BEFORE THE ENVIRONMENT COURT
I MUA I TE KOOTI TAIAO O AOTEAROA

UNDER	the Resource Management 1991
IN THE MATTER	of of appeals under Clause 14 of the First Schedule of the Act
BETWEEN	**TRANSPOWER NEW ZEALAND LIMITED** (ENV-2018-CHC-26)
	FONTERRA CO-OPERATIVE GROUP (ENV-2018-CHC-27)
	HORTICULTURE NEW ZEALAND (ENV-2018-CHC-28)
	ARATIATIA LIVESTOCK LIMITED (ENV-2018-CHC-29)
	WILKINS FARMING CO (ENV-2018-CHC-30)

(Continued next page)

STATEMENT OF EVIDENCE OF NICHOLAS WARD ON BEHALF OF THE SOUTHLAND REGIONAL COUNCIL
14 December 2018

Judicial Officer: Judge Borthwick and Judge Hassan

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(ENV-2018-CHC-31)

DAIRYNZ LIMITED
(ENV-2018-CHC-32)

H W RICHARDSON GROUP
(ENV-2018-CHC-33)

BEEF + LAMB NEW ZEALAND
(ENV-2018-CHC-34 & 35)

DIRECTOR-GENERAL OF CONSERVATION
(ENV-2018-CHC-36)

SOUTHLAND FISH AND GAME COUNCIL
(ENV-2018-CHC-37)

MERIDIAN ENERGY LIMITED Act 1991
(ENV-2018-CHC-38)

ALLIANCE GROUP LIMITED
(ENV-2018-CHC-39)

FEDERATED FARMERS OF NEW ZEALAND
(ENV-2018-CHC-40)

HERITAGE NEW ZEALAND POUHERE TAONGA
(ENV-2018-CHC-41)

STONEY CREEK STATION LIMITED
(ENV-2018-CHC-42)

THE TERRACES LIMITED
(ENV-2018-CHC-43)

CAMPBELL'S BLOCK LIMITED
(ENV-2018-CHC-44)

ROBERT GRANT
(ENV-2018-CHC-45)

SOUTHWOOD EXPORT LIMITED, SOUTHLAND PLANTATION FOREST COMPANY OF NZ, SOUTHWOOD EXPORT LIMITED
(ENV-2018-CHC-46)

TE RUNANGA O NGAI TAHU, HOKONUI RUNAKA, WAIHOPAI RUNAKA, TE RUNANGA O AWARUA & TE RUNANGA O ORAKA APARIMA
(ENV-2018-CHC-47)

PETER CHARTRES
(ENV-2018-CHC-48)

RAYONIER NEW ZEALAND LIMITED
(ENV-2018-CHC-49)

ROYAL FOREST AND BIRD PROTECTION SOCIETY OF NEW ZEALAND
(ENV-2018-CHC-50)

Appellants

AND **SOUTHLAND REGIONAL COUNCIL**

Respondent

Introduction

1 My full name is Nicholas James Haydon Ward.

2 I am a Team leader and Environmental Scientist at the Southland Regional Council (**Council**).

3 I have worked as a Freshwater/Marine Science Leader for the Council since November of 2013. Prior to this I worked as Coastal Scientist at the Council for one year. I also worked in the contaminated land and the waste industry prior to this.

4 I hold a Bachelor of Science (Honours) in Geology from the University of Leeds, UK, and a Graduate Diploma of Biology and a Post Graduate Diploma of Marine Ecology from Victoria University of Wellington.

5 I specialise in Estuarine ecological health within a range of systems within Southland. My work for the Council includes technical input for the proposed Southland Water and Land Plan (**pSWLP**), working in the science policy interface and running the regional ecosystem health monitoring programs. I am also involved in national programs to align and standardise estuarine monitoring approaches.

6 I have been involved in the pSWLP through assistance in the preparation of the section 42A report.

7 I have been asked by the Council to prepare evidence for these proceedings.

Code of Conduct

8 I confirm that I have read the Code of Conduct for expert witnesses as contained in the Environment Court Practice Note 2014. I have complied with the Code of Conduct when preparing my written statement of evidence, and will do so when I give oral evidence.

9 The data, information, facts and assumptions I have considered in forming my opinions are set out in my evidence. The reasons for the opinions expressed are also set out in my evidence.

10 Other than where I state I am relying on the evidence of another person, my evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Scope

11 I have been asked by the Council to provide evidence in relation to estuarine and lake health in Southland. My evidence addresses:

(a) Estuarine health in Southland including current state, trends, and methodology; and

(b) Current ecosystem health of lakes in Southland.

12 In preparing this evidence, I have read and considered a number of documents, which are referenced throughout my evidence, and a complete list of references is set out in **Appendix A**.

Executive Summary

13 Estuarine and lake/lagoon health is a reflection of the inherent capacity of a system to process contaminants and the pressure on the system i.e., nutrient/sediment contribution due to contemporary land use.

14 There are many estuaries and lagoons located along the coast in Southland. The main catchments in Southland all end in estuaries or lagoons and the catchments for the Waiau Lagoon, Jacobs River Estuary, New River Estuary and Toetoes (Fortrose) Estuary represent the majority of the land area (not including conservation land) in Southland. Depending on the categorisation, lagoons are either classed as a subset of lakes or estuaries. For the purpose of this evidence the lagoons Waituna, Waiau and Lake Brunton have been classed as within a subset of Intermittently Open and Closed Lakes and Lagoons (**ICOLLs**).

15 For Southland, the most sensitive type of estuary systems are those that are periodically closed to the sea (including Lake Brunton, Waituna Lagoon, and Waiau Estuary). The next most sensitive are the tidal lagoon type systems, such as New River Estuary and Jacobs River Estuary. The least sensitive to nutrient and sediment inputs are the tidal river type of estuaries (which includes Toetoes (Fortrose) Estuary).

16 The main issues for estuaries in Southland are as follows:

(a) New River Estuary, Jacobs River Estuary and Toetoes (Fortrose) Estuary are all currently receiving sediment and nutrient inputs beyond their assimilative capacity and show signs of eutrophication and expansive degraded areas. A reduction of nutrient and sediment inputs is required to prevent further deterioration.

(b) Waikawa Estuary and Haldane Estuary are currently in a moderate to good health state. However, an approximate doubling of nutrient input from land use change and/or intensification is likely to result in a deterioration of conditions, similar to those seen in New River and Jacobs River Estuary.

(c) Freshwater Estuary on Stewart Island is a near pristine system and used as a reference condition estuary.

17 Turning to lakes, there are hundreds of lakes in Southland, predominantly located in Fiordland National Park. However, the focus of monitoring has been constrained to areas of obvious value and/or proximity to stress from human activity.

18 The lakes in Southland can be grouped into three broad categories: shallow lakes; ICOLLs; and deep glacial lakes.

19 In general, shallow lakes and ICOLLs (especially when closed) are at a greater risk of developing compromised ecological states, than the deep glacial lakes, due to having less volume, their position in the landscape, and the type of land use in surrounding catchments.

20 In my opinion:

(a) The shallow lakes of Lake Vincent, The Reservoir, and Lake George are all in a state of moderate/high stress. Nutrient concentrations are elevated for all the lakes, especially Lake Vincent which is below national bottom lines[1] for Total Nitrogen (**TN**) in the National Policy statement for Freshwater Management.

(b) In respect of ICCOLLs, Waituna lagoon is a stressed lagoon, which is showing clear signs of poor water quality and eutrophication via cyanobacterial and algal blooms.

(c) The two major deep glacial lakes (Lake Te Anau and Lake Manapōuri) have the highest ecological health score of all

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1 The NPSFM sets minimum acceptable states for national values. The national bottom line requires that a minimum state be achieved.

monitored lake types in Southland and are in a slightly modified to pristine condition.

Estuary health in Southland

21 An estuary is a body of water where freshwater from rivers and streams flows into and mixes with saltwater from the sea. Estuaries play many important roles in our environment. For example, they provide critical habitat for species that are valued commercially, recreationally, and culturally. Estuaries filter contaminants from the land and so protect the nearby coastal environment and perform an important function for cycling nutrients. Estuaries are also important to commercial and recreational fishing, as they provide essential nursery areas for many fish and shellfish species.

22 In this part of my evidence I discuss the current state and trends of estuary health in Southland. I have addressed:

(a) An overview of the estuaries present in Southland;

(b) What the term “eutrophication” means and the symptoms of eutrophication in the context of estuary health;

(c) The monitoring methodology for estuary health; and

(d) The current state and trends for estuary health in Southland.

Overview of estuaries in Southland

23 In Southland there are many estuaries located along the coast, including in Fiordland and Stewart Island.

24 Estuarine health is a reflection of the inherent capacity of a system to process contaminants (which may be altered due to a reduction in the size of an estuary, through reclamation) and the pressure on the system i.e., nutrient/sediment contribution due to contemporary land use. Not all estuaries are equal, but they can be grouped broadly into those that are more or less sensitive according to residence time. The residence time is the time that a nutrient spends in the system. The longer the residence time, the more sensitive the system will likely be to nutrient and sediment inputs.

25 The main catchments in Southland all end in estuaries or lagoons (and these surface water catchments form the basis for establishing the Freshwater Management Units in the Southland region). The

catchments for the Waiau Lagoon (discussed in the Lakes section of my evidence), Jacobs River Estuary, New River Estuary and Toetoes (Fortrose) Estuary represent the majority of the land area in Southland. These systems are at most risk due to a combination of their inherent hydrological sensitivity to nutrients and sediment, and the likely stress being experienced from anthropogenic activities.

26 Estuaries in Fiordland and Stewart Island are predominately located in/adjacent to National Parks (that are largely undeveloped), which results in little stress being experienced by these estuary systems.

27 For mainland Southland (that is not conservation estate) there are 21 estuaries (as shown on Figure 1 in **Appendix B**), 7 of which are monitored on a regular/semi-regular basis. These are:

(a) New River Estuary;

(b) Jacobs River Estuary;

(c) Haldane Estuary;

(d) Waikawa Estuary;

(e) Toetoes (Fortrose) Estuary;

(f) Waimatuku Estuary; and

(g) Freshwater Estuary.

28 Freshwater Estuary on Stewart Island is monitored as a good/pristine condition system for comparison and reference purposes. The majority of the remaining (i.e., not regularly monitored) systems are tidal river systems for small coastal catchments and under little risk.

29 The most sensitive type of estuary are the tidal lagoon type systems, such as New River Estuary (Oreti/Waihopai catchments) and Jacobs River Estuary (Aparima/Pourakino catchments) which have extensive intertidal flats.

30 The least sensitive to nutrient and sediment inputs are the tidal river type of estuaries, which have much higher river dominance over the tide, and therefore push river water out to sea, as opposed to water being constrained in the estuary by the tide. This results in water, and the nutrients it contains, being flushed out of the estuary into the sea and spending less time in the estuary. This type of system includes Toetoes

(Fortrose) Estuary (in the Mataura catchment) and the Waimatuku Estuary.

Estuary eutrophication

31 The term "eutrophication" refers to the changes caused in plant and animal communities in a waterbody due to the input of excessive nutrients.

32 The presence of excessive nutrients favours a set of more opportunistic species such as rapidly reproducing macroalgae (seaweed). These opportunistic species can adversely affect the ecosystem in an estuary. A large occurrence of growth of these species, along with mud inputs, can displace the more desirable and habitat valued seagrass species, by growing over the top and shading, or through the creation of sub-optimal growing conditions.

33 Eventually these algal blooms die and then decay, leading to localised depletion of oxygen in the water and nuisance odours as the bacteria consume the algae. Oxygen depletion can lead to a degraded biological community in the sediment characterised by low species richness and high (and variable) abundance of individuals. The original community of shellfish, bristles worms and crabs is lost. Decaying algae that induces severe oxygen depleted areas can further lead to the formation of toxic hydrogen-sulphide (a biocide), creating areas where the sediment does not support either high species richness or high abundance. In these harsh conditions macroalgae appear to be unable to survive. This change in the habitat and conditions has implications for the wider biodiversity of the estuary as biological and chemical processes are undermined.

34 To measure the fate and movement of nutrients in an ecosystem is extremely complex and very expensive to monitor. Alternatively, the results or symptoms that excessive nutrients create can be monitored and measured. Much like a medical diagnosis, a collection of symptoms is taken and considered in its entirety.

Symptoms of estuary eutrophication

35 In Table 1, I have set out the measures of the affects discussed above, including the various health "symptoms" in estuaries, and the indicators and a description of each of these.

Table 1. Indicators of stress and eutrophication in estuaries.

Symptom	**Indicator**	**Description**
Sedimentation	Muddiness	As mud increases from the catchment, there is a build of mud content in the estuary. For example, a shift from sandy conditions to a more mud-rich substrate may be seen.
	Area of soft mud	As above, but the area of mud may also increase.
	Sedimentation build up	As mud builds up it may be measured as a rate at particular sites.
Habitat Quality	Coverage of Seagrass beds	This is the area of seagrass in a system. For example, a given area may have 5% of its surface covered by seagrass or it may have 80%. This is an indicator of stresses rather than direct eutrophication.
	Estuary Invertebrates	These are the “critters” living in the sediment, which need oxygen and not too much mud to thrive. As the sediment quality changes, we see a change in to a more pollution tolerant community structure (much like macroinvertebrates in rivers). More pollution tolerant communities tend to have low species richness and high (and variable) abundance of individuals.
Sediment Contamination for metals	Heavy Metal toxicity	This is measure of concentration of metals that may become elevated due to particular inputs. Usually metals are more commonly associated with urban inputs but not exclusively. This is an indicator of potential stress rather than eutrophication.

Nutrient contamination	Macroalgae cover	Macroalgae (Seaweed) grows as more nutrients are input into the system, which can become large growths. This is a key indication of environmental stress from nutrient enrichment i.e., eutrophication.
	Sediment Oxygen	Organic matter builds up on the surface (and directly below) from seaweed growth and/or nutrient rich sediment. This organic matter is consumed by bacteria which uses oxygen, sometimes to the point where oxygen becomes depleted.
	Sediment nutrients	This measure is a reflection of organic matter build up in the sediment. This organic matter when broken down consumes oxygen.

Estuary Monitoring Methodology

36 The estuary monitoring approach used by the Council has been established to provide a defensible, cost-effective way to help quickly identify the likely presence of the predominant issues affecting New Zealand estuaries (i.e., eutrophication, sedimentation, toxicity and habitat change), and to assess changes in the long-term condition of estuarine systems. The design of the monitoring approach is based on the use of primary indicators that have a documented strong relationship with water or sediment quality. This approach has areas targeted in mud flats which are considered to express symptoms of eutrophication first.

37 Monitoring for tidally dominated estuaries is conducted using two approaches; broad scale and fine scale.

38 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 National Estuarine Monitoring Protocol (NEMP) approach originally described for use in New Zealand 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. Very simply, the method involves three key steps: Obtaining laminated aerial photos for recording

dominant habitat features; carrying out field identification and mapping (i.e. ground-truthing); and digitising the field data into GIS layers (e.g. ArcMap). The results are then used with risk indicators to assess estuary condition as a response to common stressors.

39 Fine scale monitoring is based on the methods described in the National Estuary Monitoring Protocol (Robertson et al. 2002) and provides detailed information on the condition of an estuary at specific locations over time. Using the outputs of the broad scale habitat mapping, representative sampling sites are selected and samples are collected and analysed for physical, chemical and biological variables. These include: sediment mud content, nutrient concentration (Carbon, Nitrogen and Phosphorus), and metal concentration in the top 2 cm of sediment; oxygenation depth in sediment (referred to as redox potential discontinuity and which is taken and measured using probes and using a visual estimator); and, the type and number of animals living in the upper 15cm of sediments. In some instances, further sediment quality analysis has been extended beyond one point to create better representation of a system, for example mud content and oxygenated layer measures.

Estuary Health in Southland

40 In Southland there is a range of conditions for estuaries, ranging from near pristine in Freshwater Estuary[2] to degraded in New River and Jacobs River Estuary[3]. New River Estuary (Oreti) and Jacobs River Estuary (Aparima) express the worst symptoms of eutrophication.[4] Both clearly express expansive degraded areas due to nutrient and sediment stress.

41 I discuss below the current state and trends for all the estuaries currently monitored in Southland's monitoring programme. These estuaries are:

(a) New River Estuary

(b) Jacobs River Estuary;

(c) Haldane Estuary;

(d) Waikawa Estuary;

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2 Stevens and Robertson 2013a and b

3 Robertson et al. 2017

4 Robertson et al. 2017

(e) Toetoes (Fortrose) Estuary;

(f) Waimatuku Estuary; and

(g) Freshwater Estuary.

42 These estuaries above are monitored due to their catchments being a large geographical proportion of the Southland region. The four main large catchments being Oreti (New River), Aparima (Jacobs River), Mataura (Toetoes (Fortrose)) and Waiau (Waiau Lagoon – addressed in lakes and lagoons section). Secondly, these systems are most likely to be affected by anthropogenic effects from the majority of Southland population. Waikawa and Haldane Estuaries have been included as there are useful comparison types for New River and Jacobs River Estuaries. Waimatuku Estuary is a tidal river estuary similar to that of Toetoes (Fortrose) typology, its catchment located between Aparima and Oreti catchments. Lastly, Freshwater Estuary on Stewart Island has been included as it is in a pristine condition and provides good comparisons.

New River Estuary

43 New River Estuary is located just south of Invercargill City and is the largest estuary in Southland.

44 New River Estuary has lost 40% (94 to 56 hectares) of its beneficial seagrass from 2001-2018[5] and subsequently more, especially in the Waihopai Arm (see Figure 2 in **Appendix C**).

45 There has been a large macroalage cover increase from 43 to 364 hectares of the intertidal area from 2001-2016 (see Figure 3 in **Appendix D**); and areas of New River Estuary with soft mud has increased substantially from 17% to 27% of the intertidal area between 2001 -2016[6]. Macroalage has proliferated along the southern edge of bushy point through to the Oreti River edges and also in the eastern Waihopai Arm[7] (see Figure 3 in **Appendix D**).

46 Areas which have combined indicators of a high mud content, a shallow oxygen layer, elevated nutrient concentrations, and high macroalgal

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5 Robertson et al. 2017

6 Robertson et al. 2017

7 Stevens 2018

growth (>50% cover), are termed as grossly eutrophic (see Figure 4 in **Appendix E**). When present, these conditions will likely kill or displace most estuarine animals and shellfish, and also release nutrients previously bound in the sediments. Released nutrients will predominantly be in the form of ammonia, which is more readily available to fuel macroalgal growth. Thus a perpetuation of deteriorating conditions may occur that is likely to be difficult to reverse. These areas have increased from 23 hectares (1%) of the intertidal area in 2001, to 428 hectares (15%) in 2018[8] .

47 In extreme cases, sediment condition deteriorates to such an extent that macroalgae can no longer survive. These gas emissions are readily smelt by people in the most impacted areas and are high enough to cause headaches and nausea.[9] There are now large areas (which are expanding), especially in the Waihopai Arm and Bushy Point, of the New River Estuary which display these severe conditions producing hydrogen sulphide gases (see Photo - Slate 1 below).

Slate 1. Photo taken in 2015 of sulphidic area in Waihopai Arm of New River Estuary. Photo Nick Ward.

48 New River Estuary currently has an estimated aerial load (the total amount of nitrogen spread over the area of the estuary) of 215.46 mg/m^2/day (Robertson et al. 2017).

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8 Stevens 2018

9 Townsend and Lohrer, 2015

49 In my opinion, New River Estuary clearly shows signs that the assimilative capacity of the system has been exceeded, and that the estuary is severely impacted by eutrophic conditions. Sediment and nutrients have been, and continue to be, the key stressors for this estuary.

Jacobs River Estuary

50 Jacobs River Estuary is located in Riverton.

51 Overall there has been an 11.6 hectare (31%) loss of seagrass from Jacobs River Estuary.[10] Monitoring in 2016 showed parts of the estuary dominated by muddy sediments (174 hectares, comprising 35% of the unvegetated intertidal area[11]). Most of the mud has been deposited in the Pourakino Arm, Aparima Arms, and parts of the Southern flats (see Figure 5 in **Appendix F**).

52 Monitoring in 2003 showed approximately 101 hectares of the estuary supported macroalgal cover of >50% density, mostly in the Pourakino and Aparima Arms (see Figure 6 in **Appendix G**). At that time gross eutrophic areas were not apparent.[12] There was subsequently a substantial expansion of dense macroalgae cover to 263 ha in 2008 (see Figure 6 in **Appendix G**). Monitoring between 2009 and 2013 showed 5 years of consistent but extensive high density macroalgal cover (148-165 ha) but also with increasing biomass (thicker growth) evident.[13]

53 Monitoring in 2016 displayed that gross eutrophic areas (high mud content, limited oxygen in the sediment and high macroalgal growth) increased from <20 hectares (<4% of estuary area) in 2003, to 145 hectares (30% of area) in 2016 (see Figure 7 in **Appendix H**).

54 The estimated aerial load (total amount of nitrogen spread over the area of the estuary) for Jacobs River Estuary is 452.41 mg/m^2/day.[14]

55 In my opinion, Jacobs River Estuary overall is displaying signs of eutrophication, due to excessive nutrient and sediment input. In these areas of severe degradation, the sediment macroinvertebrate community

10 Robertson et al. 2017.
11 Robertson et al. 2017
12 Robertson et al. 2017
13 Robertson et al. 2017
14 Robertson et al. 2017

is compromised and there will be less availability of food quantity and quality for fish and bird life in the estuary. The assimilative capacity of the estuary has clearly been exceeded.

Haldane Estuary

56 Haldane Estuary is located near Haldane and Slope Point (south-east of Invercargill) in the Mataura catchment.

57 Haldane Estuary has a mud flat area in the northern section and does not express eutrophication signs such as high opportunistic macroalgae growth, or a shallow oxygenated layer more than 3 cm deep. However, there are some signs of muddy areas increasing from 17 hectares in 2004, to 27 hectares in 2016. Currently the estimated aerial load (total amount of nitrogen spread over the area of the estuary) of Haldane Estuary is 54.5 $mg/m^2/day$ (compared to 215.46 for New River Estuary and 452.41 for Jacobs River Estuary).[15] The approximate estimated aerial load necessary in order to prevent gross eutrophic areas for these types of systems is currently 100 $mg/m^2/day$ and 250 $mg/m^2/day$ to prevent extensive gross eutrophic areas.[16] Haldane Estuary currently shows no indication of decline, but is susceptible to a change in nutrient input should it occur, based on its similar hydrological features to New River Estuary i.e., a shallow tidally dominated estuary.

Waikawa Estuary

58 Waikawa Estuary is located south of Niagara on the Catlins Coast.

59 Waikawa Estuary expresses high mud content percentage in the large area (comprising 231 hectares) of upper northern half of the estuary, most of the area (225 hectares) also has a shallow oxygenated layer.[17] Eutrophication is not currently expressed through excessive macroalgae growth in the Estuary.

60 Given some of the hydrological similarities of Waikawa Estuary (a shallow tidally dominated estuary) to New River Estuary, this system is likely to be susceptible to eutrophication from a change in nutrient input due to land use change and/or intensification.

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[15] Robertson et al. 2017

[16] Robertson et al. 2017

[17] Robertson et al. 2017

61 Currently, Waikawa Estuary has an estimated aerial load of 57.37 mg/m^2/day (compared to 215.46 for New River and 452.41 for Jacobs River Estuary).[18] Waikawa Estuary shows no indication of decline, except the formation of a small (0.7 hectares, <1% area) gross eutrophic areas (with high macroalgal cover, high mud content and low oxygen) in arm in the north eastern side which were not present previously (see Figure 8 in **Appendix I**). This is probably due to this area being sheltered, which promotes deposition and retention of muds.

Toetoes (Fortrose) Estuary

62 Toetoes (Fortrose) Estuary is situated at the mouth of the Mataura River.

63 Toetoes (Fortrose) Estuary (Mataura and Titiroa) is a medium sized estuary (500 hectares) that has a large river flow dominance, with the majority of the fine sediment and nutrient exported to sea.[19] This means it is inherently less susceptible to nutrient and sediment input. Despite being less sensitive to contaminants, the Toetoes (Fortrose) Estuary has more recently begun to express signs of eutrophication due to nutrient stress and also with an increase in muddy areas.

64 From 2003 to 2013 there was an increase in muddiness (from 24.7 hectares, being 10.2% of the intertidal area to 60.6 hectares, being 24.9% of the intertidal area) followed by a decrease by 2016 to 27.8 hectares.[20]. Within this timeframe, there was also a change in the overall very soft mud component of the Estuary, which increased from 0.1 hectares in 2003, to 7.1 hectares in 2016, an increase of more than 2000%. This mud is predominantly associated with Gracilaria beds which are possibly acting as sediment traps. Monitoring in 2016 detected sheltered areas accumulating mud (see Figure 9 in **Appendix J**) that are coincidental with the establishment of particular macroalgae (*Chilensis gracilaria*). Macroalgal growth has increased from <1% of the Estuary in 2003 to 17% in 2016 (Stevens and Robertson 2017).

65 In 2016 monitoring found that 8.3 hectares of gross eutrophic areas (with macroalgal cover, high mud content sediment and low oxygen) have established, which were not present in previous monitoring years (see

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[18] Robertson et al. 2017

[19] Robertson et al. 2016

[20] Stevens and Robertson 2017.

Figure 10 in **Appendix K**). These recent symptoms indicate that the Toetoes (Fortrose) Estuary is unable to assimilate the current nutrient and sediment inputs into the system.

66 In my opinion, signs of eutrophication in this type of system are an indication of an excessively stressed estuary due to nutrient and sediment input. Left unabated, grossly eutrophic areas are likely to grow and accumulate more sediment, creating a self-reinforcing feedback of degradation. This is a similar situation to that seen in the New River from around 2007 onwards. Conversely, this system, if relieved of this nutrient and sediment stress, is likely to respond positively, sooner than either New River Estuary and Jacobs River Estuary (due to the inherent resilience of this system, as discussed above).

Waimatuku Estuary

67 Waimatuku Estuary is situated geographically between Jacobs River Estuary and New River Estuary at the bottom of the Waimatuku river. It is tidal river estuary that can become restricted at its opening due to sand build up.

68 The Waimatuku has a relatively low susceptibility to eutrophication. As reflected by its moderate state (some aquatic plant growth and macroalgae lower in the system)[21] despite its high estimated load (Nitrogen aerial loading of 2726 $mg/m^2/day$).[22]

69 However, this primarily because the river mouth is currently unrestricted by sand movement leaving the mouth open for exchange with the sea; restriction will increase the likelihood of eutrophication issues.[23]

Freshwater Estuary

70 This estuary is a tidal river plus intertidal delta estuary located at the sheltered western end of Paterson Inlet on Stewart Island. The estuary is in very good condition, dominated by well-oxygenated sandy sediment with very low mud and nutrients.[24] This good health is reflected in the

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21 Robertson and Robertson 2018

22 Robertson et al. 2016

23 Stevens and Robertson 2012

24 Robertson and Stevens 2013d

sediment community, very high seagrass cover and absence of widespread nuisance macroalgal impacts.[25]

71 The estuary's good condition, relatively unchanged since at least 2009, is attributed to the very low inputs of fine sediments, nutrients and toxicants from the estuary's undeveloped native forest catchment.[26]

Conclusion on estuarine health in Southland

72 Overall, New River, Jacobs River and Fortrose Estuaries are currently stressed with regard to nutrients and sediment. Regeneration of New River and Jacobs River Estuary is likely to be complex, expensive and possibly unachievable. Toetoes (Fortrose) Estuary theoretically will be more responsive (positively) to reductions of nutrients and sediment. Regardless, all of the above systems need a reduction of nutrient and sediment inputs in order to prevent further deterioration and subsequently contemplate any possible remediation. Waikawa Estuary and Haldane Estuary are in a moderate to good health but are susceptible to nutrient and sediment input should these increase. Waimatuku estuary is susceptible to eutrophication with its current estimated load should coastal restriction of its mouth occur. Freshwater Estuary is in very good condition and provides a good example of a healthy estuary.

Lakes and Lagoons

73 In this part of my evidence I address lake and lagoon health in Southland, including:

(a) An overview of the lakes in Southland;

(b) What the term "eutrophication" means and the symptoms of eutrophication in the context of lake health;

(c) The monitoring methodology for lake health; and

(d) The current state and trends of specific lake health in Southland.

Overview of lakes in Southland

74 There are hundreds of lakes in Southland, predominantly located in Fiordland National Park. However, the focus of monitoring has been

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25 Robertson and Stevens 2013d

26 Robertson and Stevens 2013d

constrained to areas of obvious value and/or proximity to stress from human activity.

75 The lakes in Southland can be grouped into three broad categories:

(a) Shallow lakes;

(b) Intermittently Open and Closed Lakes and Lagoons (**ICOLLs**); and

(c) Deep glacial lakes.

76 The monitored lakes in Southland (see Figure 11 in **Appendix L**), as part of Southland's monitoring, are constrained to areas of obvious value (such as iconic lakes) and/or proximity to stress from human activity i.e. higher human population and animal population which predominantly is on non-conservation estate in mainland Southland.

77 Shallow lakes are characterised by being shallow (approximately less than 2m depth), they are well mixed (often from wind disturbance) and much lower water volume compared to that of deep glacial lakes. They rarely, if ever thermally stratify. In Southland, the main shallow lakes include Lakes Calder and Sheila (on Stewart Island), Lake Vincent, Lake George, The Reservoir, and Lake Murihiku.

78 Intermittently Open and Closed Lakes and Lagoons are characterised by being less than 3m deep and experience periodical mouth closure or constriction. They are highly susceptibility to nutrient retention and eutrophication, with the most susceptible being those with closure periods of months (e.g. Waituna Lagoon) rather than days (e.g. Lake Onoke in the Greater Wellington Region). This high susceptibility arises from reduced dilution (absence of tidal exchange at times) and increased retention (through both enhanced plant uptake and sediment deposition).[27] The Waituna Lagoon (which is a mechanically opened to the sea) is the best remaining example of a natural coastal lagoon in New Zealand. This group also contains Waiau lagoon.

79 Deep glacial lakes are large deep lakes formed from glacial processes. They are formed when a glacier erodes the land, scouring and pulverising rock which creates a large hole. The glacier then melts and fills the hole it has created. This melt will have happened roughly 10,000 years ago as the climate warmed to modern day temperatures. In

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[27] Robertson et al. 2016

Southland some of these lakes are extremely large and deep, such as Lake Manapōuri (approximately 400m deep) and Lake Te Anau approximately 400m deep). Efforts are focused on Lakes Manapōuri and Te Anau due to their iconic status and proximity to anthropogenic stresses. Most other deep lakes in Southland are on conservation land.

Lake and lagoon eutrophication

80 As set out above, ”eutrophication” refers to the changes caused in plant and animal communities in a waterbody due to the input of excessive nutrients. The term eutrophication was first applied to lakes with algal blooms; it was first used to describe the process by which lakes become slowly filled with sediment, and concentrate nutrients in less and less water.[28] It is clear that human activity has accelerated the eutrophication process, historically and to modern day, with a proportionally higher human population and more intense agricultural practices.[29] As stress increases on a lake, due to fine sediment and nutrient input, the lake system moves from a more pristine state with clear water and aquatic plants, to a more nutrient-enriched state with turbid water and suspended algae.

81 As lakes undergo nutrient enrichment and/or increased muddiness, they can reach a point where they will undergo a rapid regime change to a more degraded turbid state dominated by algal blooms. Some of these blooms can also have toxin producing cyanobacteria (a simple photosynthetic organism); affecting fish life, other species, recreational activities, and contaminate food sources for humans. This alternate state does not have submerged plants providing the benefits of nutrient uptake, and providing habitat for other species such as zooplankton which eat the suspended algae. This means that lakes without aquatic plants are more prone to algal blooms and water quality deterioration (i.e. eutrophication) than lakes with aquatic plants.

Symptoms of lake eutrophication

82 In Table 2 I set out the measures of the effects on lake health that I have discussed above, including the symptoms of the state of lake health, and the indicators and a description of each of these.

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28 Schindler et al. 2016.

29 Schindler et al. 2016.

Table 2. Indicators of stress and eutrophication in Lakes.

Symptom	Indicator	Description
Sedimentation	Substrate type and oxygenation of sediment	Muddy bottoms are at more risk of accumulating contaminants which may drive further deterioration, especially when the sediment becomes low in oxygen.
Water quality	Nutrient concentration (Phosphorus and Nitrogen)	As nutrient concentrations increase there is more fuel for plant and algal growth.
	Water clarity	This is measured using secci disc, which tells us light attenuation through distance. The more turbid the water, the less distance can be seen.
Productivity	Plant growth – Submerged Plant Indicator (SPI)	The ecological status of a lake can be measured by looking at plant growth. Lake SPI (Submerged Plant Indicator) is one method but there are others. SPI is based on the composition of native and invasive plants growing in lakes. A higher Lake SPI percentage result is associated with better ecological health. Categories run from Poor (0-20%) through Moderate (20-50%), High (50-75%), to Excellent (75-100%).
	Phytoplankton (floating algal) community	Measures the make-up of the community and whether there are potentially toxin producing species and the type of species, if large algal blooms occur.
	Chlorophyll-a	Chlorophyll-a is a pigment in plants, which gives a measure of primary production (photosynthetic growth) in the system from photosynthesis.

Combination index	Trophic Lake Index (**TLI**)	Measures four parameters: water clarity, chlorophyll content, total phosphorus, and total nitrogen. From these parameters a TLI value is calculated. In cases where water clarity data is missing, a three parameter TLI is calculated. The higher the value, the greater the nutrients and fertility of the water, which encourages growth, including algal blooms. The categories range from very poor – Supertrophic (>5), poor - Eutrophic (4-5), average - Mesotrophic (3-4), good - Oligotrophic (2-3) to very good – Microtrophic (<2).

Monitoring Methodology

83 Lakes and lagoons water quality monitoring involves an on-lake boat component, and a stream inflow/outflow water quality sampling and gauging (flow measurement) component.

84 Water quality measurements include various nutrients (including nitrogen, phosphorus and some carbon forms), water temperature, dissolved oxygen and other contextual parameters. A phytoplankton (floating algae) sample is also taken at each lake/lagoon. Collectively these measures give us an idea of overall health of the lake and allow reporting against the National Objectives Framework (**NOF**) in the NPS-FM.

85 When under more stress from nutrient input (and sometimes sediment), water quality can often increase in concentration, more growth of aquatic plants and algal can occur, and water clarity will often decline.

86 Lakes Te Anau and Manapōuri are sampled slightly differently to the coastal lakes, due to the depth of these lakes. The depth of these lakes mean that they can often be stratified with warmer waters sitting on top of colder water, which influences some of the water quality variables that are measured, such as the presence of phytoplankton. Nutrients, Chlorophyll-a and phytoplankton can be constrained into the warmer

layer of these deep lakes when they are stratified. Understanding the depth of this layer is important to know where samples should be taken.

Ecosystem health of lakes in Southland

87 In this part of my evidence I discuss the current state and trends for lakes in Southland, according to the three broad lake categories I have discussed above (being shallow lakes, ICOLLs and deep glacial lakes).

88 In general, shallow lakes and ICOLLs (especially when closed) are at a greater risk of developing compromised ecological states than the deep glacial lakes due to having less volume, their position in the landscape, and the type of land use in surrounding catchments. The ecosystem health of each lake category is discussed below.

Shallow lakes

89 I address the ecosystem health of all the monitored shallow lakes in Southland, below:

(a) Lake Vincent;

(b) The Reservoir;

(c) Lake George;

(d) Lakes Sheila and Calder; and

(e) Lake Muruhiku.

Lake Vincent

90 Analysis against the National Objectives Framework (**NOF**) in the NPS-FM showed that Lake Vincent had total nitrogen (**TN**) levels well in excess (annual median 980 mg/m^3, band D) of the national bottom line of 800.[30] Seasonal patterns at Lake Vincent show elevated in-lake and inflow TN concentrations throughout the winter period (May-September), which is indicative of higher nutrient loss in winter.

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30 Hodson et al. 2017.

91 Lake Vincent scored in band ‘C’; for Total Phosphorus (TP). Lake Vincent scored in band ‘B’ for phytoplankton (chlorophyll-a) concentrations.[31] For 2014, Lake Vincent Lake SPI was 56%, High.[32]

92 The Trophic Lake Index (TLI) for Lake Vincent over the years has varied from poor to average condition (see Table 3).

Table 3. Trophic Lake Index over years from Lake Vincent. From LAWA 2018.

Year	**Trophic Lake Index score**	**Condition**
2013	4.1	Poor - Eutrophic
2015	4.24	Poor - Eutrophic
2016	4.4	Poor - Eutrophic
2017	3.81	Average - Mesotrophic

The Reservoir

93 The Reservoir breached the national bottom line for phytoplankton (chlorophyll-a) concentrations at one monitoring site,[33] which usually is due to a manifestation of excess TN and TP. However, this lake scored in the ‘C’ bands for both of these attributes. This may indicate that this environment is particularly responsive to nutrient loading. This can be explained by the lack of buffering capacity, due to absence of substantial aquatic plant growth i.e., the nutrients are not been taken up by plant growth, as plants are not present. In 2013, 31.9 % of The Reservoir was unvegetated compared to 15.1% for Lake Vincent and 13% for Lake George.[34]

94 The Reservoir has had some public health warnings due to potentially toxic cyanobacteria (a photosynthetic simple organism) blooms

31 Hodson et al. 2017.
32 LAWA 2018.
33 Hodson et al. 2017.
34 Robertson and Stevens 2013a,b and c.

occurring in November/December 2017. For 2014, the Reservoir Lake SPI was 67%- High.[35]

95 The Trophic Lake Index for the Reservoir over the years has been of a poor condition (see Table 4).

Table 4. Trophic Lake Index over years from The Reservoir. From LAWA 2018.

Year	**Trophic Lake Index score**	**Condition**
2013	4.7	Poor - Eutrophic
2015	4.99	Poor - Eutrophic
2016	4.74	Poor - Eutrophic
2017	4.5	Poor - Eutrophic

Lake George

96 Lake George scored in NOF band ‘C’; for TN and TP. The lake scored in band ‘B’ for phytoplankton (chlorophyll a) concentrations.[36]

97 For 2014, Lake Vincent’s Lake SPI was 96% (which is classified as “excellent”). The Trophic Lake Index has varied from 5.77 in 2012 to 3.94 in 2017, poor to average.[37]

98 The Trophic Lake Index for Lake George over the more recent years has been in an average to poor condition (Table 5).

35 LAWA 2018.
36 Hodson et al. 2017
37 LAWA 2018.

Table 5. Trophic Lake Index over years from The George. From LAWA 2018.

Year	Trophic Lake Index score	Condition
2012	5.77	Very Poor - Supertrophic
2013	3.93	Average - Mesotrophic
2015	4.58	Poor - Eutrophic
2016	4.01	Poor - Eutrophic
2017	3.94	Average - Mesotrophic

Lake Sheila and Calder

99 Lakes Sheila and Calder are located less than 1 km apart near the centre of the Freshwater River catchment in Stewart Island/Rakiura. The lakes are situated on opposite sides of Freshwater River, within an extensive unmodified wetland complex.[38] They are both pristine lakes which are strongly influenced by the surrounding wetlands. They have low nutrient concentrations and phytoplankton biomass.

100 Insufficient data is available to do assessments of Trophic Lake Index and against the National Objectives Framework in the NPSFM.

Lake Murihiku

101 Monitoring results in 2013 indicate that the lake was in a likely moderate to poor, almost in a eutrophic state.[39] The lake was found to have almost no submerged aquatic plants. Potentially this was caused by wind resuspension of the muddy sediments, elevated phytoplankton levels and the dark natural brown humic staining.[40]

102 Insufficient data is available to do assessments of Trophic Lake index and against the National Objectives Framework in the NPSFM.

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38 Schallenburg and Kelly 2012

39 Robertson and Stevens 2013f

40 Robertson and Stevens 2013f

Conclusion on shallow lakes

103 In my opinion, Lake Vincent, The Reservoir, and Lake George are all in a state of moderate/high stress. Nutrient concentrations are elevated for all the lakes, especially Lake Vincent which is below national bottom lines for TN. The Reservoir has much less buffering capacity than the other two lakes due to lack of aquatic vegetation. This seems to result in the Reservoir being more prone to algal blooms and potentially toxic cyanobacteria, which has been seen recently with public health warnings. Lake Murihiku is likely in a poor to moderate state but more up to date information is needed to make a contemporary assessment. Lakes Sheila and Calder are in pristine condition.

Intermittently open and closed lakes and lagoons

104 I address the ecosystem health of the ICOLLs in Southland, which are:

(a) Waituna Lagoon;

(b) Lake Brunton; and

(c) Waiau Lagoon.

Waituna Lagoon

105 Waituna Lagoon is one of the best remaining examples of a natural coastal lagoon in New Zealand. It is a large coastal lagoon that is fed by three creeks, and drains to the sea through a managed opening. The lagoon is mechanically opened to the sea after the water levels reach the trigger point set in the Lake Waituna Control Association's resource consent. The intermittent opening and closing of the lagoon to the sea strongly influences the lagoon’s ecology and water quality.

106 In 1976 Waituna Lagoon was designated of international significance under the Ramsar Convention. The wetlands and lagoon were recognised under Ramsar on the grounds of threatened species presence, genetic and ecological diversity and habitat provision for plants and animals at critical life stages. In 1983, it was also established as a scientific reserve and is administered by DOC. The lagoon is also culturally significant to the local Ngai Tahu people (recognised under a Statutory Acknowledgement with the Ngai Tahu Claims Settlement Act 1998).

107 Waituna Lagoon is monitored during both open and closed periods at four separate sites. Results for nitrogen and phosphorus monitoring indicate considerable nutrient stress when the lagoon is closed. This suggests that the lagoon is still at risk of changing from a clear water state, to an algal/cyanobacterial dominated state if nutrient loads are not reduced.

108 Results show that most attributes were poorer when the lagoon was closed compared to when it was open, reflecting the role of marine flushing in removing nutrients from the system.

109 All sites scored substantially lower for TN concentrations when the lagoon was closed, with two sites, Lagoon Centre and Lagoon West, breaching the national bottom line (D band). These sites are closest to major freshwater inflows (Waituna Creek, Moffat Creek, or Carrens Creek). All closed sites and two open sites, Lagoon Centre and Lagoon South, rated in the NOF 'C' band for TP concentration.[41]

110 Phytoplankton (chlorophyll a) concentrations varied spatially and were of less concern (bands A or B) when the lagoon was open to the sea, but scored in the 'C' band at all four monitoring sites when the lagoon was closed (Hodson et al. 2017).

111 The combination of high TN, sometimes in excess of the national bottom line, and moderately high TP, suggest that there is considerable nutrient stress when the lagoon is closed, which could manifest in a shift from a clear water state to an algal/cyanobacterial dominated state if phosphorus loads increase further. The 'C' band score for all four sites when the lagoon was closed to the sea, or the recent algal bloom observed at the western end of the lagoon in 2016 (Waituna Partners' News, 2016) and the recent public health warnings in April/May 2018, may be early warning signs of such a shift. The issue of algal blooms is one of the key manifestations highlighted to happen in the 2013 recommended guidelines.[42]

112 Other lagoon attributes such as ammonia (NH3) toxicity, were of less concern, with all sites (open or closed) scoring either an A or B.

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41 Hodson et al. 2017.

42 LTG 2013.

113 The Trophic Lake Index for Waituna over the years has been in an average to poor condition (see Table 6).

Table 6. Trophic Lake Index over years from Waituna. From LAWA 2018.

Year	**Trophic Lake Index score**	**Condition**
2008	4.43	Poor - Eutrophic
2009	4.81	Poor - Eutrophic
2010	4.52	Poor - Eutrophic
2011	4.43	Poor - Eutrophic
2012	4.23	Poor - Eutrophic
2013	3.4	Average - Mesotrophic
2014	4.36	Poor - Eutrophic
2015	4.67	Poor - Eutrophic
2016	3.85	Average - Mesotrophic
2017	4.27	Poor - Eutrophic

Lake Brunton

114 Little work has been done on Lake Brunton. Sampling in 2012 when it had just begun to fill after a short period of opening to the sea, found no phytoplankton issues but it was found to have high nitrate concentrations.[43] Further work in 2013 found Lake Brunton to be in an 'early eutrophic or moderate-highly enriched state'.[44] This was based on low aquatic plant cover, variable slime algae cover, low water clarity at the time and the presence of anoxic, sulphide-rich sediments.[45] The Council has plans to conduct further monitoring of the system in the current long term plan.

43 Schallenburg and Kelly 2012
44 Robertson and Stevens 2013e
45 Robertson and Stevens 2013e

115 Insufficient data is available to do assessments of Trophic Lake index and against the National Objectives Framework in the NPSFM.

<u>Waiau Lagoon</u>

116 Waiau lagoon has been heavily modified due to a change in flow after the Manapōuri Power Scheme was developed. If and how much more susceptible this has made the system to sediment and nutrient input is unclear at this time. Assessments of health in 2012 concluded Waiau Lagoon was in a moderate to poor health[46] based on high sediment mud content, elevated organic matter and nutrients, and poor and declining sediment oxygenation. The lagoon has been growing excessive introduced weed which has displaced high value native aquatic plant that are now only sparsely present.[47] The lagoon water appears to remain in an oxygenated state, presumably due to sufficient mixing and flushing from river flows and wind action.

117 There is currently a monitoring programme being conducted by the Council that will enable assessments of Trophic Lake Index and against the National Objectives Framework in the NPSFM. At this point there is insufficient data to make these assessments.

<u>Conclusion on ICOLLs</u>

118 In my opinion, Waituna lagoon is a stressed lagoon, which is showing clear signs of eutrophication via cyanobacterial and algal blooms. The poor water quality of the system further identifies that the lagoon is stressed. Left unabated this decline will lead to substantial erosion of recreational and cultural values. Lake Brunton is likely under moderate to high stress, but clear assessments cannot be made at this time. Waiau lagoon is in a moderately poor state due to stressed from sediment and nutrient input.

Deep lakes

119 There are multiple deep glacial lakes in Fiordland, but Lake Te Anau and Lake Manapōuri are monitored for lake water quality due to their iconic value, large size, level of recreational activity, and proximity to possible stressors i.e. human population activities.

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[46] Robertson and Stevens 2012

[47] Robertson and Stevens 2012

120 Assessments by Council scientists show that Lake Manapōuri and Lake Te Anau have the highest ecological health score of all monitored lake types in Southland.[48] For TN, TP, phytoplankton (chlorophyll-a) concentrations and ammonia both lakes score in NOF band 'A'.

121 The Trophic Lake Index for Te Anau and Manapōuri over the years has been in a good to very good condition (see Table 7).

Table 7. Trophic Lake Index over years from Te Anau and Manapōuri. From LAWA 2018.

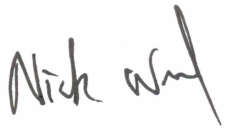
Year	Lake	Trophic Lake Index score	Condition
2008	Te Anau	2.52	Good - Oligotrohic
	Manapōuri	2.62	Good - Oligotrohic
2009	Te Anau	2.6	Good - Oligotrohic
	Manapōuri	2.58	Good - Oligotrohic
2010	Te Anau	2.58	Good - Oligotrohic
	Manapōuri	2.66	Good - Oligotrohic
2011	Te Anau	2.5	Good - Oligotrohic
	Manapōuri	2.49	Good - Oligotrohic
2012	Te Anau	2.37	Good - Oligotrohic
	Manapōuri	2.4	Good - Oligotrohic
2013	Te Anau	1.98	Very Good - Microtrophic
	Manapōuri	2	Good - Oligotrohic / Very Good - Microtrophic
2014	Te Anau	1.85	Very Good - Microtrophic
	Manapōuri	1.76	Very Good - Microtrophic
2015	Te Anau	2.04	Good - Oligotrohic
	Manapōuri	2.03	Good - Oligotrohic
2017	Te Anau	1.58	Very Good - Microtrophic
	Manapōuri	1.27	Very Good - Microtrophic

48 Hodson et al. 2017.

Conclusion on Deep Glacial Lakes

122 In my opinion both these lakes systems are in a slightly modified to pristine condition.

DATED this 14th day of December 2018



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Nicholas Ward

Appendix A

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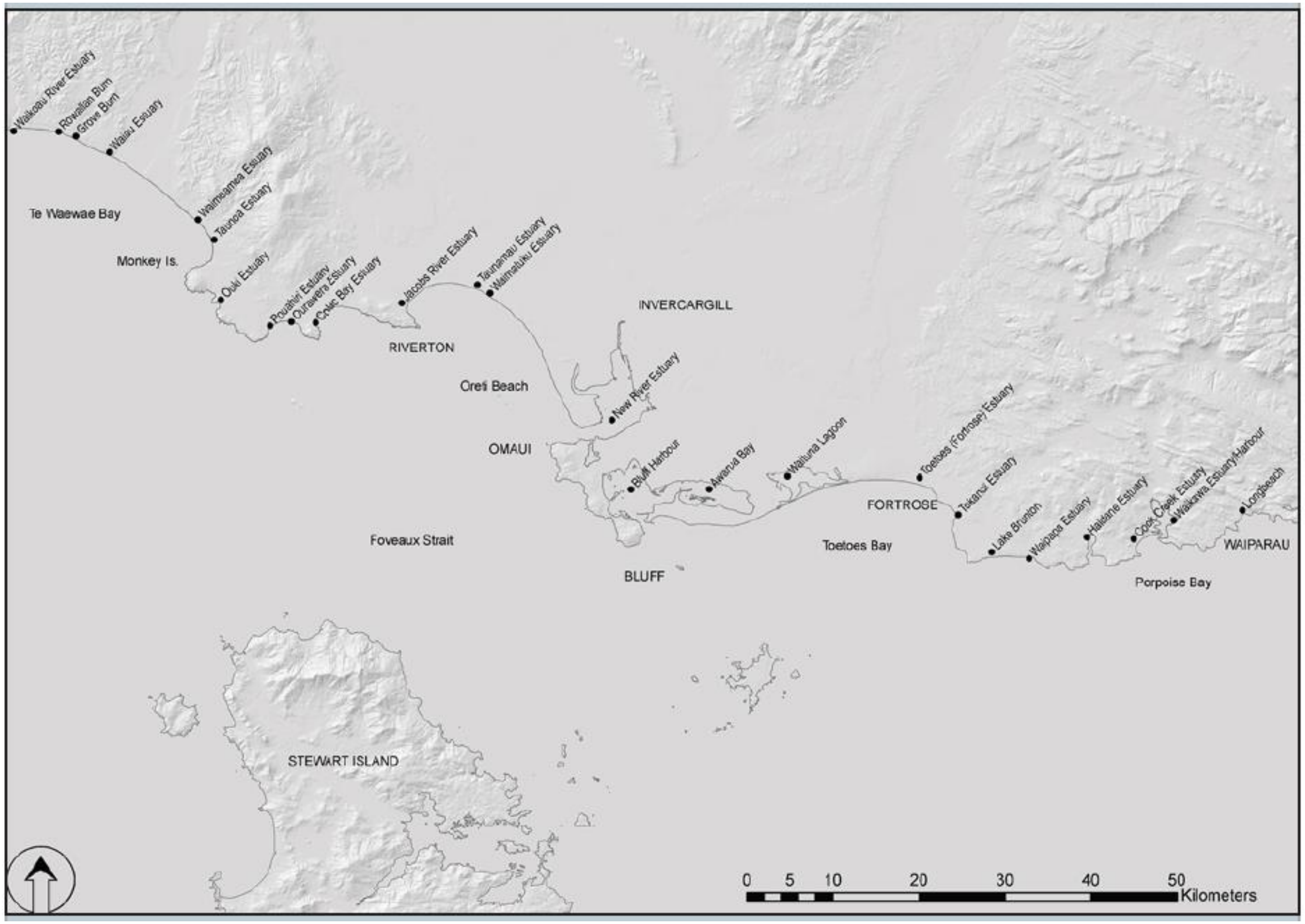
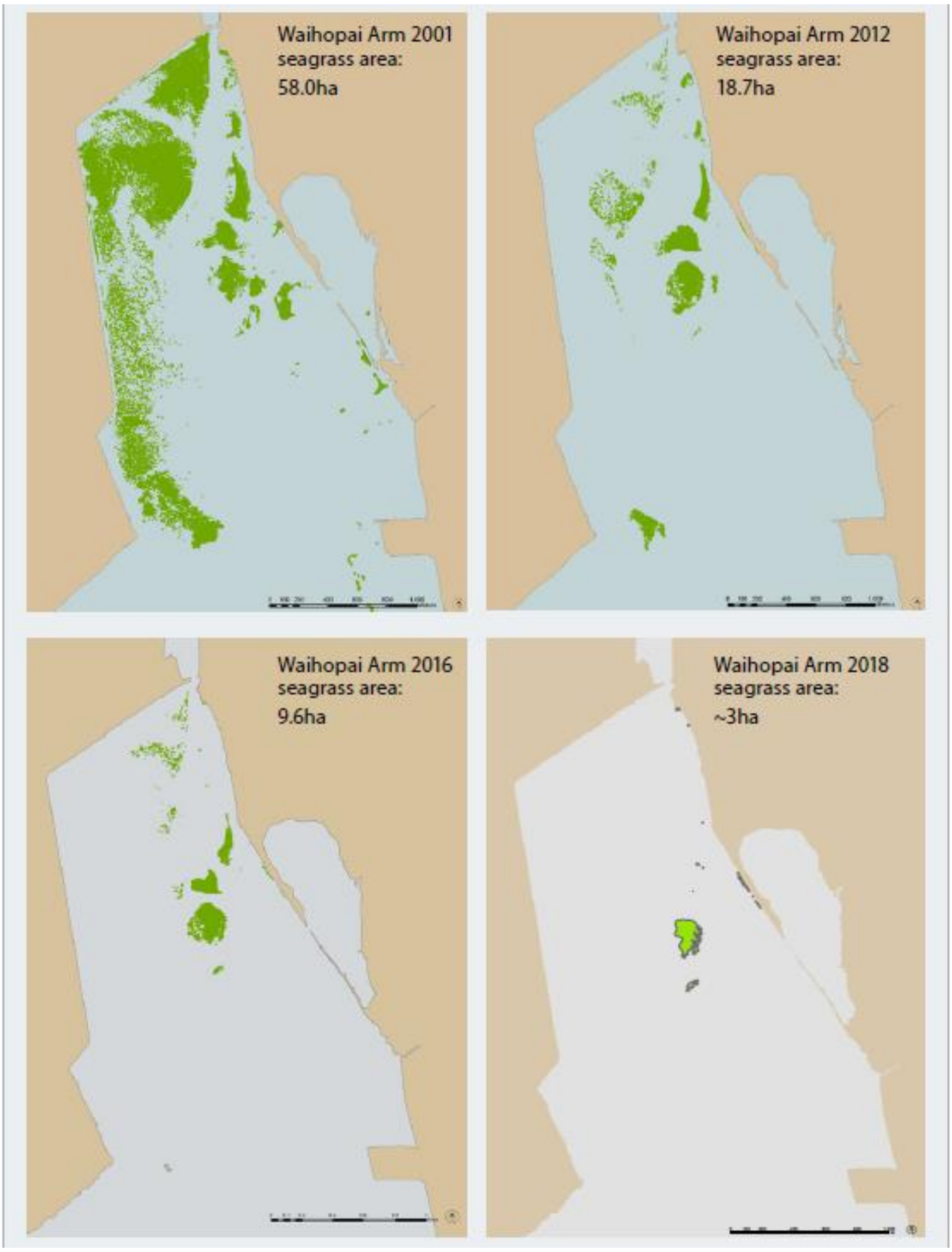
Appendix B

Figure 1. Map of Southland Estuaries. From Robertson & Stevens 2008. Note Waiau has been labelled as an estuary on the map but is classed as a lagoon for this evidence.



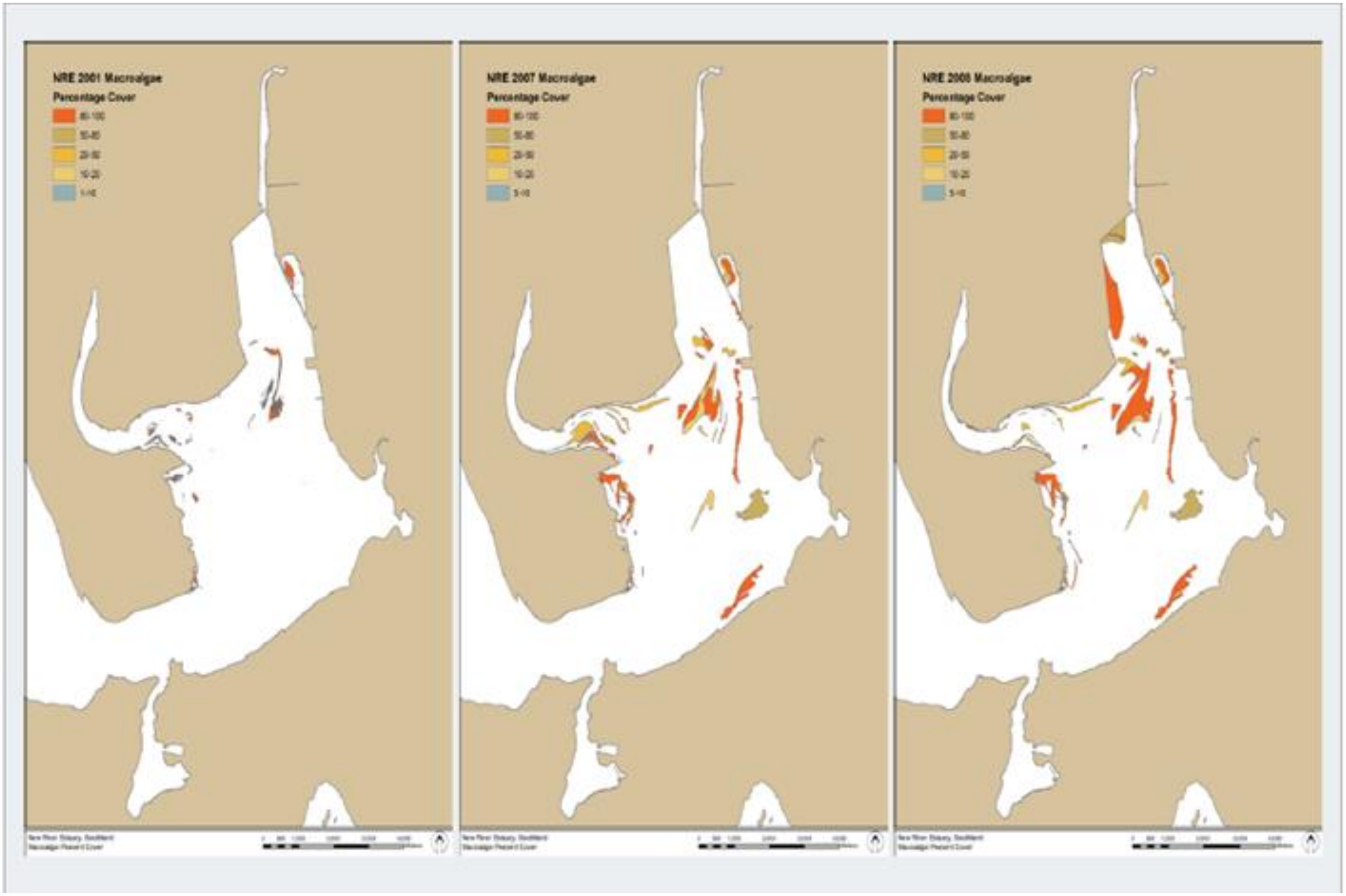
Appendix C

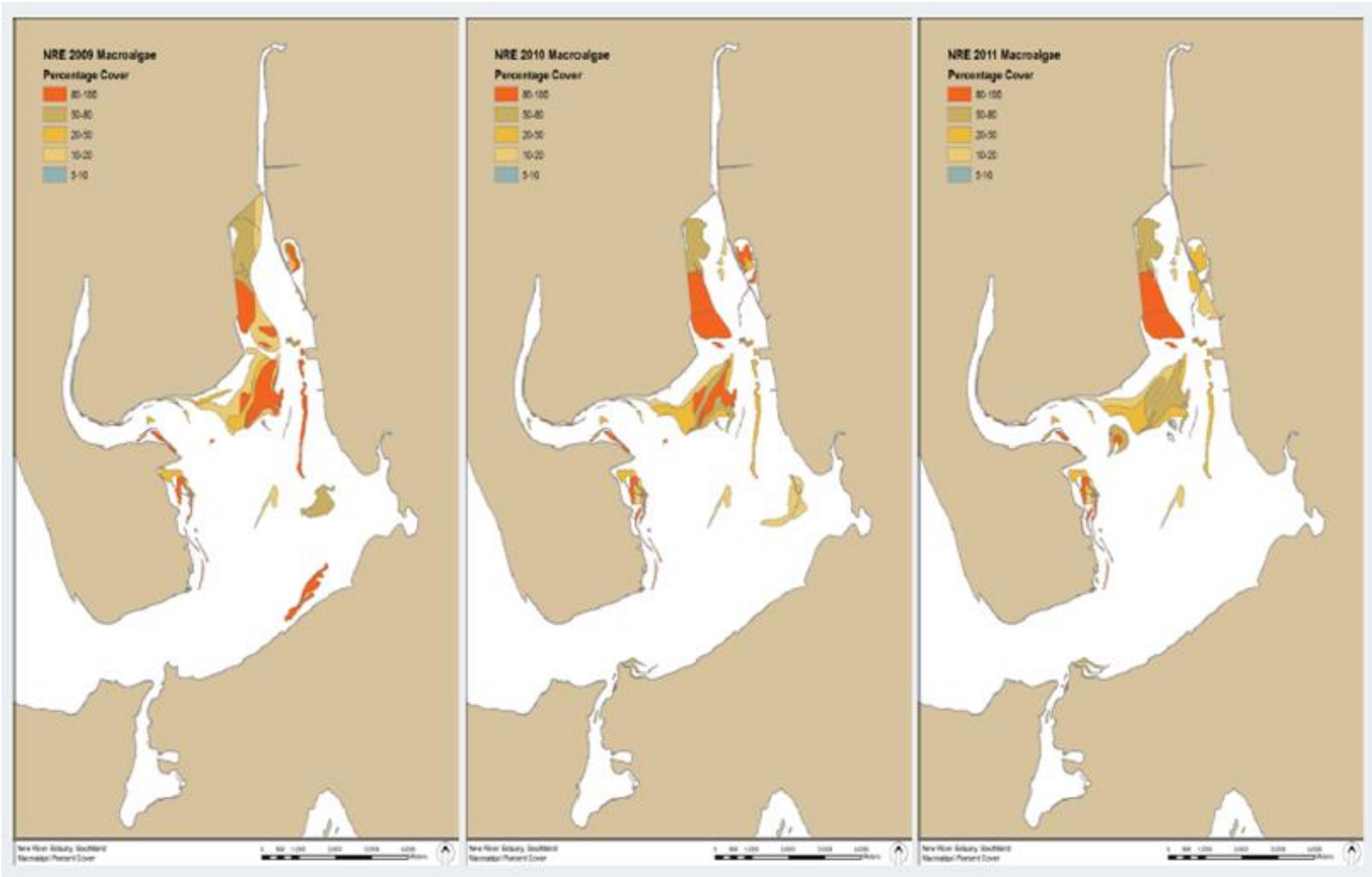
Figure 2. Changes in seagrass cover (>50% density) in Waihopai Arm, New River Estuary, 2001, 2012, 2016 2018. From Stevens 2018.

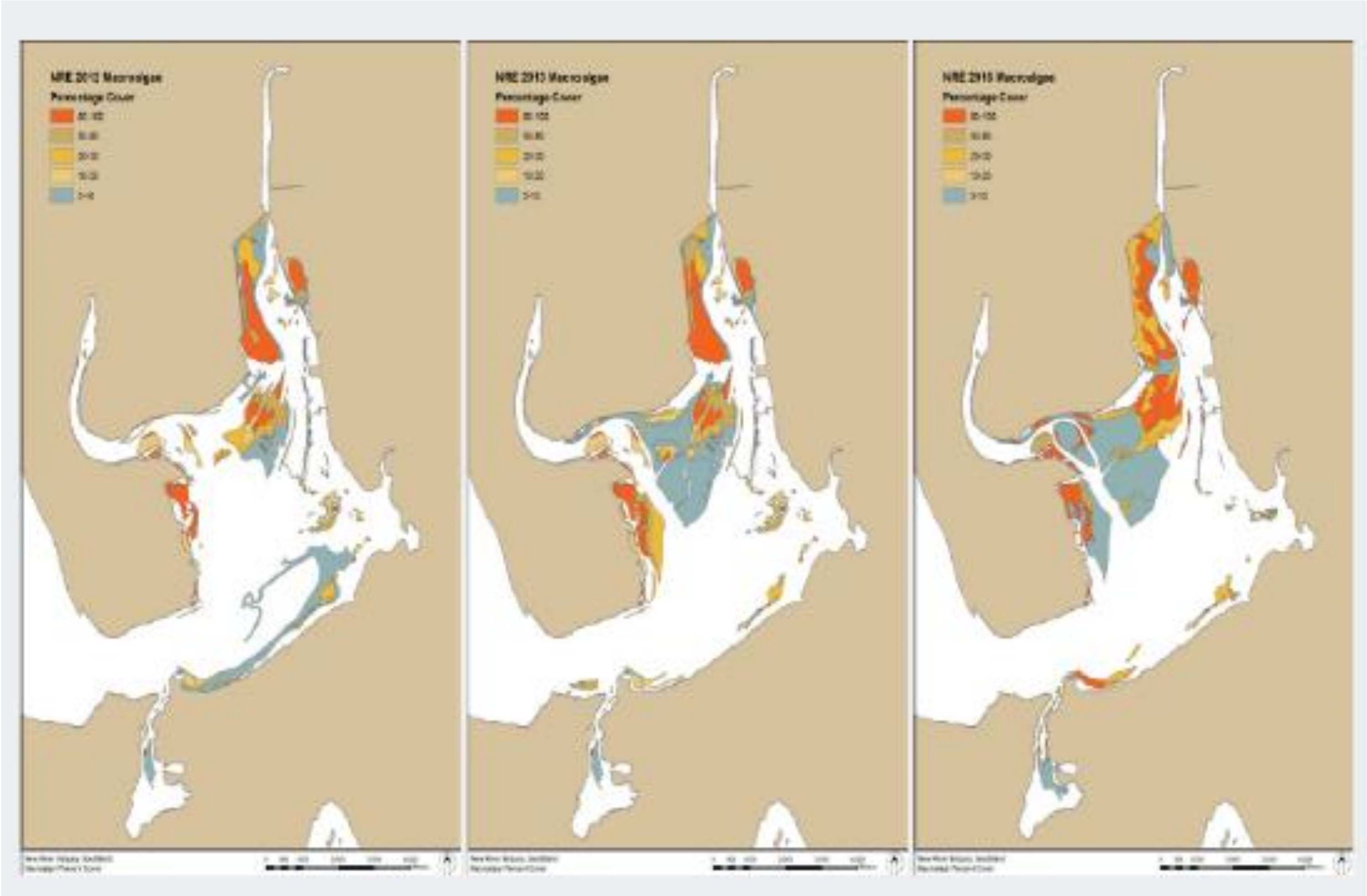


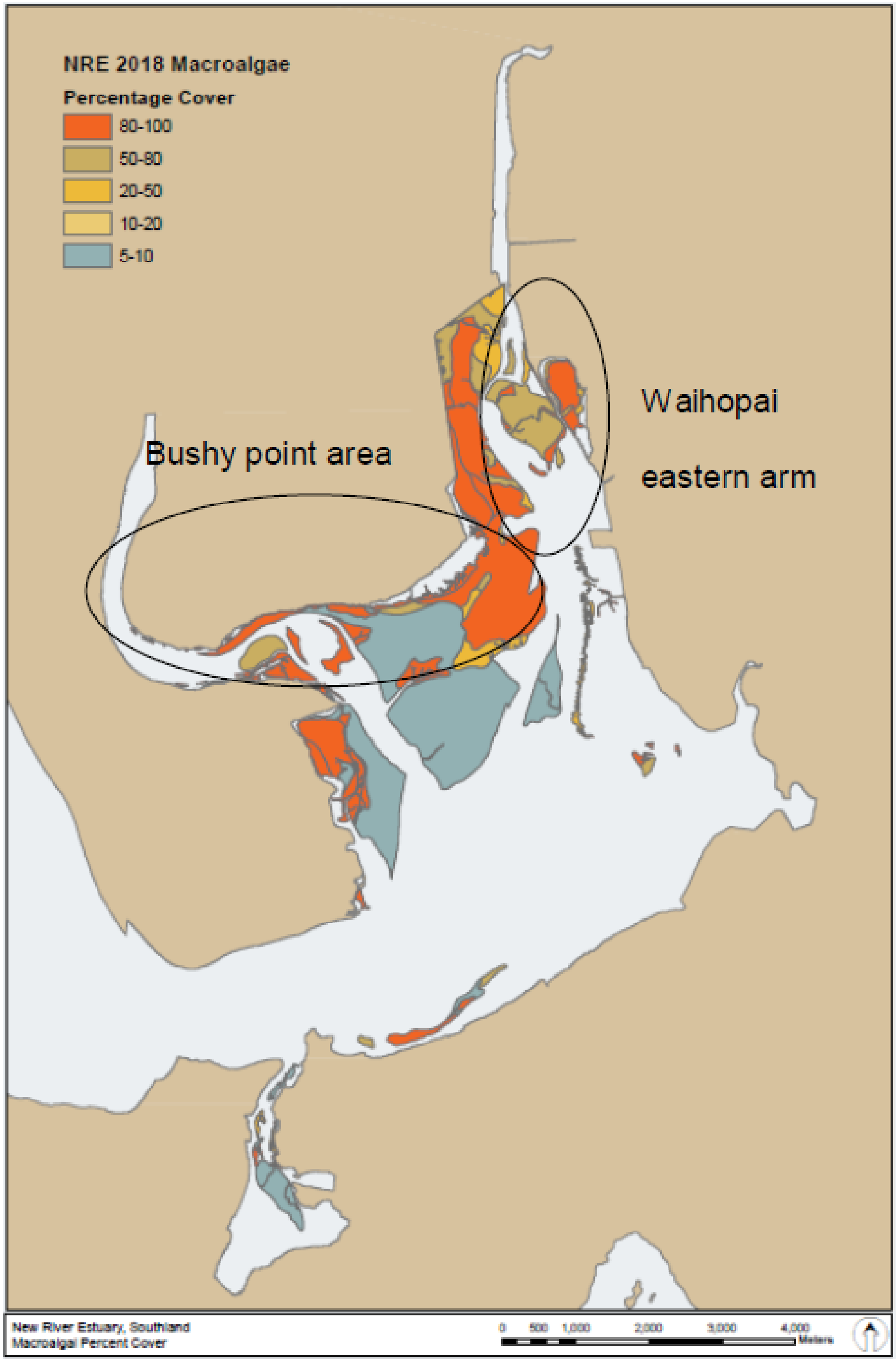
Appendix D

Figure 3. Macroalgal percentage cover in New River estuary Feb 2001, 2007,2008, 2009, 2010,2011,2012,2013,2016,2018. From Stevens 2018. Note areas highlighted.



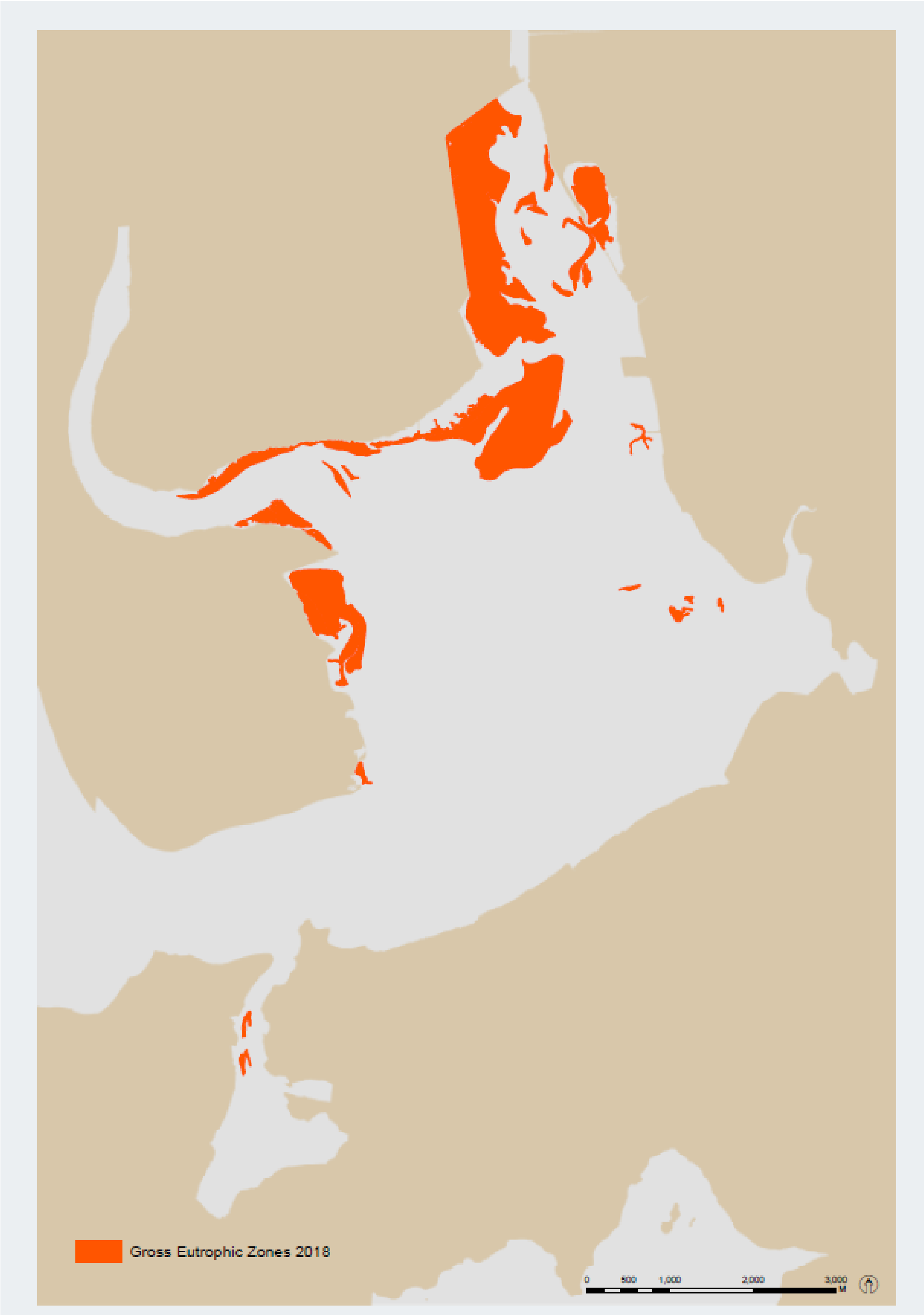

NRE 2009 Macroalgae
Percentage Cover
80-100
50-80
20-50
10-20
5-10
NRE 2010 Macroalgae
Percentage Cover
80-100
50-80
20-50
10-20
5-10
NRE 2011 Macroalgae
Percentage Cover
80-100
50-80
20-50
10-20
5-10




NRE 2018 Macroalgae
Percentage Cover
80-100
50-80
20-50
10-20
5-10
Bushy point area
Waihopai
eastern arm
New River Estuary, Southland
Macroalgal Percent Cover
0 500 1,000 2,000 3,000 4,000
Meters

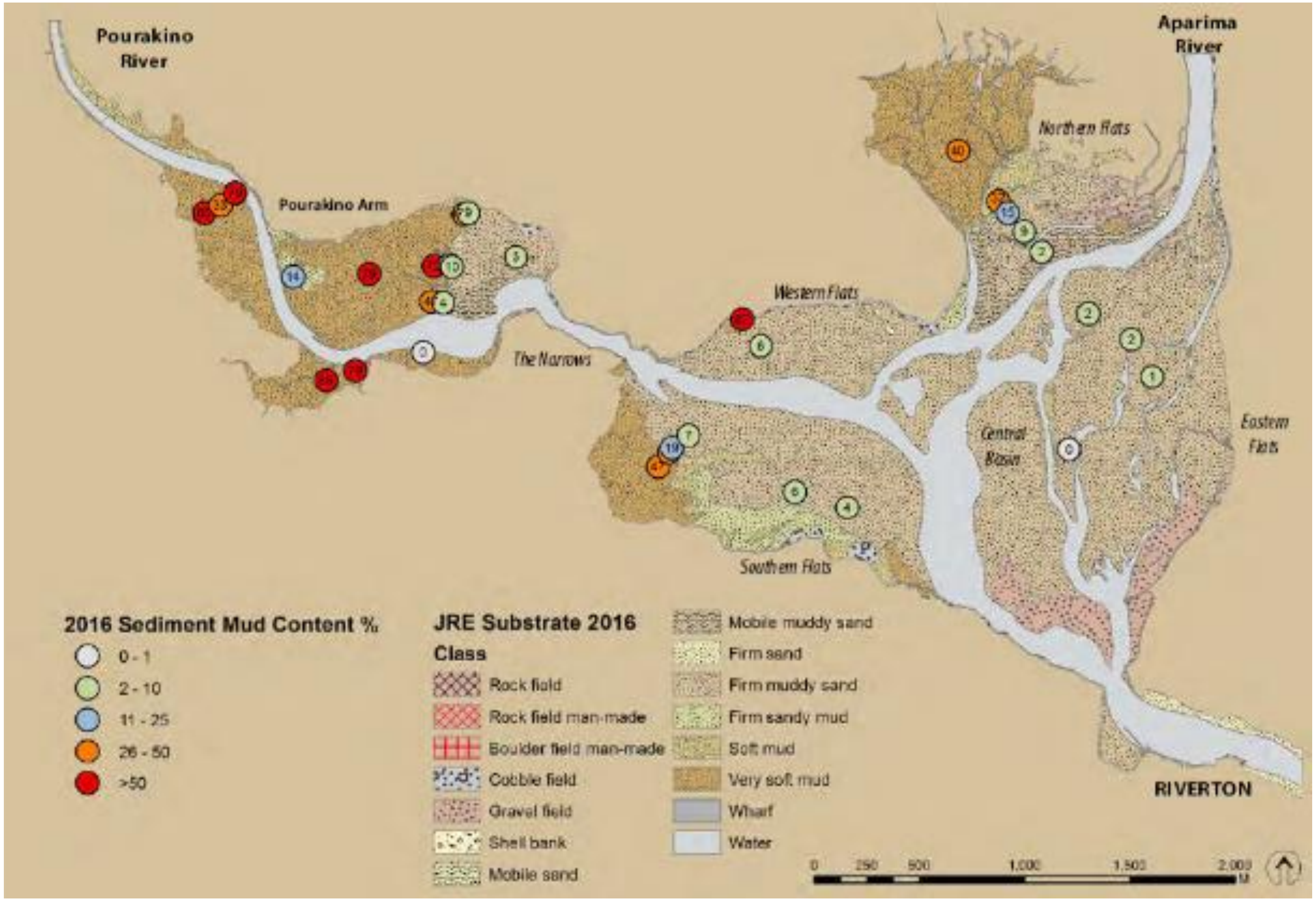
Appendix E

Figure 4. Gross eutrophic areas in New River estuary (Stevens 2018).



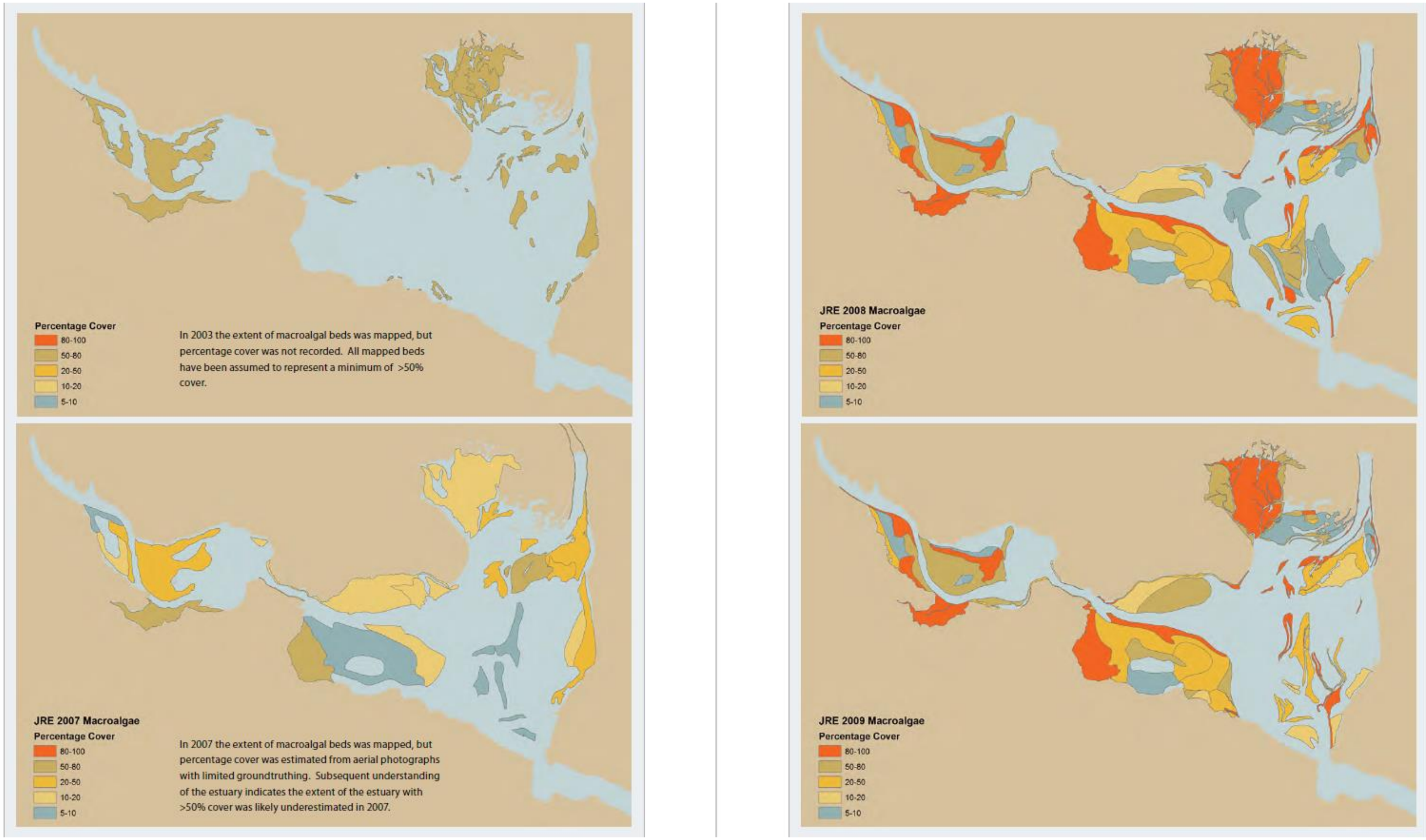
Appendix F

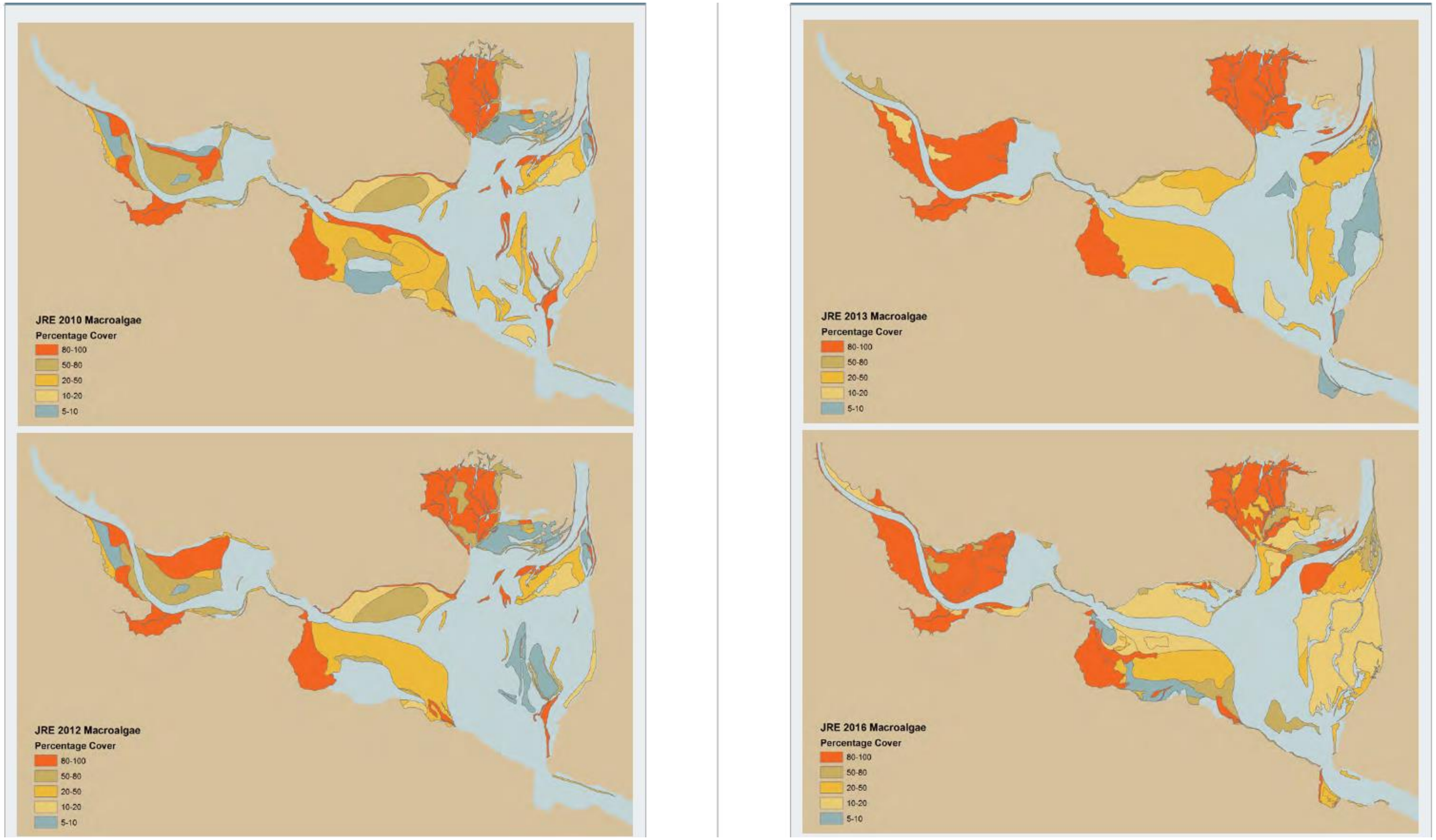
Figure 5. Jacobs River estuary with areas of dominating substrate type and mud content measures.



Appendix G

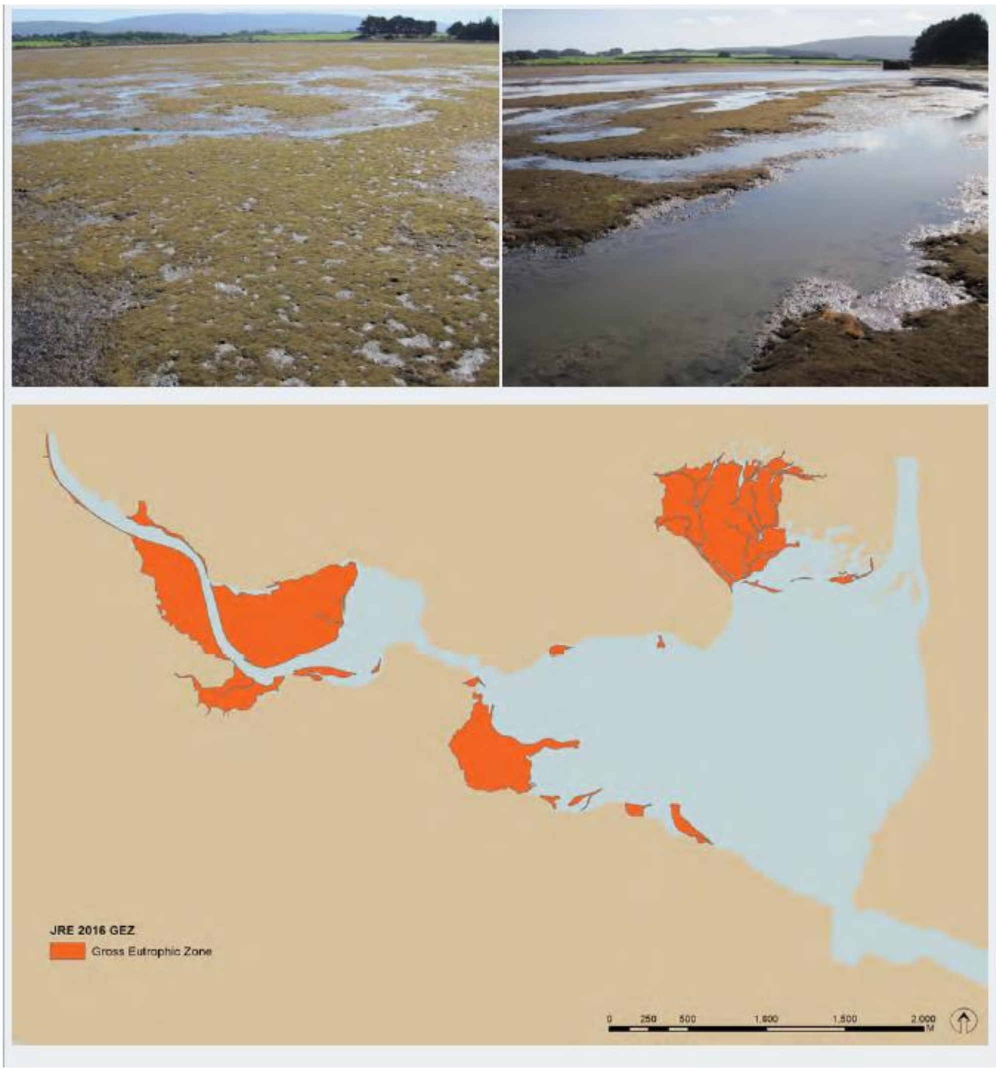
Figure 6. macroalgal cover for Jacobs River Estuary 2003-2016. From Robertson et al. 2017




JRE 2010 Macroalgae
Percentage Cover
80-100
50-80
20-50
10-20
5-10
JRE 2012 Macroalgae
Percentage Cover
80-100
50-80
20-50
10-20
5-10
JRE 2013 Macroalgae
Percentage Cover
80-100
50-80
20-50
10-20
5-10
JRE 2016 Macroalgae
Percentage Cover
80-100
50-80
20-50
10-20
5-10

Appendix H

Figure 7. Location and extent of gross eutrohic zones in Jacobs River Estuary 2016. From Robertson et al. 2017



Appendix I

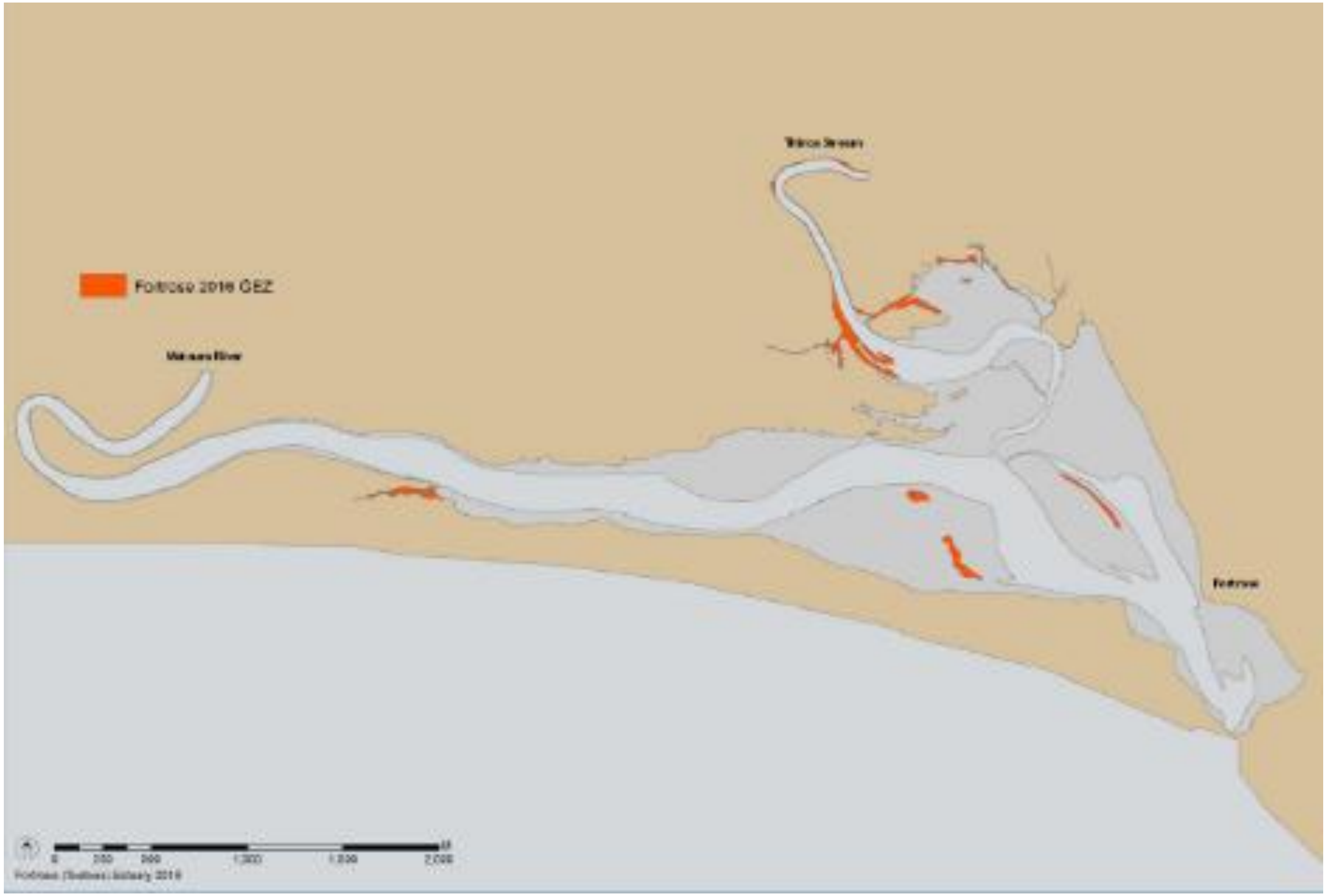
Figure 8. Location and extent of gross eutrophic zones in Waikawa estuary 2016. From Robertson et al. 2017

Appendix J

Figure 9. Substrate map for Toetoes (Fortrose) Estuary 2016. From Stevens and Robertson 2017.

Appendix K

Figure 10. Gross eutrophic areas in Toetoes (Fortrose) Estuary 2016. From Stevens and Robertson 2017.



Appendix L

Figure 11. A map depicting the location of the main lakes in Southland that are monitored. Lake Murihiku is located North West of Waituna Lagoon.