Macrophyte monitoring in Waituna Lagoon - summer 2016

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Sample of the Ruppia beds in Waituna Lagoon. [Rohan Wells, NIWA]

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1 Introduction

Waituna Lagoon is a highly valued coastal lagoon, due to its high aesthetic, biological and recreational values, and is one of the best remaining examples of a coastal lagoon in New Zealand. The diverse range of habitat in Waituna Lagoon is important 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, as well as being a national stronghold for the threatened giant kokopu, inanga, short fin eels and the threatened long fin eel (Atkinson 2008). The lagoon is a place of great significance to Ngāi Tahu, and was traditionally an important mahinga kai area.

In 1976 Waituna lagoon was New Zealand's 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.

As the lagoon has no permanent natural outlet to the sea, it is a freshwater environment for much of the time, becoming estuarine when opened. The lagoon is fed by three lowland streams that flow through agricultural pastures. As a result of increased land-use intensification in the catchment, there has been an increase in contaminant loads entering the lagoon, in particular ammonium and phosphorus (LTG 2013). This has resulted in degradation of the its water quality and the lagoon is now described as being in a eutrophic state, meaning that the lagoon has high nutrients, high phytoplankton biomass and poor water quality (LTG 2013).

The lagoon is artificially opened when the water level exceeds 2.0 meters above sea level (m.a.s.l.) and sea conditions are suitable, while closure occurs naturally. While artificial openings have been of benefit to low lying farmland areas, they also provide a mechanism to mitigate against eutrophication in the lagoon. When opened, the lagoon exchanges water with the lower nutrient sea and high nutrient concentrations in the lagoon are diluted.

Historically, Waituna Lagoon was in a macrophyte dominated state with dense beds of *Ruppia megacarpa* (horse's mane weed), along with *Myriophyllum triphyllum* (milfoil), present throughout the lagoon, particularly in deeper water (Johnson and Partridge 1998). However, in recent years, there has been a decline in macrophyte abundance, in particular *Ruppia* spp. beds. Macrophyte surveys carried out over the last seven years suggests that the macrophyte community is responsive to the status of the lagoon opening during the growing period (defined as 1 August to 31 March). When the lagoon is open during the growing period, beds are lost, either through desiccation, through wave action or by birds grazing. In contrast, when the lagoon is closed during the growing period, macrophyte beds flourish but so too does algal (both benthic and free-floating) communities.

Continued eutrophication of the lagoon, together with 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 algal 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. 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).

As part of their responsibility for managing Waituna lagoon, under their biodiversity conservation role, Department of Conservation (DOC) initiated macrophyte surveys in the 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 2016 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 2016 annual summer-time survey.

2 Methods

The methodology used during these surveys was initially developed by Robertson and Stevens (2009) and Stevens and Robertson (2010) and has remained consistent over the course of the annual surveys to date. The methodology is summarised below and the reader is directed to both Robertson and Stevens (2009) and Stevens and Robertson (2010) reports for full 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 in 2016 (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 the 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 15cm and 6cm deep were cut from the sediment, using a flat based garden hoe, and carefully lifted to the surface. Each replicate sample was then assessed for:

[1] Site T8-9 is now located within the barrier spit following migration of sediment during the lagoon closure in 2015 and is no longer included in the survey.

- Macrophyte and / or macroalgae species present.
- 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 10m 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 macrophyte survey was carried out between 25 and 29 January 2016. Due to issues with the Horiba multi-sensor meter, water quality data at half of the monitoring sites were measured on the 6 February 2016. The exception to this was dissolved oxygen, which was only recorded at half the sites in January.

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, Sutherland and Taumoepeau 2015).

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[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.

Water quality for the 2015/2016 year was summarised across the key growing season for macrophytes (1 August to 31 March) as defined by Robertson and Funnell (2012). Source data was obtained from Environment Southland from both a long term monitoring site, and from the automated ‘monitoring platform’.

3 Results

3.1 Macrophyte and macroalgae

Full measurements of the macrophyte and macroalgal communities recorded at each sites are listed in Appendices B and C.

Macrophytes were recorded at 41 of the 47 sites sampled in the lagoon during the summer 2016 survey. This was similar to the number of sites recorded with macrophyte cover during the 2015 survey, and was 3.5 times and 2 times higher than the 2014 and 2013 surveys, respectively. *Ruppia polycarpa* was the most frequently occurring species throughout the lagoon, occurring on 83% of vegetated sites, followed by *Lamprothamnium macropogon* (23%) and *Ruppia megacarpa* (9%; Figure 3-1). This equated to a 16% increase in the frequency of occurrence of *R. polycarpa* compared to 2015 making the 2016 growing season the highest frequency of occurrence of *R. polycarpa* since surveys began in 2009 (Figure 3-1).

The percentage cover of *R. polycarpa* varied across the lagoon, with the lowest percentage cover often on the southern side of the lagoon, but this was not always the case. The highest occurrence of sites were in the 1-25% cover class, followed by the 51-75% cover class (Figure 3-2). While the frequency of occurrence of *R. megacarpa* was low in the lagoon, the percentage cover was > 95% at all sites where R. *megacarpa* was recorded (Figure 3-2 and Appendix B). The lagoon-wide mean percentage cover of *L. macropogon* was 32 ± 18%, which was similar to 2015 (46 ± 39%).

Macrophyte bed height ranged from 1 – 195 cm with a mean height of 21 (± 34) cm across the lagoon (see Appendix B). The macrophyte bed height at six sites during the 2016 survey exceeded the maximum height recorded during the 2015 survey and were the tallest beds recorded since surveys began. However, overall macrophyte bed height in 2016 did not differ significantly from 2015. As with previous surveys, the tallest beds typically occurred on the western side of the lagoon (see Appendix B).

Ruppia spp. were in the flowering stage at 71% of the sites where plants were recorded (see Appendix B). This is similar to the 2015 survey (69%) and substantially higher than the 2014 survey (22%).

During the summer 2016 surveys, the extended (10m diameter circle) observations were more likely to intercept *R. polycarpa* compared to the hoe method. *R. polycarpa* was recorded on 96% of all sites using the extended observations method, compared to 72% of all sites using the hoe method. (Figure 3-3). For average cover, there was an increase in sites within the 26-50% and 51-75% cover classes using the extended observations compared to the hoe method. For maximum cover, there was an increase in sites within the 76-100% cover class using the extended observations method compared to the hoe method (Figure 3-3). Both methods had similar frequency of occurrence within the 1-25% cover class (Figure 3-3). This is consistent with results from previous surveys using both methods.

The marine macroalga, *Ulva intestinales*, occurred at 77% of the sites during the summer 2016 survey. This was the highest frequency of occurrence of *U. intestinales* in Waituna Lagoon since surveys commenced in 2009 (Figure 3-1). It is plausible to suggest that this was due to higher water levels, due to the lagoon closure, and the slight brackish water (see Water Quality section below). The percentage cover of *U. intestinales* ranged from 1 – 100%, with a mean cover score of 26 ± 31% across the lagoon. The highest percentage cover occurred on the southern side of the lagoon. Freshwater filamentous green algae, dominated by *Spirogyra* sp. occurred at 38% of sites during the

2016 survey. This is a substantial reduction in the frequency of occurrence compared to 2015 but similar to that recorded in 2012 (Figure 3-1). The percentage cover of filamentous green algae ranged from 1 – 100, with a mean cover score of 49 ± 40% across the lagoon. The percentage cover of both algae were highly variable across the lagoon, which reflects their localised distribution (*Spirogyra* sp. near the freshwater inflows and *U. intestinales* near the sea). A large proportion of the algal biomass (both *U. intestinales* and filamentous green algae) was in an 'unhealthy' state exhibiting signs of stress, or was in the stages of dying (Figure 3-4). The marine species *Bachelotia antillarum* was not observed in the lagoon during the summer 2016 survey.

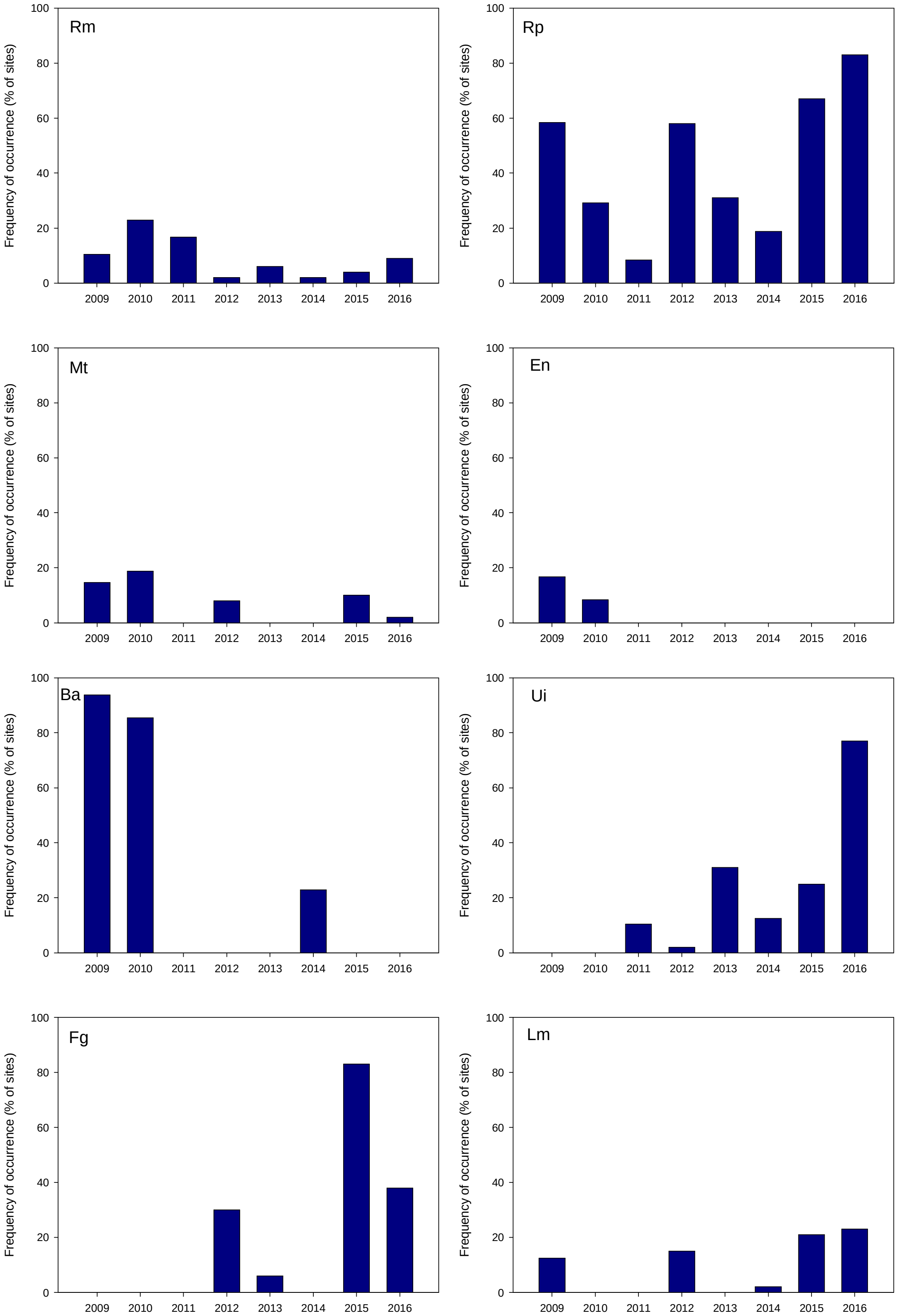

Figure 3-1: Frequency of occurrence of macrophytes and macroalgae in Waituna Lagoon between 2009 and 2016. Rm= *Ruppia megacarpa*, Rp = *Ruppia polycarpa*, Mt= *Myriophyllum triphyllum*, En = *Entromorpha* sp., Ba= *Bachelotia antillarum*, Ui = *Ulva intestinales*, Fg = Filamentous green algae, Lm = *Lamprothamnium macropogon*.

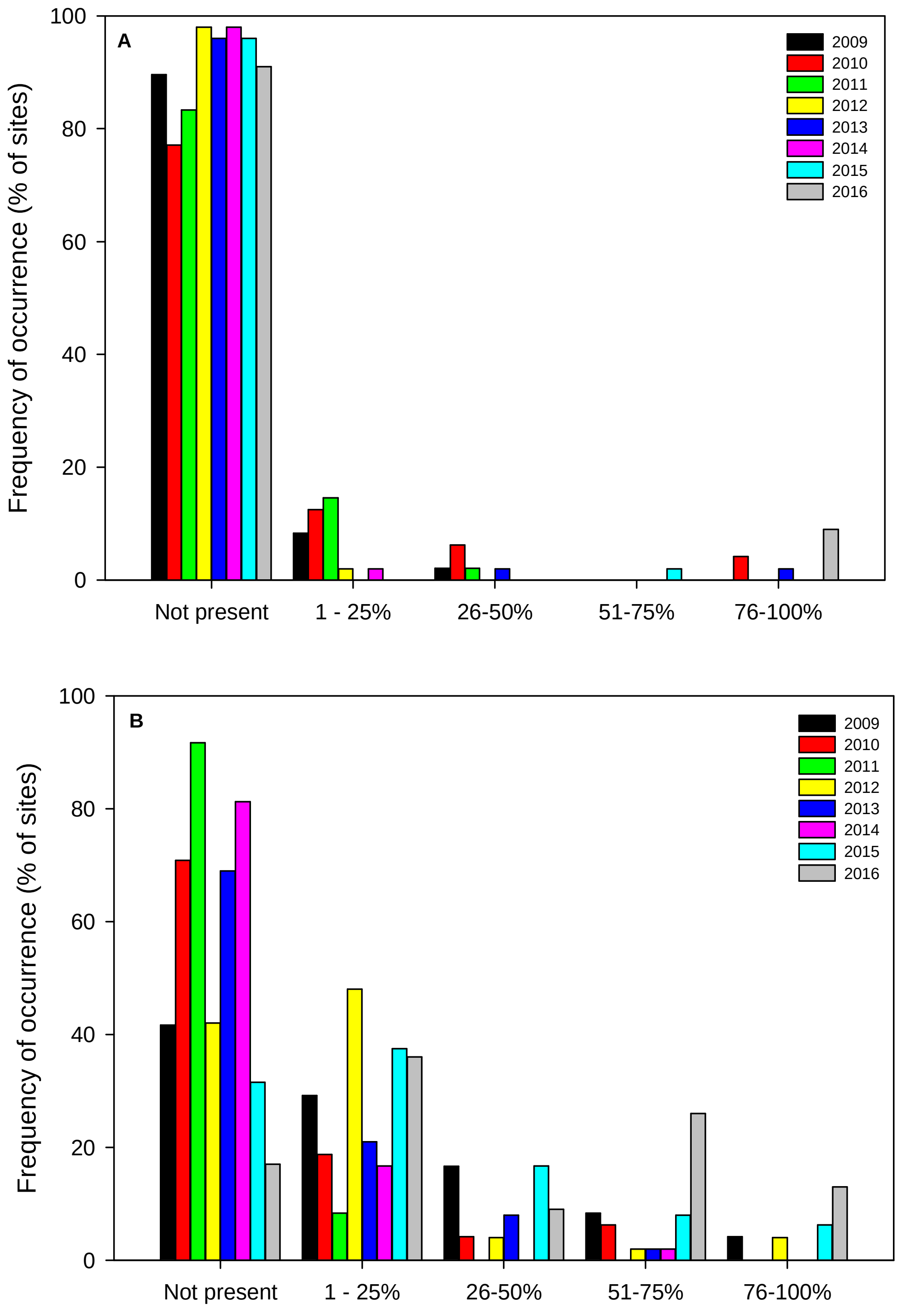

Figure 3-2: Frequency of occurrence of A) *Ruppia megacarpa* and B) *Ruppia polycarpa* across the cover abundance classes from 2009 to 2016.

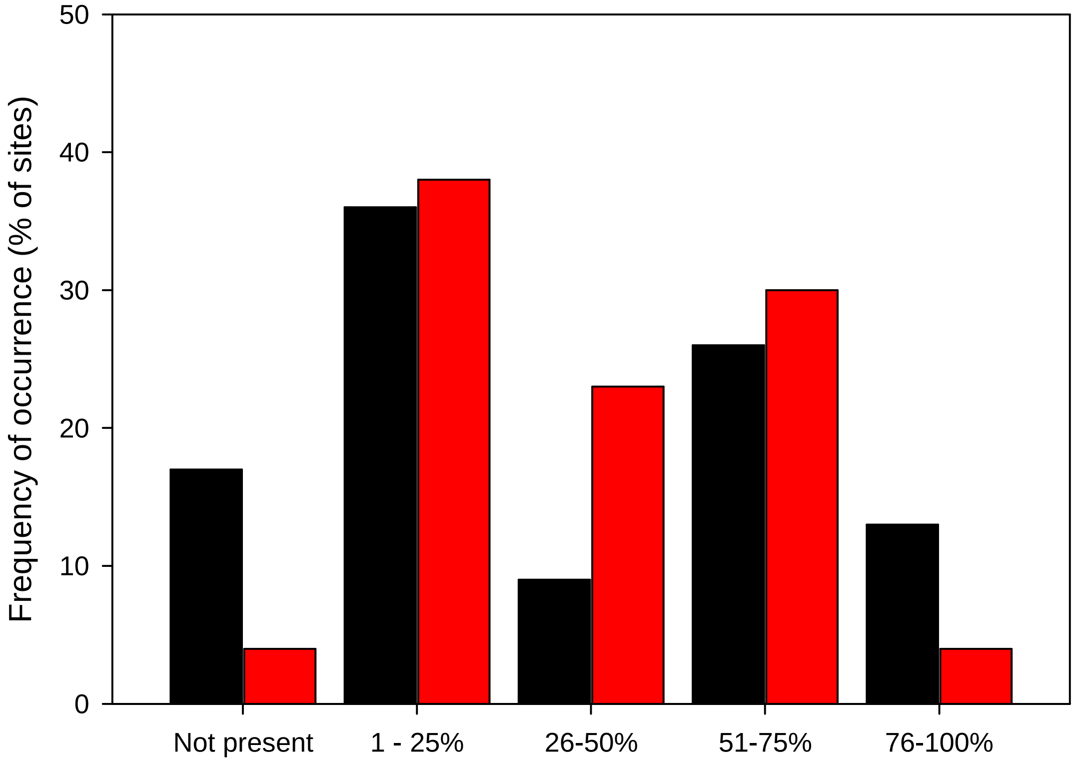

Figure 3-3: Frequency of occurrence of *Ruppia polycarpa* in each cover abundance class as recorded by spot sampling and extended observations (10m diameter). Spot sampling indicated by black bars, and extended observations average cover indicated by red bars.

Figure 3-4: Lift-off mats of filamentous green algae in the early stages of death and decay (brown material) in Waituna Lagoon.

3.2 Water quality

3.2.1 Water depth

During the 2015-16 growing 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 1.25 m.a.s.l. This was similar to the median water level recorded during the 2014-15 growing season and was significantly higher ($p < 0.01$) than the median water level during the 2013-14 growing season (0.53 m.a.s.l).

3.2.2 Substrate type

Sand, fine sand and gravel were the dominant substrate types across the 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. This is consistent with previous surveys. In 2015, it was noted that there was an increase in the dominance of soft mud at all sites on transect 6, however, this was not the case in 2016, with transect 6 dominated by gravel and sand on all sites, with the exception of site 5, which was dominated by soft mud, sand and gravel.

[See Appendix D for substrate type categories recorded at 47 sites during the summer 2016 survey].

3.2.3 Sediment health

28% of the sites surveyed did not contain a visible blackened layer within the sampled sediment on all four replicates (> 4cm), while another 16 sites had at least one replicate sample that did not have a visible blackened layer. For the remaining sites, a blackened layer was observed at the surface on 2% of sites, between 0 – 2cm on 28% of sites and between 2-4cm on 38% of survey sites (including those sites with at least one replicate > 4cm; Figure 3-5). For sites with a blackened layer, the greatest frequency of occurrence was within the 2–4cm classification. This was an improvement on previous years where the greatest frequency of occurrence was within the >0-2cm classification (Figure 3-5).

[See Appendix D for depth of blackened sediment layer recorded at 47 sites during the summer 2016 survey].

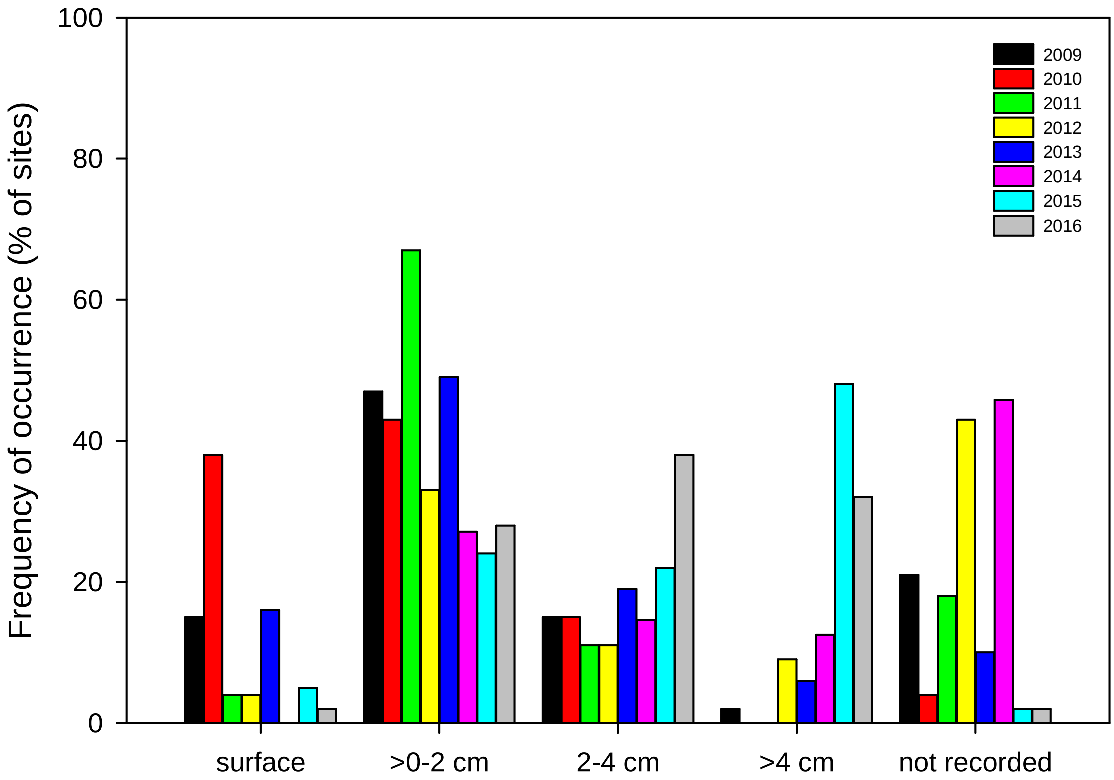

Figure 3-5: Frequency of occurrence of blackened sediment on all submerged sites between 2009 and 2016 using depth classes.

3.2.4 Dissolved oxygen

During the period the lagoon was open to the sea (33 days during September – October 2015) dissolved oxygen (DO) concentrations in the surface water measured at the monitoring station ranged from 78 – 132%, with a median value of 98 % (± 6%). DO concentrations in the bottom water was more variable, ranging from 28 – 130 %, with a median value of 98 % (± 7). Low dissolved oxygen levels that occurred in the bottom water were also accompanied by diurnal rises in DO during this period, suggesting that a fragment of plant or algae may have been caught on the DO probe.

Of the sites where DO was recorded during the February 2016 survey, surface DO concentrations ranged from 88 – 117%, with a median value of 98%. For the bottom waters, DO concentrations ranged from 83 – 130 %, with a median value of 98%. Only two surface water value (T1-1 = 88%, T2-1 = 89%) and two bottom water values (T1-1 = 83%, T2-1 = 85%) were slightly below the 90% threshold adopted by management agencies for many New Zealand waterbodies. For those sites surveyed there was no clear indication of DO stratification, with both surface and bottom water DO similar.

[See Appendix D for dissolved oxygen concentrations recorded in surface and bottom waters at 23 sites during the February 2015 survey].

3.2.5 Water clarity

Black disc measurements ranged from 0.25 to 2.16m across the lagoon, giving an equivalent Secchi depth (SD) range of 0.33 to 2.89m, with a median SD of 1.65m $\pm$ 0.8m (as per conversion protocol in Davis-Colley 1994). SD was greater than the depth of the water column at 39 out of the 47 sites surveys. Water clarity was highly variable throughout the lagoon and there was no relationship between water depth (a proxy to wave action effects) and water clarity. The lagoon-wide median SD was similar to that recorded during the summer 2015 survey, and higher than that recorded during the 2013 and 2014 summer surveys.

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 1.27m, meaning that at the time of the survey 36 out of 47 sites were more shallow than the 10% irradiance depth limit.

[See Appendix D for black disc measurements recorded at 47 sites during the summer 2016 survey].

3.2.6 Turbidity

Water column turbidity was low across the lagoon, ranging from 2 – 10 NTU in the surface waters and 3 - 11 NTU in the bottom waters. Turbidity in the surface and bottom waters did not differ significantly from each other at all sites across the lagoon. Turbidity during summer 2016 was similar to that measured during summer 2015. Over the growing season (1 August – 31 March), turbidity (as measured as part of the State of the Environment monitoring undertaken by Environment Southland) ranged from 2.2 – 16.8 NTU, with a median value of 4.6 (± 2.7) NTU during the closed period and a median value of 6.8 (± 1.4) NTU during the open period (33 days in September – October).

[See Appendix D for turbidity measurements recorded at 47 sites during the summer 2016 survey].

3.2.7 Salinity

Salinity was low across the lagoon with surface water salinity ranging from 1.0 to 8.2 ppt and bottom water salinity ranging from 0.0 – 9.1 ppt, with a lagoon-wide median salinity of 6.3 ppt. Salinity did not differ significantly between sampling occasions. This salinity range classifies the lagoon water as brackish. This is consistent with the lagoon being closed to the sea and receiving its main water inputs from freshwater sources. Salinity in the lagoon was slightly higher (although not statistically significant) than that recorded in 2015 and contrasts with higher values recorded during 2012- 2013 (36.3 ppt) and 2013-2014 (39.3 ppt) when the lagoon was open to the sea.

[See Appendix D for salinity measurements recorded at 47 sites during the summer 2016 survey].

3.2.8 Temperature

At the time of the 2016 summer survey temperature across the lagoon ranged from 12.0 – 22.4 ^{o}C (median = 18.6 ^{o}C ± 3.2) in the surface waters and from 12.0 – 22.1 ^{o}C (median = 18.7 ^{o}C ± 3.0) in the bottom waters across the lagoon. Surface water temperatures measured during the first week (median = 14.0 ^{o}C ± 3.0; range = 12.0 – 18.5^{o}C) were significantly lower ($p < 0.01$) than surface water temperatures measured during the second week (median = 19.8 ^{o}C ± 1.0; range = 18.6 – 22.4^{o}C). This was similar for bottom water temperatures with those measured during the first week (median = 14.0 ^{o}C ± 1.6; range = 12.0 – 18.5^{o}C) significantly lower ($p < 0.01$) than surface water temperatures measured during the second week (median = 19.7 ^{o}C ± 1.0; range = 18.6 – 22.1^{o}C). 26 out of 47 sites showed slight differences in temperature between the surface and bottom waters (ranging from 0.1 – 0.9 ^{o}C), with 70% of these being < 0.5 ^{o}C difference.

[See Appendix D for temperature measurements recorded at 47 sites during the summer 2016 survey].

3.3 Water quality over the key growing period of macrophytes

With the exception of a brief (33 days) period in September – October, the lagoon was closed to the sea for the majority (210 days) of the 2015-2016 growing period, which is defined as the period between 1 August and 31 March (Robertson and Funnell 2012). This is similar to the 2011-2012 growing period where the lagoon was closed for 228 days and to 2014-15 growing period where the lagoon was closed for the entire period (243 days; Table 3-1).

A rapid increase in salinity occurred when the mouth of the lagoon was opened to the sea, while higher water levels and lower salinity were associated with periods where the lagoon was closed to the sea (Figure 3-6).

Often, nutrient concentrations in the lagoon have been responsive to the status of the lagoon mouth, with decreases in both total nitrogen (TN) and total phosphorus (TP) occurring as a result of flushing from the sea with lower nutrient concentration seawater. However, this was not the case during the 2015-15 growing season with no significant difference detected between the closed and open periods for both TN and TP concentrations (Table 3-1). As with TN and TP, phytoplankton chlorophyll *a* (Chl-*a*) biomass did not differ significantly between the closed and open periods during 2015-16 growing season (Table 3-1). Phytoplankton Chl-*a* biomass did not differ significantly to the 2014-15 growing season (closed for 243 days) but was significantly higher ($p < 0.05$) than the 2013-14 growing season (open for 243 days).

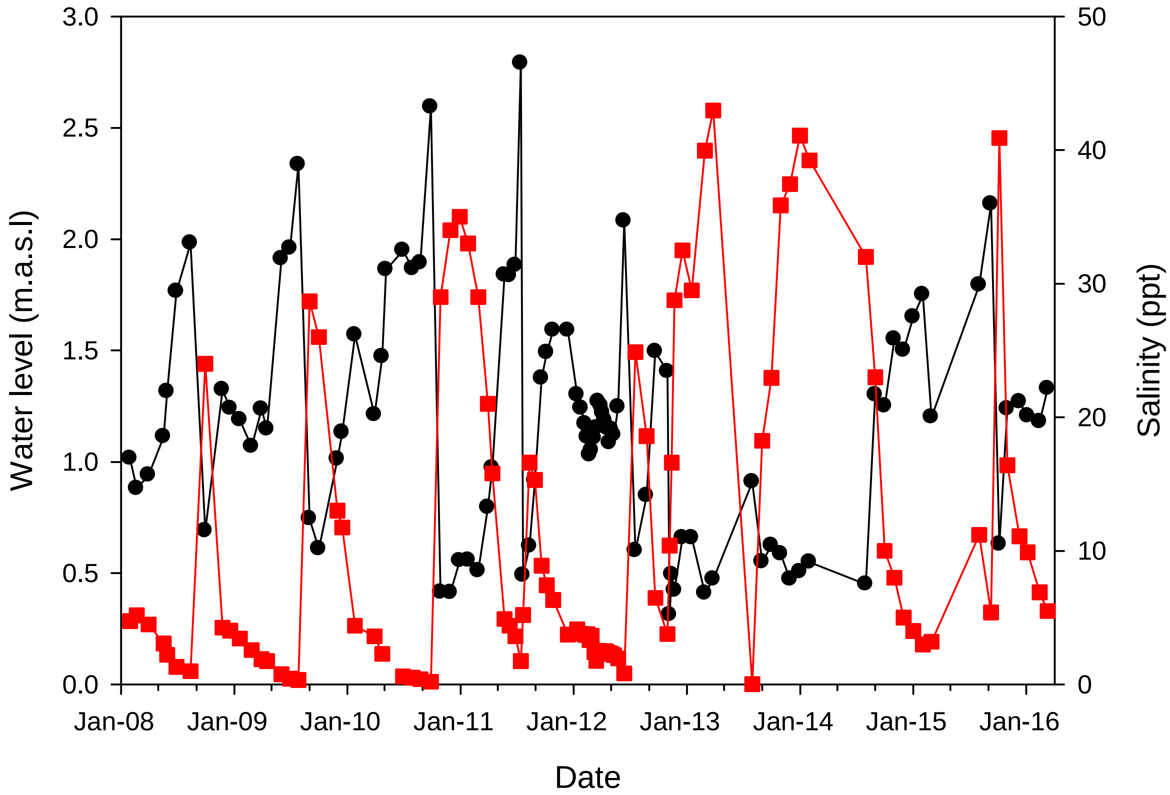

Figure 3-6: Variation in salinity (red line) in Waituna Lagoon between 2008 and 2016 relative to changes in water level (black line). Periodic increases in salinity correspond to lagoon opening events and intrusion of sea water.

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 - 2016). This is defined as the period between 1 August and 31 March. * data collected from Environment Southland's monitoring platform. n.p = data not provided

Variable	2008-2009		2009-2010		2010-2011		2011-2012		2012-2013		2013-2014		2014-2015		2015-2016	
	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)	Open (n=0)	Closed (n=1)
Duration open / closed (% growing season)	18% (43 d)	82% (200 d)	26% (64 d)	74% (179 d)	74% (181 d)	26% (62 d)	6% (15 d)	94% (228 d)	75% (182 d)	25% (61 d)	100% (243 d)	0% (0 d)	0% (0 d)	100% (243 d)	14% (33 d)	86% (210 d)
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)	35.8 (8.7)	9.8 (4.7)
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)	6.8 (1.4)	4.6 (2.7)
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)	n.p	n.p
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)	10.6 (1.6)	13.4 (4.3)
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)	0.0031 (0.0011)	0.0047 (0.0066)
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)	0.92 (0.38)	0.83 (0.33)
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)	0.04 (0.01)	0.03 (0.01)
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)	n.p	n.p
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)	n.p	n.p
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	24:1	32:1

4 Discussion

In 2013, the Lagoon Technical Group (LTG) set a recommended target of > 30-60% cover of *Ruppia* spp. and other native macrophytes as the basis for an ecological health objective for Waituna Lagoon (LTG 2013). During the summer 2016 survey, this target was met with an average lagoon-wide total macrophyte cover of 58% and a *Ruppia* spp. lagoon-wide cover of 57%. This was an almost doubling of the summer 2015 survey lagoon-wide macrophyte cover of only 30%. This increase was partially a result of macrophyte re-colonisation occurring at sites that previously had been de-vegetated when the lagoon was open.

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 supports this recommendation with both the frequency of occurrence and the percent cover of *Ruppia* spp. beds responsive to lagoon openings. Results over the last two years show that macrophyte recovery, following wholesale losses, is achievable but slow (2 years). Complete (2014-15) and near-complete (2015-16) closure during the growing season were likely to be the main drivers of recovery of the macrophyte bed. Closure meant that sufficient water depth and reduced salinities assisted macrophyte beds to re- establish. Prolonged closure events during the growing period is likely to further enhance the expansion of macrophyte beds, where suitable growth conditions (substrate type, water depth, wave exposure) permit.

While management of the lagoon openings is vital to ensure stability of the macrophyte beds, lagoon openings also allow for the "flushing" of the lagoon to reduce nutrient concentrations thereby reducing the opportunity for algal blooms to occur. The LTG (2013) recommends winter time opening to allow for the "flushing" to occur in order to reduce nutrient concentrations at the onset of the growing period. The short opening near the onset of the growing season did not result in a decrease in TN or TP, suggesting that the desired "flushing" was not achieved and filamentous green algae remained the dominant algae in the lagoon.

'Temporal' monitoring has been carried out across different seasons from 2014-2016. This data will add another dimension to the population dynamics of the *Ruppia* spp. community. This dataset comprises water quality, species, cover, biomass and *Ruppia* spp. seed bank at 16 of the 47 annual monitoring sites. We recommend temporal data is analysed using a technique to explore spatial and temporal correlations between multiple parameters while incorporating response-time lags (i.e., site 'history').

Overall, the ecological health objective target of > 30-60% macrophyte cover has been successfully achieved through the management of the lagoon openings, in particular, ensuring that the lagoon remained closed during the growing season. However, there was still a high abundance of algae, both filamentous and phytoplankton, in the lagoon. Managing both the lagoon opening regime and nutrient loads entering into the lagoon from freshwater inputs will assist with managing both the macrophyte beds and algal growth.

5 Acknowledgements

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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 of spot samples in Waituna Lagoon.

Rp = *Ruppia polycarpa*, Rm = *Ruppia megacarpa*, Lmp = *Lamprothamnium macropogon*, Ui – Ulva intestinalis, Fg = freshwater filamentous green algae (predominantly *Spirogyra* sp., along with *Cladophora* sp., and *Zygnema* sp.). f= fruiting, v = vegetative.

Site	Rep	Species code	% Cover	Height (cm)	Stage
1.1	1	Rm	100	178	F
1.1	2	Rm	100	180	F
1.1	2	Ui	5		
1.1	3	Rm	100	195	F
1.1	4	Rm	100	180	F
1.1	4	Ui	5		
2.1	1	Rp	90	17	F
2.1	1	Fg	5		
2.1	1	Ui	10		
2.1	2	Rp	80	9	F
2.1	2	Eg	50	4	
2.1	2	Fg	20		
2.1	2	Ui	80		
2.1	2	Mt	15	23	
2.1	3	Rp	50	9	V
2.1	3	Mt	30	21	
2.1	3	Eg	45	6	
2.1	3	Ui	20		
2.1	3	Fg	80		
2.1	4	Rp	70	8	V
2.1	4	Eg	10	4	
2.2	1	Rp	98	18	F
2.2	2	Rp	100	20	F
2.2	3	Rp	95	18	F
2.2	4	Rp	45	20	F
2.3	1	-	-		
2.3	2	-	-		
2.3	3	-	-		
2.3	4	-	-		
3.1	1	Rp	95	13	F
3.1	1	Fg	100		
3.1	1	Ui	5		

Site	Rep	Species code	% Cover	Height (cm)	Stage
3.1	2	Rp	100	14	F
3.1	2	Fg	100		
3.1	2	Ui	60		
3.1	3	Rm	95	12	F
3.1	3	Fg	100		
3.1	3	Ui	50		
3.1	3	Rp	60	15	V
3.1	4	Rp	50	12	F
3.1	4	Fg	100		
3.1	4	Ui	5		
3.2	1	-	-		
3.2	2	-	-		
3.2	3	-	-		
3.2	4	-	-		
3.3	1	Fg	70		
3.3	2	Fg	70		
3.3	3	Rp	98	28	F
3.3	4	Rp	100	29	F
4.1	1	Rp	2	5	V
4.1	1	Lmp	8	5	
4.1	2	Rp	10	5	V
4.1	2	Lmp	34	3	
4.1	2	Ui	2		
4.1	2	Ui	1		
4.1	3	Rp	1	5	V
4.1	3	Lmp	2	3	
4.1	3	Ui	1		
4.1	4	Lmp	15	2	
4.1	4	Ui	2		
4.2	1	Rp	55	14	F
4.2	1	Lmp	20	10	
4.2	1	Ui	10		
4.2	1	Ui	10		
4.2	2	Rp	55	12	F
4.2	2	Lmp	25	2	
4.2	3	Rp	60	12	F
4.2	3	Lmp	2	5	
4.2	3	Fg	10		

Site	Rep	Species code	% Cover	Height (cm)	Stage
4.2	3	Fg	10		
4.2	4	Rp	70	14	F
4.2	4	Lmp	40	9	
4.2	4	Ui	5		
4.2	4	Ui	20		
4.2	4	Fg	10		
4.3	1	Rm	100	104	F
4.3	2	Rm	100	103	F
4.3	2	Fg	10		
4.3	3	Rp	90	35	F
4.3	4	Rm	100	124	F
4.3	4	Fg	5		
4.3	4	Ui	5		
4.4	1	Rp	100	14	F
4.4	1	Ui	60		
4.4	2	Rp	80	33	F
4.4	2	Ui	10		
4.4	3	Rp	95	30	F
4.4	3	Ui	5		
4.4	4	Rp	90	17	F
4.4	4	Ui	10		
4.5	1	Rm	95	100	F
4.5	1	Ui	5		
4.5	1	Fg	5		
4.5	2	Rm	100	110	F
4.5	3	Rm	100	120	F
4.5	3	Ui	5		
4.5	4	Rm	100	117	F
5.1	1	Rp	40	5	V
5.1	1	Lmp	8	1	
5.1	1	Fg	80		
5.1	2	Rp	1	4	V
5.1	2	Lmp	20	1	
5.1	2	Fg	80		
5.1	3	Lmp	20	3	
5.1	3	Fg	70		
5.1	3	Fg	1		
5.1	4	Lmp	67	3	

Site	Rep	Species code	% Cover	Height (cm)	Stage
5.1	4	Fg	90		
5.1	4	Ui	1		
5.1	4	Fg	1		
5.2	1	Rp	70	15	F
5.2	1	Ui	5		
5.2	2	Rp	80	17	F
5.2	2	Ui	5		
5.2	3	Rp	90	10	F
5.2	4	Rp	85	13	F
5.2	4	Fg	10		
5.3	1	-	-		
5.3	2	-	-		
5.3	3	-	-		
5.3	4	-	-		
5.4	1	Rp	85	14	V
5.4	1	Ui	5		
5.4	2	Rp	90	17	F
5.4	2	Ui	5		
5.4	3	Rp	95	15	F
5.4	3	Ui	5		
5.4	4	Rp	50	15	F
5.4	4	Ui	70		
5.5	1	Rp	90	15	F
5.5	1	Lmp	3	6	
5.5	1	Ui	10		
5.5	1	Fg	100		
5.5	2	Rp	100	11	F
5.5	2	Fg	100		
5.5	2	Ui	10		
5.5	3	Rp	70	12	F
5.5	3	Fg	90		
5.5	3	Ui	90		
5.5	4	Rp	100	16	F
5.5	4	Ui	100		
5.5	4	Lmp	15		
5.5	4	Fg	100		
6.1	1	Rp	50	9	V
6.1	1	Fg	40		

Site	Rep	Species code	% Cover	Height (cm)	Stage
6.1	2	Rp	40	6	
6.1	2	Lmp	1	5	
6.1	2	Ui	10		
6.1	3	Rp	60	10	V
6.1	4	Rp	25	6	V
6.2	1	Ui	15		
6.2	1	Ui	15		
6.2	1	Lmp	30	2	
6.2	2	Rp	5	5	F
6.2	2	Ui	4		
6.2	2	Ui	5		
6.2	2	Lmp	35	2	
6.2	3	Ui	15		
6.2	3	Ui	2		
6.2	3	Lmp	20	2	
6.2	4	Ui	10		
6.2	4	Ui	4		
6.2	4	Lmp	70	2	
6.3	1	Rp	65	10	V
6.3	2	Rp	75	22	F
6.3	3	Rp	80	14	F
6.3	4	Rp	75	13	F
6.3	4	Lmp	1	1.5	
6.4	1	-	-		
6.4	2	-	-		
6.4	3	Rp	8	13	V
6.4	4	Rp	3	12	V
6.5	1	Ui	50		
6.5	1	Ui	20		
6.5	1	Lmp	15	1.5	
6.5	2	Ui	10		
6.5	2	Ui	10		
6.5	2	Ui	10		
6.5	2	Lmp	10	3	
6.5	3	Rp	5	55	V
6.5	3	Ui	70		
6.5	3	Fg	20		
6.5	3	Ui	20		

Site	Rep	Species code	% Cover	Height (cm)	Stage
6.5	3	Lmp	5	2	
6.5	4	Ui	95		
6.5	4	Fg	20		
6.5	4	Ui	30		
6.5	4	Lmp	15	2.5	
7.1	1	Rp	57	10	F
7.1	1	Fg	80		
7.1	2	Rp	80	7	F
7.1	2	Fg	10		
7.1	2	Ui	10		
7.1	3	Rp	95	7	F
7.1	3	Fg	90		
7.1	3	Ui	50		
7.1	4	Rp	70	7	F
7.1	4	Ui	50		
7.1	4	Fg	95		
7.2	1	-	-		
7.2	2	-	-		
7.2	3	-	-		
7.2	4	-	-		
7.3	1	Ui	5		
7.3	1	Ui	5		
7.3	2	-	-		
7.3	3	Ui	5		
7.3	4	Ui	5		
7.4	1	Rp	70	18	F
7.4	2	Rp	95	17	F
7.4	2	Ui	30		
7.4	3	Rp	60	19	F
7.4	3	Ui	5		
7.4	4	Rp	75	19	F
7.4	4	Ui	90		
7.5	1	Rp	4	20	V
7.5	1	Ui	20		
7.5	2	Rp	1	19	V
7.5	2	Ui	10		
7.5	3	Rp	15	20	V
7.5	3	Ui	15		

Site	Rep	Species code	% Cover	Height (cm)	Stage
7.5	3	Fg	5		
7.5	4	Rp	1	20	V
7.6	1	Rp	15	17	F
7.6	2	Rp	70	22	F
7.6	3	Rp	60	25	F
7.6	4	Rp	35	13	F
7.7	1	Rp	45	10	F
7.7	2	Rp	60	11	V
7.7	3	Rp	50	16	F
7.7	3	Ui	10		
7.7	4	Rp	70	14	F
7.7	4	Ui	10		
8.1	1	Rp	15	7	F
8.1	1	Fg	25		
8.1	1	Ui	5		
8.1	2	Ui	5		
8.1	2	Fg	15		
8.1	3	Ui	80		
8.1	3	Fg	80		
8.1	4	Rp	5	8	V
8.1	4	Fg	100		
8.1	4	Ui	40		
8.1	4	Ui	90		
8.1	4	Ui	10		
8.2	1	Rp	30	13	V
8.2	2	Rp	35	14	F
8.2	3	Rp	50	12	F
8.2	3	Ui	10		
8.2	4	Rp	60	14	V
8.3	1	Rp	2	10	V
8.3	1	Ui	10		
8.3	2	Rp	4	9	V
8.3	3	-	-		
8.3	4	Rp	1	4	V
8.4	1	Rp	1	9	V
8.4	2	-	-		
8.4	3	-	-		
8.4	4	Rp	15	16	V

Site	Rep	Species code	% Cover	Height (cm)	Stage
8.5	1	Ui	1		
8.5	1	Ui	10		
8.5	2	Ui	10		
8.5	3	Ui	5		
8.5	4	-	-		
8.6	1	Rp	1	100	V
8.6	1	Ui	5		
8.6	1	Ui	100		
8.6	1	Ui	80		
8.6	2	Fg	15		
8.6	2	Ui	10		
8.6	3	Ui	1		
8.6	4	-	-		
8.7	1	Ui	95		
8.7	1	Rp	55	13	V
8.7	1	Ui	90		
8.7	3	Rp	65	9	V
8.7	3	Ui	80		
8.7	4	Ui	10		
8.7	4	Ui	20		
8.8	1	Rp	35	17	F
8.8	1	Ui	30		
8.8	1	Ui	15		
8.8	1	Ui	5		
8.8	2	Rp	40	20	F
8.8	2	Ui	10		
8.8	2	Ui	35		
8.8	2	Ui	5		
8.8	3	Rp	65	19	F
8.8	3	Ui	40		
8.8	3	Ui	20		
8.8	3	Ui	5		
8.8	4	Rp	90	22	F
8.8	4	Ui	40		
8.8	4	Ui	20		
8.8	4	Ui	10		
9.1	1	Rp	70	12	F
9.1	1	Ui	100		

Site	Rep	Species code	% Cover	Height (cm)	Stage
9.1	1	Ui	30		
9.1	2	Rp	30	10	F
9.1	2	Ui	100		
9.1	2	Ui	20		
9.1	3	Rp	70	13	F
9.1	3	Ui	100		
9.1	3	Ui	80		
9.1	3	Ui	30		
9.1	4	Rp	50	13	F
9.1	4	Ui	50		
9.1	4	Ui	90		
9.1	4	Ui	30		
9.2	1	-	-		
9.2	2	-	-		
9.2	3	-	-		
9.2	4	Rp	1	5	V
9.3	1	Rp	1	5	V
9.3	1	Ui	10		
9.3	2	Rp	1	80	V
9.3	2	Fg	50		
9.3	2	Fg	1		
9.3	3	Rp	1	4	F
9.3	3	Fg	100		
9.3	3	Ui	50		
9.3	4	Ui	100		
9.3	4	Fg	100		
9.3	4	Ui	1		
9.4	1	Rp	65	20	F
9.4	1	Fg	50		
9.4	2	Rp	65	18	F
9.4	2	Ui			
9.4	3	Rp	75	17	F
9.4	3	Ui	5		
9.4	3	Ui	90		
9.4	4	Rp	65	16	F
9.4	4	Ui	15		
9.4	4	Ui	25		
9.5	1	Rp	65	17	F

Site	Rep	Species code	% Cover	Height (cm)	Stage
9.5	2	Rp	70	16	F
9.5	2	Lmp	4	6	
9.5	3	Rp	20	17	F
9.5	3	Lmp	2	2	
9.5	4	Rp	70	18	F
9.5	4	Ui	10		
9.5	4	Lmp	1	1	
9.6	1	Rp	5	9	F
9.6	1	Lmp	1	1	
9.6	2	Rp	10	7	F
9.6	2	Lmp	5		
9.6	3	Rp	50	7	F
9.6	3	Lmp	25	4	F
9.6	3	Ui	5		
9.6	4	Rp	10	9	F
9.6	4	Lmp	10	1.5	
9.7	1	Rp	5	7	V
9.7	2	Ui	5		
9.7	2	Ui	1		
9.7	3	Rp	2	7	V
9.7	4	Rp	2	10	V
9.7	4	Lmp	1	1.5	
10.1	1	Rp	95	24	F
10.1	1	Ui	5		
10.1	1	Ui	1		
10.1	2	Rp	95	22	F
10.1	2	Ui	5		
10.1	3	Rp	90	33	F
10.1	3	Ui	5		
10.1	4	Rp	85	26	F
10.1	4	Ui	10		
10.2	1	Rp	55	14	F
10.2	2	Rp	60	20	F
10.2	2	Ui	5		
10.2	3	Rp	35	7	F
10.2	3	Ui	20		
10.2	3	Fg	10		
10.2	4	Rp	80	21	F

Site	Rep	Species code	% Cover	Height (cm)	Stage
10.2	4	Ui	10		
10.3	1	Rp	70	8	F
10.3	1	Ui	92		
10.3	1	Ui	30		
10.3	2	Rp	30	4	V
10.3	2	Fg	1		
10.3	2	Ui	1		
10.3	3	Fg	1		
10.3	4	-	-		

Appendix C Macrophyte cover in 10m diameter.

Transect	Site	Species	Percent cover Average	maximum
1	1	*Ruppia megacarpa*	100	100
		Ulva intestinalis	20	50
		Filamentous greens	5	5
2	1	*Ruppia megacarpa*	5	55
		Ruppia polycarpa	50	90
		Elatine gratioloides	45	80
		Myriophyllum triphyllum	10	40
		Ulva intestinalis	30	100
		Filamentous greens	60	100
2	2	*Ruppia polycarpa*	60	90
		Ulva intestinalis	45	90
2	3	Filamentous greens	1	5
3	1	*Ruppia polycarpa*	55	90
		Ruppia megacarpa	1	5
		Ulva intestinalis	20	60
		Filamentous greens	85	100
3	2	*Ruppia polycarpa*	1	1
3	3	*Ruppia polycarpa*	70	95
		Ruppia megacarpa	1	1
		Ulva intestinalis	10	50
		Filamentous greens	50	100
		Myriophyllum triphyllum	1	1
4	1	*Ruppia polycarpa*	10	20
		Ulva intestinalis	5	10
		Filamentous greens	60	80
		Lamprothamnium macropogon	5	10
4	2	*Ruppia polycarpa*	46	70
		Lamprothamnium macropogon	5	5
		Ulva intestinalis	45	100
		Filamentous greens	30	80
4	3	*Ruppia megacarpa*	60	95
		Ruppia polycarpa	30	85
		Filamentous greens	40	70
		Ulva intestinalis	30	60

Transect	Site	Species	Percent cover Average	maximum
4	4	*Ruppia megacarpa*	5	90
		Ruppia polycarpa	65	95
		Ulva intestinalis	50	80
		Filamentous greens	20	50
4	5	*Ruppia megacarpa*	75	100
		Ruppia polycarpa	10	20
		Ulva intestinalis	40	60
5	1	*Elatine gratioloides*	5	20
		Lamprothamnium macropogon	10	15
		Ulva intestinalis	5	10
		Filamentous greens	55	80
		Ruppia polycarpa	8	20
5	2	*Ruppia megacarpa*	15	100
		Ruppia polycarpa	60	90
		Ulva intestinalis	20	60
		Filamentous greens	40	70
5	3	*Ruppia polycarpa*	1	5
		Ruppia megacarpa	1	1
		Myriophyllum triphyllum	1	1
		Filamentous greens	5	15
5	4	*Ruppia polycarpa*	70	95
		Ruppia megacarpa	4	10
		Ulva intestinalis	60	100
5	5	*Myriophyllum triphyllum*	1	5
		Ruppia polycarpa	60	100
		Ulva intestinalis	85	100
		Filamentous greens	60	100
6	1	*Ruppia polycarpa*	30	80
		Filamentous greens	70	100
6	2	*Ruppia polycarpa*	1	5
		Ulva intestinalis	30	60
		Filamentous greens	10	30
		Lamprothamnium macropogon	35	70
6	3	*Ruppia megacarpa*	5	50
		Ruppia polycarpa	60	80

Transect	Site	Species	Percent cover Average	maximum
		Filamentous greens	20	40
		Ulva intestinalis	1	5
6	4	*Myriophyllum triphyllum*	1	1
		Ruppia polycarpa	10	40
		Filamentous greens	1	5
		Ulva intestinalis	1	5
6	5	*Myriophyllum triphyllum*	20	30
		Ruppia polycarpa	15	35
		Ulva intestinalis	100	100
		Lamprothamnium macropogon	50	70
		Filamentous greens	10	20
7	1	*Ruppia polycarpa*	20	50
		Ulva intestinalis	10	40
		Filamentous greens	80	100
7	2	*Ruppia polycarpa*	2	5
		Filamentous greens	5	40
7	3	*Ruppia polycarpa*	5	5
		Ulva intestinalis	10	20
7	4	*Ruppia polycarpa*	70	95
		Ulva intestinalis	60	85
7	5	*Ruppia polycarpa*	5	5
		Filamentous greens	5	10
		Ulva intestinalis	40	100
7	6	*Ruppia polycarpa*	60	85
		Ulva intestinalis	10	10
7	7	*Ruppia polycarpa*	55	70
		Ulva intestinalis	100	100
8	1	*Ruppia polycarpa*	30	65
		Ulva intestinalis	60	80
		Filamentous greens	80	100
8	2	*Ruppia polycarpa*	55	90
		Ulva intestinalis	20	70
8	3	*Ruppia polycarpa*	1	5
8	4	*Ruppia polycarpa*	2	5
		Ulva intestinalis	2	5

Transect	Site	Species	Percent cover Average	maximum
8	5	*Ruppia polycarpa*	1	2
		Ulva intestinalis	40	100
		Filamentous greens	5	10
8	6	*Ruppia polycarpa*	2	1
		Filamentous greens	40	100
		Ulva intestinalis	80	100
8	7	*Ruppia polycarpa*	60	80
		Ulva intestinalis	80	100
8	8	*Ruppia polycarpa*	50	90
		Ulva intestinalis	80	100
9	1	*Ulva intestinalis*	100	100
		Ruppia polycarpa	50	80
9	2	*Ruppia polycarpa*	5	5
9	3	*Ruppia polycarpa*	2	5
		Ulva intestinalis	100	100
		Filamentous greens	100	100
9	4	*Myriophyllum triphyllum*	1	10
		Ruppia polycarpa	60	70
		Lamprothamnium macropogon	2	5
		Ulva intestinalis	65	100
9	5	*Ruppia polycarpa*	40	60
		Ulva intestinalis	30	90
9	6	*Ruppia polycarpa*	30	65
		Myriophyllum triphyllum	10	40
		Lamprothamnium macropogon	10	20
9	7	*Ruppia polycarpa*	10	20
		Ulva intestinalis	80	100
10	1	*Ruppia polycarpa*	85	100
		Ulva intestinalis	80	60
10	2	*Ruppia polycarpa*	45	80
		Ulva intestinalis	80	100
		Filamentous greens	50	60
10	3	*Ruppia polycarpa*	30	60
		Ulva intestinalis	100	100
		Filamentous greens	5	10

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, gr = gravel, m = mud, sm = soft mud. nr = not recorded.

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	1.70	13.0	13.0	8.0	8.0	9.4	8.7	5	5	207	VSM/S	VSM/S	VSM/S	VSM/S	0	0	0	0
2	1	0.40	14.0	14.0	1.0	1.0	9.1	8.8	4	4	34	FM/S	FM/S	FM/S	FM/S	1	> 4	> 4	> 4
2	2	0.90	13.0	13.0	8.0	8.0	9.7	9.5	5	6	180	S/Gr	S/Gr	S/Gr	S/Gr	1	1	2	1
2	3	0.65	14.0	14.0	8.0	8.0	10.1	10.1	10	7	140	Gr/S	Gr/S	Gr/S	Gr/S	> 4	> 4	> 4	> 4
3	1	0.50	14.0	14.0	6.0	6.0	12.1	12.1	3	4	61	SM/S/Gr	SM/S/Gr	SM/S/Gr	SM/S/Gr	1	1	> 4	> 4
3	2	2.00	13.0	13.0	8.0	8.0	9.8	9.8	5	5	152	FM/S	FM/S	FM/S	FM/S	0.2	0.2	0.2	0.2
3	3	0.75	15.0	15.0	8.0	8.0	10.7	10.7	5	5	170	S/Gr	S/Gr	S/Gr	S/Gr	0.2	> 4	0	> 4
4	1	0.50	13.0	13.0	3.0	4.0	10.7	10.7	6	6	55	SM/S/Gr	SM/S/Gr	SM/S/Gr	SM/S/Gr	> 4	> 4	> 4	> 4
4	2	0.90	12.0	12.0	4.0	4.0	10.1	10.2	4	4	93	FS	FS	FS	FS	1	1	1	1
4	3	1.55	15.0	15.0	8.0	8.0	9.8	10.0	5	6	202	SM/S/Gr	SM/S/Gr	SM/S/Gr	SM/S/Gr	> 4	> 4	> 4	> 4
4	4	0.90	15.0	15.0	8.0	8.0	10.0	9.9	4	4	nr	SM/S/Gr	SM/S/Gr	SM/S/Gr	SM/S/Gr	> 4	1	> 4	> 4
4	5	1.30	14.0	14.0	8.0	8.0	11.5	13.4	3	3	216	SM/S	SM/S	SM/S/G	SM/S	> 4	> 4	> 4	> 4
5	1	0.50	13.0	13.0	4.0	4.0	10.7	10.7	5	5	60	S/Gr	S/Gr	S/Gr	S/Gr	> 4	> 4	> 4	> 4
5	2	0.90	15.0	15.0	7.0	7.0	9.5	9.0	3	4	155	S/Gr	S/Gr	S/Gr	S/Gr	> 4	> 4	> 4	1
5	3	1.80	13.0	13.0	8.0	8.0	10.3	10.3	5	5	170	FM/S	FM/S	FM/S	FM/S	0.2	0.2	0.2	0.2
5	4	1.00	15.0	15.0	8.0	8.0	9.8	10.5	2	3	202	S/Gr	S/Gr	S/Gr	S/Gr	1	> 4	> 4	> 4
5	5	0.60	14.0	14.0	8.0	8.0	11.1	11.6	2	3	110	S/Gr	S/Gr	S/Gr	S/Gr	1	1	> 4	1.5
6	1	0.65	19.8	19.8	6.6	6.6	nr	nr	5	4	84	FS	FS	FS	FS	3	3	> 4	> 4
6	2	0.55	19.3	19.2	6.7	6.7	nr	nr	3	3	84	Gr/S	Gr/S	Gr/S	Gr/S	2	> 4	> 4	2
6	3	1.00	15.0	15.0	8.0	8.0	8.9	8.8	5	5	209	Gr/S	Gr/S	Gr/S	Gr/S	> 4	> 4	2	2
6	4	1.40	15.0	15.0	8.0	8.0	9.2	9.3	5	8	203	Gr/S	Gr/S	Gr/S	Gr/S	2	2	2	2
6	5	0.45	18.6	18.7	6.1	6.1	nr	nr	6	6	153	SM/S/Gr	SM/S/Gr	SM/S/Gr	SM/S/Gr	> 4	> 4	> 4	> 4
7	1	0.50	21.6	20.7	6.3	6.4	nr	nr	4	5	103	Gr/S	Gr/S	Gr/S	Gr/S	> 4	> 4	> 4	> 4
7	2	1.20	19.5	18.6	6.0	6.1	nr	nr	5	6	106	S/Gr	S/Gr	S/Gr	S/Gr	> 4	> 4	> 4	> 4

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	3	1.10	19.0	18.7	5.8	5.9	nr	nr	6	6	117	S/Gr	S/Gr	S/Gr	S/Gr	1	1	1	1
7	4	1.00	19.5	19.3	5.9	5.9	nr	nr	6	9	200	FS	FS	FS	FS	1	1.5	1.5	1
7	5	1.30	19.5	18.9	5.9	5.9	nr	nr	6	7	40	FS	FS	FS	FS	2	2	2	2
7	6	0.90	19.4	19.4	5.9	5.9	nr	nr	5	5	175	FS	FS	FS	FS	> 4	> 4	> 4	> 4
7	7	0.70	19.7	19.0	5.8	5.8	nr	nr	5	5	122	FS	F/Gr	F/Gr	F/Gr	2	2	1	0.2
8	1	0.55	21.6	21.8	5.2	5.2	nr	nr	4	3	146	Gr/S	Gr/S	Gr/S	Gr/S	> 4	> 4	> 4	> 4
8	2	1.15	15.6	15.5	7.9	7.9	8.8	8.7	4	4	135	SM/S/Gr	SM/S/Gr	SM/S/Gr	SM/S/Gr	> 4	> 4	1	1
8	3	1.30	19.7	19.6	5.8	5.8	nr	nr	6	6	53	FS	FS	FS	FS	1.5	2.5	3	> 4
8	4	1.50	19.8	19.8	5.7	5.7	nr	nr	6	6	58	FS	FS	FS	FS	3	> 4	> 4	2
8	5	1.50	19.9	19.3	5.7	5.8	nr	nr	6	7	49	s	s	s	s	2.5	1	1	2.5
8	6	0.50	21.1	20.9	5.8	9.1	nr	nr	7	6	62	S/Gr	Gr/S	S	S/Gr	> 4	> 4	> 4	> 4
8	7	0.55	19.9	20.2	6.7	6.7	nr	nr	4	4	177	Gr/S	Gr/S	Gr/S	Gr/S	>4	0.5	0.5	> 4
8	8	0.95	20.1	19.4	6.6	6.7	nr	nr	5	6	140	FM/S	FM/S	FM/S	FM/S	1.5	> 4	1	> 4
9	1	0.60	22.4	22.1	4.4	4.6	nr	nr	5	10	130	Gr/S	Gr/S	Gr/S	Gr/S	> 4	> 4	> 4	> 4
9	2	1.15	20.1	20.1	5.3	5.4	nr	nr	6	6	51	FS	FS	FS	FS	2	3	3	3
9	3	0.90	20.0	19.9	5.1	5.2	nr	nr	10	8	44	FM/S	FM/S	FM/S	FM/S	2	2	1	2
9	4	0.75	18.5	18.5	8.2	8.2	8.8	9.0	3	4	144	SM/S	SM/S	SM/S	SM/S	1	0.5	0.5	0.5
9	5	0.80	18.2	18.3	8.0	8.0	9.2	9.1	3	3	125	FM/S	FM/S	FM/S	FM/S	1	> 4	> 4	> 4
9	6	0.45	18.2	18.2	8.0	8.0	9.4	9.4	2	2	148	FS	FS	FS	FS	> 4	1	2	> 4
9	7	0.80	19.4	19.4	7.2	7.1	nr	nr	10	9	110	SM/S	SM/S	SM/S	SM/S	0.3	1	0.3	1
10	1	0.80	22.0	21.4	4.4	4.8	nr	nr	8	10	55	SM/S	SM/S	SM/S	SM/S	> 4	> 4	> 4	> 4
10	2	0.95	21.4	20.5	3.0	4.3	nr	nr	9	11	29	SM/S	SM/S	SM/S	SM/S	2	> 4	2	1
10	3	0.60	21.1	20.9	3.5	3.8	nr	nr	10	11	25	Gr/S	Gr/S	Gr/S	Gr/S	> 4	> 4	> 4	> 4