Macrophyte monitoring in Waituna Lagoon

- results of the December 2011 and February 2012 surveys

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1 Introduction

Waituna Lagoon is a highly valued coastal lagoon. It forms part of the Awarua complex and is recognised as a wetland of international importance under the Ramsar Convention on wetlands. 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.

The lagoon is fed by three lowland streams that flow through agricultural pastures and has no permanent natural outlet. Openings now occur artificially when the lagoon level is above 2.2 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 2011). Waituna Lagoon is described as meso-eutrophic on the Trophic Level Index, a measure of the life supporting capacity of a lake or lagoon (Schallenberg et al. 2010). This means that the lagoon 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* were present in the lagoon in the 1960's (Roger McNaughton pers comm. 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 in 1995 (Johnson and Partridge 1998).

Given the trophic level of the lagoon, concern has been raised over the potential for the lagoon to switch from macrophyte dominated to phytoplankton dominated state. A macrophyte dominated state typically has high values for biodiversity; aesthetic, recreational and tourist needs and is usually the desired state. The process 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 phytoplankton dominated it is often difficult to reverse.

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. Surveys were repeated in 2009, 2010 and 2011. DOC commissioned NIWA to undertake the 2012 macrophyte survey to document the status of the lagoon vegetation using the methodology used by Robertson and

Stevens (2009) and Stevens and Robertson (2010) to provide an inter-annual comparison of its condition. In December 2011, DOC requested NIWA undertake an additional survey when the lagoon was closed and water levels were relatively high. This report summarises the results of the December 2011 additional survey and the 2012 annual survey.

2 Methods

The methodology used during these surveys was carried out in accordance with Robertson and Stevens (2009) and Stevens and Robertson (2010). 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 eight sites situated on ten transects orientated north-south were surveyed across Waituna Lagoon (Figure 6-1). 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.

2.2 Survey methodology

2.2.1 Water quality

Water quality parameters were measured at each site (Appendix A) using a calibrated Horiba multi-sensor meter. The parameters measured were:

- Temperature
- Dissolved oxygen
- Salinity
- Turbidity
- Secchi depth

2.2.2 Macrophyte and sediment samples

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.
- Cover score[1] of each species present.
- Mean height of each species present.
- Life stage[2] of *Ruppia* spp. (where applicable).
- Sediment type.
- Depth to blackened sulphide layer.

[1] 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%.
[2] Life stage categories were V = vegetative, F = flowering, PF = post flowering.

2.3 Additional observations

During the December 2011 survey additional observations were made in the immediate vicinity of the standard sampling sites, but weather conditions precluded the wider use of sonar between sites. Benthic observations with a drop camera (video viewer) were made along the boat length (2-3 m) and wider snorkel observations were carried out within a 10 by 10 m area. In-water visibility constrained observations to 0.5 m distance on the 8th December but the following day visibility had improved to c. 1 m. Species presence, and average and maximum covers were integrated over the area observed.

The application of sonar to map wide-scale distribution of vegetation was tested at T8, on the 9th December, when weather conditions were amenable to recording profiles. A profile was run from approximately T8-1 to T8-4, at an average boat speed of 8.2 to 8.5 kph. Recording time was 8 minutes.

A Lowrance LCX-15MT depth sounder/GPS/chart plotter digitally logged position, depth and signals for any detectable vegetation. The transducer (HS-200-DX) used a frequency of 200 kHz with a 20 degree cone. The ping speed was set at 100%. Adjustment of sensitivity (60%) and colourline (c. 70%) settings allowed for maximum differentiation of lagoon vegetation. Detected plant heights and covers were ground truthed by snorkel diving. Sonar Viewer version 1.2.2 software by Lowrance was used to extract raw data as recorded by the depth sounder, and an image reconstructed of the profile data.

2.4 Timing

The additional survey was undertaken on the 8 and 9 of December 2011, while the annual survey was carried out between 31 January and 2 February 2012.

3 Results

3.1 Water quality

3.1.1 Water level and depth

Lagoon levels at the time of the December 2011 survey were 0.45 to 0.53 m above normal and approximately 1 m higher than the March/April 2011 survey. During the February 2012 survey, lagoon levels were -0.04 to 0.08 m above normal, approximately 0.5 m above the March/April 2011 survey (Figure 6-2).

All sites were submerged during the December 2011 survey, while 46 out of the 48 sites were submerged during the February 2012 survey. During the March/April 2011 survey only 28 sites were submerged (Figure 6-3, Figure 6-4).

3.1.2 Temperature

Water temperatures were cooler in February 2012 (range 13–17^{o}C) than December 2011 (range 15–18^{o}C). Water depth was the main contributor to variance in temperature across the lagoon with warmer temperatures at shallower sites (Figure 6-5). There was no stratification present at any site during the December 2011 and February 2012 surveys. Differences between surface and bottom water temperatures are within the error of the instrument. Temperature was well below temperatures considered inhibitory for most organisms.

3.1.3 Dissolved oxygen

During the December 2011 survey, dissolved oxygen (DO) was above saturation in both surface and bottom waters, at each site (Figure 6-6). At the time of the December 2011 survey, conditions on the lagoon were regarded as ‘choppy’. This turbulent mixing of the lagoon would have resulted in saturating DO levels. DO was lower in both surface and bottom waters in February 2012 compared to December 2011. Conditions on the lagoon on day 2 and 3 of the survey were calm. On some sites, the bottom water DO breached the 90% desirable minimum for freshwater-bodies adopted by many councils, including Environment Southland. These sites, including 3.1, 7.6, and 7.7 were shallow and often contained decaying periphyton (particularly *Cladophora* sp. – see Section 3.3).

3.1.4 Turbidity

During the December 2011 survey, turbidity was low across the entire lagoon, ranging from 5 to 25 NTU (Figure 6-7). Lowest turbidity was recorded in sheltered bays, suggesting that the increased turbidity was a result of re-suspended sediments.

In February 2012, turbidity was more variable than December 2011, ranging from 8 to 100 NTU (Figure 6-7). Turbidity was often higher in the bottom waters than the surface waters. Both re-suspended sediment and *Spirogyra* sp. in the water column are likely to be the main contributors to increased turbidity in the bottom waters.

3.1.5 Salinity

Salinity was low in the lagoon during the December 2011 and February 2012 surveys (Figure 6-8), compared to March/April 2011 when the lagoon was open. Top and bottom waters did not differ much in February, indicating little to no salinity stratification. The influence on reducing salinity caused by freshwater inflows is seen on transects 1, 2 and 9.

3.1.6 Blackened 'sulphide' layer

The depth to the blackened sediment layer ranged from 0.5 cm to >6 cm across the lagoon, with many sites in excess of 6 cm. Compared to the April/March 2011 survey, in the February 2012 survey the blackened layer was generally deeper, or not detected within the sediment profile with the exception of four sites where it was more shallow (Figure 6-9).

3.2 Macrophytes

Macrophytes were recorded at a total of 31 sites in December 2011 and 29 sites in February 2012, with the most frequently recorded species being *Ruppia polycarpa* at 25 sites in December 2011 and 27 sites in February 2012 (Figure 6-10, Figure 6-11 and Figure 6-14) and the charophyte *Lamprothamnium macropogon* at 15 and 13 sites in December 2011 and February 2012, respectively (Figure 6-12, Figure 6-13 and Figure 6-14).

R. polycarpa was recorded across an overall depth range of 0.9 to 1.8 m in December 2011 and 0.4 to 1.2 m in February 2012 [3] (Appendix B).

The cover score of *R. polycarpa* ranged from 1 (0-5%) to 6 (80-100%) across the lagoon during both surveys (Figure 6-10 and Figure 6-11) while bed height ranged from 3 to 70 cm in December and from 5 to 35 cm in February. *R. polycarpa* was mostly vegetative in December, while during February, fruiting occurred on over 50% of sites where *R. polycarpa* was recorded.

L. macropogon was recorded at depths of between 0.9 and 1.8 m in December 2011 and between 0.49 and 0.95 m in February 2012, with cover scores ranging from 1 (0-5%) to 6 (80-100%) during both surveys (Appendix B; Figure 6-12 and Figure 6-13). At the time of the December survey, *L. macropogon* was mostly vegetative, although early stages of fruiting were noted. During the February survey, over 90% of material sampled was fruiting, bearing oospores.

Other species recorded in low frequency during the December 2011 and February 2012 surveys (Figure 6-14) included *Ruppia megacarpa*, *Myriophyllum propinquum*, *Myriophyllum triphyllum*, *Lilaeopsis novae-zelandiae* and the macroalga *Ulva intestinales.*

3.3 Periphyton observations

During the 2012 survey, there were copious amounts of filamentous green algae around Waituna Lagoon, particularly along marginal habitat on the northern shoreline. This was consistent with observations made during the December 2011 survey. *Spirogyra* sp. was the most abundant live filamentous green alga present in the lagoon (Figure 6-15); however, with such large quantities of dead *Cladophora* sp. biomass present, this suggests a recent bloom (Figure 6-16). The dead *Cladophora*

[3] At the time of the February 2012 survey, water levels were approximately 0.5 m lower than during the December 2011 survey. Depth ranges are reported as depth recorded on the day.

sp., covering macrophytes on a number of survey sites, was brown and superficially resembled the marine brown filamentous alga *Bachelotia antillarum;* however, identification was confirmed when viewed under a compound microscope. *B. antillarum* is often regarded as an indicator of degraded water quality in inter-tidal habitats (Díez et al. 2009). During the 2009 survey, *B. antillarum* was considered to be widespread throughout Waituna Lagoon, with thick smothering growths evident on the sediment and epiphytic on the plants (Robertson and Stevens 2009). Stevens and Robertson (2010) noted a decline in the occurrence of *B. antillarum* throughout the lagoon. In 2011 and 2012 surveys, *B. antillarum* was not recorded at any site on any transect.

3.4 Additional macrophyte survey

Integrated observations over wider spatial scale

Additional observations using drop camera and snorkel diving revealed covers of plants undetected by the hoe sampling in the vicinity of T1-1, T3-3, T5-4, T7-2, 3 & 4, T8-3 & 6 and T10-3, either where covers were very low <5%, or plants occurred as isolated clumps. Snorkelling also picked up rarer or spatially restricted species that included *R. megacarpa* near T1-1, and *M. triphyllum* at T10-2 & 3, while *Gracilaria chilensis* was also observed. Occurrence and percent cover of macrophyte species encountered during additional observations are presented in Appendix C.

Sonar

Ground truthing by snorkel diving confirmed that sonar was able to detect patchy *R. polycarpa* beds at plant covers of greater than approximately 20%, and heights of greater than 0.25 m. The shallow nature of the lagoon, and the transducer cone angle of 20% meant that a spatial width of 0.4-0.5 m was scanned along the transect between approximately T8-1 and T8-4 (Figure 6-17). Nevertheless, this was sufficient to detect and map significant covers of plants despite their patchy nature (Figure 6-18).

The sonar trace detected an extensive area of *R. polycarpa* that began at 1.3 m depth and extended to 1.4 m depth (Figure 6-17 and Figure 6-18). The trace showed plant cover to become increasingly patchy in nature at about 1.5 m, with the deepest detected patch at 1.6 m depth.

4 Discussion

Macrophyte recovery

A wide scale recovery of macrophytes has occurred since the March/April 2011 survey, following filling of the lagoon after an extended summer opening. Macrophyte occurrence and cover were similar across the lagoon in December 2011 and February 2012, although there was a loss in plant bed height recorded in February. This is most likely a result of lower lagoon levels and the effects of wave action on the plant beds (Figure 6-2).

As far as we are aware this is the first record for *Lamprothamnium macropogon* at Waituna Lagoon, although unidentified charophytes recorded in previous surveys may have included this species. *L. macropogon* (previously *L. papulosum*) is native, but not endemic to New Zealand. It is a brackish water charophyte that is essentially restricted to coastal water bodies in New Zealand. In the past it has been recorded from Lake Kohangapiripiri, in or near Lake Onoke, at a Wairau River lagoon in Marlborough, Lake Grassmere, Lake Windermere, Lake Ellesmere, and inland at Middlemarch (Wood & Mason 1977). More recently it has been recorded from Waihora Lagoon in Northland, Whakaki Lagoon near Wairoa, and the Chatham Islands (NIWA unpublished records), but has not been re-recorded at any of the historic sites, indicating the species is in decline in New Zealand. All specimens examined from Waituna Lagoon agreed with the species concept, although we note that new *Lamprothamnium* species have recently been distinguished in Australia, to which New Zealand material has not yet been compared.

While the macrophytes were relatively clean and free of epiphytic algal growth, there was a large amount of filamentous green algae present throughout the lagoon, and in some instances, smothering the plant beds. *Cladophora* spp. and *Spirogyra* spp. (the dominant species observed during the two surveys) can form large blooms in summer and autumn often in response to sources of enrichment (Biggs and Kilroy, 2000). The recent dry spell, and therefore low inflow to dilute nutrient loads to the lagoon, would have helped to enhance periphyton development over the summer period. Periphyton positioned near the land-water interface, intercept land derived nutrients before they become diluted in the open water. Periphyton, therefore, are the first responders to nutrient change in lakes and lagoons. The measurement of periphyton development along shoreline habitats may represent a better tool for early detection of changes as a result of increased nutrient inputs than classic methods based on pelagic characteristics (Lambert et al. 2008).

Additional survey techniques

The current methodology is a good measure of patch dynamics of the macrophytes, in particular *Ruppia*, in Waituna Lagoon over time. However, the limited survey area (using the points method) at each sampling site on a transect meant that important information was missed. Sutherland and Taumoepeau (2011) noted that large patches of high cover (> 80%) were present between sampling sites but was not reflected in the sampling sites with cover recorded as low (1-5%). During the December 2011 survey additional survey techniques were trialled and observations made over a wider spatial scale (c. 10 x 10 m) showed that spot sampling with the hoe method, although a practical remote method, was likely to underestimate the presence and cover of plants, whereas integrating observed covers over 2 m^2 to 10 m^2 provides a more representative measurement.

The use of sonar for wide scale mapping of significant macrophyte beds in Waituna Lagoon showed considerable merit. Detection of *Ruppia* dominated growth was achieved and the boundaries of significant beds could be delineated and geo-referenced for mapping. This approach is very cost-effective as transects can be rapidly recorded in the field. However, a restriction to this method is the requirement for calm weather conditions, due to the amplified effect of surface waves and ripples on the traces in such a shallow water body. Even in relatively calm conditions for the lagoon, with a 0.2 m wind chop, some artefact is evident on the trace of the lagoon bottom (Figure 6-18). Also, high water levels are required both for boat navigation and for clarity of sonar signal. Shallow water depths of about 0.6 m or less can restrict sonar use because the lack of differentiation of the signal means background 'noise' obscures vegetation details and coverage is less as beam width is narrow. Large blooms of macro or filamentous algae may also make differentiation of *Ruppia* beds difficult.

5 Recommendations

In order to improve the understanding in the temporal variability of *Ruppia* beds in Waituna Lagoon we recommend undertaking more frequent monitoring (intra-annual) at fixed sentinel sites. Based on cover scores recorded from 2007 to 2012, sites with stable high cover of *Ruppia*, and therefore better indicators of change, are:

- T2-2
- T5-2
- T7-4
- T9-4 or T9-5

We recommend that at each site, visual macrophyte surveys are undertaken in three areas of a minimum of 2 m by 2 m in size, using either divers, underwater viewers, sonar scans or a combination of these. The reason for this is to cover a larger area in order to ensure that cover recorded is representative of the area, and to minimise destructive sampling, particularly of the area being re-monitored.

We also recommend incorporating periphyton monitoring along northern shoreline sites (in particular at locations near inflow sites) including per cent cover and community composition, in order to detect change.

6 References

Atkinson, E. (2008). What's lurking in the Waituna wetlands? A freshwater fish survey – Arawai Kakariki project. Department of Conservation, 32 p.

Biggs, B.F.G.; Kilroy, C. (2000). Stream periphyton monitoring manual. Prepared for the New Zealand Ministry for the Environment.

Johnson, P.N.; Partridge, T.R. (1998). Vegetation and water level regime at Waituna Lagoon, Southland. *Science for Conservation: 98*. New Zealand Department of Conservation, Wellington, New Zealand. 55 p.

Lambert, D.; Cattaneo, A.; Carignan, R. (2008). Periphyton as early indicators of perturbation in recreational lakes. *Canadian Journal of Fisheries and Aquatic Science 65*: 258–265.

LTG Lagoon Technical Group (2011). Interim recommendations to reduce the risk of Waituna Lagoon flipping to an algal-dominated state. Report prepared for Environment Southland.

Robertson, B.M.; Stevens, L. (2009). Waituna Lagoon: Macrophyte (Ruppia) mapping. Report prepared for Department of Conservation, Southland Conservancy. 10 p+ Appendix.

Schallenberg, M.; Larned, S.T.; Hayward, S.; Arbuckle, C. (2010). Contrasting effects of managed opening regimes on water quality in two intermittently closed and open coastal lakes. *Estuarine, Coastal and Shelf Science 86*: 587–597.

Stevens, L.; Robertson, B. (2010). Waituna Lagoon. Macrophyte (Ruppia) monitoring. Report prepared for Department of Conservation, Southland Conservancy. 11 p + Appendix.

Sutherland, D.; Taumoepeau, A. (2011). Macrophyte monitoring of Waituna Lagoon 2011. *NIWA Client Report HAM2011-054*.

Wood, R.D.; Mason, R. (1977): Characeae of New Zealand. *New Zealand Journal of Botany 15*: 87–180.

Figure 6-1: 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.

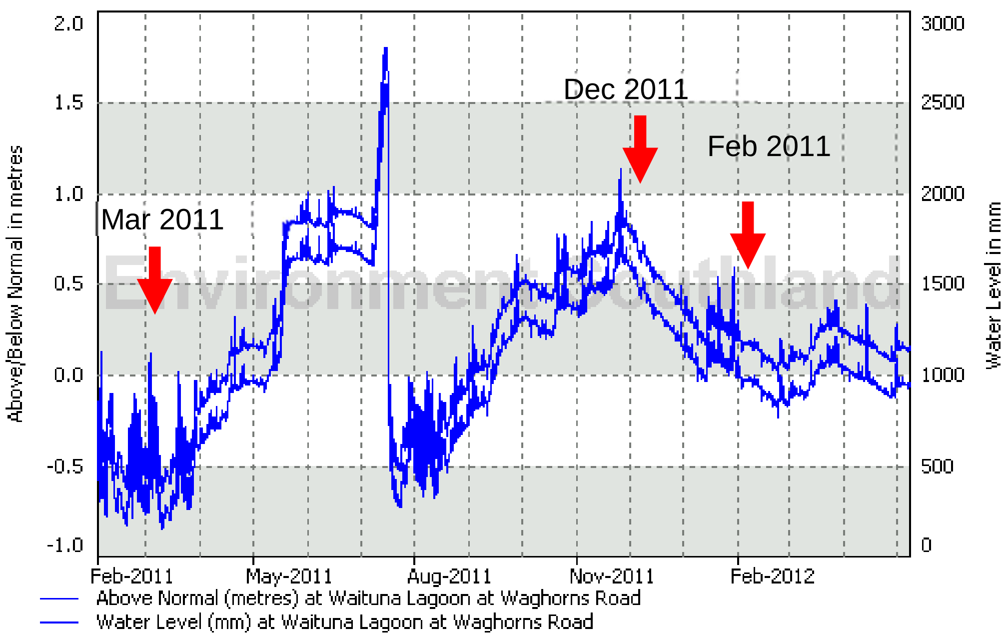

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Figure 6-2: Water level data for Waituna Lagoon at Waghorn Road. Source: Environment Southland. Arrows show the timing of surveys.

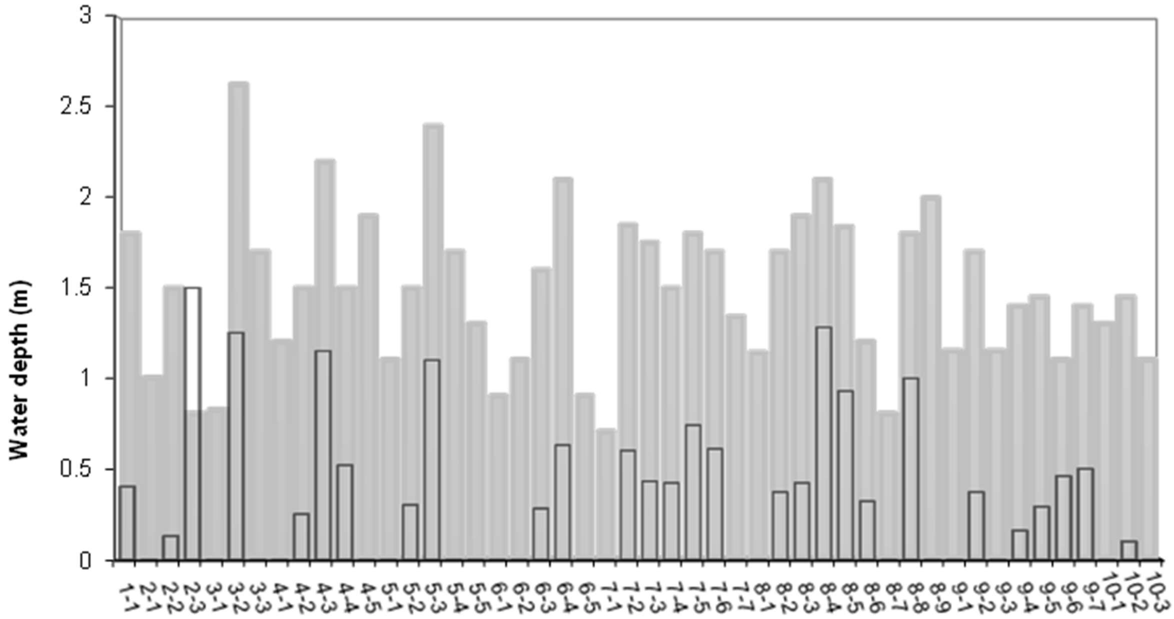


Figure 6-3: Water depth recorded at 48 sampling sites in December 2011 (grey), and March/April 2011 (dark outline). The site number is given as the transect number then the site number on the y axis.

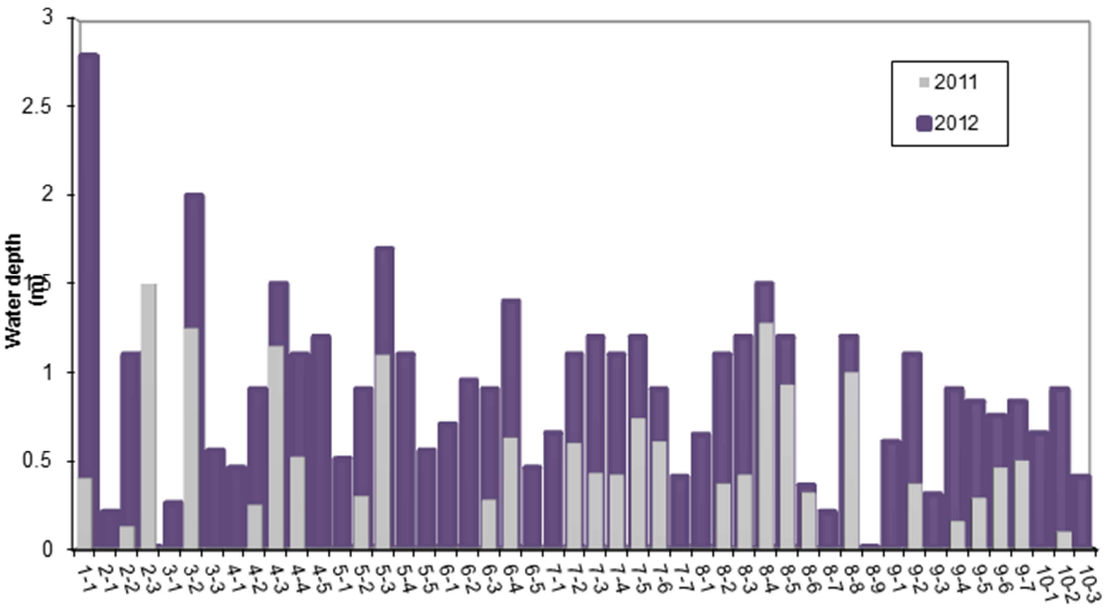
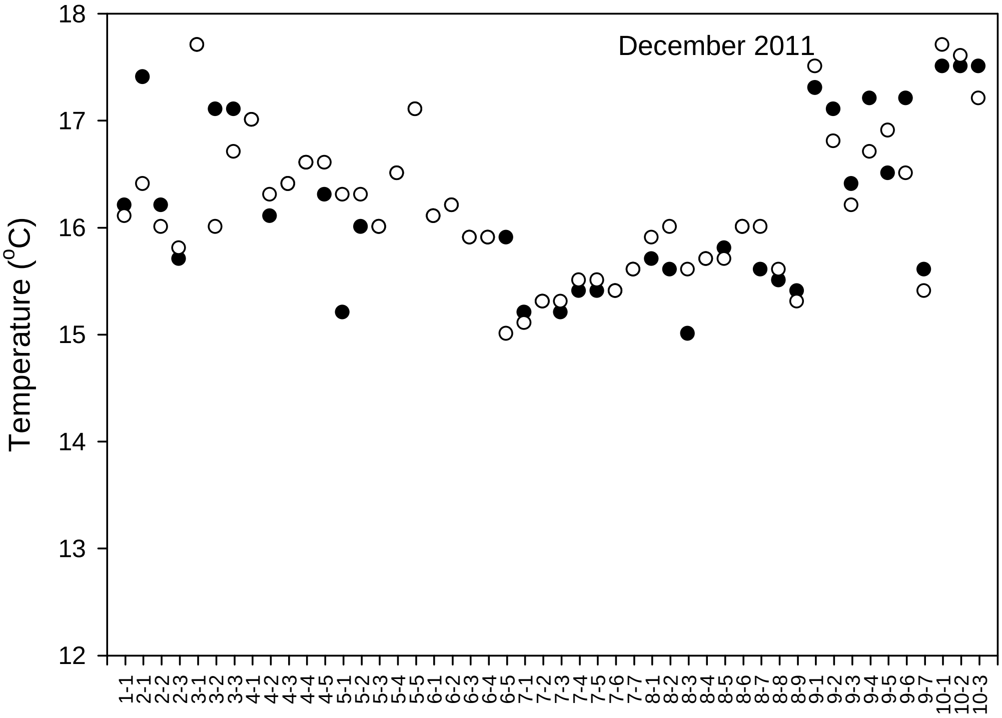


Figure 6-4: Water depth at 48 sampling sites in February 2012 (purple bars) compared to water depth recorded in March/April 2011 (grey bars). The site number is given as the transect number then site number on the y-axis.



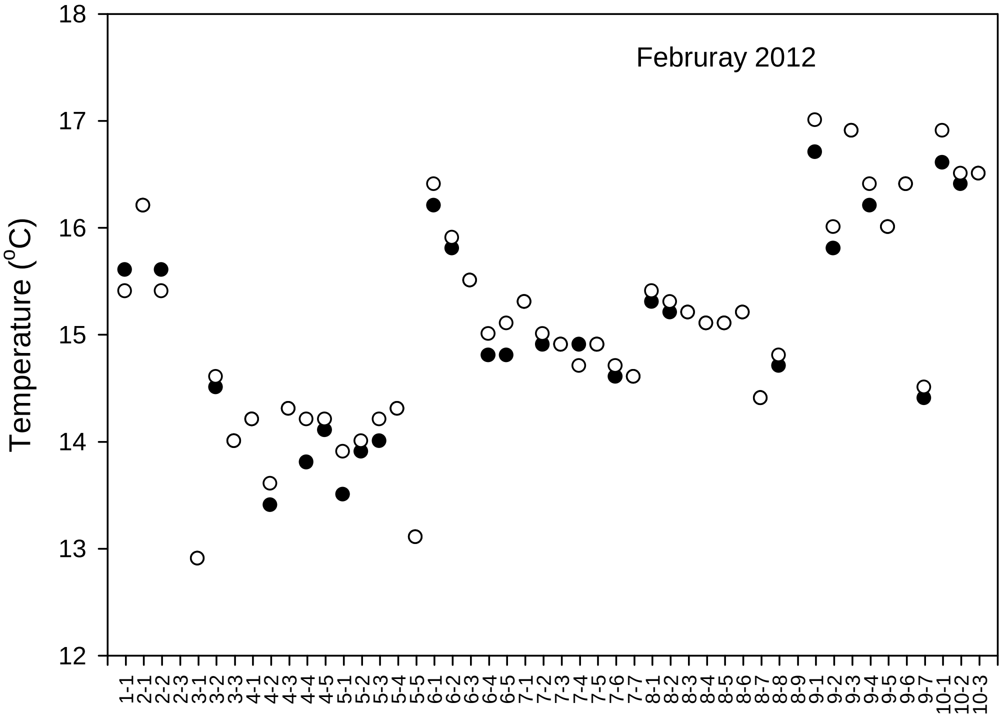
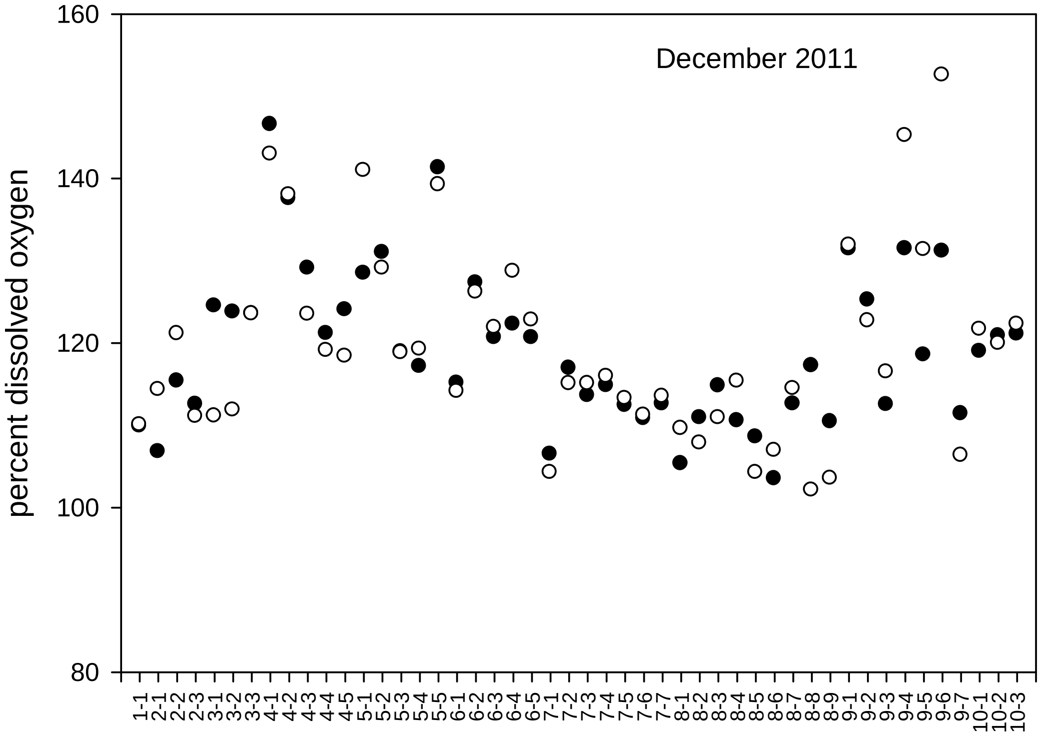


Figure 6-5: Surface (white dots) and bottom (black dots) water temperature at survey sites in Waituna Lagoon. Top graph: December 2011 survey, bottom graph: February 2012 survey.



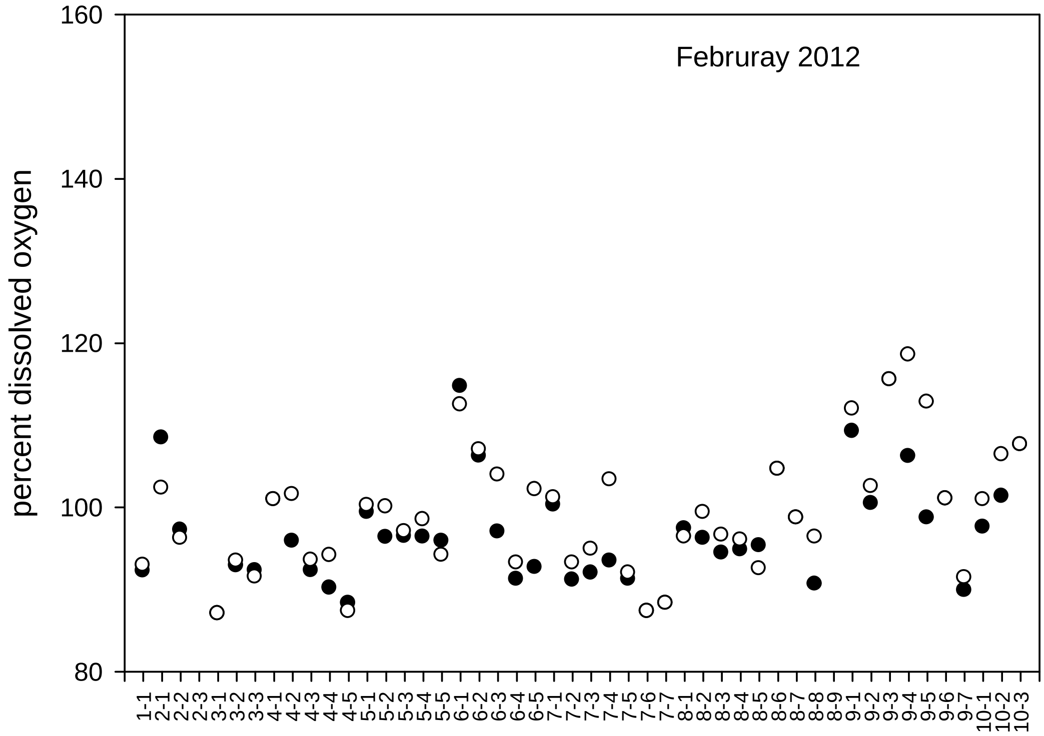
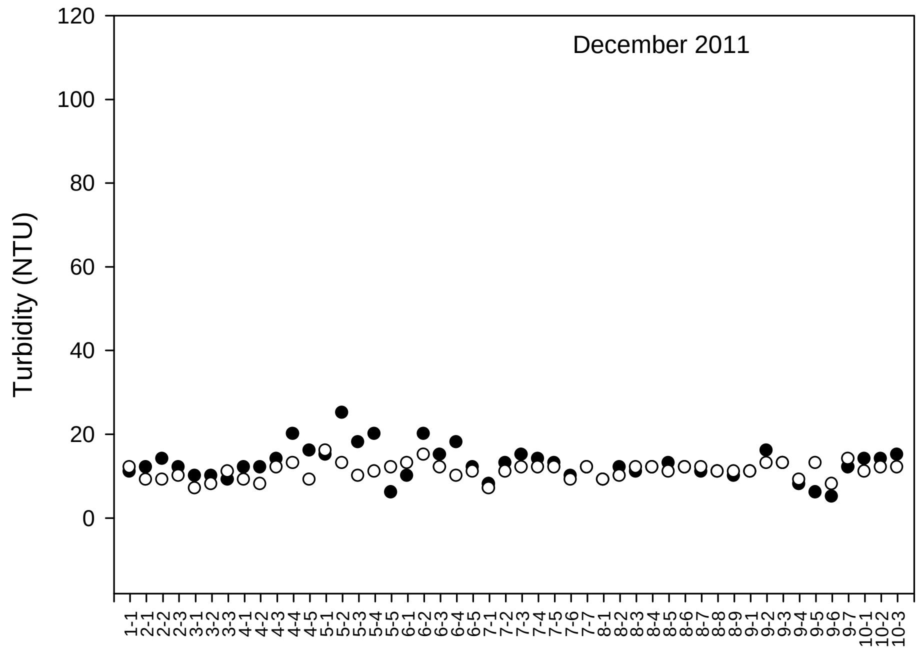


Figure 6-6: Surface (white dots) and bottom (black dots) dissolved oxygen (%) at survey sites in Waituna Lagoon. Top graph: December 2011 survey, bottom graph: February 2012 survey.



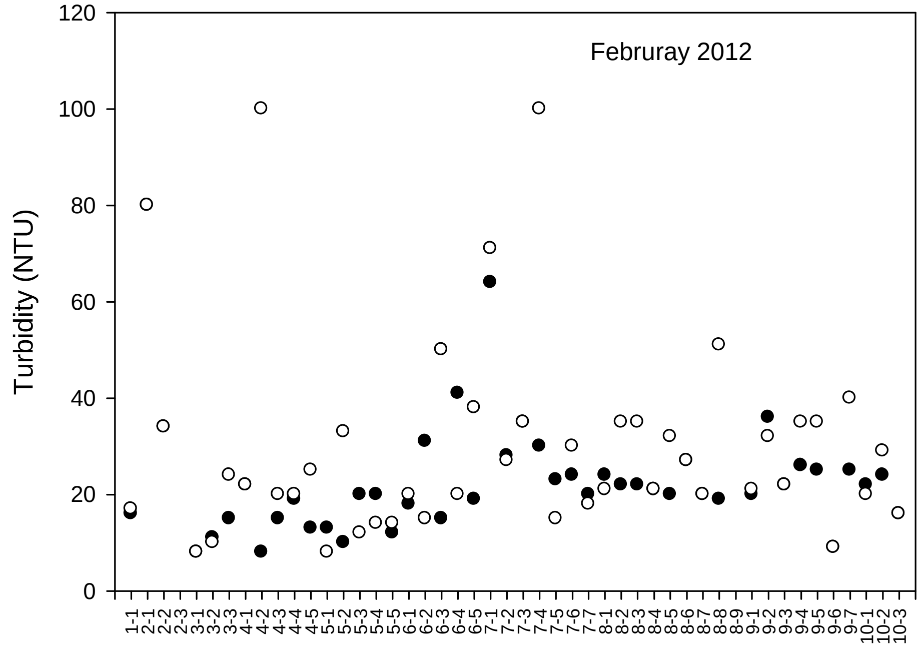


Figure 6-7: Surface (white dots) and bottom (black dots) turbidity (NTU) at survey sites in Waituna Lagoon. Top graph: December 2011 survey, bottom graph: February 2012 survey.

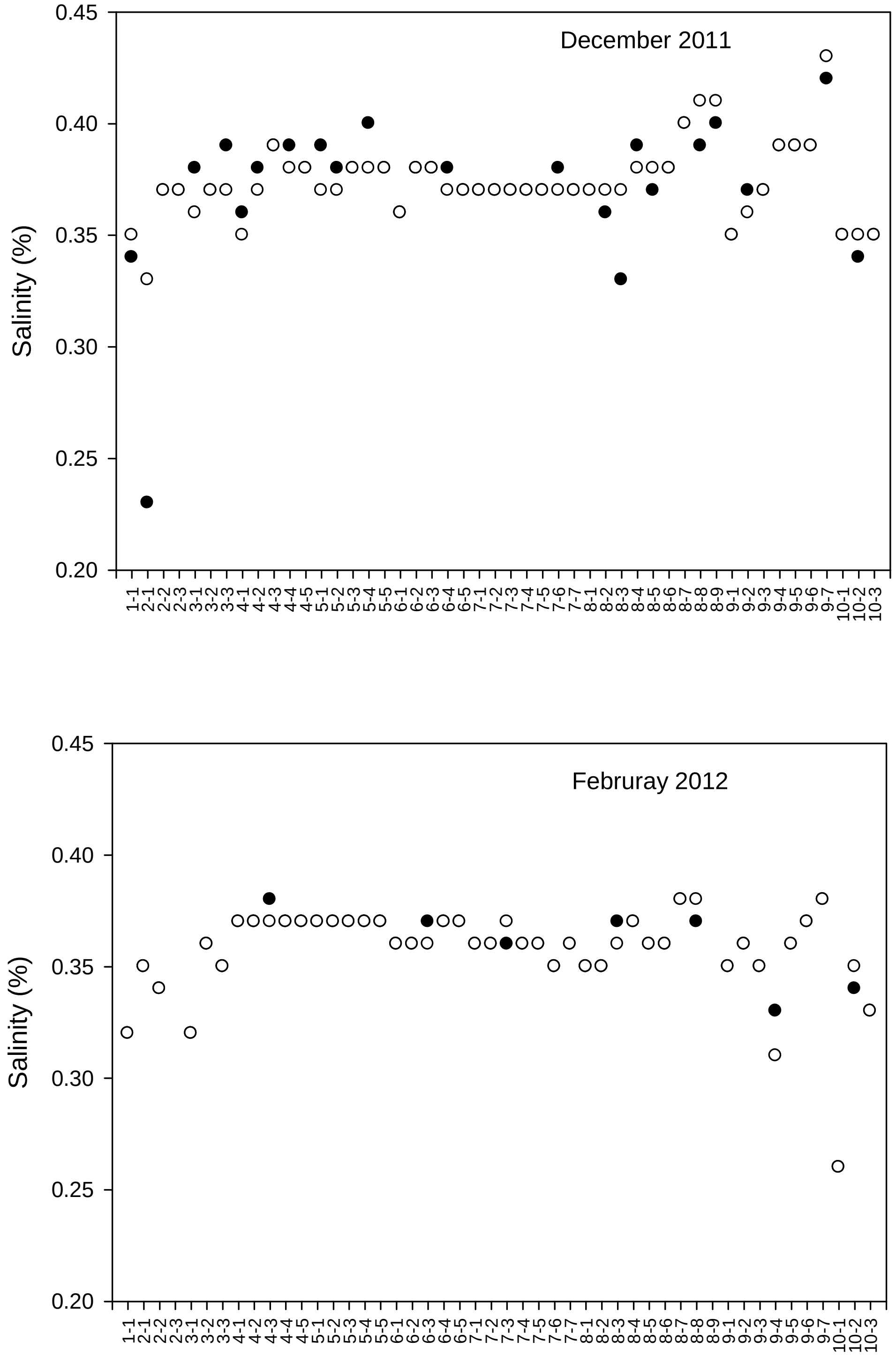


Figure 6-8: Surface (white dots) and bottom (black dots) water salinity (%) at survey sites in Waituna Lagoon. Top graph: December 2011 survey, bottom graph: February 2012 survey.

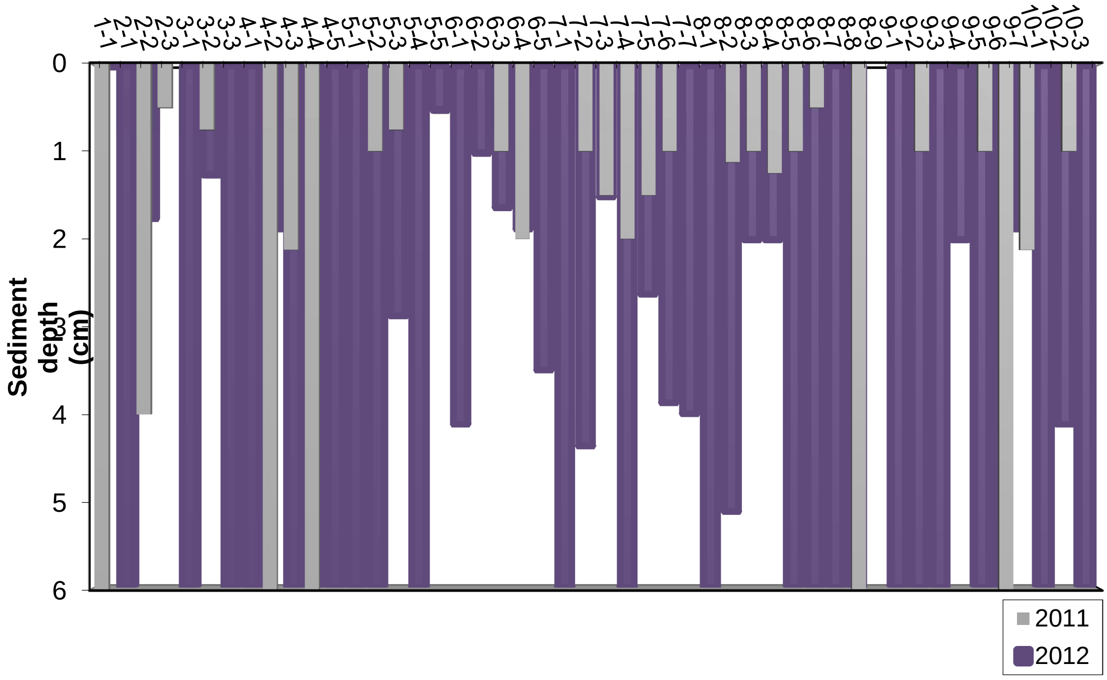


Figure 6-9: Depth (cm) to the blackened 'sulphide' layer at submerged sites in February 2012 (purple bars) compared to March 2011 (grey bars).

Figure 6-10: Cover score of Ruppia spp. at survey sites in Waituna Lagoon during the December 2011 survey.

Figure 6-11: Cover of Ruppia spp. at the survey sites in Waituna Lagoon during the February 2012 survey.

Figure 6-12: Cover of Lamprothamnium macropogon at survey sites in Waituna Lagoon during the December 2011 survey.

Figure 6-13:Cover of Lamprothamnium macropogon at survey sites in Waituna Lagoon during the February 2012 survey.

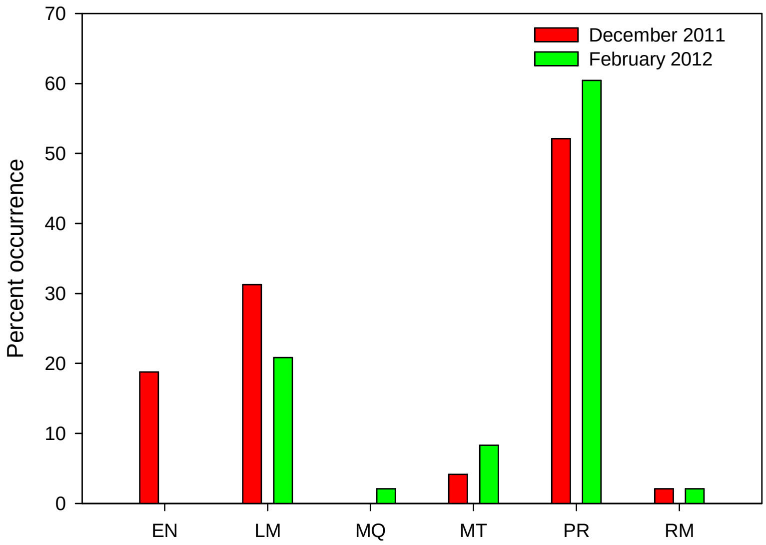


Figure 6-14: Percent occurrence of each macrophyte recorded in Waituna Lagoon in December 2011 and February 2012. EN = *Ulva intestinales*, LM = *Lamprothamnium macropogon*, MQ = *Myriophyllum propinquum*, MT = *Myriophyllum triphyllum*, PR = *Ruppia polycarpa*, RM = *Ruppia megacarpa*.

Figure 6-15: Spirogyra sp. washed up on the shore and suspended in the water column in Waituna Lagoon during the February 2012 survey.

Figure 6-16: Brown clumps of dead Cladophora sp. in Waituna Lagoon during the February 2012 survey.

Figure 6-17: Location of sonar trace to test application for mapping macrophytes in Waituna Lagoon (GPS points extracted from trace). Start and finish points are shown in yellow and the main extent (start and finish) of plant growth marked with blue arrow heads.

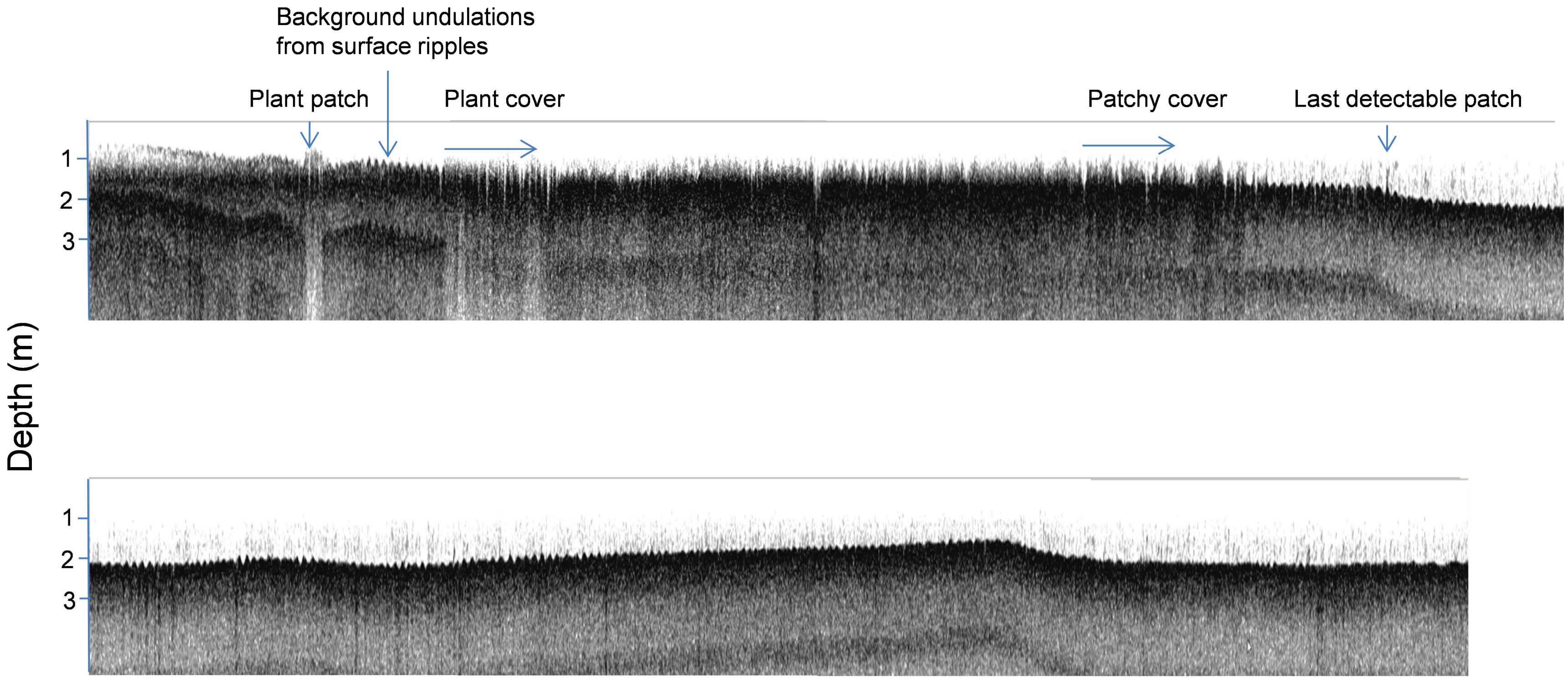


Figure 6-18: Sonar trace between site T8-1 and T8-4 in Waituna Lagoon during the December 2011 survey. The second one is an extension of the first.

Appendix A Water quality parameters

Table A-1: Water quality parameters measured at sites along ten transects in Waituna Lagoon during the December 2011 survey. DO = dissolved oxygen.

Transect	Site	Depth (m)	Sample	Temp (^{o}C)	DO (mg/L)	Turbidity (NTU)	Salinity ppt
1	1	1.8	Top	16.2	10.86	11	0.34
			Bottom	16.1	10.9	12	0.35
2	1	1	Top	17.4	10.29	12	0.23
			Bottom	16.4	11.25	9	0.33
2	2	1.5	Top	16.2	11.4	14	0.37
			Bottom	16	12.02	9	0.37
3	3	0.8	Top	15.7	11.24	12	0.37
			Bottom	15.8	11.07	10	0.37
3	1	0.82	Top	17.7	11.92	10	0.38
			Bottom	17.7	10.64	7	0.36
3	2	2.63	Top	17.1	12	10	0.37
			Bottom	16	11.1	8	0.37
3	3	1.7	Top	17.1	11.98	9	0.39
			Bottom	16.7	12.08	11	0.37
4	1	1.2	Top	17	14.24	12	0.36
			Bottom	17	13.89	9	0.35
4	2	1.5	Top	16.1	13.62	12	0.38
			Bottom	16.3	13.61	8	0.37
4	3	2.2	Top	16.4	12.7	14	0.39
			Bottom	16.4	12.15	12	0.39
4	4	1.5	Top	16.6	11.87	20	0.39
			Bottom	16.6	11.67	13	0.38
4	5	1.9	Top	16.3	12.23	16	0.38
			Bottom	16.6	11.6	9	0.38
5	1	1.1	Top	15.2	12.97	15	0.39
			Bottom	16.3	13.9	16	0.37
5	2	1.5	Top	16	13	25	0.38
			Bottom	16.3	12.73	13	0.37
5	3	2.4	Top	16	11.8	18	0.38
			Bottom	16	11.79	10	0.38
5	4	1.7	Top	16.5	11.5	20	0.4
			Bottom	16.5	11.71	11	0.38
5	5	1.3	Top	17.1	13.7	6	0.38
			Bottom	17.1	13.5	12	0.38
6	1	1.6	Top	16.1	11.4	10	0.36
			Bottom	16.1	11.3	13	0.36
6	2	1.1	Top	16.2	12.58	20	0.38
			Bottom	16.2	12.47	15	0.38
6	3	1.6	Top	15.9	12	15	0.38
			Bottom	15.9	12.12	12	0.38
6	4	2.1	Top	15.9	12.16	18	0.38
			Bottom	15.9	12.8	10	0.37
6	5	0.9	Top	15.9	12	12	0.37
			Bottom	15	12.45	11	0.37
7	1	0.7	Top	15.2	10.75	8	0.37
			Bottom	15.1	10.55	7	0.37
7	2	1.85	Top	15.3	11.78	13	0.37
			Bottom	15.3	11.59	11	0.37

Transect	Site	Depth (m)	Sample	Temp (^{o}C)	DO (mg/L)	Turbidity (NTU)	Salinity ppt
7	3	1.75	Top	15.2	11.47	15	0.37
			Bottom	15.3	11.59	12	0.37
7	4	1.5	Top	15.4	11.54	14	0.37
			Bottom	15.5	11.63	12	0.37
7	5	1.8	Top	15.4	11.3	13	0.37
			Bottom	15.5	11.36	12	0.37
7	6	1.7	Top	15.4	11.14	10	0.38
			Bottom	15.4	11.18	9	0.37
7	7	1.34	Top	15.6	11.27	12	0.37
			Bottom	15.6	11.36	12	0.37
8	1	1.14	Top	15.7	10.52	9	0.37
			Bottom	15.9	10.9	9	0.37
8	2	1.7	Top	15.6	11.1	12	0.36
			Bottom	16	10.7	10	0.37
8	3	1.9	Top	15	11.64	11	0.33
			Bottom	15.6	11.1	12	0.37
8	4	2.1	Top	15.7	11.04	12	0.39
			Bottom	15.7	11.52	12	0.38
8	5	1.84	Top	15.8	10.82	13	0.37
			Bottom	15.7	10.41	11	0.38
8	6	1.2	Top	16	10.27	12	0.38
			Bottom	16	10.61	12	0.38
8	7	0.8	Top	15.6	11.27	11	0.4
			Bottom	16	11.36	12	0.4
8	8	1.8	Top	15.5	11.76	11	0.39
			Bottom	15.6	10.22	11	0.41
8	9	2	Top	15.4	11.1	10	0.4
			Bottom	15.3	10.43	11	0.41
9	1	1.15	Top	17.3	12.69	11	0.35
			Bottom	17.5	12.68	11	0.35
9	2	1.7	Top	17.1	12.14	16	0.37
			Bottom	16.8	11.97	13	0.36
9	3	1.15	Top	16.4	11.07	13	0.37
			Bottom	16.2	11.51	13	0.37
9	4	1.4	Top	17.2	12.72	8	0.39
			Bottom	16.7	14.2	9	0.39
9	5	1.45	Top	16.5	11.64	6	0.39
			Bottom	16.9	12.79	13	0.39
9	6	1.1	Top	17.2	12.69	5	0.39
			Bottom	16.5	14.98	8	0.39
9	7	1.4	Top	15.6	11.15	12	0.42
			Bottom	15.4	10.69	14	0.43
10	1	1.3	Top	17.5	11.44	14	0.35
			Bottom	17.7	11.65	11	0.35
10	2	1.45	Top	17.5	11.62	14	0.34
			Bottom	17.6	11.51	12	0.35
10	3	1.1	Top	17.5	11.64	15	0.35
			Bottom	17.2	11.83	12	0.35

Table A-2: Water quality parameters measured at sites along ten transects in Waituna Lagoon during the 2012 survey. DO = dissolved oxygen.

Transect	Site	Depth (m)	Sample	Temp (°C)	DO (mg/L)	Turbidity (NTU)	Salinity ppt
1	1	2.8	TOP	15.6	9.3	16	0.32
			BOTTOM	15.4	9.37	17	0.32
2	1	0.2	TOP	16.2	10.7	80	0.35
			BOTTOM	16.2	10.1	80	0.35
2	2	1.1	TOP	15.6	9.8	34	0.34
			BOTTOM	15.4	9.7	34	0.34
3	3	DRY					
3	1	0.25	TOP	12.9	9.38	8	0.32
			BOTTOM	12.9	9.38	8	0.32
3	2	2	TOP	14.5	9.57	11	0.36
			BOTTOM	14.6	9.63	10	0.36
3	3	0.55	TOP	14	9.51	15	0.35
			BOTTOM	14	9.43	24	0.35
4	1	0.45	TOP	14.2	10.4	22	0.37
			BOTTOM	14.2	10.4	22	0.37
4	2	0.9	TOP	13.4	10.1	8	0.37
			BOTTOM	13.6	10.7	100	0.37
4	3	1.5	TOP	14.3	9.51	15	0.38
			BOTTOM	14.3	9.64	20	0.37
4	4	1.1	TOP	13.8	9.5	19	0.37
			BOTTOM	14.2	9.7	20	0.37
4	5	1.2	TOP	14.1	9.1	13	0.37
			BOTTOM	14.2	9	25	0.37
5	1	0.5	TOP	13.5	10.47	13	0.37
			BOTTOM	13.9	10.56	8	0.37
5	2	0.9	TOP	13.9	10.15	10	0.37
			BOTTOM	14	10.31	33	0.37
5	3	1.7	TOP	14	9.94	20	0.37
			BOTTOM	14.2	10	12	0.37
5	4	1.1	TOP	14.3	9.93	20	0.37
			BOTTOM	14.3	10.15	14	0.37
5	5	0.55	TOP	13.1	10.1	12	0.37
			BOTTOM	13.1	9.92	14	0.37
6	1	0.7	TOP	16.2	11.32	18	0.36
			BOTTOM	16.4	11.1	20	0.36
6	2	0.95	TOP	15.8	10.71	31	0.36
			BOTTOM	15.9	10.79	15	0.36
6	3	0.9	TOP	15.5	9.78	15	0.37
			BOTTOM	15.5	10.48	50	0.36
6	4	1.4	TOP	14.8	9.4	41	0.37
			BOTTOM	15	9.4	20	0.37
6	5	0.45	TOP	14.8	9.55	19	0.37
			BOTTOM	15.1	10.3	38	0.37
7	1	0.65	TOP	15.3	10.11	64	0.36
			BOTTOM	15.3	10.2	71	0.36
7	2	1.1	TOP	14.9	9.39	28	0.36
			BOTTOM	15	9.4	27	0.36
7	3	1.2	TOP	14.9	9.48	35	0.36
			BOTTOM	14.9	9.78	35	0.37
7	4	1.1	TOP	14.9	9.63	30	0.36
			BOTTOM	14.7	10.65	100	0.36

Transect	Site	Depth (m)	Sample	Temp (^{o}C)	DO (mg/L)	Turbidity (NTU)	Salinity ppt
7	5	1.2	TOP	14.9	9.4	23	0.36
			BOTTOM	14.9	9.48	15	0.36
7	6	0.9	TOP	14.6	9	24	0.35
			BOTTOM	14.7	9	30	0.35
7	7	0.4	TOP	14.6	9.1	20	0.36
			BOTTOM	14.6	9.1	18	0.36
8	1	0.64	TOP	15.3	9.82	24	0.35
			BOTTOM	15.4	9.72	21	0.35
8	2	1.1	TOP	15.2	9.7	22	0.35
			BOTTOM	15.3	10.02	35	0.35
8	3	1.2	TOP	15.2	9.52	22	0.37
			BOTTOM	15.2	9.74	35	0.36
8	4	1.5	TOP	15.1	9.56	21	0.37
			BOTTOM	15.1	9.68	21	0.37
8	5	1.2	TOP	15.1	9.61	20	0.36
			BOTTOM	15.1	9.33	32	0.36
8	6	0.35	TOP	15.2	10.55	27	0.36
			BOTTOM	15.2	10.55	27	0.36
8	7	0.2	TOP	14.4	10.17	20	0.38
			BOTTOM	14.4	10.17	20	0.38
8	8	1.2	TOP	14.7	9.34	19	0.37
			BOTTOM	14.8	9.93	51	0.38
8	9	0	DRY				
9	1	0.6	TOP	16.7	10.78	20	0.35
			BOTTOM	17	10.82	21	0.35
9	2	1.1	TOP	15.8	10.13	36	0.36
			BOTTOM	16	10.12	32	0.36
9	3	0.3	TOP	16.9	11.4	22	0.35
			BOTTOM	16.9	11.4	22	0.35
9	4	0.9	TOP	16.2	10.48	26	0.33
			BOTTOM	16.4	11.7	35	0.31
9	5	0.83	TOP	16	9.74	25	0.36
			BOTTOM	16	11.13	35	0.36
9	6	0.75	TOP	16.4	9.97	9	0.37
			BOTTOM	16.4	9.97	9	0.37
9	7	0.83	TOP	14.4	9.26	25	0.38
			BOTTOM	14.5	9.42	40	0.38
10	1	0.65	TOP	16.6	9.63	22	0.26
			BOTTOM	16.9	9.96	20	0.26
10	2	0.9	TOP	16.4	10	24	0.34
			BOTTOM	16.5	10.5	29	0.35
10	3	0.4	TOP	16.5	10.62	16	0.33
				16.5	10.62	16	0.33

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Appendix B Sediment type and macrophyte occurrence in Waituna Lagoon.

Table B-1: Explanation of codes used in Tables B-2 and B-3 for sediment and macrophyte species.

Code	Substrate	Code	Species
M	Mud	BT	*Bachelotia sp.*
VSM	Very soft mud	EN	*Ulva intestinales*
SM	Soft mud	FA	Filamentous algae
FM	Firm mud	LM	*Lamprothamnium macropogon*
S	Sand	LN	*Lilaeopsis novae-zelandiae*
FS	Firm sand	MM	*Mimulus cf. repens*
Gr	Gravel	MT	*Myriophyllum triphyllum*
		PR	*Ruppia polycarpa*
		RM	*Ruppia megacarpa*
		RM	*Ruppia megacarpa*

Table B-2: Aquatic macrophyte species present, water clarity and substrate type at each sampling site in Waituna Lagoon in December 2011. Cover scores were 1 = 1–5%, 2 = 5–10%, 3 = 10–20%, 4 = 20–50%, 5 = 50–80%, 6 = 8–100%. Life stage categories were V = vegetative, F = flowering, PF = post flowering.

Site	Rep	Depth (m)	Secchi depth (m)	Substrate	Sulphide depth (cm)	Species	Height (cm)	Stage	Cover score
T7.1	1	0.7	0.79*	S/Gr	Nil	Nil			
	2			S/Gr	Nil	EN			1
	3			S/Gr	Nil	PR	3	V	1
	4			S/Gr	Nil	Nil			
T7.2	1	1.85	0.8	FS	3	Nil			
	2			FS	3	Nil			
	3			FS	3	Nil			
	4			FS	3	Nil			
T7.3	1	1.75	0.8	GR/S	Nil	Nil			
	2			GR/S	Nil	Nil			
	3			GR/S	Nil	Nil			
	4			GR/S	Nil	Nil			
T7.4	1	1.5	0.8	SM/S	4	PR	40	V	4
	2			SM/S	4	Nil			
	3			SM/S	4	Nil			
	4			SM/S	4	Nil			
T7.5	1	1.8	0.8	SM/S	2	Nil			
	2			SM/S	1	Nil			
	3			SM/S	2	Nil			
	4			SM/S	2	Nil			
T7.6	1	1.7	0.89	SM/S	3	Nil			
	2			SM/S	4	Nil			
	3			SM/S	3	Nil			
	4			SM/S	3	Nil			
T7.7	1	1.34	0.8	FM/S	2	Nil			
	2			FM/S	4	Nil			
	3			FM/S	4	Nil			
	4			SM/S	4	Nil			
T6.5	1	0.9	0.79	GR/S	Nil	LM	1	F	3
	2			GR/S	Nil	MM			1
	2					LM	3	V	4
	3			GR/S	Nil	LM	3	F	3
	3					MM			3
	4			GR/S	Nil	LM	2	F	4
T6.4	1	2.1	0.82	S/Gr	2	Nil			
	2			S/Gr	2	Nil			
	3			S/Gr	2	Nil			

Site	Rep	Depth (m)	Secchi depth (m)	Substrate	Sulphide depth (cm)	Species	Height (cm)	Stage	Cover score
	4			S/Gr	2	Nil			
T6.3	1	1.6	0.85	S/Gr	4	PR	40	V	5
	2	1.6		S/Gr	2	PR	30	V	5
	3	1.6		S/Gr	2	PR	30	V	5
	4	1.6		S/Gr	2	PR	40	V	5
T6.2	1	1.1	1	SM/S	1	PR			1
						LM	10	V	5
	2			SM/S	1	LM	10	V	3
						PR			1
	3			SM/S	2	LM	15	V	4
						PR			1
	4			SM/S	2	LM	10	V	5
						PR			1
T6.1	1	0.9	0.85	S/Gr	2	PR	10	V	2
	2			S/Gr	2	Nil			
	3			S/Gr	2	Nil			
	4			S/Gr	3	Nil			
T5.1	1	1.1	0.96	Gr	Nil	LM	1	V	2
						FA			
	2			SM/S/G	1	LM	1	V	5
	3			SM/S/G	1	LM	1	V	4
	4			SM/S/G	1	PR	40	F	6
						FA			
T5.2	1	1.5	0.85	FM/S	2	PR	70	F	6
	2			FM/S	2	PR	70	F	6
	3			FM/S	2	PR	60	F	6
						FA			
	4			FM/S	1	PR	70	F	6
T5.3	1	2.4	0.85	SM/S	3	Nil			
	2			SM/S	2	Nil			
	3			SM/S	2	Nil			
	4			SM/S	2	Nil			
T5.4	1	1.7	0.9	SM/S	3	FA			
	2			S/Gr	3	Nil			
	3			S/Gr	3	Nil			
	4			S/Gr	3	LM			1
T5.5	1	1.3	0.9	FS	3	PR	40	F	5
	2			FS	1	LM	1		1
	3			FS	2	PR	50	F	5
						LM			1

Site	Rep	Depth (m)	Secchi depth (m)	Substrate	Sulphide depth (cm)	Species	Height (cm)	Stage	Cover score
	4			FS	3	PR	40	V	5
						LM			1
T4.5	1	1.9	0.95	S/Gr	3	Nil			
	2			S/Gr	3	Nil			
	3			S/Gr	3	Nil			
	4			S/Gr	3	Nil			
T4.4	1	1.5	0.95	S/Gr	2	Nil			
	2			FM/S	2	Nil			
	3			S/Gr	2	Nil			
	4			S/Gr	2	EN			
T4.3	1	2.2	1.1	SM/S	2	Nil			
	2			SM/S	2	Nil			
	3			SM/S	2	Nil			
	4			SM/S	2	PR	10	V	1
T4.2	1	1.5	1.1	SM/S	3	LM	20	V	5
						PR			1
	2			SM/S	4	LM	20	V	1
						PR			1
	3			SM/S	5	LM	20	V	6
						PR			1
	4			SM/S	6	RM	100		1
						LM		V	6
T4.1	1	1.2	0.95	Gr/S	Nil	LM	1	V	4
	2			Gr/S	Nil	LM	1	V	3
	3			Gr/S	Nil	LM	2	V	4
	4			Gr/S	Nil	PR	2		1
					Nil	LM	1	V	5
T8.1	1	1.14	1.01	Gr/S	Nil	EN			1
				Gr/S	Nil	Nil			
	3			Gr/S	Nil	FA			
	4			Gr/S	Nil	EN			
						FA			
T8.2	1	1.7	1.05	FS	3	PR	40	V	4
	2			FS	3	PR	10	V	1
	3			FS	2.5	Nil			
	4			FS	2.5	Nil			
T8.3	1	1.9	1.05	FM/S	3	Nil			
	2			FM/S	3	Nil			
	3			FM/S	3	Nil			
	4			FM/S	2.5	Nil			

Site	Rep	Depth (m)	Secchi depth (m)	Substrate	Sulphide depth (cm)	Species	Height (cm)	Stage	Cover score
T8.4	1	2.1	1	SM/S	2	Nil			
	2	2.1	1	SM/S	2	MT	2.5	V	1
	3	2.1	1	SM/S	2	Nil			
	4	2.1	1	SM/S	2	Nil			
T8.5	1	1.84	1.08	FM/S	3.5	Nil			
	2			FM/S	3.5	Nil			
	3			FM/S	4	Nil			
	4			FM/S	4	Nil			
T8.6	1	1.2	0.93	SM/S/G	Nil	PR	16	V	1
	2			SM/S/G	Nil	Nil			
	3			SM/S/G	Nil	PR	3	V	1
					Nil	EN			
	4			SM/S/G	Nil	Nil			
T8.7	1	0.8	0.8+	S/Gr	Nil	EN			1
					Nil	PR	12	V	2
	2			S/Gr	Nil	EN			
					Nil	PR	16	V	1
	3			S/Gr	Nil	EN			
	4			S/Gr	Nil	EN			6
T8.8	1	1.8	1.1	SM/S/G	Nil	PR	35	V	2
	2			SM/S/G	Nil	PR	30	V	2
	3			SM/S/G	Nil	EN			1
					Nil	PR	15	V	1
	4			SM/S/G	Nil	PR	15	V	3
T8.9	1	2	1.04	SM/S/G	0.5	Nil			
	2			SM/S/G	0.5	Nil			
	3			SM/S/G	Nil	Nil			
	4			SM/S/G	0.5	PR	5	V	1
T9.7	1	1.4	1.01	SM/S	4	FA			5
	2			SM/S	4	FA			5
	3			SM/S	4	PR	12	V	1
	4			SM/S	4	FA			3
T1.1	1	1.8	0.89	SM/S	Nil	LM		V	1
	2			SM/S	Nil	Nil			
	3			SM/S	Nil	Nil			
	4			SM/S	Nil	Nil			
T2.1	1	1	0.9	S/Gr	Nil	FA			5
	2			S/Gr	3.5	FA			5
	3			S/Gr	Nil	FA			5
	4			S/Gr	Nil	FA			6

Site	Rep	Depth (m)	Secchi depth (m)	Substrate	Sulphide depth (cm)	Species	Height (cm)	Stage	Cover score
T2.2	1	1.5	1.09	SM/S	3.5	PR	55	V	5
	2			SM/S	2.5	PR	45	V	4
	3			SM/S	2.5	PR	60	V	5
	4			SM/S	2.5	PR	60	V	4
T2.3	1	0.8	0.8+	Gr	Nil	Nil			
	2			Gr	Nil	Nil			
	3			Gr	Nil	Nil			
	4			Gr	Nil	Nil			
T3.1	1	0.82	0.82+	SM/S/G	Nil	FA			6
	2			SM/S/G	Nil	FA			1
	3			SM/S/G	Nil	FA			1
	4			SM/S/G	Nil	FA			1
T3.2	1	2.63	1.06	VSM/S	1.5	Nil			
	2			VSM/S	3	Nil			
	3			VSM/S	0.5	Nil			
	4			VSM/S	1	Nil			
T3.3	1	1.7	1.15	SM/S	1.5	Nil			
	2			SM/S	1.5	LM	3	V	1
	3			SM/S	2.5	Nil			
	4			SM/S	2	Nil			
T9.6	1	1.1	1.1+	SM/S	Nil	LM	1	V	1
	2			SM/S	3	LM	0.5	V	1
	3			SM/S	3	LM	2	V	1
						PR	10	V	1
	4			SM/S	Nil	LM	3	V	1
T9.5	1	1.45	1.06	SM/S	Nil	LM	20	V	5
						PR	40	V	1
	2			SM/S	Nil	PR	30	V	5
						LM	15	V	1
	3			SM/S	Nil	PR	50	V	4
						LM	25	V	1
	4			SM/S	Nil	PR	55	F	5
						LM	30		2
T9.4	1	1.4	1.05	SM/S	3.5	LM	40	V	6
						PR	40	F	2
	2			SM/S	2.5	PR	65	F	4
						LM	40	V	4
						MT			1
	3			SM/S	1	PR	40	V	3
						LM	25	V	2

Site	Rep	Depth (m)	Secchi depth (m)	Substrate	Sulphide depth (cm)	Species	Height (cm)	Stage	Cover score
	4			SM/S	1	LM	30	V	9
						PR	50	V	2
T9.3	1	1.15	1.15+	Gr/S	Nil	PR	40	V	1
						LM			1
						BT			4
						EN			
	2			Gr/S	4.5	Nil			
	3			Gr/S	4.5	PR	4	V	1
	4			Gr/S	4.5	EN	4		1
T9.2	1	1.7	1.03	FS	Nil	Nil			
	2			FS	3	PR	60	V	5
	3			FS	Nil	PR	60	V	5
	4			FS	Nil	Nil			
T9.1	1	1.15	0.95	Gr/s	Nil	Nil			
	2			Gr/s	Nil	LM			1
					Nil	LN			1
	3			Gr/s	Nil	PR	15	V	1
					Nil	EN			1
	4			Gr/s	Nil	EN			3
					Nil	LM	2	V	2
T10.1	1	1.3	0.96	Gr/S	Nil	Nil			
	2			Gr/s	Nil	Nil			
	3			Gr/s	Nil	Nil			
	4			Gr/s	Nil	Nil			
T10.2	1	1.45	0.9+	SM/S	Nil	PR	10	V	1
	2			SM/S	3	Nil			
	3			SM/S	3	Nil			
	4			SM/S	3	FA			2
T10.3	1	1.1	0.95	SM/S/G	Nil	LM	1	V	1
	2			SM/S/G	Nil	Nil			
	3			SM/S/G	Nil	EN			1
						FA			1
	4			SM/S/G	Nil	EN			1
						FA			1

Table B-3: Aquatic macrophyte species present, water clarity and substrate type at each sampling site in Waituna Lagoon in February 2012. Cover scores were 1 = 1–5%, 2 = 5–10%, 3 = 10–20%, 4 = 20–50%, 5 = 50–80%, 6 = 80–100%. Life stage categories were V = vegetative, F = flowering, PF = post flowering.

Site	Rep	Depth (m)	Secchi (m)	Substrate	Sulphide depth (cm)	Species	Height	Stage	Cover score
T1	1	2.8	66	VSM/S	0	NIL			
	2			VSM/S	0	NIL			
	3			VSM/S	0	NIL			
	4			VSM/S	0	NIL			
T2.1	1	0.2	24	SG	> 5	NIL			
	2			SG	> 5	NIL			
	3			SG	> 5	NIL			
	4			SG	> 5	NIL			
T2.2	1	1.1	60	GSM	0	PR	8	V	1
	2			GSM	0	PR	10	F	5
	3			GSM	> 5	PR	20	F	6
	4			GSM	1	PR	15	F	5
T2.3	1	DRY							
	2	DRY							
	3	DRY							
	4	DRY							
T3.1	1	0.25	>25	GS	> 5	NIL			
	2			GS	> 5	NIL			
	3			GS	> 5	PR	5	V	3
	4			GS	> 5	NIL			
T3.2	1	2	80	MS	2	NIL			
	2			MS	2	NIL			
	3			MS	0.5	NIL			
	4			MS	0.5	NIL			
T3.3	1	0.55	> 55	GS	> 5	NIL			
	2			GS	> 5	NIL			
	3			GS	> 5	NIL			
	4			GS	> 5	NIL			
T4.1	1	0.45	> 45	GS	> 5	LM	5	F	3
	1					MT	5	V	1
	2			SG	> 5	LM	5	F	2
	3			SG	> 5	LM	5	F	1
	4			GS	> 5	LM	5	F	1
T4.2	1	0.9	80	SM	0.5	LM	25	F	6
	2			SM	> 5	LM	15	F	6
	3			SM	0.5	LM	20	F	6
	4			SM	0.5	LM	30	F	6
T4.3	1	1.5	80	SG	> 5	NIL			
	2			SG	> 5	NIL			

Site	Rep	Depth (m)	Secchi (m)	Substrate	Sulphide depth (cm)	Species	Height	Stage	Cover score
	3			SG	> 5	NIL			
	4			SG	> 5	PR	8	V	1
	4					MT		V	1
T4.4	1	1.1	80	SG	> 5	NIL			
	2			SG	> 5	PR	5	V	1
	3			SG	> 5	PR	5	V	1
	4			SG	> 5	NIL			
T4.5	1	1.2	80	S	> 5	NIL	10	V	
	2			S	> 5	PR			1
	3			S	> 5	NIL			
	4			S	> 5	NIL			
T5.1	1	0.5	> 50	GS	> 5	LM	10	F	1
	2			GS	> 5	LM	10	F	1
	3			GS	> 5	LM	10	F	1
	4			GS	> 5	LM	10	F	1
T5.2	1	0.9	85	GS	> 5	PR	15	F	2
	2			SG	> 5	PR	20	F	5
	3			SG	> 5	PR	15	F	2
	4			SG	> 5	PR	25	F	4
T5.3	1	1.7	70	M	3	NIL			
	2			M	3	PR			
	3			M	3	NIL			
	4			M	2.5	NIL			
T5.4	1	1.1	66	S	> 5	PR	5	V	1
	2			S	> 5	PR	< 5	V	1
	2					MT	< 5	V	1
	3			S	> 5	PR	5	V	1
	4			S	> 5	PR	5	V	1
T5.5	1	0.55	> 55	SG	0.5	LM	20	F	4
	1					PR	20	F	1
	2			SG	0.5	LM	20	F	5
	2					PR	20	F	1
	3			SG	0.5	LM	20	F	5
	3					PR	20	F	1
	4			SG	0.5	LM	25	F	4
	4					PR	25	F	1
T6.1	1	0.7	>70	S	>5	LM	5	v	1
	1					PR	5	V	1
	2			S	2	PR	5	V	1
	3			S	>5	PR	15	F	3
T6.2	1	0.95	68	SG	1	LM	5	F	3
	1					PR	5	F	1
	2			SG	1	LM	8	F	1

Site	Rep	Depth (m)	Secchi (m)	Substrate	Sulphide depth (cm)	Species	Height	Stage	Cover score
	2					PR	8	F	1
	3			SG	1	LM	10	F	4
	3					PR	10	F	1
	4			SG	1	LM	8	F	4
	4					PR	8	F	1
T6.3	1	0.9	77	GS	1	PR	20	F	6
	2			GS	1.5	PR	20	F	5
	3			GS	2	PR	30	F	6
	4			GS	2	PR	30	F	6
T6.4	1	1.4	85	MSG	2	NIL			
	2			MSG	1.5	NIL			
	3			MSG	2	NIL			
	4			MSG	2	NIL			
T6.5	1	0.45	>45	GS	>5	LM	10	F	6
	2			GS	>5	PR	10	V	1
	2					LM	10	F	1
	3			GS	1	LM	10	F	5
	4			GS	1	LM	10	F	5
T7.1	1	0.65	28	SMG	>5	PR	10	F	4
	2			SMG	>5	PR	10	F	4
	3			SM	>5	PR	8	V	
	4			SMG	>5	PR	10	F	
T7.2	1	1.1	59	FS	>5	NIL			
	2			FS	>5	NIL			
	3			FSG	2	NIL			
	4			FSG	3.5	NIL			
T7.3	1	1.19	59	SG	2	NIL			
	2			SG	0.5	NIL			
	3			SG	1	NIL			
	4			SG	2.5	PR	10	V	1
T7.4	1	1.1	69	SM	>5	PR	30	F	6
	2			SM	>5	PR	30	F	6
	3			SM	>5	PR	30	F	5
	4			SM	>5	PR	30	F	5
T7.5	1	1.16	67	SM	2.5	PR	15	V	1
	2			SM	4	PR	10	F	1
	3			SM	1.5	NIL			
	4			SM	2.5	PR	10	V	1
	2					PR	8	F	1
	3			SG	1	LM	10	F	4
T7.6	1	0.9	54	SM	>5	NIL			
	2			SM	4	NIL			
	3			SM	3.5	NIL			

Site	Rep	Depth (m)	Secchi (m)	Substrate	Sulphide depth (cm)	Species	Height	Stage	Cover score
	4			SM	2	NIL			
T7.7	1	0.4	>40	GS	2	NIL			
	2			GS	>5	PR	10	V	2
	3			SG	4	NIL			
	4			SG	4	NIL			
T8.1	1	0.64	60	GFS	>5	NIL			
	2			GFS	>5	NIL			
	3			GFS	>5	NIL			
	4			GFS	>5	NIL			
T8.2	1	1.1	67	S	>5	PR	5	V	2
	2			S	>5	PR	10	V	4
	3			S	>5	PR	10	V	3
	4			S	2.5	PR	8	V	2
T8.3	1	1.2	63	S	3	NIL			
	2			S	1	NIL			
	3			S	2	NIL			
	4			S	2	NIL			
T8.4	1	1.5	56	MS	2	NIL			
	2			MS	2	NIL			
	3			MS	2	NIL			
	4			MS	2	NIL			
T8.5	1	1.2	51	S	>5	NIL			
	2			S	>5	NIL			
	3			S	>5	NIL			
	4			S	>5	NIL			
T8.6	1	0.35	>35	SG	>5	NIL			
	2			SG	>5	NIL			
	3			SG	>5	NIL			
	4			SG	>5	NIL			
T8.7	1	0.2	>20	G	>5	NIL			
	2			G	>5	PR	10	V	1
	3			G	>5	PR	10	V	1
	4			G	>5	NIL	20	F	
T8.8	1	1.2	90	GSM	>5	PR	20	F	5
	2			GS	>5	PR	20	F	4
	3			GS	>5	PR	15		4
	4			GS	>5	PR			4
	4			SM	2	NIL			
T8.9	1	DRY							
	2								
	3								
	4								
Y9.1	1	0.6	60	GS	>5	PR	5	V	1

Site	Rep	Depth (m)	Secchi (m)	Substrate	Sulphide depth (cm)	Species	Height	Stage	Cover score
	1					LM	5	V	1
	2			GS	>5	PR	5	V	1
	3			GS	>5	PR	5	V	3
	4			GS	>5	PR	5	V	3
T9.2	1	1.1	70	S	>5	NIL			
	2			S	>5	NIL			
	3			S	>5	NIL			
	4			S	>5	NIL			
T9.3	1	0.3	>30	GS	>5	NIL			
	2			GS	>5	NIL			
	3			GS	>5	NIL			
	4			GS	>5	PR	5	F	2
T9.4	1	0.9	62	SM	2	PR	35	F	5
	2			SM	2	PR	30	F	4
	3			SM	2	RM	60	V	2
	3					MQ	60	V	1
	4			SM	2	PR	20	F	1
	4					MT	20	V	1
T9.5	1	0.83	68	SM	>5	LM	30	F	2
	1					PR	30	V	2
	2			SM	>5	LM	30	F	3
	2					PR	10	V	1
	3			SM	>5	LM	30	F	4
	3					PR	10	F	1
	4			SM	>5	LM	30	F	4
	4					PR	10	F	2
T9.6	1	0.75	70	SM	>5	LM	10	F	2
	1					PR	10	F	1
	2			SM	>5	PR	15	F	3
	2					LM	10	F	1
	3			SM	>5	PR	15	F	3
	3					LM	10	F	2
	4			SM	>5	PR	15	F	3
	4					LM	10	F	3
T9.7	1	0.83	55	SM	2	NIL			
	2			SM	2	PR	10	V	1
	3			SM	1.5	NIL			
	4			SM	2	UI			1
T10.1	1	0.65	60	SG	>5	NIL			
	2			SG	>5	NIL			
	3			SG	>5	NIL			
	4			SG	>5	NIL			
T10.2	1	0.9	60	MS	>5	NIL			

Site	Rep	Depth (m)	Secchi (m)	Substrate	Sulphide depth (cm)	Species	Height	Stage	Cover score
	2			MS	>5	NIL			
	3			MS	3.5	PR	5	V	1
	4			MS	1	PR	20	V	2
T10.3	1	0.4	40	SGM	>5	PR	5	V	1
	2			SGM	>5	NIL			
	3			SG	>5	PR	10	V	2
	4			SG	>5	NIL			

Appendix C Additional observations made during December 2011 survey

Table C.1: Percent cover of all macrophyte species encountered during additional observations during the December 2011 survey. Explanation for species codes for is detailed in Table B.1. Cover scores were 1 = 1–5%, 2 = 5–10%, 3 = 10–20%, 4 = 20–50%, 5 = 50–80%, 6 = 80–100%.

Date	Site	Depth (m)	PR % cover	Algae % cover	LM % cover	MT % cover	RM % cover	LN % cover
9/12/2011	T1.1	1.8					1	
9/12/2011	T2.1	1		6				
9/12/2011	T2.2	1.5	5					
9/12/2011	T2.3	0.8						
9/12/2011	T3.1	0.82		6				
9/12/2011	T3.2	2.63						
9/12/2011	T3.3	1.7	1		1			
8/12/2011	T4.1	1.2	2	6	4		1	
8/12/2011	T4.2	1.5	6	6	5			
8/12/2011	T4.3	2.2	1	1				
8/12/2011	T4.4	1.5		1				
8/12/2011	T4.5	1.9						
8/12/2011	T5.1	1.1	1	6	4			
8/12/2011	T5.2	1.5	6					
8/12/2011	T5.3	2.4		1				
8/12/2011	T5.4	1.7	4	4				
8/12/2011	T5.5	1.3	5	1	6			
8/12/2011	T6.1	1.6	1					
8/12/2011	T6.2	1.1	3	4	6			
8/12/2011	T6.3	1.6	6	1				
8/12/2011	T6.4	2.1		2				
8/12/2011	T6.5	0.9		2		1		
8/12/2011	T7.1	0.7						
8/12/2011	T7.2	1.85	1					
8/12/2011	T7.3	1.75	1					
8/12/2011	T7.4	1.5	1					
8/12/2011	T7.5	1.8	1					
8/12/2011	T7.6	1.7						
8/12/2011	T7.7	1.34						
9/12/2011	T8.1	1.14		4				
9/12/2011	T8.2	1.7	4					
9/12/2011	T8.3	1.9	1					
9/12/2011	T8.4	2.1				1		
9/12/2011	T8.5	1.84						
9/12/2011	T8.6	1.2	1					
9/12/2011	T8.7	0.8	1	6				
9/12/2011	T8.8	1.8	2					
9/12/2011	T8.9	2						
9/12/2011	T9.1	1.15	1		1			1
9/12/2011	T9.2	1.7	4					
9/12/2011	T9.3	1.15	1	4	1			
9/12/2011	T9.4	1.4	6	2	6			
9/12/2011	T9.5	1.45	6		6			

Date	Site	Depth (m)	PR % cover	Algae % cover	LM % cover	MT % cover	RM % cover	LN % cover
9/12/2011	T9.6	1.1	1		1			
9/12/2011	T9.7	1.4	1					
9/12/2011	T10.1	1.3						
9/12/2011	T10.2	1.45	1		1	1		
9/12/2011	T10.3	1.1	1		3	3		