentrations of windblown algae.
2010	4	20	Most macroalgal growth and localised concentrations of windblown algae located on the Eastern Flats. Little growth across the north, west or lower estuary flats.
2011	1	12	Most extensive as windblown deposits on the Eastern Flats. Little growth across the north, west or lower estuary flats. Reduced cover in central basin.
2012	2	8	Little growth across the north, west or lower estuary flats. Low cover in central basin. Most extensive growths near river channel margins.
2013	38	23	Widespread growth in central basin and eastern side of estuary. Little growth in the west and across the lower estuary. Most extensive growths near river channel margins.
2016	38	17	Widespread growth in central basin and eastern side of estuary. Little growth in the west and across the lower estuary. Most extensive growths near river channel margins. Significant establishment of dense raised beds of entrained *Gracilaria* in sheltered areas, particularly near Titiroa Stream which were retaining substantial amounts of soft mud.

Figure 8. Field photos illustrating the widespread low biomass macroalgal cover on well flushed intertidal flats, Feb. 2016.

Figure 9. Field photos illustrating very high biomass growths and anoxic sulphide-rich sediments in the Fortrose central basin, Feb. 2016.

Figure 10. Photos illustrating the recent establishment of dense *Gracilaria* beds trapping fine sediment, Fortrose Estuary, Feb. 2016.

Figure 11. Photos of dense *Gracilaria* and *Ulva* beds near Titiroa Stream, Fortrose Estuary, Feb. 2016.

Figure 12. Dense *Gracilaria* and *Ulva* beds in an embayment on the south side of Fortrose Estuary, Feb. 2016.

Figure 13. Photos of dense *Gracilaria* and *Ulva* beds in shallow subtidal areas, Fortrose Estuary, Feb. 2016.

4. RESULTS AND DISCUSSION (CONTINUED)

4.3. GROSS EUTROPHIC CONDITIONS

When sediments exhibit combined symptoms of a high mud content, a shallow RPD (<1cm), and high macroalgal growth (>50% cover), they represent gross eutrophic conditions. These conditions will kill or displace most estuarine animals and shellfish, and also release nutrients previously bound in the sediments. As these nutrients will predominantly be released in the form of ammonia, which is much more readily available to fuel macroalgal growth, a cycle of increasing habitat deterioration will establish that is likely to be difficult to reverse. These conditions are most likely to be establish in the relatively rare sheltered tidal flats of an estuary where the combined influence of flocculation at the saltwater/freshwater interface, widening of river channels entering the estuary (reducing flow velocities), and limited tidal flushing all served to concentrate catchment inputs of sediments and nutrients, and provide good conditions for the growth of macroalgae. These also tend to be the areas most favourable for the growth of high value seagrass habitat.

The condition rating recognises that gross eutrophic conditions should not be present in short residence time tidal lagoon estuaries (like Fortrose), with their presence providing a clear signal that the assimilative capacity of the estuary is being exceeded. Figure 14 shows where gross eutrophic conditions have developed in the estuary. The condition rating for 2016 places the estuary in the "MODERATE" category with 8.3ha (3%) of the estuary in a severely degraded state, but the rapid shift from no gross eutrophic conditions in 2013 to those recorded in 2016 shows clearly worsening conditions in Fortrose Estuary over the last 3 years, a condition (ecological impairment) rating of "HIGH".

4.4. SEAGRASS COVER

Seagrass (*Zostera muelleri*) beds are important ecologically because they enhance primary production and nutrient cycling, stabilise sediments, elevate biodiversity, and provide nursery and feeding grounds for a range of invertebrates and fish. Though tolerant of a wide range of conditions, seagrass is vulnerable to excessive nutrients, fine sediments in the water column, and sediment quality (particularly if there is a lack of oxygen and production of sulphide).

The results of the 2016 intertidal seagrass survey showed that less than 1% of the estuary (0.3ha) had dense (>50%) seagrass cover. These beds are shown in Figure 15. Since 2013 there has been a decrease in seagrass cover of 0.2ha, a 40% loss that is directly attributable to macroalgal impacts. The photos below show how the remaining seagrass beds in the estuary are becoming smothered by macroalgae with obvious die off in the beds. The decrease in seagrass cover has a condition (ecological impairment) band of "HIGH".

Examples of seagrass beds being over grown by macroalgae - *Ulva* on seagrass in firm sands in the eastern estuary (left) and *Gracilaria* in soft muds near Titiroa Stream (right).

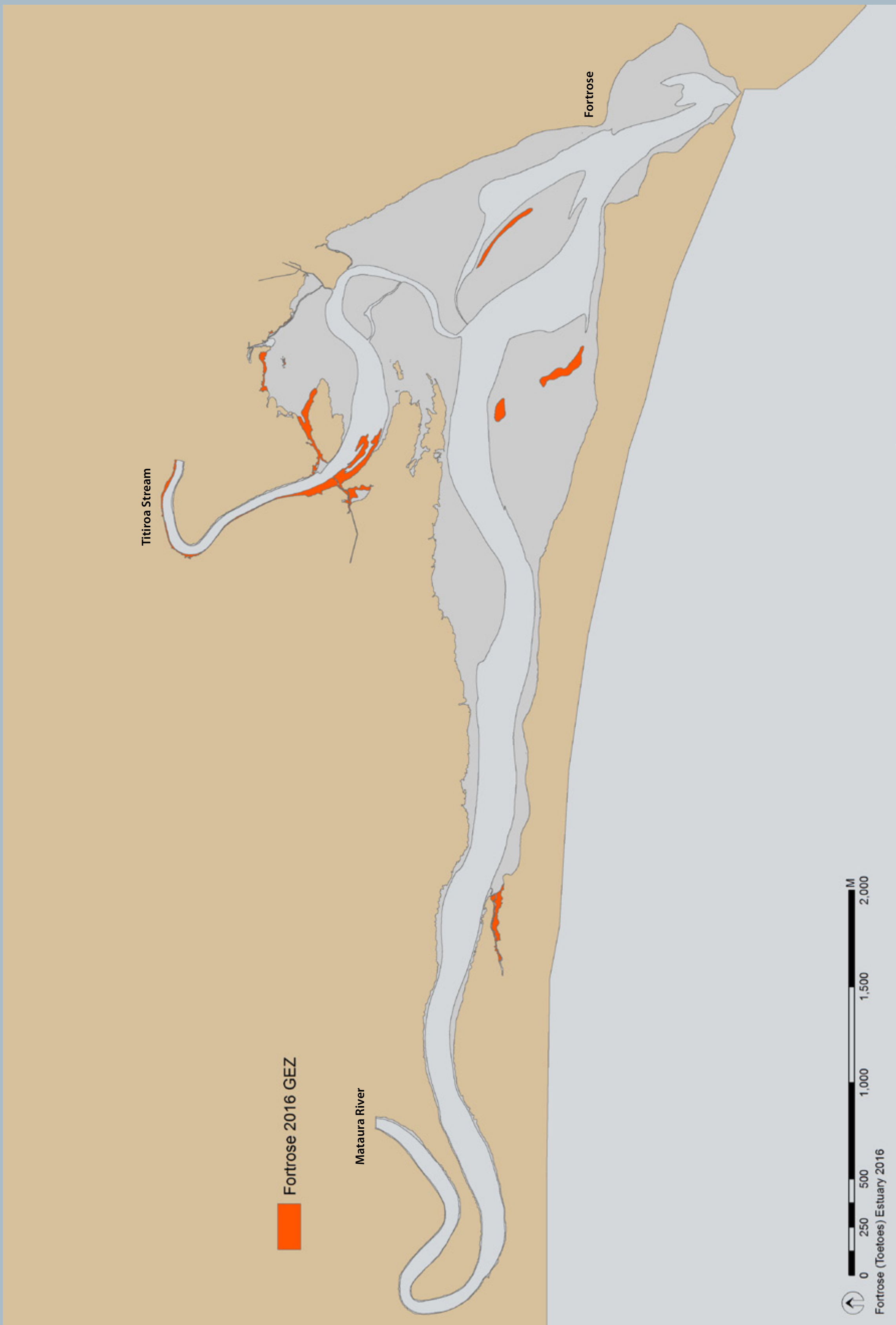


Figure 14. Location and extent of gross eutrophic zones - Fortrose Estuary, Feb. 2016.

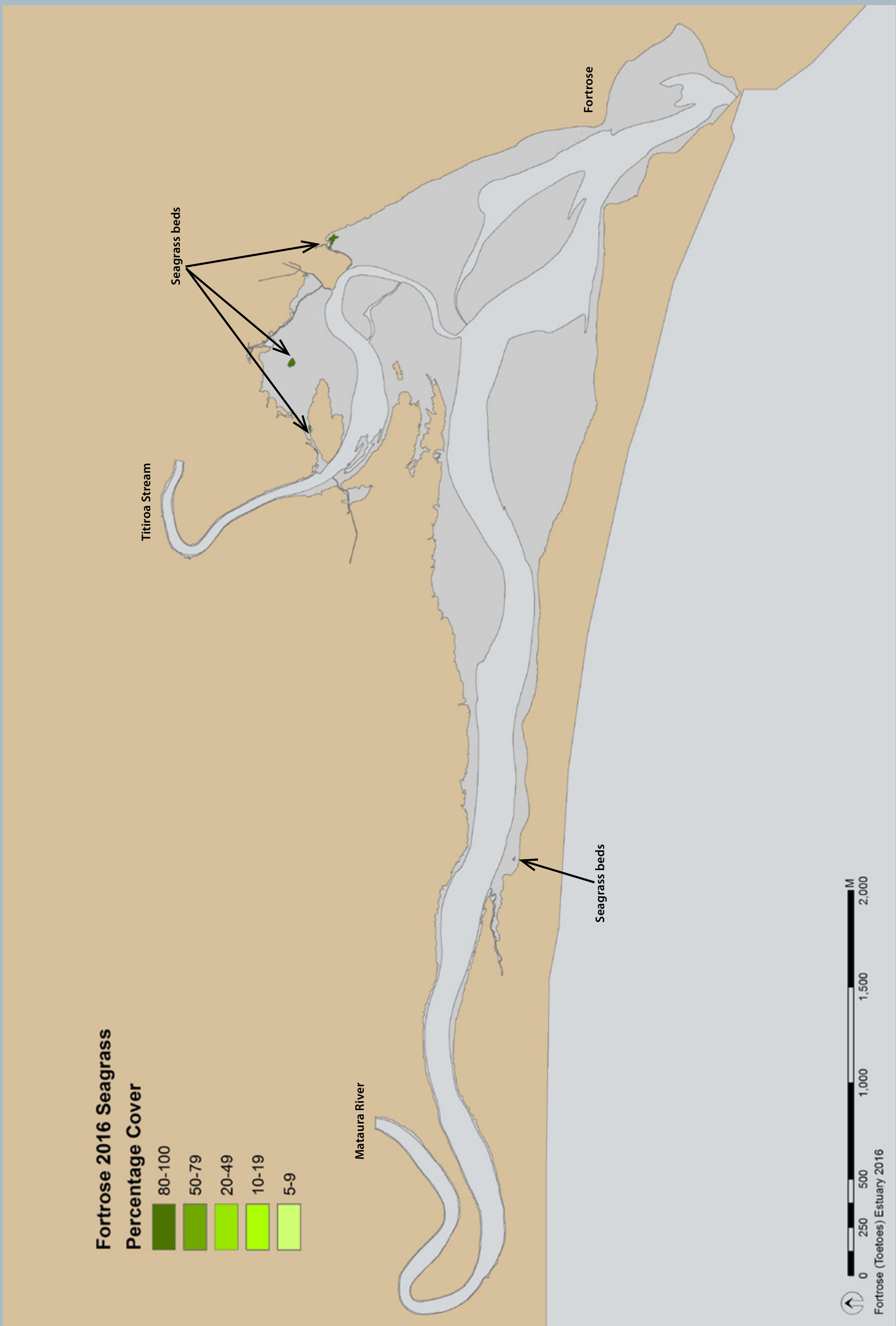


Figure 15. Map of seagrass cover - Fortrose Estuary, Feb. 2016.

5. SUMMARY AND CONCLUSIONS

Overall, the majority of the intertidal area was characterised by unvegetated sand flats (79%) and soft muds (11%), with remaining areas comprising gravel, cobble and rock. Sediment oxygenation was generally good throughout most intertidal areas but there were significant areas (57ha, 23%) of the estuary with reduced oxygenation. These were predominantly located in sheltered deposition zones in the estuary where fine muds accumulate, but a large area was also located on sandy intertidal flats on the southern edge of the Mataura River.

Macroalgal growth (dominated by *Gracilaria* and *Ulva*) was at moderate levels, with widespread low biomass cover, and localised areas of high biomass cover, particularly near low tide channels fed by nutrient-rich river flows. Significant subtidal growths were evident and there has been a significant increase in stable sediment entrained macroalgal beds that, since 2013, have developed into gross eutrophic zones over 8.3ha (3%) of the estuary.

Seagrass (*Zostera*) beds were scarce with only 0.3ha (<1%) in the estuary. The cause of the low coverage is uncertain but may relate to elevated nutrient inputs. Fortrose Estuary has an estimated nitrogen areal load of $2723mg.m^{-2}.d^{-1}$ (data from NIWA CLUES model), well above the $36.5mg.m^{-2}.d^{-1}$ threshold reported for the disappearance of seagrass in New England estuaries (Latimer and Rego 2010). Secondary stressors are also likely to result from macroalgal smothering and increased muddiness contributing to reduced sediment oxygenation and poor water clarity. Macroalgal smothering appears the probable direct cause of a 40% loss in seagrass since 2013.

Overall, there has been a change in several key condition indicators over the past decade indicating a decline in estuary health. The primary drivers of the changes identified are almost certainly related to elevated catchment inputs of nutrients and fine sediments, and nutrient inputs in particular need to be reduced below current levels to achieve a more moderately enriched estuary and to protect it from further degradation.

6. MONITORING

Fortrose (Toetoes) Estuary has been identified by ES as a priority for monitoring, and was a key part of ES's coastal monitoring programme undertaken between 2003 and 2013. This arose because the estuary is large, has moderate ecological and human use values (particularly whitebaiting), is rated as of outstanding importance in the "Wetlands of National Significance to Fisheries Database", and is internationally recognised as part of the 'Awarua wetland complex' in the Ramsar convention list. The estuary is moderately vulnerable to sediment muddiness, eutrophication and disease risk, with the vulnerability mitigated somewhat by the high rate of flushing and consequent export of a large portion of the elevated catchment sediment and nutrient load to the surrounding coastline. Based on the 2016 monitoring results and condition ratings, and changes since 2003, it is recommended that monitoring continue as follows:

Broad Scale Habitat Mapping. Repeat broad scale intertidal habitat mapping on a 10 yearly cycle. Next monitoring due in February 2023.

Fine Scale Monitoring. Repeat fine scale intertidal monitoring at 5 yearly intervals (last undertaken in 2009).

Sediment Monitoring. Measure sediment plate depths annually, and deploy additional plates in obvious intertidal deposition areas where sediment is rapidly accumulating.

Macroalgal Monitoring. Based on the widespread cover of macroalgae, the trend of increased biomass, and the establishment of nuisance conditions, annual monitoring of macroalgal cover is strongly recommended.

7. MANAGEMENT

The presence of increasing macroalgal growth in Fortrose Estuary (widespread throughout the central basin and eastern side of the estuary in 2009, 2010, 2013 and 2016) indicates catchment nutrient loads to the estuary exceed the ability of the estuary to assimilate these loads, as noted by Robertson and Stevens (2008). Previous recommendations (e.g. Robertson and Stevens 2009, Stevens and Robertson 2011, 2012, 2013) are reiterated, specifically the development of catchment nutrient and sediment guideline criteria for each estuary type in Southland to derive thresholds protecting against adverse sediment and nutrient impacts. Fortrose (Toetoes) Estuary has been identified as a priority for this work behind assessments for New River and Jacobs River estuaries and is included as a key component of the EHP currently being developed by ES for the Southland region.

8. ACKNOWLEDGEMENTS

Many thanks to Nick Ward (Coastal Scientist, Environment Southland) for his support of this work and review of this report.

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APPENDIX 1. 2016 FIELD MEASUREMENTS

Site	NZMG East	NZMG North	Substrate	aRPDcm	mV@1cm	mV@3cm	mV@5cm	mV@10cm	%Gravel	%Sand	%Mud
31	1277483	4834470	mS	7	135	nm	nm	nm	6.6	92.2	1.2
32	1277445	4834422	mS	1	65	-15	-75	-90	6.8	90.5	2.7
33	1277405	4834401	fmS	3	55	-35	-111	-150	9.5	83.7	6.7
34	1277357	4834373	fmSG	10	65	nm	nm	nm	17.4	73.6	9
35	1277118	4834218	fmSG	3	72	-115	-160	-165	5.3	86.1	8.6
36	1276965	4834133	fmS	4	55	-72	-170	-190	3.1	87	10
37	1277007	4834078	fmSG	3	45	90	-145	-220	13.3	75.9	10.8
38	1277192	4833816	mS	2	35	-130	-198	-210	30.8	65.6	3.7
24	1277461	4833644	mS	3	67	15	-142	-219	8.6	90.6	0.8
23	1277522	4833683	mS	3	42	-60	-230	290	0	94.9	5
39	1277467	4833761	sM	0	-440	-440	-434	-215	34.2	42.6	23.2
22	1277720	4833894	CFgf	0	0	nm	nm	nm	nm	nm	nm
21	1277762	4833903	fS	0	23	0	nm	nm	26.1	73.7	0.2
0	1277176	4834781	mS	2	35	-200	-215	-215	0.5	97.6	1.8
41	1276927	4834965	fmS	3	36	-8	-180	-220	0.3	96.1	3.7
42	1276936	4834903	fmS	3	10	-15	-164	-185	2	91.4	6.6
43	1276947	4834846	fmS	3	15	-22	-155	-180	1.5	89.4	9.1
44	1276937	4834675	mS	1	-50	-60	-108	-170	10.2	88	1.8
51	1276632	4835125	vsM	0	-360	-390	-410	-430	1.1	31.4	67.5
52	1276643	4835105	sM	1	-50	-130	-235	-240	0.8	37.8	61.4
53	1276657	4835058	sMs	2	15	-35	-180	-175	1.5	61.4	37
54	1276667	4835021	fmS	2	-10	-157	-215	-240	3.3	69.9	26.8
55	1276700	4834914	fMs	2	30	-75	-210	-230	2.9	72.3	24.8
56	1276741	4834746	fMs	2	35	-60	-160	nm	0.2	89.6	10.2
500	1276321	4834900	vsM	0	-325	-405	-420	-450	nm	nm	nm
57	1276791	4834499	sMs	2	-25	-102	-116	-349	8.7	60.1	31.3
58	1276817	4834450	fMs	1	90	-93	-119	-129	3.4	84.4	12.1
71	1275541	4834247	fMs	10	100	68	14	0	3	75.1	21.9
72	1275537	4834212	fMs	3	120	110	70	-55	3.7	78.5	17.8
73	1275538	4834167	fMs	2	93	70	42	-10	6.4	71.6	21.9
74	1275540	4833934	mS	0	105	90	64	nm	1.9	93.6	4.4
501	1276091	4834725	vsM	0	-280	-296	-299	-396	0.2	10.1	89.6
0	1278192	4833161	mS	10	140	125	90	nm	0	99.2	0.8
61	1276028	4833557	fMs	1	-110	-152	-184	-207	0.4	85.9	13.7
62	1276183	4833651	fMs	0	-334	-355	-387	-407	0.1	87.1	12.8
63	1276401	4833922	sM	0	-366	-385	-422	-421	8	54	38
64	1276516	4833930	gf	na	56	108	nm	nm	49.7	46.9	3.3
80	1271813	4834319	fMs	1	-141	-234	-265	-315	0	86	14
81	1271818	4834065	fMsG	1	0	nm	nm	nm	0	70.7	29.3
82	1273124	4834299	fMs	1	0	nm	nm	nm	0	84	15.9
83	1273696	4834224	sM	3	-51	-135	-150	-184	0	71.3	28.7
84	1273875	4833927	vsM	0	-404	-440	-440	-452	1.8	9.2	89
85	1275012	4833763	fmS	1	-174	-200	-241	-290	0.2	80.2	19.6

APPENDIX 2. BROAD SCALE HABITAT CLASSIFICATION DEFINITIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Mobile sand: Granular beach sand characterised by a rippled surface layer from strong tidal or wind-generated currents. Often forms bars and beaches.

Firm or soft sand: Sand flats may be mud-like in appearance but are granular when rubbed between the fingers and no conspicuous fines are evident when sediment is disturbed e.g. a mud content <1%. Classified as firm sand if an adult sinks <2 cm or soft sand if an adult sinks >2 cm.

Firm muddy sand: A sand/mud mixture dominated by sand with a moderate mud fraction (e.g. 1-10%), the mud fraction conspicuous only when sediment is mixed in water. The sediment appears brown, and may have a black anaerobic layer below. From a distance appears visually similar to firm sandy mud, firm or soft mud, and very soft mud. When walking an adult sinks 0-2 cm. Granular when rubbed between the fingers.

Firm sandy mud: A sand/mud mixture dominated by sand with an elevated mud fraction (e.g. 10-25%), the mud fraction visually conspicuous when walking on it. The surface appears brown, and may have a black anaerobic layer below. From a distance appears visually similar to firm muddy sand, firm or soft mud, and very soft mud. When walking an adult sinks 0-2 cm. Granular when rubbed between the fingers, but with a smoother consistency than firm muddy sand.

Firm or soft mud: A mixture of mud and sand where mud is a major component (e.g. >25% mud). Sediment rubbed between the fingers retains a granular component but is primarily smooth/silken. The surface appears grey or brown, and may have a black anaerobic layer below. From a distance appears visually similar to firm muddy sand, firm sandy mud, and very soft mud. Classified as firm mud if an adult sinks <5 cm (usually if sediments are dried out or another component e.g. gravel prevents sinking) or soft mud if an adult sinks >5 cm.

Very soft mud: A mixture of mud and sand where mud is the major component (e.g. >50% mud), the surface appears brown, and may have a black anaerobic layer below. When walking an adult sinks >5 cm unless another component e.g. gravel prevents sinking. From a distance appears visually similar to firm muddy sand, firm sandy mud, and firm or soft mud. Sediment rubbed between the fingers may retain a slight granular component but is primarily smooth/silken.

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

Sabellid field: Area that is dominated by raised beds of sabellid polychaete tubes.

Shell bank: Area that is dominated by dead shells.

Artificial structures: Introduced natural or man-made materials that modify the environment. Includes rip-rap, rock walls, wharf piles, bridge supports, walkways, boat ramps, sand replenishment, groynes, flood control banks, stopgates.

APPENDIX 3. SUMMARY OF BROAD SCALE MONITORING RESULTS

Summary of broad scale monitoring results for Fortrose (Toetoes) Estuary, 2003-2016.

Condition (Impairment) Band	No Rating	Band A - Very Low	Band B - Low	Band C - Moderate	Band D - High

Year	NZ ETI Band	Macroalgae		Soft Mud		Low Sed O_2 Zone		GEZ		Seagrass >20%	
		Cover >50% Ha	EQR Score	Ha	%	Ha	%	Ha	%	Ha	% loss
2003	na	<1	0.9*	24.7	10.2%	na	na	0	0	0.3	baseline
2009	na	20	na	na	na	na	na	na	na	na	na
2010	na	20	na	na	na	na	na	na	na	na	na
2011	na	12	na	na	na	na	na	na	na	na	na
2012	na	8	na	na	na	na	na	na	na	na	na
2013	na	23	na	60.6	24.9%	na	na	0	0	0.5	0%
2016	C	17	0.447	27.8	11.4%	57	23%	8.4	<3%	0.3	0%

*Estimated. na=not assessed or data not available.
NOTE: % cover calculations are determined using the area of intertidal flats (i.e. excludes saltmarsh and subtidal water).