NIWA
Taihoro Nukurangi

Macrophyte monitoring in Waituna Lagoon - Summer 2015

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Surface reaching Ruppia beds in Waituna Lagoon. [Aleki Taumoepeau, NIWA]

Contents

Tables

Figures

1 Introduction

Waituna Lagoon is a highly valued coastal lagoon forming part of the Awarua complex. It is significant because of the important diverse habitats in the area that support a wide range of fauna. It is a nationally significant natural feature and landscape. Waituna lagoon provides important habitat for waterfowl, migratory birds, coastal birds and native fish. Over 81 species of birds have been recorded in the area, including paradise shelduck, grey duck, black swan and shoveler, and is an important safe moulting area for large numbers of these waterfowl. The Waituna catchment contains marine, estuarine and freshwater fish species. These include a national stronghold for the threatened giant kokopu as well as inanga, short fin eels and the threatened long fin eel (Atkinson 2008).

It is a place of great significance to Ngai Tahu and was traditionally an important mahika kai area. The lagoon has high aesthetic and recreational values, including fishing and duck hunting.

In 1976 the Waituna lagoon was our first wetland to gain Ramsar registration. The Ramsar Convention is an intergovernmental treaty aimed to halt and where possible reverse damage to wetlands. Wetlands accepted for registration need to meet very high standards and participating governments agree to accept their obligation to protect and manage them. The Department of Conservation administers the Convention in New Zealand but needs support as it has no control over land use practices in much of the catchment.

The catchment was mostly wetland, but early on was drained for pastoral sheep farming. Much has now been converted to dairying and most recently this activity has been intensifying with consequential downstream effects on sedimentation, nutrient levels, water clarity and water levels. The lagoon is fed by three lowland streams that flow through agricultural pastures. There is no permanent natural outlet to the sea. Artificially managing the opening of the lagoon to the sea has been of benefit to low lying farmland that is subsiding as drained peat mineralizes. Openings now occur artificially when the lagoon level is above 2.2 meters above sea level (m.a.s.l.) and sea conditions are suitable, however, closing occurs naturally. The lagoon is a freshwater environment when closed and becomes estuarine when open. Increased land-use intensification in the catchment has resulted in a decline in water quality, in particular increased ammonium and phosphorus concentrations entering the lagoon (LTG 2013). Waituna Lagoon is described as being in a eutrophic state based on the Trophic Level Index, a measure of the life supporting capacity of a lake or lagoon (LTG 2013). This means that the lagoon now has high nutrients, high phytoplankton biomass and poor water quality. Increased nutrient run-off has been linked to increased phytoplankton biomass and turbidity in the lagoon, which poses a threat to the macrophyte beds.

Waituna Lagoon has historically been a macrophyte dominated system. Dense beds of *Ruppia* sp. were present in the lagoon in the 1960's (Johnson and Partridge 1998). Dominant beds of *Ruppia megacarpa* (horse's mane weed) along with *Myriophyllum triphyllum* (milfoil) were present throughout the lagoon, particularly in deeper water as late as 1995 (Johnson and Partridge 1998). However, in recent years, macrophyte monitoring has shown that the *Ruppia* spp. dynamics in the lagoon appear to be very responsive to the status of the lagoon mouth. When the lagoon remains open during the growth period, beds are lost, either through desiccation of sites or through increased pressure from wave action or grazing birds as a result of lowered water levels (Sutherland et al. 2014). Increased salinity during prolonged openings during the growth period was also associated with a shift in productivity in the *Ruppia* spp. beds (Robertson and Funnell 2012). Prolonged lagoon openings during the growth period in recent years (2012-2013, 2013-2014) resulted in major loss of *Ruppia* spp. beds throughout the lagoon (see Sutherland et al. 2013, Sutherland et al. 2014 for details). Understanding the trade-off between improved water quality during lagoon opening and protecting the *Ruppia* spp. habitat is pivotal in management decisions regarding the likely impact of opening events on the ecological character of Waituna Lagoon (Robertson and Funnell 2012).

The current trophic level of the lagoon coupled with increased land-use intensification in the catchment as well as loss of macrophyte beds during summer-time lagoon openings, has raised concern over the potential for the lagoon to switch from a macrophyte dominated to an algal dominated state. A macrophyte dominated state typically has high values for biodiversity, aesthetic, recreational and tourist values and is usually considered to be the desired state. In contrast, an algal dominated state can often lead to decreased values and increased risk of toxic blooms. The process by which a lagoon moves from one state to the next can be quite rapid and is termed “flipping”. Once a lagoon flips from macrophyte dominated to algal dominated it is often difficult or impossible to reverse so it enters a new stable state – an algal dominated lagoon without submerged macrophytes.

Department of Conservation (DOC), as part of their responsibility for managing the lagoon under their biodiversity conservation role, initiated macrophyte surveys in Waituna Lagoon in 2007. The purpose of these surveys is to better understand the dynamics of the macrophyte community in relation to present day water quality and to assess changes in the community over time. The surveys have been undertaken at least annually since 2009. DOC commissioned NIWA to undertake the 2015 summer-time macrophyte survey to document the status of the lagoon vegetation using the methodology used by Robertson and Stevens (2009) and Stevens and Robertson (2010) and to provide an inter-annual comparison of its condition. This report summarises the results of the 2015 annual summer-time survey.

2 Methods

The methodology used during these surveys was developed by Robertson and Stevens (2009) and Stevens and Robertson (2010) and has remained consistent over the course of the annual surveys to date. As the methodology is not entire in either report, the reader is directed to both reports for background to the methodology used.

2.1 Survey sites

A total of forty seven[1] sites situated on ten transects (orientated north-south) were surveyed across Waituna Lagoon (Figure 2-1). The sites were established in 2009 by Robertson and Stevens (2009) and are positioned in locations designed to represent both the shallow and deeper water habitats of the lagoon, with additional sites established on longer transects to improve spatial cover.

Easting and Northing co-ordinates (NZ map grid) of the survey sites are in Appendix A.

Figure 2-1: Geo-referenced survey sites located in Waituna Lagoon. Transects are numbered 1 to 10 from East to West and numbered on each transect in ascending order from North to South.

2.2 Survey methodology

2.2.1 Macrophyte and macroalgae

At each site, 4 replicate samples 15 x 15 cm and 6 cm deep were cut from the sediment, using a flat based garden hoe, and carefully lifted to the surface. Each replicate was then assessed for:

- Macrophyte and / or macroalgae species present.

[1] Site T8-9 could not be sampled as it is now located within the barrier spit following migration of sediment during the last lake closing.

- Cover score[2] of each species present.
- Mean height of each species present.
- Life stage[3] of *Ruppia* spp. (where applicable).

In addition to the spot surveys, at each of the survey sites extended macrophyte observations were made within a circular area of 10 m diameter by snorkel / SCUBA diver where the bottom could not be viewed from the surface. The maximum and average cover scores and the average height were recorded for each macrophyte species present. Full results are detailed in Appendices B and C.

2.2.2 Water quality and sediment parameters

Water quality and clarity and well as sediment parameters were measured at each site (Appendix D). Water quality parameters were measured using a calibrated Horiba multi-sensor meter. The parameters measured were:

- Temperature
- Dissolved oxygen
- Salinity
- Turbidity
- Black disc measurements (as a proxy for Secchi depth)
- Sediment type
- Depth to blackened sulphide layer

2.3 Timing

The annual survey was carried out between 16 and 19 February 2015.

2.4 Analysis

Data analysis follows Robertson and Funnell (2012). Frequency of occurrence of key macrophytes and macroalgae was compared based on data from previous surveys (Robertson and Stevens 2009, Stevens and Robertson 2010, Sutherland and Taumoepeau 2011, Sutherland and Taumoepeau 2012, Sutherland et al. 2013, Sutherland et al. 2014).

Water quality for the 2014/2015 year was summarised across the key growing season for macrophytes (1 August to 31st March) as defined by Robertson and Funnell (2012). Source data was obtained from Environment Southland from both a long term monitoring site, and also a recently installed (mid 2012) 'monitoring platform'.

[2] The cover scores are based on the categories established by Robertson and Stevens (2009). These cover scores were 1 = 1-5%, 2 = 5-10%, 3 = 10-20%, 4 = 20-50%, 5 = 50=80%, 6 = 80-100%.

[3] Life stage categories were V = vegetative, F = flowering, PF = post flowering.

3 Results

3.1 Macrophyte and macroalgae

The species present, macrophyte bed height, percent cover of vegetation and vegetative stage of the macrophytes as well as the species and percent cover of macroalgae, recorded for each site are listed in Appendix B.

Macrophytes were recorded on 32 of the 47 sites sampled in the lagoon during the February 2015 survey. This was 3.5 times the number of sites recorded with macrophyte cover in January 2014 and nearly twice as many sites as February 2013. *Ruppia polycarpa* was the most frequently occurring species throughout the lagoon, occurring on 67% of vegetated sites, followed by *Lamprothamnium macropogon* (21%) and *Myriophyllum triphyllum* (10%; Figure 3-1). The percent cover of *R. polycarpa* varied across the lagoon, with most cover recorded in the 1-25% cover class, followed by the 26-50% cover class (Figure 3-2). Both the frequency of occurrence and the percent cover of *Ruppia macrocarpa* was low across the lagoon, with the species absent at 82% of sites surveyed (Figure 3-2).

Macrophyte bed height ranged from 5 – 175 cm with a mean height of 40 (± 37) cm across the lagoon. Some of the tallest macrophyte beds were recorded since monitoring began, with the taller beds typically occurring on the western side of the lagoon (see Appendix B). The taller beds also supported macrophytes during the 2013-2014 growth period (see Sutherland et al. 2014).

The frequency of occurrence of macrophyte beds observed in a 10 m diameter circle was higher than that observed with spot sampling (Figure 3-3). There was an increase in the average percent cover of macrophytes recorded with the extended macrophyte survey (10 m circle) with a greater frequency of occurrence in the all three cover classes above 25%, at the expense of the categories of 1-25% and 'not present' relative to the spot sampling (Figure 3-3).

The frequency of occurrence of macroalgae was high across the lagoon, with freshwater filamentous green algae occurring on 83% of sites and *Ulva intestinales* occurring on 25% of sites (Figure 3-1). The freshwater filamentous green algae was comprised of *Cladophora* sp (co-dominant), Spirogyra sp. (co-dominant), *Zygnema* sp. and *Mougeotia* sp. Filamentous green algae were found occurring loosely attached to macrophytes, on the sediment and along the shoreline vegetation (Figure 3-4). The percent cover of filamentous green algae ranged from 2 – 100% with a mean cover score of 57 (±35) % across the lagoon. The marine species *Bachelotia antillarum* was not observed in the lagoon during the February 2015 survey.

Ruppia spp. was in the flowering stage at 69% of the sites where plants were recorded (see Appendix B). During the 2013-2014 summer survey, *Ruppia* spp. was flowering at only 22% of sites where plants were recorded.

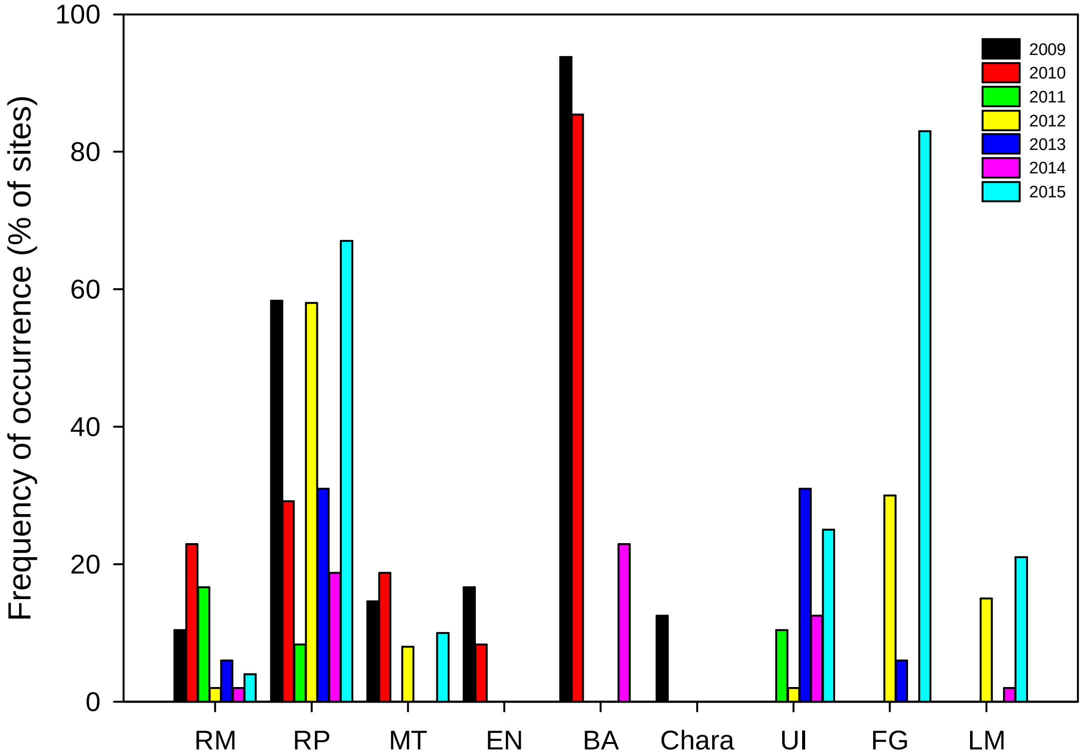

Figure 3-1: Frequency of occurrence of macrophytes and macroalgae in Waituna Lagoon between 2009 and 2015. RM= *Ruppia megacarpa*, RP = *Ruppia polycarpa*, MT= *Myriophyllum triphyllum*, EN = *Entromorpha* sp., BA = *Bachelotia antillarum*, Chara = Charophyte undefined, UI = *Ulva intestinales*, FG = Filamentous green algae, LM = *Lamprothamnium macropogon*.

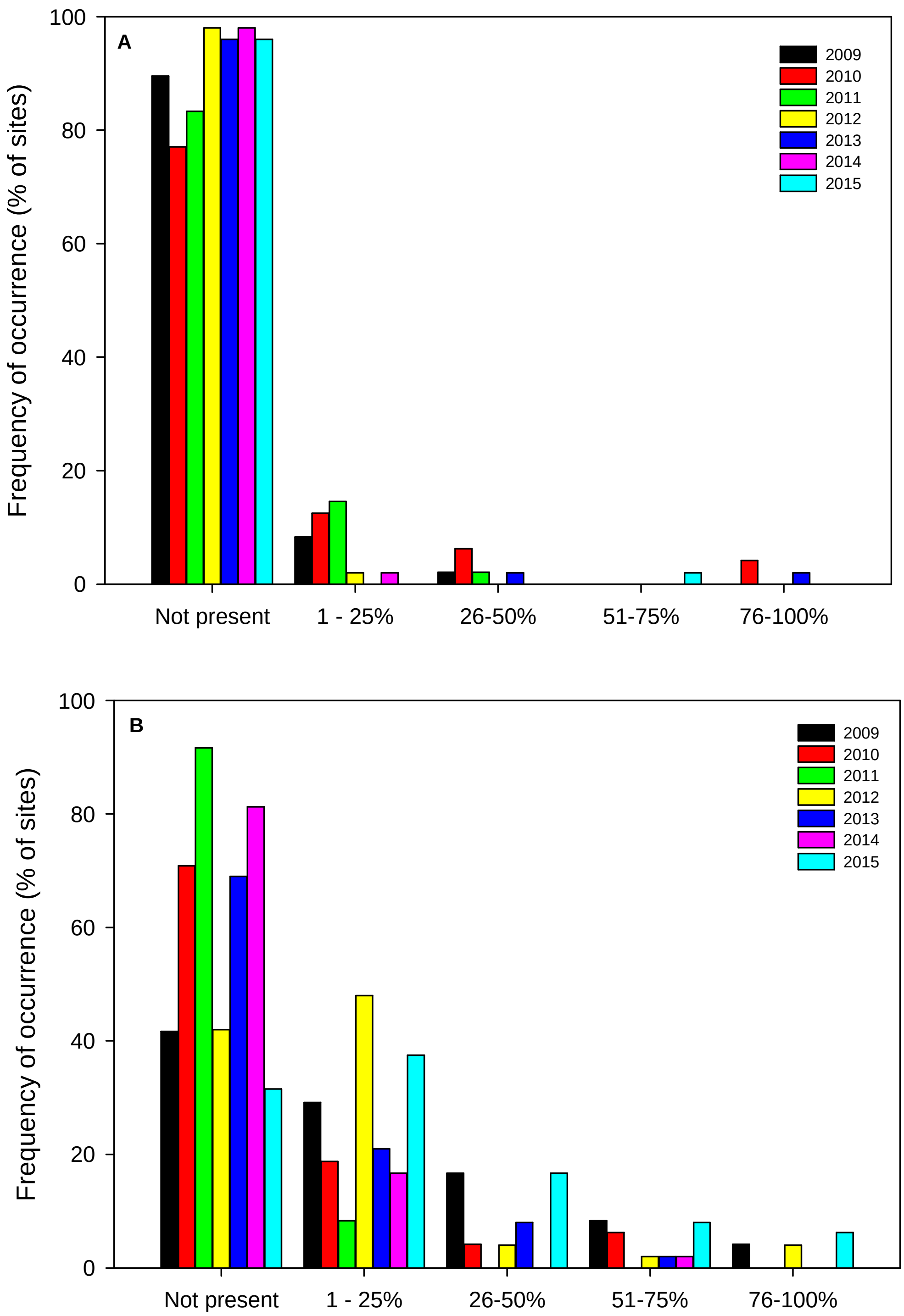

Figure 3-2: Frequency of occurrence of A) *Ruppia megacarpa* and B) *Ruppia polycarpa* across the cover abundance classes from 2009 to 2015.

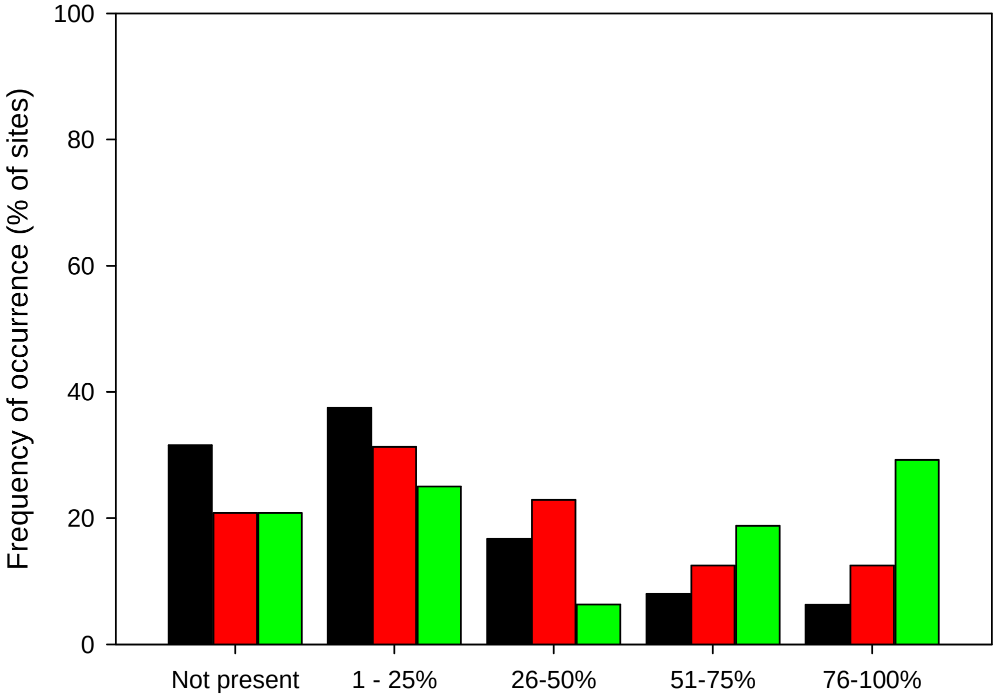

Figure 3-3: Frequency of occurrence of *Ruppia polycarpa* in each cover abundance class as recorded by spot sampling and extended observations (10m diameter). Spot sampling indicated by black bars, and extended observations average cover indicated by red bars and maximum cover indicated by green bars.

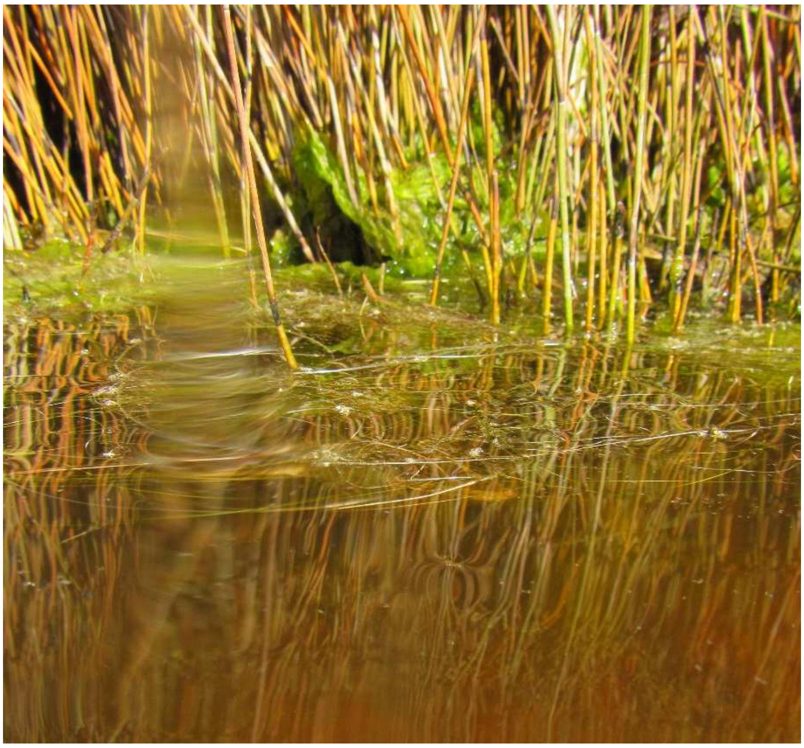

Figure 3-4: Accumulation of *Spirogyra* sp. dominated filamentous green algae along the shoreline of Waituna Lagoon.

3.2 Water quality

3.2.1 Water depth

During the 2014-15 growth season (defined as 1 August to 31 March; Robertson and Funnell 2012) the median water depth recorded at the Environment Southland monitoring station in Waituna Lagoon was 1.37 m.a.s.l. This was 2.6 times higher than the median water level during the 2013-14 growth season and was 1/3 higher than the water depth of the 2010-11 and 2011-12 growth seasons.

3.2.2 Substrate type

As with previous years, sand and gravel were the two dominant substrates across all sites in Waituna Lagoon. Sites on the western side of the lagoon were typically characterised by sand / mud while sites on the eastern side were characterised by gravel / sand. There was an increase in the dominance of soft mud at all sites on transect 6, while substrate type at all other sites remained similar to previous surveys.

[See Appendix D for substrate type categories recorded at 47 sites during the February 2015 survey].

3.2.3 Sediment health

46% of the sites surveyed did not contain a visible blackened layer within the sampled sediment (> 4cm). For the remaining sites, a blackened layer was observed at the surface on 8% of sites, between 0 – 2 cm on 24% of sites and between 2-4 cm on 22% of survey sites (Figure 3-5). For sites with a blackened layer, the greatest frequency of occurrence (>0-2cm) was consistent with previous years (Figure 3-5). While there appears to be more sites where a blackened layer was not observed in the first 4 cm (> 4cm sediment depth) relative to previous surveys, this result must be viewed with caution as a number of these sites were classified as “not recorded” in 2012 and 2014 due to the sites being dry.

[See Appendix D for depth of blackened sediment layer recorded at 47 sites during the February 2015 survey].

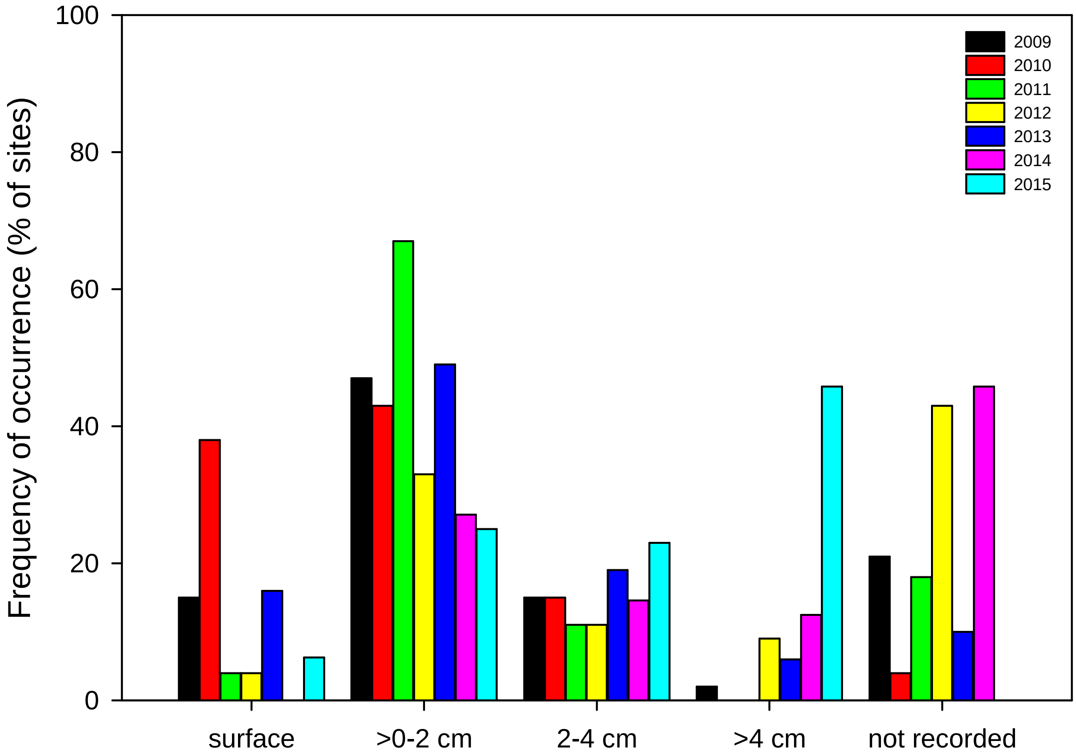

Figure 3-5: Frequency of occurrence of blackened sediment on all submerged sites between 2009 and 2015 using depth classes.

3.2.4 Dissolved oxygen

Over the course of the growth season, dissolved oxygen (DO) concentrations in the surface water ranged from 80 – 135%, with a median value of 97 % (± 6%). DO concentrations in the bottom water was more variable, ranging from 8 – 119 %, with a median value of 98 % (± 8). During the course of the February 2015 survey, surface DO concentrations ranged from 81 – 141 %, with a median value of 110%. For the bottom waters, DO concentrations ranged from 37 – 162%, with a median value of 114%. Only 1 surface water value (T6-1 = 81%) and 3 bottom water values (T1-1 = 37%, T4-1 = 89%, T6-1 = 80%) were below the 90% threshold adopted by management agencies for many New Zealand waterbodies. For the majority of sites, DO in the bottom waters was similar to, or slightly higher than, the surface waters, while only 28% of sites exhibited slight DO stratification. Overall, the lagoon was well aerated across all sites during the summer survey.

[See Appendix D for dissolved oxygen concentrations recorded in surface and bottom waters at 47 sites during the February 2015 survey].

3.2.5 Water clarity

Black disc measurements ranged from 0.56 to 2.12 m across the lagoon, giving an equivalent Secchi depth (SD) range of 0.75 to 2.83 m, with a median SD of 1.67 m (as per conversion protocol in Davis-Colley 1994). SD was greater than the depth of the water column at 32 out of the 47 sites surveys. Water clarity in the lagoon was greater during the 2015 survey than previous surveys, with the lagoon wide median SD approximately 0.5 m higher than 2013 and 2014.

Light attenuation (K_d) through tannin stained water columns can be approximated from SD by the equation (Davis-Colley 1994):

$$K_d = \frac{3}{SD}$$

K_d allows the depth to which a specific proportion of surface irradiance penetrates to be estimated and consequences for macrophyte growth to be considered. In the case of *Ruppia* sp., a 10% light threshold has been shown to affect productivity, i.e. light levels in the water column that are < 10% will negatively affect the productivity of *Ruppia* spp. (Congdon and McComb 1979). The median depth of the water column where light is ~10% of surface irradiance was estimated to be 1.28 m, meaning that at the time of the survey 35 out of 47 sites were more shallow than the 10% irradiance depth limit. Based on the estimated attenuation of the water column at the time of the survey, the average light that macrophytes within the lagoon would have been exposed to was ~40% of surface irradiance.

[See Appendix D for black disc measurements recorded at 47 sites during the February 2015 survey].

3.2.6 Turbidity

Water column turbidity was low across the lagoon, ranging from 1 – 8 NTU in the surface waters and 1- 9 NTU in the bottom waters. Turbidity in the surface and bottom waters were similar to each other at all sites across the lagoon. In contrast, turbidity was considerably higher during 2014, however, this may have reflected wave induced sediment re-suspension during low lagoon water levels. Over the growth season, turbidity (as measured at the Environment Southland monitoring platform) ranged from 0 – 113 NTU, with a median value of 2.5 (± 12.3) NTU.

[See Appendix D for turbidity measurements recorded at 47 sites during the February 2015 survey].

3.2.7 Salinity

Salinity was low across the lagoon ranging from 1.4 to 2.4 ppt, with a lagoon-wide median salinity of 2.1 ppt. This is consistent with the lagoon being closed to the sea and receiving its inputs from freshwater sources. Salinity in the lagoon was similar to that recorded in 2012, when the lagoon was last closed during summer and contrasts with those recorded during 2013 and 2014 when the lagoon was open to the sea.

[See Appendix D for salinity measurements recorded at 47 sites during the February 2015 survey].

3.2.8 Temperature

At the time of the 2015 summer survey temperature ranged from 16.2 – 21. 7 °C (median = 18.5 °C ± 1.6) in the surface waters and from 15.2 – 21.6 °C (median = 18.0 °C ± 1.7) in the bottom waters across the lagoon. 27 out of 47 sites showed slight differences in temperature between the surface and bottom waters (ranging from 0.1 – 3 °C), with over half of these being < 0.5 °C difference.

[See Appendix D for temperature measurements recorded at 47 sites during the February 2015 survey].

3.3 Water quality over the key growing period of macrophytes

The lagoon was closed to the sea for the duration of the 2014-2015 growing period (243 days), which is defined as the period between 1 August and 31 March (Robertson and Funnell 2012). This contrasts with the previous two growth periods, where the lagoon was closed for 61 days (2012-

2013) and 0 days (2013-14), but is similar to the 2011-2012 growth period where the lagoon was closed for 228 days (Table 3-1).

Closure of the lagoon during the growth period resulted in high water levels and low salinity levels (Figure 3-6). This was in contrast to the two previous growth periods where salinity increased and water level decreased in response to opening of the lagoon (Figure 3-6).

Total nitrogen (TN) was significantly higher ($p < 0.01$) during the 2014-2015 growth period compared to 2013- 2014 when the lagoon was closed for the entire growth period, but did not differ significantly from 2012-2013 or 2011-2012 (Table 3-1). Nitrate, total phosphorus (TP) and dissolved reactive phosphorus concentrations did not differ significantly in 2014-2015 growth period compared to 2013-2014 (Table 3-1). Nutrient concentrations in the lagoon are responsive to the status of the lagoon mouth, with decreases in both TN and TP occurring as a result of flushing from the sea. Lower nutrient concentration seawater dilutes the higher nutrient freshwater in the lagoon. While TP did not differ significantly between 2013-2014 (open) and 2014-2015 (closed) significant differences in TP concentrations have occurred between closed and open status within a growth season (e.g. 2010-2011; Table 3-1).

Phytoplankton chlorophyll *a* (Chl-*a*) biomass across the lagoon varied from 0.4 – 20 $\mu g\ L^{-1}$, with a mean Chl-*a* of 5.3 (± 4.6) $\mu g\ L^{-1}$. Chl-*a* was significantly higher ($p < 0.05$) during the 2014-2015 growth period compared to 2013-2014 (Table 3-1). The trophic level index (TLI), an indicator of the health of a waterbody, is calculated using Chl-*a*, TN and TP values. The TLI for 2014-2015 growth period is calculated as TLI = 4.8, meaning that Waituna Lagoon was classified as eutrophic during this period, according to Burns et al. (1999). The 3-yearly average TLI for the lake during the growth period was TLI = 4.5 (eutrophic). During the 2013-2014 growth period when the lagoon was open, TLI = 3.6 (mesotrophic).

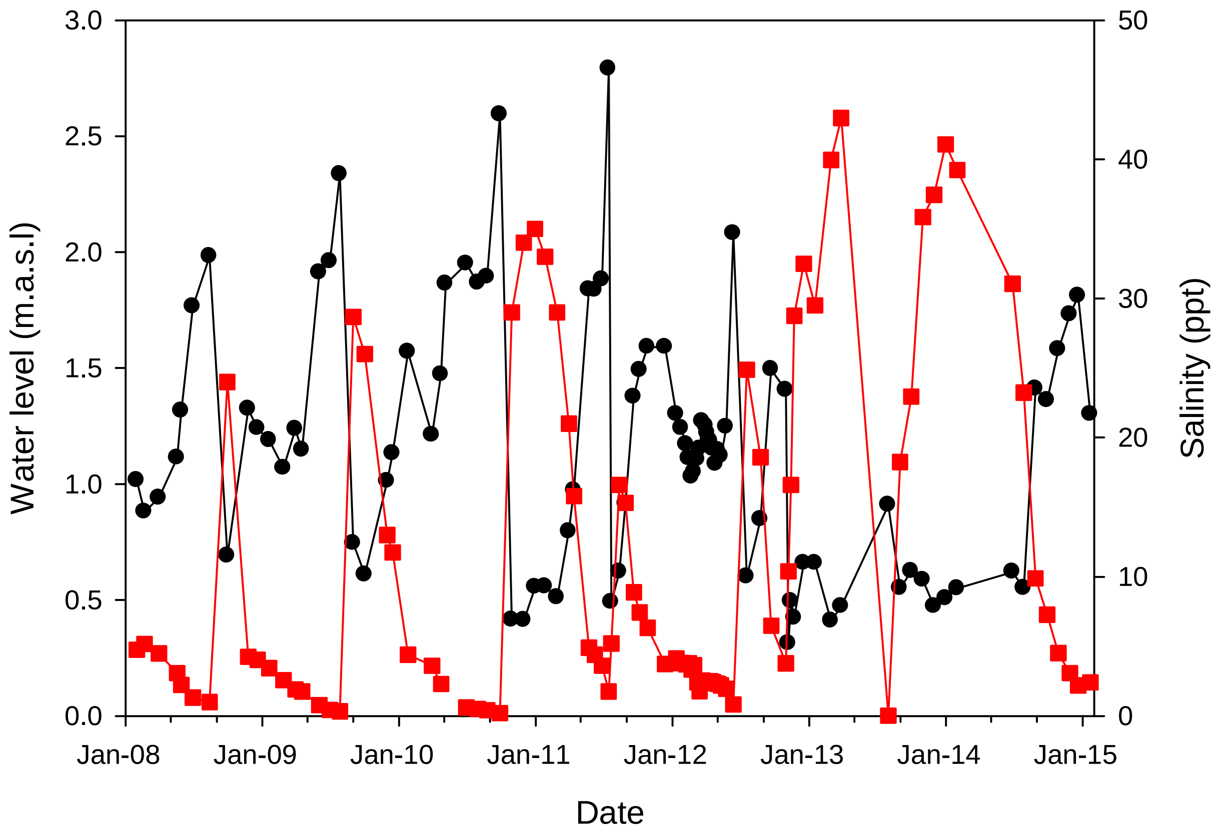

Figure 3-6: Variation in salinity (red line) in Waituna Lagoon between 2008 and 2015 relative to changes in water level (black line). Periodic increases in salinity correspond to lagoon opening events and intrusion of sea water.

Table 3-1: Summary of water quality (mean ± s.d.) in Waituna Lagoon during open and closed periods for the key macrophyte growing season (2008 - 2015). This is defined as the period between 1 August and 31 March. * data collected from Environment Southland's monitoring platform.

Variable	2008-2009		2009-2010		2010-2011		2011-2012		2012-2013		2013-2014		2014-2015	
	Open (n=1)	Closed (n=6)	Open (n=2)	Closed (n=4)	Open (n=6)	Closed (n=3)	Open (n=1)	Closed (n=1)	Open (n=2)	Closed (n=1)	Open (n=1)	Closed (n=0)	Open (n=0)	Closed (n=1)
Duration open / closed (% growing season)	18% (43 days)	82% (200 days)	26% (64 days)	74% (179 days)	74% (181 days)	26% (62 days)	6% (15 days)	94% (228 days)	75% (182 days)	25% (61 days)	100% (243 days)	0% (0 days)	0% (0 days)	100% (243 days)
Salinity (ppt)*	28.0	2.8 (0.5)	29.5 (3.5)	7.9 (2.4)	30.2 (2.1)	0.4 (0.1)	16.6	5.3	36.3 (6.8)	11.3	39.3 (6.9)	-	-	4.7 (3.9)
Turbidity (NTU)*	5.8	10.1 (2.0)	13.8 (10.2)	5.4 (1.0)	4.6 (1.3)	8.3 (2.7)	3.7	3.7	3.3 (2.1)	7.7	7.5 (9.1)	-	-	7.5 (12.3)
pH	8.0	7.5 (0.2)	7.85 (0.05)	7.8 (0.1)	8.0 (0.1)	7.5 (0.1)	7.5	8.1	8.0 (0.1)	7.5	8.0 (0.1)	-	-	7.7 (0.1)
Temperature (°C)*	9.6	14.7 (0.8)	10.7 (0.8)	15.0 (1.3)	15.8 (0.8)	7.43 (0.6)	6.3	14.4	14.1 (3.7)	10.0	13.8 (3.2)	-	-	12.2 (3.3)
Chl *a* (mg/L)	<0.01	0.01 (<0.01)	<0.01 (<0.01)	<0.01 (<0.01)	<0.01 (<0.01)	<0.01 (<0.01)	<0.01	<0.01	<0.01 (<0.01)	<0.01	0.0025 (0.0034)	-	-	0.0053 (0.0046)
TN (mg/L)	0.33	1.08 (0.21)	0.49 (0.14)	0.64 (0.18)	0.37 (0.09)	1.76 (0.01)	1.23	0.77	0.43 (0.3)	1.52	0.43 (0.3)	-	-	1.13 (0.31)
TP (mg/L)	0.03	0.26 (0.21)	0.07 (0.07)	0.05 (0.05)	0.06 (0.06)	0.91 (0.04)	0.02	0.03	0.03 (0.01)	0.05	0.01 (0.005)	-	-	0.04 (0.02)
NO_3 (mg/L)	0.03	0.05 (0.01)	0.06 (0.04)	0.03 (<0.01)	0.02 (<0.01)	0.06 (0.02)	0.9	0.11	0.08 (0.16)	0.75	0.10 (0.26)	-	-	0.47 (0.41)
DRP (mg/L)	<0.01	<0.01 (<0.01)	<0.01 (<0.01)	<0.01 (<0.01)	<0.01 (<0.01)	0.01 (<0.01)	<0.01	<0.01	0.01 (0.01)	0.01	0.004 (0.003)	-	-	0.007 (0.01)
TN:TP	17:1	22.1	8:1	21:1	19:1	29:1	62:1	26:1	14:1	30:1	43:1	-	-	28:1

4 Discussion

Ecological guidelines for Waituna Lagoon specifies a recommended target of > 30-60% cover of *Ruppia* spp. and other native macrophytes as a basis for an ecological health objective (LTG 2013). During the 2014-2015 growth season this target was just achieved with a 30% lagoon-wide macrophyte cover, despite many sites supporting cover > 50%. However, given that a number of sites that did not support macrophyte cover during the February 2015 survey had been un-vegetated over several surveys, re-colonisation of these sites, from either the seedbank or from fragment dispersal, may take some time. Competition for available light, nutrients and habitat with the filamentous green algae also likely restricted growth of the macrophyte beds.

The ecological guidelines recommend a winter opening regime that will allow a high chance of closing before summer (LTG 2013). Results from the annual surveys conducted over the last 5 years supports this recommendation with both the frequency of occurrence and the percent cover of *Ruppia* spp. beds responsive to the status of the lagoon mouth. The complete closure of the lagoon during the 2014-2015 growth period has been of positive benefit to the macrophyte community with the tallest macrophyte beds recorded along with the highest percentage of plants that were in the flowering / fruiting stage of growth since the start of monitoring. Flowering and fruiting are probably vital to ensure community persistence in the lagoon. Prolonged closure events during the growth period is likely to further enhance the expansion of macrophyte beds in the lagoon if this practice is continued.

High filamentous green algae as well as high phytoplankton Chl-*a* biomass is indicative of the degraded water quality in the lagoon during periods of closure. When opened to the sea, lower nutrient seawater allows for the dilution of nutrients from the catchment inputs. The LTG (2013) recommends winter time opening to allow for "flushing" of the lagoon to reduce nutrient concentrations at the onset of the growth period. At the start of the 2014-2015 growth period nutrient concentrations, particularly TN were highest and decreased over time (data not shown). This may reflect biological uptake, sedimentation or changes in the inflow loads over the course of the growth period. Nutrient loads entering the lagoon can be reduced via a number of options, including on-farm best management practices, high rate algal ponds, algal turf scrubbers or constructed wetlands.

Overall, closure of the lagoon during the growth season resulted in increased macrophyte bed development, in particular *R. polycarpa*, however, there was also an increase in the growth of algae, both filamentous and phytoplankton, as a result of higher nutrient concentrations in the lagoon. Managing both the lagoon opening regime and nutrient loads entering into the lagoon from freshwater inputs is vital for ensuring the lagoon remains in a macrophyte dominated state.

5 Acknowledgements

Chris Owen is thanked for his skilled boat skipper duties and assistance in the field.

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Appendix A Easting and Northing (NZMG) for sampling sites in Waituna Lagoon.

Transect	Site	Easting (NZMG)	Northing (NZMG)
1	1	2177865	5395520
2	1	2177014	5395517
2	2	2177033	5395373
2	3	2177067	5395234
3	1	2176005	5395562
3	2	2176009	5395432
3	3	2176048	5395245
4	1	2175050	5396183
4	2	2175047	5396001
4	3	2175050	5395363
4	4	2174994	5394989
4	5	2175035	5394643
5	1	2174118	5395889
5	2	2174129	5395817
5	3	2174104	5395284
5	4	2174060	5394866
5	5	2174017	5394771
6	1	2173090	5396803
6	2	2173085	5396617
6	3	2173087	5396013
6	4	2173102	5395536
6	5	2173134	5395398
7	1	2172004	5397069
7	2	2172017	5396657
7	3	2172050	5395872
7	4	2172047	5395297
7	5	2172012	5394838
7	6	2172010	5394041
7	7	2172000	5393900
8	1	2171028	5396501
8	2	2171042	5396368
8	3	2171049	5396071
8	4	2171048	5395470
8	5	2171120	5394893
8	6	2171195	5394495
8	7	2170958	5393126
8	8	2170989	5393047
8	9	2171015	5392974
9	1	2170021	5396268
9	2	2169973	5395831
9	3	2169946	5395338
9	4	2169832	5395189
9	5	2169946	5394950
9	6	2170245	5394350
9	7	2170280	5392766
10	1	2169042	5396141
10	2	2169028	5395949
10	3	2169050	5395759

Appendix B Macrophyte percent cover, height and growth stage on spot samples in Waituna Lagoon.

Rp = *Ruppia polycarpa*, Rm = *Ruppia megacarpa*, Lm = *Lamprothamnium macropogon*, f= fruiting, v = vegetative. Freshwater filamentous green algae includes *Spirogyra* sp, *Cladophora* sp, and *Zygnema* sp.

Transect	Site	Rep	Macrophyte	Height (cm)	Stage	% cover	Filamentous green algae % cover
1	1	1	Rm/Rp	175	f	100	20
		2	Rm/Rp	175	f	100	15
		3	Rm/Rp	175	f	100	20
		4	Rm/Rp	175	f	100	15
2	1	1	Rp	15	v	10	70
		2	Rm	74	f	90	10
		3	Rm	10	v	14	5
		4	-	-	-	-	-
2	2	1	Rm	57	f	70	20
		2	Rm	44	f	80	20
		3	Rp	43	f	75	20
		4	Rp	74	f	65	20
2	3	1	-	-	-	-	100
		2	-	-	-	-	50
		3	-	-	-	-	50
		4	-	-	-	-	30
3	1	1	-	-	-	-	-
		2	Rp	8	v	30	-
		3	Rp	30	v	5	-
		4	Rp	40	f	85	-
3	2	1	-	-	-	-	100
		2	-	-	-	-	100
		3	-	-	-	-	100
		4	-	-	-	-	80
3	3	1	-	-	-	-	-
		2	Rp	12	v	5	-
		3	-	-	-	-	-
		4	Rp	13	v	5	-
4	1	1	Rp, Lm	43, 58	v, v	1, 100	100
		2	Lm	40	v	100	100
		3	Lm	30	v	100	100
		4	Lm	32	f	100	100
4	2	1	Rp, Lm	55, 28	f, f	45, 55	100
		2	Rp, Lm	54, 45	f, f	50, 50	100
		3	Rp, Lm	54, 16	f, f	60, 40	100
		4	Rp, Lm	35, 60	f, f	80, 5	100
4	3	1	-	-	-	-	-
		2	Rp / Rm	150	f	30	-
		3	-	-	-	-	-
		4	Rp / Rm	120	f	25	-
4	4	1	Rp	40	f	50	-
		2	-	-	-	-	-
		3	Rp	60	f	20	30
		4	Rp	50	f	70	20
4	5	1	Rp / Rm	110	f	4	10

Transect	Site	Rep	Macrophyte	Height (cm)	Stage	% cover	Filamentous green algae % cover
		2	Rp / Rm	60	v	2	5
		3	Rp / Rm	116	v	15	5
		4	Rp / Rm	25	v	5	-
5	1	1	Lm	13	v	90	20
		2	Lm	18	v	70	30
		3	Lm	18	f	70	30
		4	Lm	15	v	30	70
5	2	1	Rp	70	f	70	50
		2	Rp	73	f	90	10
		3	Rp	64	f	90	50
		4	Rp	81	f	90	10
5	3	1	-	-	-	-	100
		2	-	-	-	-	100
		3	-	-	-	-	100
		4	-	-	-	-	100
5	4	1	Rp	77	f	70	70
		2	Rp	57	f	90	50
		3	Rp	68	f	70	80
		4	Rp	57	f	70	40
5	5	1	Rp, Lm	46, 10	f, v	50, 5	20
		2	Rp, Lm	25, 10	f, v	20, 3	15
		3	Rp	78	f	80	50
		4	Rp, Lm	48, 35	f, f	40, 5	40
6	1	1	Rp, Lm	23, 14	v, v	8, 1	10
		2	Rp	30	v	10	10
		3	Rp, Lm	32, 10	f, v	60, 1	-
		4	Rp, Lm	35, 12	v, v	25, 15	30
6	2	1	Rp, Lm	13, 30	f, f	2, 100	90
		2	Rp, Lm	21, 52	f, f	2, 100	100
		3	Rp, Lm	26, 40	v, f	2, 100	100
		4	Rp, Lm	27, 33	f, f	4, 100	100
6	3	1	Rp	65	f	90	20
		2	Rp	65	f	100	30
		3	Rp	65	f	80	40
		4	Rp	65	f	95	50
6	4	1	-	-	-	-	-
		2	-	-	-	-	-
		3	-	-	-	-	-
		4	-	-	-	-	-
6	5	1	Rp, Lm	10, 21	v, v	5, 50	20
		2	Rp, Lm	20, 24	f, v	10, 40	20
		3	Lm	24	v	10	20
		4	Rp, Lm	12, 20	v, v	5, 30	20
7	1	1	-	-	-	-	-
		2	-	-	-	-	-
		3	Rp	6	v	1	-
		4	Rp	6	v	10	-
7	2	1	-	-	-	-	100
		2	-	-	-	-	100
		3	-	-	-	-	50
		4	-	-	-	-	30
7	3	1	-	-	-	-	-

Transect	Site	Rep	Macrophyte	Height (cm)	Stage	% cover	Filamentous green algae % cover
		2	-	-	-	-	-
		3	-	-	-	-	-
		4	-	-	-	-	-
7	4	1	Rp	13	v	1	-
		2	-	-	-	-	-
		3	-	-	-	-	-
		4	-	-	-	-	-
7	5	1	-	-	-	-	-
		2	Rp	11	v	2	-
		3	Rp	15	v	4	-
		4	-	-	-	-	2
7	6	1	-	-	-	-	50
		2	-	-	-	-	20
		3	-	-	-	-	60
		4	-	-	-	-	60
7	7	1	Rp	20	f	50	70
		2	Rp	26	f	60	100
		3	Rp	18	f	70	40
		4	Rp	14	f	60	30
8	1	1	Rp	10	v	5	5
		2	Rp	13	f	80	5
		3	Rp	18	v	45	-
		4	Rp	19	v	65	10
8	2	1	Rp	23	v	3	-
		2	-	-	-	-	-
		3	Rp	12	v	1	-
		4	-	-	-	-	-
8	3	1	-	-	-	-	-
		2	-	-	-	-	-
		3	-	-	-	-	-
		4	-	-	-	-	-
8	4	1	-	-	-	-	-
		2	-	-	-	-	-
		3	-	-	-	-	-
		4	-	-	-	-	-
8	5	1	-	-	-	-	-
		2	-	-	-	-	-
		3	-	-	-	-	-
		4	-	-	-	-	-
8	6	1	-	-	-	-	100
		2	-	-	-	-	100
		3	-	-	-	-	100
		4	-	-	-	-	100
8	7	1	Rp	18	f	10	70
		2	Rp	30	f	60	80
		3	Rp	20	f	15	70
		4	Rp	16	f	25	80
8	8	1	Rp	36	f	30	100
		2	Rp	33	v	5	100
		3	Rp	20	v	3	100
		4	Rp	24	v	1	100
9	1	1	Rp	13	v	35	-

Transect	Site	Rep	Macrophyte	Height (cm)	Stage	% cover	Filamentous green algae % cover
		2	Rp	20	v	75	-
		3	Rp	16	v	60	-
		4	Rp	15	v	35	-
9	2	1	-	-	-	-	-
		2	-	-	-	-	-
		3	-	-	-	-	-
		4	-	-	-	-	-
9	3	1	-	-	-	-	100
		2	-	-	-	-	100
		3	-	-	-	-	100
		4	-	-	-	-	100
9	4	1	Rp, Lm	10, 17	v, v	1, 2	60
		2	-	-	-	-	60
		3	Lm	5	v	3	60
		4	Lm	31	v	3	80
9	5	1	Rp, Lm	33, 5	f, v	10, 4	100
		2	Rp, Lm	32, 20	v, v	50, 10	100
		3	Lm	16	f	40	100
		4	Rp, Lm	28, 16	f, v	30, 8	100
9	6	1	Lm	35	f	70	50
		2	Rp, Lm	26, 34	f, f	60, 30	60
		3	Rp, Lm	25, 24	v, v	15, 95	80
		4	Rp, Lm	28, 23	f, v	2, 80	60
9	7	1	-	-	-	-	60
		2	-	-	-	-	60
		3	-	-	-	-	60
		4	-	-	-	-	60
10	1	1	-	-	-	-	40
		2	Rp	21	v	10	40
		3	Rp	15	v	10	20
		4	Rp	12	v	4	20
10	2	1	-	-	-	-	20
		2	-	-	-	-	20
		3	-	-	-	-	20
		4	-	-	-	-	20
10	3	1	Rp	11	v	5	50
		2	Rp	20	f	50	50
		3	Rp	10	v	1	100
		4	Pr	21	f	50	50

Appendix C Macrophyte cover in 10m diameter.

Transect	Site	Species	Percent cover Average	maximum
1	1	*Ruppia polycarpa*	100	100
		Ruppia megacarpa	100	100
		filamentous green algae - mixed	15	20
2	1	*Ruppia megacarpa*	65	100
		filamentous green algae - mixed	25	70
2	2	*Ruppia polycarpa*	60	80
		Ruppia megacarpa	60	80
		filamentous green algae - mixed	50	70
2	3	*Ruppia polycarpa*	5	15
		filamentous green algae - mixed	50	100
3	1	*Ruppia polycarpa*	50	90
		filamentous green algae - mixed	10	30
3	2	*Ruppia polycarpa*	35	60
		filamentous green algae - mixed	70	100
3	3	*Ruppia polycarpa*	10	10
		filamentous green algae - mixed	20	20
4	1	*Ruppia polycarpa*	1	5
		Lamprothamnium macropogon	95	100
		filamentous green algae - mixed	100	100
4	2	*Ruppia polycarpa*	70	90
		Lamprothamnium macropogon	30	60
		filamentous green algae - mixed	100	100
4	3	*Ruppia polycarpa*	100	100
		filamentous green algae - mixed	30	100
4	4	*Ruppia polycarpa*	80	100
		filamentous green algae - mixed	40	60
4	5	*Ruppia polycarpa*	50	70
		filamentous green algae - mixed	20	40
5	1	*Ruppia polycarpa*	5	10
		Lamprothamnium macropogon	30	40
		filamentous green algae - mixed	30	40
5	2	*Ruppia polycarpa*	90	100
		filamentous green algae - mixed	90	90
5	3	*Ruppia polycarpa*	1	4
		filamentous green algae - mixed	90	100
5	4	*Ruppia polycarpa*	80	100
		filamentous green algae - mixed	70	100

Transect	Site	Species	Percent cover Average	maximum
5	5	*Ruppia polycarpa*	70	80
		Lamprothamnium macropogon	40	70
		filamentous green algae - mixed	80	100
6	1	*Ruppia polycarpa*	50	80
		Lamprothamnium macropogon	10	30
		filamentous green algae - mixed	65	80
6	2	*Ruppia polycarpa*	15	30
		Lamprothamnium macropogon	95	100
		filamentous green algae - mixed	40	60
6	3	*Ruppia polycarpa*	90	100
		filamentous green algae - mixed	80	90
6	4	*Ruppia polycarpa*	1	5
		filamentous green algae - mixed	10	10
6	5	*Ruppia polycarpa*	20	30
		Lamprothamnium macropogon	50	60
		filamentous green algae - mixed	50	60
7	1	*Ruppia polycarpa*	40	60
7	2	filamentous green algae - mixed	60	100
7	3	filamentous green algae - mixed	80	100
7	4	*Ruppia polycarpa*	10	15
		filamentous green algae - mixed	80	100
7	5	*Ruppia polycarpa*	4	5
		filamentous green algae - mixed	90	100
7	6	*Ruppia polycarpa*	55	80
		filamentous green algae - mixed	70	100
7	7	*Ruppia polycarpa*	50	85
		filamentous green algae - mixed	75	100
8	1	*Ruppia polycarpa*	50	70
		filamentous green algae - mixed	70	85
8	2	*Ruppia polycarpa*	15	15
		filamentous green algae - mixed	50	100
8	3	filamentous green algae - mixed	40	80
8	4	filamentous green algae - mixed	40	100
8	5	filamentous green algae - mixed	100	100
8	6	*Ruppia polycarpa*	5	10
		filamentous green algae - mixed	90	100
8	7	*Ruppia polycarpa*	70	100
		filamentous green algae - mixed	80	100

Transect	Site	Species	Percent cover Average	maximum
8	8	*Ruppia polycarpa*	50	60
		filamentous green algae - mixed	90	100
9	1	*Ruppia polycarpa*	45	70
		filamentous green algae - mixed	65	80
9	2	filamentous green algae - mixed	60	100
9	3	filamentous green algae - mixed	100	100
9	4	*Ruppia polycarpa*	15	40
		Lamprothamnium macropogon	20	40
		filamentous green algae - mixed	40	90
9	5	*Ruppia polycarpa*	30	60
		Lamprothamnium macropogon	15	40
		filamentous green algae - mixed	40	90
9	6	*Ruppia polycarpa*	10	15
		Lamprothamnium macropogon	90	100
9	7	filamentous green algae - mixed	65	100
10	1	*Ruppia polycarpa*	40	60
		filamentous green algae - mixed	50	80
10	2	*Ruppia polycarpa*	10	10
		filamentous green algae - mixed	40	80
10	3	*Ruppia polycarpa*	30	60
		filamentous green algae - mixed	100	100

Appendix D Water quality and sediment parameters in Waituna Lagoon.

T = transect, S= site, (top) and (bot) = top and bottom of water column, Temp = temperature, Sal = salinity, DO = dissolved oxygen, Turb = turbidity, Sed = sediment. Sediment codes are s = sand, g = gravel, m = mud, sm = soft mud.

T	S	Depth (m)	Temp (°C) (top)	Temp (°C) (bot)	Sal ppt (top)	Sal ppt (bot)	DO (mg/l) (top)	DO (mg/l) (bot)	Turb NTU (top)	Turb NTU (bot)	Black disk (cm)	Sed Rep 1	Sed Rep 2	Sed Rep 3	Sed Rep 4	Sulphide depth 1 (cm)	Sulphide depth 2 (cm)	Sulphide depth 3 (cm)	Sulphide depth 4 (cm)
1	1	1.75	19.1	16.1	1.5	1.5	11.04	3.69	1	4	130	sm	sm	sm	sm	0	0	0	0
2	1	0.55	18.1	18.2	1.9	1.9	9.76	9.91	3	3	123	sm/s/g	sm/s/g	sm/s/g	sm/s/g	> 4	> 4	> 4	> 4
2	2	1.00	17.9	17.3	1.8	2.0	9.79	9.69	3	2	155	s/g	s/g	s/g	s/g	> 4	> 4	> 4	1.5
2	3	0.70	17.9	17.5	1.7	1.8	9.18	9.55	2	2	104	g/s	g/s	g/s	g/s	> 4	> 4	> 4	> 4
3	1	0.30	16.3	16.4	1.9	1.9	10.30	10.35	1	2	91	g/s	g/s	g/s	g/s	> 4	> 4	> 4	> 4
3	2	2.10	16.5	16.0	2.0	2.2	10.46	10.77	2	2	161	sm/s	sm/s	sm/s	sm/s	2	1	2	2
3	3	0.60	16.5	16.5	1.9	1.9	10.11	10.08	3	3	135	g	g	g	g	> 4	> 4	> 4	> 4
4	1	0.70	19.3	19.4	1.8	1.8	9.25	8.21	0	1	138	s/g	s/g	s/g	s/g	0	0	0	0
4	2	0.80	19.1	19.2	1.8	1.8	8.91	9.93	1	1	113	s/g	s/g	s/g	s/g	> 4	> 4	> 4	> 4
4	3	1.67	17.2	15.2	2.1	2.2	11.47	11.56	3	2	186	sm/s/g	sm/s/g	sm/s/g	sm/s/g	1	> 4	> 4	> 4
4	4	0.98	17.5	17.0	2.1	2.1	12.04	15.00	5	1	125	s/g	s/g	s/g	s/g	2	> 4	2	> 4
4	5	1.38	19.7	17.1	2.1	2.1	10.89	11.20	2	2	138	sm/s/g	sm/s/g	sm/s/g	sm/s/g	> 4	> 4	> 4	> 4
5	1	0.52	20.8	20.9	1.9	1.9	12.12	12.80	3	2	122	g/s	g/s	g/s	g/s	> 4	1	0.5	1
5	2	1.10	19.7	18.0	2.0	2.1	11.50	15.38	4	3	165	sm/s	sm/s	sm/s	sm/s	2	1	1.5	1
5	3	1.90	18.1	17.7	2.2	2.2	10.63	10.89	2	2	175	sm/s	sm/s	sm/s	sm/s	1.5	0.5	1	0.5
5	4	1.17	20.2	17.4	2.2	2.1	10.86	12.80	2	2	175	sm/s	sm/s	sm/s	sm/s	> 4	> 4	0.1	1
5	5	0.78	21.1	19.2	2.2	2.2	11.20	11.75	2	2	152	sm/s	sm/s	sm/s	sm/s	2	1.5	1	1
6	1	0.45	18.3	18.3	2.0	2.0	7.66	7.62	3	3	119	sm/s/g	sm/s/g	sm/s/g	sm/s/g	> 4	> 4	> 4	> 4
6	2	0.60	17.9	17.9	2.1	2.1	9.07	9.36	1	1	145	sm/s	sm/s	sm/s	sm/s	> 4	> 4	> 4	> 4
6	3	1.10	17.5	16.7	2.2	2.2	11.51	11.62	2	2	143	sm/s/g	sm/s/g	sm/s/g	sm/s/g	0.5	> 4	2.5	2
6	4	1.60	17.3	17.2	2.1	2.1	11.44	11.55	3	4	122	sm/s/g	sm/s/g	sm/s/g	sm/s/g	1	1	1	1
6	5	0.60	20.5	20.6	2.2	2.2	12.79	12.66	3	4	130	sm/s	sm/s	sm/s	sm/s	1	> 4	1	0.5

T	S	Depth (m)	Temp (°C) (top)	Temp (°C) (bot)	Sal ppt (top)	Sal ppt (bot)	DO (mg/l) (top)	DO (mg/l) (bot)	Turb NTU (top)	Turb NTU (bot)	Black disk (cm)	Sed Rep 1	Sed Rep 2	Sed Rep 3	Sed Rep 4	Sulphide depth 1 (cm)	Sulphide depth 2 (cm)	Sulphide depth 3 (cm)	Sulphide depth 4 (cm)
7	1	0.52	18.6	18.6	2.2	2.2	9.64	10.37	2	2	141	s/g	s/g	s/g	s/g	> 4	> 4	> 4	> 4
7	2	1.23	17.9	17.9	2.1	2.1	10.22	10.27	2	2	119	s	s	s	s	> 4	1.5	2	2
7	3	1.30	16.5	15.3	2.0	2.0	10.30	11.26	7.5	7.5	72	g/s	g/s	g/s	g/s	3	1	1	1
7	4	1.10	16.2	16.1	2.1	2.1	10.90	11.30	2	3	121	s	s	s	s	1.5	1	1.5	2
7	5	1.40	17.6	17.5	2.2	2.2	11.44	11.41	2	2	135	s	s	s	s	2	1.5	2	2
7	6	0.95	18.8	18.6	2.2	2.2	10.48	10.80	2	2	171	s	s	s	s	2.5	2.5	3	3
7	7	0.55	19.4	19.4	2.2	2.2	11.57	11.83	3	2	130	s/g	s/g	s/g	s/g	> 4	2.5	> 4	2
8	1	0.60	18.5	18.5	2.1	2.1	10.51	10.85	3	2	150	g/s	g/s	g/s	g/s	> 4	> 4	> 4	> 4
8	2	1.20	17.3	17.2	2.1	2.1	10.70	10.71	5	5	95	sm/s/g	sm/s/g	sm/s/g	sm/s/g	3	3	3	3
8	3	1.30	16.9	16.8	2.1	2.1	10.52	10.63	7	7	85	sm/s	sm/s	sm/s	sm/s	2	2	2.5	2.5
8	4	1.60	16.5	16.3	2.1	2.1	10.56	10.64	5	5	86	sm/s	sm/s	sm/s	sm/s	> 4	> 4	1	> 4
8	5	1.50	17.5	17.5	2.1	2.1	11.54	11.54	5	5	88	s	s	s	s	1.5	1.5	1.5	1.5
8	6	0.70	18.6	18.6	2.2	2.2	9.38	9.55	4	4	107	s	s	s	s	> 4	2	0.5	> 4
8	7	0.60	20.9	20.9	2.3	2.3	11.97	13.70	1	2	166	g/sm	g/sm	g/sm	g/sm	1	> 4	> 4	> 4
8	8	1.40	20.0	19.5	2.3	2.3	10.02	13.10	1	1	212	sm/s	sm/s	sm/s	sm/s	> 4	> 4	> 4	> 4
9	1	0.60	18.4	18.4	2.0	2.0	10.30	10.40	7	4	124	g/s	g/s	g/s	g/s	> 4	> 4	> 4	> 4
9	2	1.20	17.3	17.2	2.0	2.0	10.51	10.62	7	7	78	s	s	s	s	3.5	> 4	2.5	3
9	3	0.70	20.3	20.0	1.9	2.0	11.57	11.99	4	3	101	vsm/s	vsm/s	vsm/s	vsm/s	0	0	0	0
9	4	0.90	21.0	21.0	2.2	2.2	10.52	10.40	4	3	115	vsm/s	vsm/s	vsm/s	vsm/s	2	> 4	> 4	> 4
9	5	0.90	20.4	20.1	2.2	2.2	11.54	11.50	2	2	116	sm/s	sm/s	sm/s	sm/s	> 4	> 4	> 4	> 4
9	6	0.80	20.2	19.7	2.2	2.2	10.57	11.31	2	3	156	s	s	s	s	> 4	> 4	> 4	> 4
9	7	0.85	19.4	19.0	2.4	2.4	9.53	9.59	1	2	182	s	s	s	s	1	1	1	1
10	1	0.80	21.5	21.5	1.8	1.8	10.78	11.57	8	9	77	sm/s/gs	sm/s/gs	sm/s/gs	sm/s/gs	> 4	> 4	> 4	> 4
10	2	0.90	20.8	20.8	1.7	1.7	11.20	11.40	6	6	92	vsm/s	vsm/s	vsm/s	vsm/s	3	3.5	3.5	3.5
10	3	0.58	21.7	21.6	1.4	1.4	12.06	11.90	8	9	56	sm/s/g	sm/s/g	sm/s/g	sm/s/g	> 4	3	> 4	> 4