

# Waituna Lagoon 2010

## Macrophyte (*Ruppia*) Monitoring



Prepared  
for  
Department  
of  
Conservation  
May 2010

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Measuring water quality and collecting bottom samples in the southwestern arm of Waituna Lagoon.



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By

Leigh Stevens and Barry Robertson

Cover Photo: Bottom sample showing dense brown slimy macroalgal layer (*Bachelotia antillarum*) and *Ruppia megacarpa*.

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All photos by Wriggle except where noted otherwise.



# 1. INTRODUCTION



Waituna Lagoon (1350ha) is an exceptional example of a largely unmodified intermittently open/closed “coastal lake or lagoon” type estuary, located within the Awarua-Waituna wetland complex and internationally recognised Ramsar site in Toetoes Bay, Eastern Southland. Historically, the lagoon was surrounded by a huge peat bog wetland (area approximately 20,000ha stretching from Fortrose Estuary to New River Estuary), whose drainage gave the lagoon water its characteristic clear brown humic stain, low nutrient status, and low pH.

Because the lagoon is shallow, poorly flushed, and has a long residence time, it is particularly susceptible to elevated nutrient, sediment, and pathogen inputs from the grassland dominated catchment (primarily intensive sheep, beef and dairying). Based on recent assessments, current nutrient inputs are at levels likely to cause problems, in particular, a shift to a phytoplankton-dominated state (e.g. Johnson & Partridge 1998, Thompson & Ryder 2003, Cadmus & Schallenberg 2007, Schallenberg & Tyrrell 2007, Stevens and Robertson 2007a,b). In addition, artificial opening of the lagoon (to limit flooding of low-lying farmland) places additional pressure on the range of wetland and aquatic habitats present, primarily through changes to lagoon salinity and water levels.

One of the aquatic habitats, the submerged macrophyte community (dominated by horse’s mane weed, *Ruppia*) has been identified as playing a key role in regulating water quality and providing habitat for aquatic fauna (e.g. Schallenberg and Tyrrell 2007, Ryder Consulting 2008). This type of community is susceptible to a predictable pattern of degradation through eutrophication in response to increased nutrients, particularly nitrogen and phosphorus (e.g. de Wit et al. 2001, Viaroli et al. 2004, Zaldivar et al. 2008), although the extent that the lagoon is N or P limited is uncertain.

A generalised outline of the response of a coastal lagoon to increasing eutrophication is shown in Figure 1. In essence, the survival of the *Ruppia* macrophyte community relies in a large part on the maintenance of high light levels in the lagoon. Light levels can be reduced by nuisance growths of phytoplankton which can establish in response to excessive nutrient inputs, or by high levels of suspended sediment. The resulting decrease in clarity (among other factors) may displace macrophytes from the lagoon. In addition, when excessive growths of phytoplankton and macroalgae begin to decompose, they reduce sediment oxygen levels which, in turn, release sediment-bound nutrients and further fuel eutrophication processes. However, because the lagoon is typically well mixed, depleted oxygen levels may not be a critical factor.

In recognition that the survival of this important macrophyte community relies on the effective management of both catchment inputs and the timing and frequency of artificial openings, the Department of Conservation (DOC), in their biodiversity conservation role in the Southland region, initiated broad scale monitoring of the distribution of submerged aquatic macrophytes (including *Ruppia*) and macroalgae in Waituna Lagoon in 2007 (Robertson and Stevens 2007).

As part of the Arawai Kākāriki Wetland Restoration Programme, a second macrophyte survey was undertaken by Wriggle Coastal Management in February 2009 using replicated sampling at georeferenced transect sites (10 transects, 47 sites, 4 replicates/site) which, through future repeat sampling, will provide a quantifiable and robust technique to indicate change in macrophyte composition and cover.

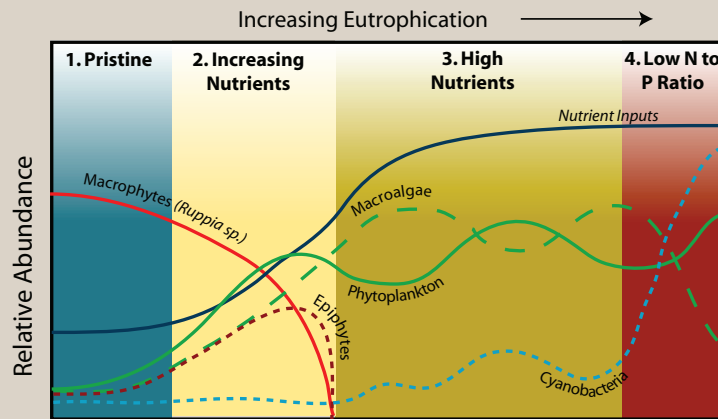
The current report describes the results of a repeat of the 2009 survey undertaken on 15 February 2010. The specific objectives of the survey were to:

1. Collect data on the abundance and height of macrophyte species in Waituna Lagoon.
2. Collect information on water quality and sediment type in Waituna Lagoon.
3. Report all data collected during fieldwork and prepare a brief summary of the work undertaken (methods, limitations, monitoring recommendations).

The results will be used by DOC to 1) examine the status and vulnerability of macrophytes in the lagoon, and 2) gain a better understanding of the effect of artificial openings of the lagoon on the macrophyte communities.

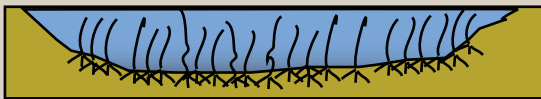


FIGURE 1. COASTAL LAGOON RESPONSE TO INCREASING EUTROPHICATION



Conceptual representation of response of aquatic vegetation to increased nutrients in coastal lagoons (modified from de Wit et al. 2001, Viaroli et al. 2004, Zaldivar et al. 2008)

1. Pristine Condition



2. Moderate Nutrient Supply



3. High Nutrient Concentrations



4. Low N to P Ratio



**Stage 1. Pristine.**

In their pristine state, the net nutrient inputs to such coastal lagoons are low and they are dominated by extensive meadows of macrophyte species (e.g. *Ruppia*), which take advantage of nutrient supply from the sediment. Under these conditions water clarity is high. If such lagoons are closed to the sea (as in the case of Waituna Lagoon in 2007 and 2009), the nutrient supply must be very low to maintain pristine conditions compared with lagoons that are open to the sea.

**Stage 2. Increasing Macroalgae, Declining *Ruppia*.**

As nutrient levels increase to a moderate level, the estuary tips into a stage where nuisance macroalgae, phytoplankton and epiphyte growth increases, and *Ruppia* growth, sediment oxygenation and water clarity declines. In lagoons like Waituna, even a small nutrient increase is enough to cause this shift.

**Stage 3. *Ruppia* Absent, Nuisance Macroalgae Dominant .**

When nutrients reach high concentrations, *Ruppia* is lost from the lagoon and replaced with nuisance short-lived macroalgae and phytoplankton. Water clarity is low, sediments are anoxic close to the surface and sulphide rich, and sediment macrofauna is dominated by high numbers of a few tolerant species only.

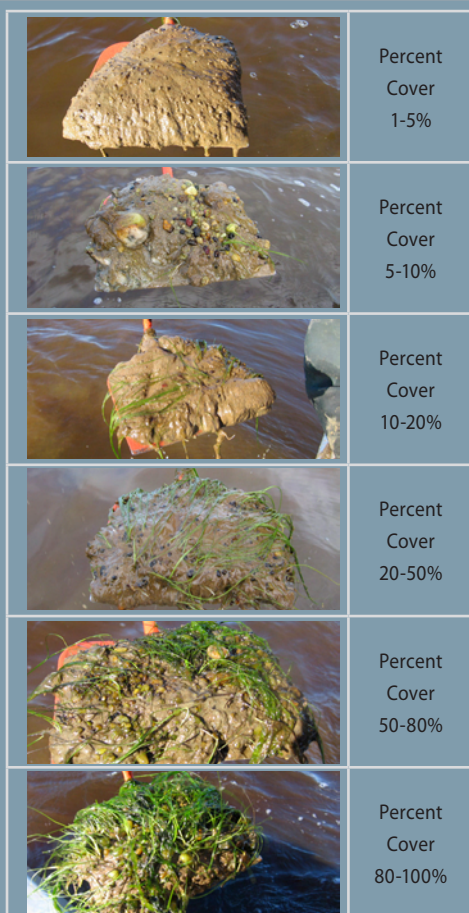
**Stage 4. Nuisance Cyanobacterial Blooms Dominant.**

At the fourth stage, the nitrogen to phosphorus ratio declines to low levels and results in nuisance cyanobacteria and toxic bloom events. Sediment macrofauna are often absent, but nuisance short-lived macroalgae (e.g. *Bachelotia* and *Enteromorpha* sp.) and phytoplankton are still present. Water clarity is low and sediment quality is poor (high and increasing mud content, high sulphides and surface anoxia).





## 2. METHODS



The locations of 48 previously established sampling sites along 10 transects were entered as waypoints into a GPS and marked on an aerial photograph for guidance in the field (Figure 2). During field sampling (undertaken by 2 scientists on 15 February 2010, each site was located using the GPS coordinates. Four replicate sediment samples were collected by digging up a 5-6cm deep layer of the surface sediments with a garden hoe (area 15 x 15cm) and carefully bringing the contents to the surface.

At the surface, the sample was photographed and records taken of;

- the aquatic vegetation (taxa, height, percentage cover and life stage),
- the sediment type,
- depth to the blackened sulphide rich layer (redox potential discontinuity layer - RPD).

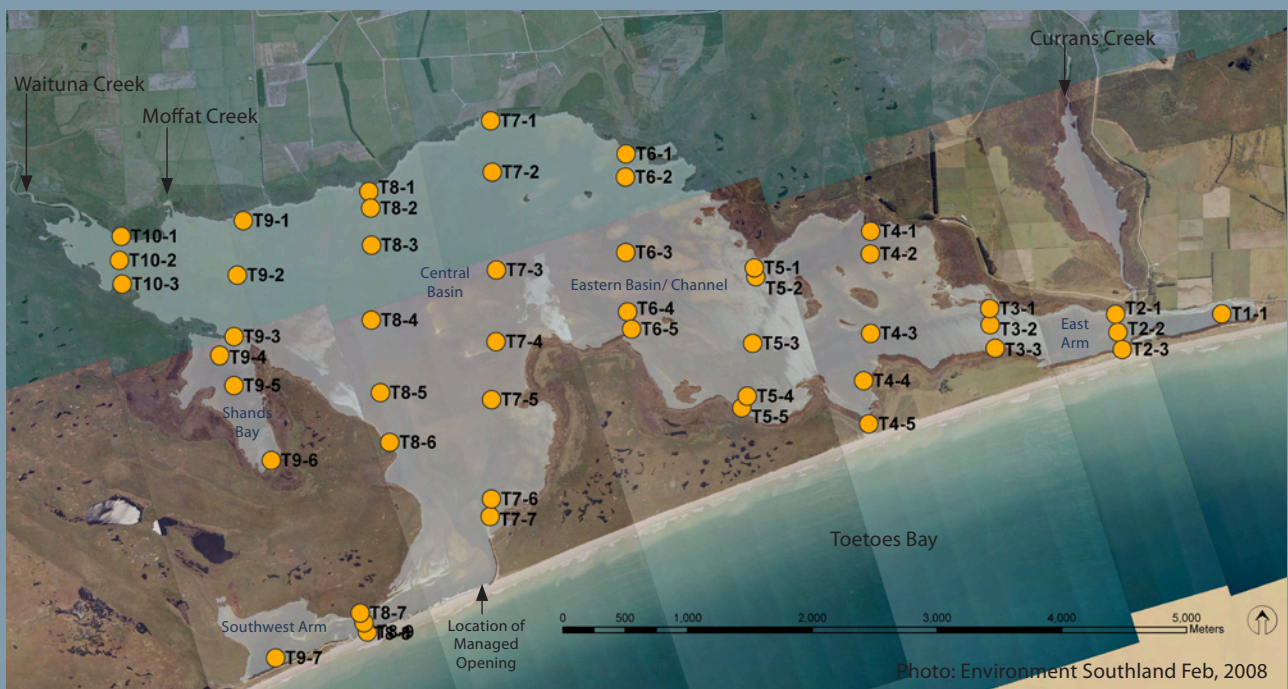
Examples of percentage cover estimates for *Ruppia* spp. are shown in the margin figure.

In addition, the water column at each site was sampled for the following;

- water clarity (secchi disc),
- water depth,
- temperature and salinity (at surface and bottom).

Appendix 1 contains the geo-referenced sampling positions, field measurements, and photograph locations. The data are also available as an Excel spreadsheet along with an ArcMap GIS layer containing georeferenced digital field photos (GPS- Photolink).

Figure 2. Waituna Lagoon showing transect sampling sites.



### 3. RESULTS

Appendix 1 contains the detailed results for the 15 February 2010 sampling, with a brief summary of the key findings, and a comparison with last years results, presented below. At the time of sampling, the lagoon had been closed since 1 October 2009 (137 days), with salinity remaining high (>11ppt) for at least 75 days, indicating low freshwater flows entering the lagoon over this period.

#### Macrophyte and Macroalgal Cover

As in 2009, the macrophyte community was dominated by *Ruppia* (Table 2, Figure 3). *Ruppia polycarpa* was present predominantly in shallower water, and in the east of the lagoon, while *Ruppia megacarpa* was concentrated in the deeper water of the Central Basin and in Shands Bay. The water milfoil *Myriophyllum triphyllum* was also common in Shands Bay, and was present elsewhere in isolated patches.

The biggest change from 2009 to 2010 was a large decline in *Ruppia polycarpa* at the sampling sites - down from 30 to 14 sites, and 88 to 32 replicates (Table 1, Figures 3 and 4). It remained more common than *Ruppia megacarpa* which had increased in presence from 5 to 11 sites and 18 to 26 replicates. Various charophyte species, including *Nitella*, present in 2009 were not observed in 2010.

Another important change between 2009 and 2010 was a decrease in the filamentous slime macroalgae, *Bachelotia antillarum*. While still widespread at both moderate and thick cover throughout the lagoon in 2010, the thick smothering growths evident on the sediment surface and as epiphytic growth on macrophytes in 2009 had reduced considerably. There were also no areas of very thick suspended growths in the lagoon water as found in 2009 (see left photo below).

Nuisance macroalgal growths of *Enteromorpha* were present around the lagoon margins as in 2009, but had decreased slightly at the sampling sites in 2010.

At site T4-3, decaying roots indicated the recent loss of *Ruppia megacarpa* from this location (see right photo below).



Table 1. Summary of presence, height, and percentage cover (range and average) of dominant macrophytes and macroalgae in Waituna Lagoon (number of sites = 48).

| Macrophyte/Macroalgae          | 2009     |      |             |         |               |         | 2010     |      |             |         |               |         |
|--------------------------------|----------|------|-------------|---------|---------------|---------|----------|------|-------------|---------|---------------|---------|
|                                | Presence |      | Height (cm) |         | Percent Cover |         | Presence |      | Height (cm) |         | Percent Cover |         |
|                                | Sites    | Reps | Range       | Average | Range         | Average | Sites    | Reps | Range       | Average | Range         | Average |
| <i>Ruppia polycarpa</i>        | 30       | 88   | 1-50        | 14      | 1-100         | 38      | 14       | 32   | 5-30        | 22      | 2-100         | 44      |
| <i>Ruppia megacarpa</i>        | 5        | 18   | 15-50       | 33      | 1-100         | 69      | 11       | 26   | 10-100      | 45      | 2-100         | 58      |
| <i>Myriophyllum triphyllum</i> | 7        | 16   | 1-50        | 24      | 1-100         | 34      | 9        | 23   | 2-80        | 42      | 1-80          | 25      |
| <i>Enteromorpha</i> spp.       | 8        | 17   | 1-50        | 20      | 1-100         | 32      | 4        | 11   | 10-50       | 29      | 3-100         | 42      |
| Charophyte spp.                | 3        | 7    | 5-15        | 10      | 1-50          | 30      | 0        | 0    | -           | -       | -             | -       |
| <i>Nitella</i> spp.            | 3        | 5    | 1-15        | 7       | 1-10          | 3.5     | 0        | 0    | -           | -       | -             | -       |
| <i>Bachelotia antillarum</i>   | 45       | 180  | -           | -       | -             | -       | 41       | 164  | -           | -       | -             | -       |
| No growth                      | 9        | 63   | -           | -       | -             | -       | 6        | 107  | -           | -       | -             | -       |

### 3. Results (Continued)

#### Macrophyte and Macroalgal Cover



Table 2. Summary of 2010 species composition at each site, plus water depth and sediment RPD depth. The number in the macrophyte/macroalgae cells is the number of replicates containing the identified species at each site.

| Transect | Site  | Water depth (m) | RPD depth (cm) | Macrophyte/Macroalgae |                         |                      |                     |                     | General Location        |
|----------|-------|-----------------|----------------|-----------------------|-------------------------|----------------------|---------------------|---------------------|-------------------------|
|          |       |                 |                | <i>B. antillarum</i>  | <i>Enteromorpha</i> sp. | <i>M. triphyllum</i> | <i>R. polycarpa</i> | <i>R. megacarpa</i> |                         |
| T1       | T1-1  | 2.0             | 0              | 4                     |                         |                      |                     |                     | Currrens Creek/East Arm |
| T2       | T2-1  | 0.7             | 1              | 4                     |                         |                      |                     |                     |                         |
|          | T2-2  | 1.0             | 1              | 4                     |                         |                      | 3                   |                     |                         |
| T3       | T2-3  | 1.0             | 5              |                       |                         |                      |                     |                     |                         |
|          | T3-1  | 1.0             | 1              | 4                     |                         |                      | 2                   |                     |                         |
|          | T3-2  | 2.2             | 0              | 4                     |                         |                      |                     |                     |                         |
| T4       | T3-3  | 0.7             | 1              | 4                     |                         |                      | 2                   |                     |                         |
|          | T4-1  | 0.6             | 0              | 4                     |                         |                      | 2                   |                     |                         |
|          | T4-2  | 1.0             | 1              | 4                     |                         |                      |                     |                     |                         |
|          | T4-3  | 1.5             | 0              | 4                     |                         | 1                    |                     |                     |                         |
|          | T4-4  | 1.0             | 1              | 4                     |                         |                      | 1                   |                     |                         |
| T5       | T4-5  | 1.4             | 0              | 4                     |                         |                      |                     |                     |                         |
|          | T5-1  | 0.6             | 1              | 4                     |                         |                      | 1                   |                     |                         |
|          | T5-2  | 1.1             | 1              | 4                     |                         | 1                    | 4                   |                     |                         |
|          | T5-3  | 1.9             | 0              | 4                     |                         |                      |                     |                     |                         |
|          | T5-4  | 1.2             | 1              | 4                     |                         |                      |                     |                     |                         |
| T6       | T5-5  | 0.9             | 1              | 4                     |                         | 4                    |                     |                     |                         |
|          | T6-1  | 0.6             | 0              | 4                     |                         |                      |                     |                     |                         |
|          | T6-2  | 0.7             | 1              | 4                     |                         |                      | 2                   |                     |                         |
|          | T6-3  | 1.2             | 2              | 4                     |                         |                      | 4                   |                     |                         |
|          | T6-4  | 1.5             | 0              | 4                     |                         |                      |                     | 2                   |                         |
| T7       | T6-5  | 0.5             | 1              | 4                     |                         |                      | 2                   |                     |                         |
|          | T7-1  | 0.5             | 5              |                       |                         |                      |                     |                     |                         |
|          | T7-2  | 1.1             | 1              |                       |                         |                      |                     |                     |                         |
|          | T7-3  | 1.3             | 1              | 4                     |                         |                      |                     | 2                   |                         |
|          | T7-4  | 1.2             | 1              | 4                     |                         |                      |                     | 4                   |                         |
|          | T7-5  | 1.4             | 0              | 4                     |                         |                      |                     | 2                   |                         |
|          | T7-6  | 1.4             | 0              | 4                     |                         |                      |                     | 4                   |                         |
| T8       | T7-7  | 0.6             | 0              | 4                     |                         |                      | 4                   |                     |                         |
|          | T8-1  | 0.9             | 1              | 4                     |                         |                      |                     |                     |                         |
|          | T8-2  | 1.1             | 1              | 2                     | 2                       |                      | 2                   |                     |                         |
|          | T8-3  | 1.6             | 0              | 4                     |                         |                      |                     |                     |                         |
|          | T8-4  | 1.6             | 1              | 4                     |                         |                      |                     |                     |                         |
|          | T8-5  | 1.3             | 1              | 4                     |                         |                      |                     |                     |                         |
|          | T8-6  | 0.6             | 1              | 4                     | 3                       |                      |                     |                     |                         |
|          | T8-7  | 0.6             | 1              | 4                     |                         |                      |                     | 2                   |                         |
| T9       | T8-8  | 1.1             | 0              | 4                     | 2                       |                      |                     | 2                   |                         |
|          | T8-9  | 0.6             | 0              | 4                     | 4                       |                      |                     |                     |                         |
| T9       | T9-1  | 1.0             | 3              |                       | 2                       |                      | 1                   |                     |                         |
|          | T9-2  | 1.4             | 2              |                       |                         |                      |                     |                     |                         |
|          | T9-3  | 0.8             | 1              | 4                     |                         | 2                    |                     |                     |                         |
|          | T9-4  | 1.0             | 0              | 4                     |                         | 4                    |                     | 1                   |                         |
|          | T9-5  | 1.0             | 0              | 4                     |                         | 3                    |                     | 2                   |                         |
|          | T9-6  | 1.0             | 0              | 4                     |                         | 4                    |                     | 1                   |                         |
|          | T9-7  | 1.0             | 0              | 4                     |                         | 1                    |                     | 4                   |                         |
| T10      | T9-7  | 1.0             | 0              | 4                     |                         | 1                    |                     | 4                   |                         |
|          | T10-1 | 1.0             | 1              |                       |                         |                      |                     |                     |                         |
|          | T10-2 | 1.0             | 2              | 4                     |                         | 3                    | 2                   |                     |                         |
|          | T10-3 | 1.0             | 2              |                       |                         |                      |                     |                     |                         |

*Bachelotia* cover: MOD  
HIGH



### 3. Results (Continued)

Figure 3. Percent cover of *Ruppia* (mean of 4 replicates) along the 10 transects on 15 February 2010.

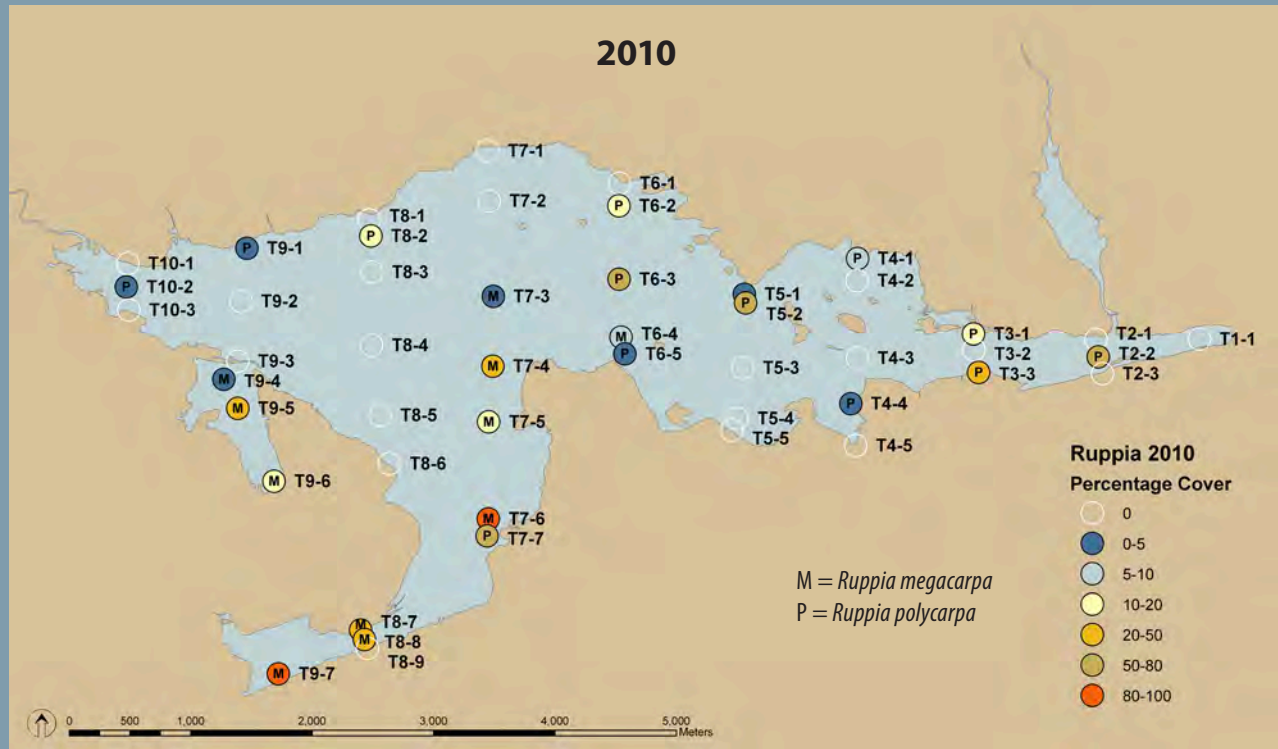
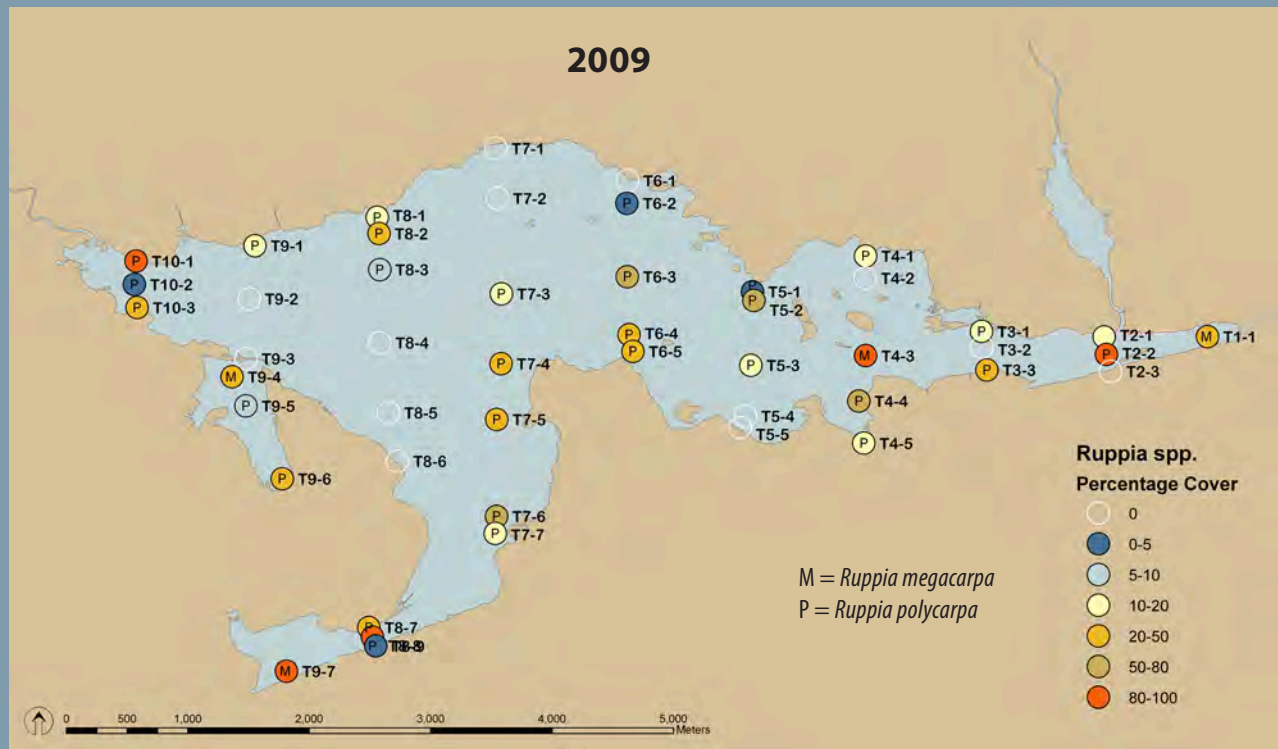


Figure 4. Percent cover of *Ruppia* (mean of 4 replicates) along the 10 transects on 25 February 2009.



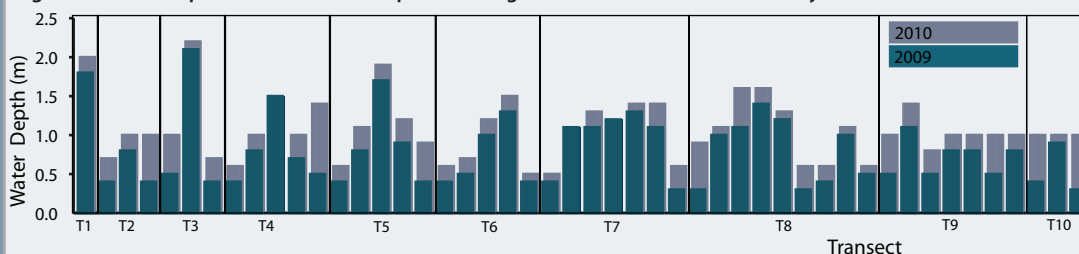


### 3. Results (Continued)

#### Water Depth

Water depth at each site for 2009 and 2010 is shown in Figure 5. 2010 sampling depths ranged from 50cm near the margins to 2.2m in the channel at the east end. The lagoon water level was 1.325 above mean sea level on the day of sampling, 27cm deeper than in 2009.

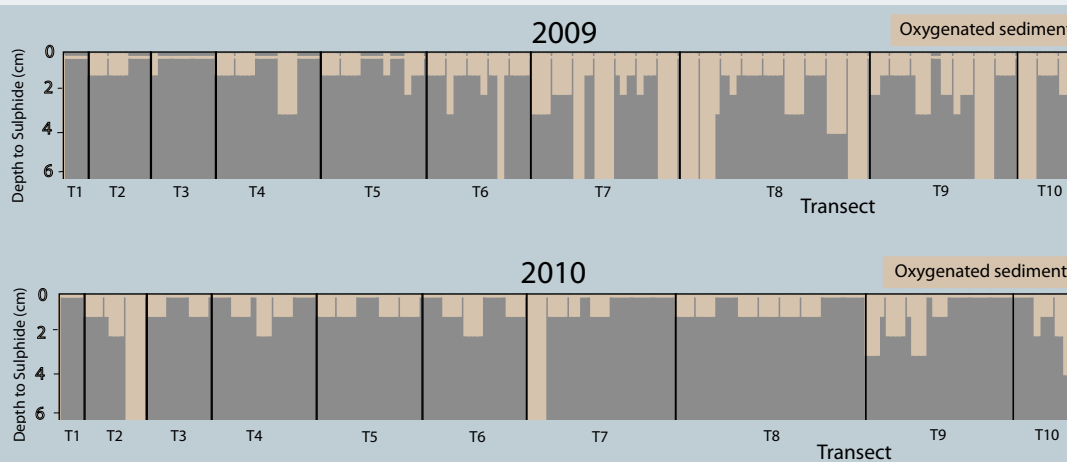
Figure 5. Water depth at each site and replicate along the 10 transects on 15 February 2010.



#### Depth to Black Sulphide (Anoxic) Layer

At the majority of sites in 2010, the depth to the black anoxic sulphide layer was in the 0-1cm range (Figure 6), indicative of low sediment oxygenation. Compared to 2009, sediment oxygen levels had decreased at most sites (Figure 6). In addition, while in 2009 the anoxic layer was often present only near the sediment surface, in 2010 the anoxic layer was deeper indicating a deterioration of sediment conditions, most likely due to rotting masses of decaying macroalgae - primarily *Bachelotia*. Overall, the RPD tended to be closest to the surface in finer sediments, although there was significant localised variation depending on the extent of decaying macroalgae present. Anoxic surface sediments were primarily located in the narrow eastern arm of the lagoon in 2009 but were widespread in 2010. The areas where the RDP was >5cm were in coarse gravels in the shallow lagoon margins.

Figure 6. Depth to black anoxic sulphide layer at each site on 25 February 2009 and 15 February 2010.



#### Substrate Type

At each of the sites sampled, substrate type was generally dominated by sand or gravel but the majority of sites also included sand, gravel and mud. Muddy sites dominated in Shands Bay. A slight increase in muddiness was observed in some sediments in 2010.

#### Water Salinity

The lagoon was brackish with a relatively constant salinity of around 4ppt (range 3.5-4.6). In contrast to 2009, salinity was not noticeably lower near the mouths of the three input streams (Waituna, Moffat and Curran Creeks). There was very little difference between surface and bottom salinities (or temperatures), reflecting well-mixed lagoon waters.

#### Water Clarity

In 2010, water clarity ranged from 0.4-1.5m (average 1.2m), with the lowest clarity measured in Shands Bay (0.4-0.8m). Consequently, at the time of sampling (which was during a period of moderately calm weather), light was able to reach the bed of much of the lagoon. This contrasted significantly with 2009 when clarity was low throughout most of the lagoon (range 0.2-0.7m, average 0.4) and light could not reach the bottom in many areas. Such limited data however, is not representative of the wide range of water clarity that is expected to occur in this lagoon, particularly during wind events. More intensive surveys (light measurement using loggers) are currently being undertaken by DOC to assess this variability.

## 4. DISCUSSION AND CONCLUSIONS

The results of the 2010 monitoring indicate the continuing presence of the ecologically important macrophyte species *Ruppia* within Waituna Lagoon. However, *Ruppia* had decreased in presence from 35 of 48 sites sampled in 2009, to 25 sites in 2010. Nuisance macroalgal species, particularly the slimy filamentous brown macroalgae *Bachelotia antillarum*, and accompanying black, anoxic, sulphide-rich surface sediments remained widespread in the lagoon, and sediment anoxia had increased since 2009.

While the lagoon waters appeared in a better condition in 2010 than compared to 12 months earlier (higher clarity, less suspended filamentous algae), the 2010 results indicate a continuing shift towards more eutrophic conditions. Specifically, a decline in the condition of the *Ruppia* beds, decreased sediment oxygen, rotting organic matter on the sediment surface, and the continued presence of nuisance macroalgae, as summarised in Table 3. High nutrient loads are considered the primary driver of the decline observed. The opening/closing regime of the lagoon is also a key driver of lagoon condition as it will flush sediment and nutrients from the lagoon, change light levels (via changes in water depth) and salinity, and expose parts of the lagoon bed.

Based on the sequence of change described in Figure 1, the results suggest the lagoon is moving further towards the point to which a switch to an algal dominated system is predicted. Consequently, the viability of *Ruppia* under the current conditions in Waituna Lagoon continues to be at risk.

Table 3. Summary of conditions in Waituna Lagoon, March 2007 and February 2009 and 2010.

| Indicators                             | March 2007   | February 2009  | February 2010  |
|--|--|--|--|
| <b>Macrophytes</b>                     | <i>Ruppia polycarpa</i> dominant in shallower waters and <i>Ruppia megacarpa</i> in the deeper waters. <i>Myriophyllum</i> presence very low.                              | <i>Ruppia polycarpa</i> dominant growing and fruiting at moderate levels within the lagoon. <i>R. megacarpa</i> less apparent. Increased presence of <i>Myriophyllum</i> .   | <i>Ruppia polycarpa</i> remained dominant but reduced sharply within the lagoon. Increased presence of <i>R. megacarpa</i> . Little change to <i>Myriophyllum</i> .  |
| <b>Macroalgae and Epiphytic Growth</b> | Green filamentous <i>Enteromorpha</i> sp. present around edge in localised areas. Brown filamentous slime algae <i>Bachelotia antillarum</i> present but in low abundance. | Bloom growths of the nuisance macroalgae <i>Bachelotia antillarum</i> were found throughout much of the lagoon. It was most dense in suspension near the lagoon bed, but was also present as epiphytic growth over <i>Ruppia</i> and other macrophyte species. <i>Enteromorpha</i> was common around lagoon margins.                                   | Bloom growths of the nuisance macroalgae <i>Bachelotia antillarum</i> throughout much of the lagoon. Most dense in suspension near the lagoon bed. Reduced epiphytic growth over <i>Ruppia</i> and other macrophyte species. <i>Enteromorpha</i> common around lagoon margins.   |
| <b>Sediment Quality</b>                | Clean, well-oxygenated sediments throughout most of lagoon. Sand and gravels dominant. Black, anoxic, sulphide rich layer only at surface in a few localised areas.        | Eutrophic sediments; poorly oxygenated, often muddy on surface but still dominated by sands and gravels. Black, anoxic, sulphide rich layer often at surface or close to surface.  | Eutrophic sediments; poorly oxygenated, often muddy on surface but still dominated by sands and gravels. Black, anoxic, sulphide rich layer often at surface (or close) and worse conditions than 2009.  |
| <b>Water Quality</b>                   | Moderately high water clarity. Secchi Disc 1.5-2m. But at other times it has been reported as low.   | Brackish (salinity 0.4-3.2 ppt). Temperature 12-16 deg. C. Low water clarity. Secchi Disc 0.5m (range 0.2-0.72m). Likely low concentrations of dissolved nutrients available for plant growth based on previous months WQ data. High concentrations of total N (likely organic).<br>DIN < 0.014 mg/l, TN 0.73 mg/l.<br>DRP < 0.004 mg/l, TP 0.03 mg/l. | Brackish (salinity 3.5-4.2 ppt). Temperature 13-14 deg. C. Moderate water clarity. Secchi Disc 1.2m (range 0.4-1.5m). Likely low concentrations of dissolved nutrients available for plant growth based on previous months WQ data. High concentrations of total N (likely organic).<br>DIN 0.02 mg/l, TN 1.1 mg/l.<br>DRP < 0.004 mg/l, TP 0.03 mg/l. |
| <b>Lagoon Open/Closed</b>              | Lagoon closed since 2 June 2006 (272 days) following a long period (10 mths) of opening/high salinities.   | Lagoon closed since 7 October 2008 (144 days).   | Lagoon closed since 1 October 2009 (137 days).   |
| <b>Trophic Stage</b>                   | MARCH 2007<br>Stage 2. Towards the PRISTINE side of Stage 2.   | FEBRUARY 2009<br>Stage 2. Towards the increasing eutrophication side of Stage 2.   | FEBRUARY 2010<br>Stage 2. Towards the increasing eutrophication side of Stage 2.   |

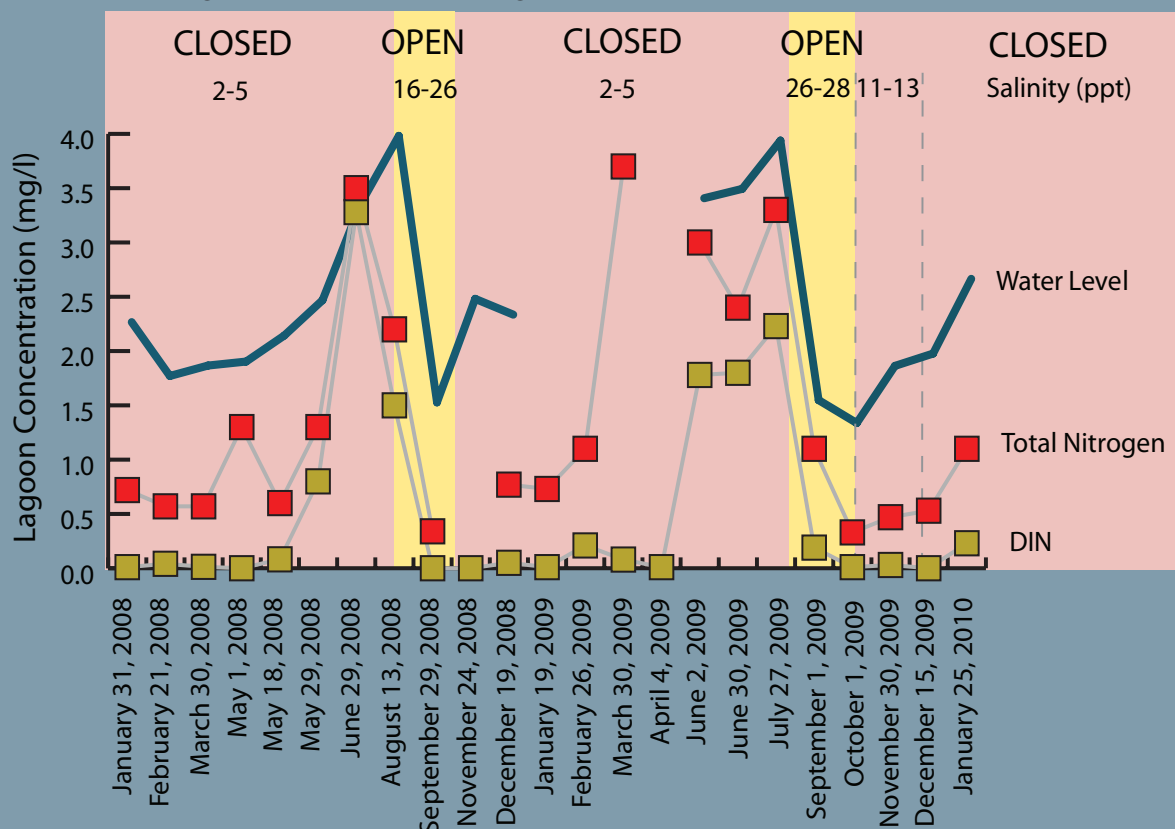
## 5. MANAGEMENT RECOMMENDATIONS

A shift from a macrophyte-dominated to algal-dominated lagoon is predicted if Waituna Lagoon follows the recent pattern shown in other coastal lagoons where nutrient inputs have increased to unsustainable levels (e.g. Lake Ellesmere, Gerbeaux and Ward 1991). If such a switch occurs, it is likely to result in the loss of *Ruppia* from the lagoon, potentially for good. In Waituna, the switch is likely to be initially driven by the availability of nutrients (nitrogen and phosphorus), rather than light limitation (Schallenberg et al. 2010).

To prevent such a shift occurring, recommendations were made in 2009 to set limits on nutrient inputs to Waituna Lagoon, and to manage lagoon opening to increase flushing and dilution of nutrients (Robertson and Stevens 2009). The 2010 results again highlight the need for these management recommendations. For example, Figure 7 shows clearly how nutrient concentrations steadily increase when the lagoon is closed, fall dramatically when it is opened, then steadily increase again as the lagoon refills from the catchment.

Unless current catchment nutrient inputs are reduced in the near future, opening the lagoon to the sea is likely to be one of the few effective ways of limiting the excessive buildup of nutrient concentrations in the lagoon. At present the lagoon opening is managed primarily to control flooding on low lying farmland. In order to manage the lagoon for ecological purposes, there are many factors to take into consideration - including timing, water depth, fish migration, and salinity impact on germination and nutrient concentrations. While DOC further study the range of factors controlling lagoon dynamics, it is recommended that a nutrient limit be set as an interim measure to trigger the opening of the lagoon to the sea when lagoon nutrient concentrations reach a level where a shift to an algal (particularly phytoplankton)-dominated community is predicted to occur. Setting such a limit requires the likely switch point from a macrophyte-dominated to algal-dominated lagoon to be estimated. Because the current decline in lagoon condition appears strongly linked to nutrient inputs, establishing the likely switch point and setting a nutrient trigger are considered high priorities for effective management of the lagoon.

Figure 7. Measured nitrogen concentrations in Waituna Lagoon 2008 - 2010.



## 6. MONITORING RECOMMENDATIONS



The changing patterns of submerged aquatic vegetation, water and sediment quality, and the apparent shift towards increased eutrophication in Waituna Lagoon emphasises the importance of the following ongoing monitoring:

- Annual monitoring during likely worst case conditions (February to March), of:
  - \* Aquatic macrophytes (including *Ruppia*) and nuisance macroalgae presence, location, percentage cover, and life stage.
  - \* Sediment quality - depth to RPD layer, sediment type.
  - \* Water clarity and depth.
- Identification of the types and characteristics of phytoplankton in the lagoon.
- Monthly monitoring of water quality within the lagoon, including chlorophyll a, water clarity, nutrients, and dissolved oxygen.
- Monitoring of sediment nutrient concentrations at representative sites.
- Targeted monitoring of streams and groundwater to determine daily N and P loads to the lagoon.
- Monitoring of intensive landuse in the catchment and identification of hotspots where high N and P loadings originate from.

To understand and optimise seed germination and seed survival requirements, salinity, light level, and exposure tolerances of *Ruppia* in Waituna also need to be defined.

Currently tools to predict the switch point from a macrophyte-dominated to algal-dominated lagoon (e.g. a model or set of equations to describe the relationship between the major variables) do not exist for New Zealand lagoons and shallow lakes. Therefore, the relationship between the major variables that drive the switch-point (e.g. water residence time, wind fetch, nutrient concentrations, substrate type, extent of saltmarsh, and water depth) need to be established.

In the interim, determining the limiting nutrient (N or P) and setting guidelines for nutrient concentrations in the lagoon that trigger its opening, and refining previously estimated limits on catchment nutrient and sediment areal loadings, are considered a priority.

## 7. ACKNOWLEDGEMENTS

This survey and report has been undertaken with help from various people: Chris Owen who provided and skippered the boat, Environment Southland (Greg Larkin and Kirsten Meijer) who provided aerial photos, monitoring data, and field support, and staff of the Department of Conservation (DOC), particularly Dr Hugh Roberston, (Wetland Scientist, Aquatic & Threats Unit, Research & Development Group), Sally Chesterfield and Emily Funnell (DOC - Southland) who made it all happen and provided comments on the draft report.





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## APPENDIX 1

### Aquatic Vegetation, and Site Details Waituna Lagoon 15 February 2010

**Note:** Brown filamentous macroalgae, *Bachelotia antillarum* covered the bed of almost all sites, and was not present on most photographs because it had slid off as it was brought to the surface.



# Appendix 1

| WAY-POINT | DATE    | TIME     | NZMG EAST | NZMG NORTH | SITE | Rep | Depth m | Temp C | Sal_ ppt | Secchi_ cm | Substrate        | cm_to_Sulphide | Species          | Height_ cm | Stage | Percent Cover | Photo Number |
|-----------|---------|----------|-----------|------------|------|-----|---------|--------|----------|------------|------------------|----------------|------------------|------------|-------|---------------|--------------|
| 513       |         |          | 2177865   | 5395520    | T1-1 |     | 0.0     | 14.10  | 3.90     | n/a        | n/a              | n/a            | n/a              | n/a        | n/a   | n/a           |              |
| 513       | 16/2/10 | 14:05:43 | 2177838   | 5395503    | T1-1 | i   | 2.0     | 14.10  | 3.90     | 1.35       | sandyMUD         | 0              | nil              | 0          | nil   | 0             | IMG_5600.jpg |
| 513       | 16/2/10 | 14:06:25 | 2177833   | 5395479    | T1-1 | ii  | 2.0     | 14.10  | 3.90     | 1.35       | sandyMUD         | 0              | nil              | 0          | nil   | 0             | IMG_5601.jpg |
| 513       | 16/2/10 | 14:06:44 | 2177835   | 5395478    | T1-1 | iii | 2.0     | 14.10  | 3.90     | 1.35       | sandyMUD         | 0              | nil              | 0          | nil   | 0             | IMG_5602.jpg |
| 513       | 16/2/10 | 14:07:07 | 2177831   | 5395484    | T1-1 | iv  | 2.0     | 14.10  | 3.90     | 1.35       | sandyMUD         | 0              | nil              | 0          | nil   | 0             | IMG_5603.jpg |
| 510       |         |          | 2177014   | 5395517    | T2-1 |     | 0.0     | 14.80  | 4.18     | n/a        | n/a              | n/a            | n/a              | n/a        | n/a   | n/a           |              |
| 510       | 16/2/10 | 13:54:16 | 2177020   | 5395509    | T2-1 | i   | 0.7     | 14.80  | 4.18     | bottom     | muddygraveSAND   | 1              | nil              | 0          | nil   | 0             | IMG_5588.jpg |
| 510       | 16/2/10 | 13:54:29 | 2177022   | 5395508    | T2-1 | ii  | 0.7     | 14.80  | 4.18     | bottom     | muddygraveSAND   | 1              | nil              | 0          | nil   | 0             | IMG_5589.jpg |
| 510       | 16/2/10 | 13:54:51 | 2177026   | 5395507    | T2-1 | iii | 0.7     | 14.80  | 4.18     | bottom     | muddygraveSAND   | 1              | nil              | 0          | nil   | 0             | IMG_5590.jpg |
| 510       | 16/2/10 | 13:55:05 | 2177028   | 5395508    | T2-1 | iv  | 0.7     | 14.80  | 4.18     | bottom     | muddygraveSAND   | 1              | nil              | 0          | nil   | 0             | IMG_5591.jpg |
| 511       |         |          | 2177033   | 5395373    | T2-2 |     | 0.0     | 14.20  | 4.09     | n/a        | n/a              | n/a            | n/a              | n/a        | n/a   | n/a           |              |
| 511       | 16/2/10 | 13:56:23 | 2177023   | 5395361    | T2-2 | i   | 1.0     | 14.20  | 4.09     | bottom     | muddygravel/SAND | 1              | nil              | 0          | nil   | 0             | IMG_5592.jpg |
| 511       | 16/2/10 | 13:56:40 | 2177019   | 5395365    | T2-2 | ii  | 1.0     | 14.20  | 4.09     | bottom     | muddygravel/SAND | 2              | Ruppia polycarpa | 30-50      | v     | 80-100        | IMG_5593.jpg |
| 511       | 16/2/10 | 13:57:33 | 2177024   | 5395379    | T2-2 | iii | 1.0     | 14.20  | 4.09     | bottom     | muddygravel/SAND | 2              | Ruppia polycarpa | 15-30      | v     | 20-50         | IMG_5594.jpg |
| 511       | 16/2/10 | 13:57:52 | 2177023   | 5395379    | T2-2 | iv  | 1.0     | 14.20  | 4.09     | bottom     | muddygravel/SAND | 2              | Ruppia polycarpa | 30-50      | v     | 80-100        | IMG_5595.jpg |
| 512       |         |          | 2177067   | 5395234    | T2-3 |     | 0.0     | 14.80  | 3.90     | n/a        | n/a              | n/a            | n/a              | n/a        | n/a   | n/a           |              |
| 512       | 16/2/10 | 14:00:40 | 2177057   | 5395215    | T2-3 | i   | 1.0     | 14.80  | 3.90     | bottom     | muddysand/GRAVEL | >5             | nil              | 0          | nil   | 0             | IMG_5596.jpg |
| 512       | 16/2/10 | 14:01:04 | 2177057   | 5395215    | T2-3 | ii  | 1.0     | 14.80  | 3.90     | bottom     | muddysand/GRAVEL | >5             | nil              | 0          | nil   | 0             | IMG_5597.jpg |
| 512       | 16/2/10 | 14:01:46 | 2177057   | 5395215    | T2-3 | iii | 1.0     | 14.80  | 3.90     | bottom     | muddysand/GRAVEL | >5             | nil              | 0          | nil   | 0             | IMG_5598.jpg |
| 512       | 16/2/10 | 14:02:04 | 2177057   | 5395215    | T2-3 | iv  | 1.0     | 14.80  | 3.90     | bottom     | muddysand/GRAVEL | >5             | nil              | 0          | nil   | 0             | IMG_5599.jpg |
| 509       |         |          | 2176005   | 5395562    | T3-1 |     | 0.0     | 14.30  | 4.24     | n/a        | n/a              | n/a            | n/a              | n/a        | n/a   | n/a           |              |
| 509       | 16/2/10 | 13:40:19 | 2176002   | 5395557    | T3-1 | i   | 1.0     | 14.30  | 4.24     | bottom     | gravel,muddySAND | 1              | Ruppia polycarpa | 30-50      | v     | 20-50         | IMG_5575.jpg |
| 509       | 16/2/10 | 13:41:07 | 2176009   | 5395556    | T3-1 | ii  | 1.0     | 14.30  | 4.24     | bottom     | gravel,muddySAND | 1              | nil              | 0          | nil   | 0             | IMG_5576.jpg |
| 509       | 16/2/10 | 13:41:26 | 2176011   | 5395556    | T3-1 | iii | 1.0     | 14.30  | 4.24     | bottom     | gravel,muddySAND | 1              | nil              | 0          | nil   | 0             | IMG_5577.jpg |
| 509       | 16/2/10 | 13:41:43 | 2176011   | 5395557    | T3-1 | iv  | 1.0     | 14.30  | 4.24     | bottom     | gravel,muddySAND | 1              | Ruppia polycarpa | 30-50      | v     | 20-50         | IMG_5578.jpg |
| 508       |         |          | 2176009   | 5395432    | T3-2 |     | 0.0     | 14.00  | 4.20     | n/a        | n/a              | n/a            | n/a              | n/a        | n/a   | n/a           |              |
| 508       | 16/2/10 | 13:45:55 | 2176002   | 5395406    | T3-2 | i   | 2.2     | 14.00  | 4.20     | 1.2        | muddySAND        | 0              | nil              | 0          | nil   | 0             | IMG_5579.jpg |
| 508       | 16/2/10 | 13:46:17 | 2176008   | 5395399    | T3-2 | ii  | 2.2     | 14.00  | 4.20     | 1.2        | muddySAND        | 0              | nil              | 0          | nil   | 0             | IMG_5580.jpg |
| 508       | 16/2/10 | 13:46:36 | 2176012   | 5395394    | T3-2 | iii | 2.2     | 14.00  | 4.20     | 1.2        | muddySAND        | 0              | nil              | 0          | nil   | 0             | IMG_5581.jpg |
| 508       | 16/2/10 | 13:47:15 | 2176016   | 5395385    | T3-2 | iv  | 2.2     | 14.00  | 4.20     | 1.2        | muddySAND        | 0              | nil              | 0          | nil   | 0             | IMG_5582.jpg |

# Appendix 1

| WAY-POINT | DATE    | TIME     | NZMG EAST | NZMG NORTH | SITE | Rep | Depth m | Temp C | Sal_ppt | Sechi_cm | Substrate        | cm_to_Sulphide | Species          | Height_cm | Stage | Percent Cover | Photo Number |
|-----------|---------|----------|-----------|------------|------|-----|---------|--------|---------|----------|------------------|----------------|------------------|-----------|-------|---------------|--------------|
| 507       |         |          | 2176048   | 5395245    | T3-3 |     | 0.0     | 14.50  | 4.38    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 507       | 16/2/10 | 13:49:12 | 2176046   | 5395235    | T3-3 | i   | 0.7     | 14.50  | 4.38    | bottom   | muddysand/GRAVEL | 1              | Ruppia polycarpa | 15-30     | v     | 20-50         | IMG_5583.jpg |
| 507       | 16/2/10 | 13:49:54 | 2176051   | 5395233    | T3-3 | ii  | 0.7     | 14.50  | 4.38    | bottom   | muddysand/GRAVEL | 1              | Ruppia polycarpa | 30-50     | v     | 80-100        | IMG_5584.jpg |
| 507       | 16/2/10 | 13:50:42 | 2176053   | 5395233    | T3-3 | iii | 0.7     | 14.50  | 4.38    | bottom   | muddysand/GRAVEL | 1              | nil              | 0         | nil   | nil           | IMG_5585.jpg |
| 507       | 16/2/10 | 13:51:09 | 2176064   | 5395237    | T3-3 | iv  | 0.7     | 14.50  | 4.38    | bottom   | muddysand/GRAVEL | 1              | nil              | 0         | nil   | nil           | IMG_5586.jpg |
| 502       |         |          | 2175050   | 5396183    | T4-1 |     | 0.0     | 14.20  | 4.38    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 502       | 16/2/10 | 13:34:29 | 2175066   | 5396181    | T4-1 | i   | 0.6     | 14.20  | 4.38    | bottom   | muddygravel/SAND | 0              | Ruppia polycarpa | 5-15      | v     | 5-10          | IMG_5570.jpg |
| 502       | 16/2/10 | 13:35:19 | 2175067   | 5396182    | T4-1 | ii  | 0.6     | 14.20  | 4.38    | bottom   | muddygravel/SAND | 0              | nil              | 0         | nil   | nil           | IMG_5571.jpg |
| 502       | 16/2/10 | 13:35:35 | 2175067   | 5396182    | T4-1 | iii | 0.6     | 14.20  | 4.38    | bottom   | muddygravel/SAND | 0              | nil              | 0         | nil   | nil           | IMG_5572.jpg |
| 502       | 16/2/10 | 13:35:52 | 2175067   | 5396182    | T4-1 | iv  | 0.6     | 14.20  | 4.38    | bottom   | muddygravel/SAND | 0              | Ruppia polycarpa | 15-30     | v     | 20-50         | IMG_5573.jpg |
| 503       |         |          | 2175047   | 5396001    | T4-2 |     | 0.0     | 13.80  | 4.44    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 503       | 16/2/10 | 13:31:15 | 2175044   | 5396001    | T4-2 | i   | 1.0     | 13.80  | 4.44    | bottom   | muddySAND        | 1              | nil              | 0         | nil   | nil           | IMG_5566.jpg |
| 503       | 16/2/10 | 13:31:45 | 2175038   | 5395998    | T4-2 | ii  | 1.0     | 13.80  | 4.44    | bottom   | muddySAND        | 1              | nil              | 0         | nil   | nil           | IMG_5567.jpg |
| 503       | 16/2/10 | 13:32:00 | 2175037   | 5395995    | T4-2 | iii | 1.0     | 13.80  | 4.44    | bottom   | muddySAND        | 1              | nil              | 0         | nil   | nil           | IMG_5568.jpg |
| 503       | 16/2/10 | 13:32:16 | 2175030   | 5395996    | T4-2 | iv  | 1.0     | 13.80  | 4.44    | bottom   | muddySAND        | 1              | nil              | 0         | nil   | nil           | IMG_5569.jpg |
| 504       |         |          | 2175050   | 5395363    | T4-3 |     | 0.0     | 13.90  | 4.41    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 504       | 16/2/10 | 13:27:14 | 2175054   | 5395366    | T4-3 | i   | 1.5     | 13.90  | 4.41    | 1.25     | MUD              | 0              | Myriophyllum     | 1-5       | v     | 1-5           | IMG_5562.jpg |
| 504       | 16/2/10 | 13:27:36 | 2175055   | 5395366    | T4-3 | ii  | 1.5     | 13.90  | 4.41    | 1.25     | MUD              | 2              | nil              | 0         | nil   | nil           | IMG_5563.jpg |
| 504       | 16/2/10 | 13:28:14 | 2175055   | 5395376    | T4-3 | iii | 1.5     | 13.90  | 4.41    | 1.25     | MUD              | 2              | nil              | 0         | nil   | nil           | IMG_5564.jpg |
| 504       | 16/2/10 | 13:28:30 | 2175057   | 5395378    | T4-3 | iv  | 1.5     | 13.90  | 4.41    | 1.25     | MUD              | 2              | nil              | 0         | nil   | nil           | IMG_5565.jpg |
| 505       |         |          | 2174994   | 5394989    | T4-4 |     | 0.0     | 14.00  | 4.39    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 505       | 16/2/10 | 13:23:44 | 2175004   | 5395003    | T4-4 | i   | 1.0     | 14.00  | 4.39    | bottom   | muddysand/GRAVEL | 1              | nil              | 0         | nil   | nil           | IMG_5558.jpg |
| 505       | 16/2/10 | 13:24:07 | 2175003   | 5395003    | T4-4 | ii  | 1.0     | 14.00  | 4.39    | bottom   | muddysand/GRAVEL | 1              | nil              | 0         | nil   | nil           | IMG_5559.jpg |
| 505       | 16/2/10 | 13:24:24 | 2175004   | 5395003    | T4-4 | iii | 1.0     | 14.00  | 4.39    | bottom   | muddysand/GRAVEL | 1              | nil              | 0         | nil   | nil           | IMG_5560.jpg |
| 505       | 16/2/10 | 13:25:08 | 2175008   | 5395003    | T4-4 | iv  | 1.0     | 14.00  | 4.39    | bottom   | muddysand/GRAVEL | 1              | Ruppia polycarpa | 5-15      | v     | 10-20         | IMG_5561.jpg |
| 506       |         |          | 2175035   | 5394643    | T4-5 |     | 0.0     | 14.20  | 4.45    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 506       | 16/2/10 | 13:20:56 | 2175028   | 5394646    | T4-5 | i   | 1.4     | 14.20  | 4.45    | 1.3      | sandyMUD         | 0              | nil              | 0         | nil   | nil           | IMG_5554.jpg |
| 506       | 16/2/10 | 13:21:11 | 2175028   | 5394648    | T4-5 | ii  | 1.4     | 14.20  | 4.45    | 1.3      | sandyMUD         | 0              | nil              | 0         | nil   | nil           | IMG_5555.jpg |
| 506       | 16/2/10 | 13:21:24 | 2175027   | 5394653    | T4-5 | iii | 1.4     | 14.20  | 4.45    | 1.3      | sandyMUD         | 0              | nil              | 0         | nil   | nil           | IMG_5556.jpg |
| 506       | 16/2/10 | 13:21:36 | 2175026   | 5394657    | T4-5 | iv  | 1.4     | 14.20  | 4.45    | 1.3      | sandyMUD         | 0              | nil              | 0         | nil   | nil           | IMG_5557.jpg |



# Appendix 1

| WAY-POINT | DATE    | TIME     | NZMG EAST | NZMG NORTH | SITE | Rep | Depth m | Temp C | Sal_ppt | Sechi_cm | Substrate        | cm_to_Sulphide | Species          | Height_cm | Stage | Percent Cover | Photo Number |
|-----------|---------|----------|-----------|------------|------|-----|---------|--------|---------|----------|------------------|----------------|------------------|-----------|-------|---------------|--------------|
| 501       |         |          | 2174118   | 5395889    | T5-1 |     | 0.0     | 13.60  | 4.27    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 501       | 16/2/10 | 13:01:13 | 2174123   | 5395881    | T5-1 | i   | 0.6     | 13.60  | 4.27    | bottom   | gravel,muddySAND | 1              | Ruppia polycarpa | 5-15      | v     | 5-10          | IMG_5533.jpg |
| 501       | 16/2/10 | 13:01:36 | 2174127   | 5395881    | T5-1 | ii  | 0.6     | 13.60  | 4.27    | bottom   | gravel,muddySAND | 1              | nil              | 0         | nil   | 0             | IMG_5534.jpg |
| 501       | 16/2/10 | 13:01:58 | 2174131   | 5395881    | T5-1 | iii | 0.6     | 13.60  | 4.27    | bottom   | gravel,muddySAND | 1              | nil              | 0         | nil   | 0             | IMG_5535.jpg |
| 501       | 16/2/10 | 13:02:12 | 2174134   | 5395877    | T5-1 | iv  | 0.6     | 13.60  | 4.27    | bottom   | gravel,muddySAND | 1              | nil              | 0         | nil   | 0             | IMG_5536.jpg |
| 500       |         |          | 2174129   | 5395817    | T5-2 |     | 0.0     | 13.50  | 4.41    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 500       | 16/2/10 | 13:03:54 | 2174138   | 5395815    | T5-2 | i   | 1.1     | 13.50  | 4.41    | bottom   | gravel,muddySAND | 1              | Ruppia polycarpa | 30-50     | v     | 80-100        | IMG_5537.jpg |
| 500       | 16/2/10 | 13:05:02 | 2174140   | 5395802    | T5-2 | ii  | 1.1     | 13.50  | 4.41    | bottom   | gravel,muddySAND | 1              | Ruppia polycarpa | 30-50     | v     | 50-80         | IMG_5538.jpg |
| 500       | 16/2/10 | 13:05:21 | 2174139   | 5395799    | T5-2 | iii | 1.1     | 13.50  | 4.41    | bottom   | gravel,muddySAND | 1              | Ruppia polycarpa | 30-50     | v     | 50-80         | IMG_5539.jpg |
| 500       | 17/2/10 | 14:05:21 | 2174139   | 5395799    | T5-2 | iii | 1.1     | 13.50  | 4.41    | bottom   | gravel,muddySAND | 1              | Myriophyllum     | 30-50     | v     | 10-20         | IMG_5539.jpg |
| 500       | 16/2/10 | 13:05:49 | 2174129   | 5395801    | T5-2 | iv  | 1.1     | 13.50  | 4.41    | bottom   | gravel,muddySAND | 1              | Ruppia polycarpa | 30-50     | v     | 80-100        | IMG_5540.jpg |
| 499       |         |          | 2174104   | 5395284    | T5-3 |     | 0.0     | 13.60  | 4.40    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 499       | 16/2/10 | 13:09:02 | 2174117   | 5395270    | T5-3 | i   | 1.9     | 13.60  | 4.40    | 1.5      | sandyMUD         | 0              | nil              | 0         | nil   | 0             | IMG_5541.jpg |
| 499       | 16/2/10 | 13:09:35 | 2174121   | 5395268    | T5-3 | ii  | 1.9     | 13.60  | 4.40    | 1.5      | sandyMUD         | 0              | nil              | 0         | nil   | 0             | IMG_5542.jpg |
| 499       | 16/2/10 | 13:09:55 | 2174122   | 5395268    | T5-3 | iii | 1.9     | 13.60  | 4.40    | 1.5      | sandyMUD         | 0              | nil              | 0         | nil   | 0             | IMG_5543.jpg |
| 499       | 16/2/10 | 13:10:16 | 2174123   | 5395269    | T5-3 | iv  | 1.9     | 13.60  | 4.40    | 1.5      | sandyMUD         | 0              | nil              | 0         | nil   | 0             | IMG_5544.jpg |
| 498       |         |          | 2174060   | 5394866    | T5-4 |     | 0.0     | 13.40  | 4.38    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 498       | 16/2/10 | 13:12:26 | 2174049   | 5394856    | T5-4 | i   | 1.2     | 13.40  | 4.38    | bottom   | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5545.jpg |
| 498       | 16/2/10 | 13:12:45 | 2174048   | 5394855    | T5-4 | ii  | 1.2     | 13.40  | 4.38    | bottom   | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5546.jpg |
| 498       | 16/2/10 | 13:13:03 | 2174048   | 5394855    | T5-4 | iii | 1.2     | 13.40  | 4.38    | bottom   | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5547.jpg |
| 498       | 16/2/10 | 13:13:21 | 2174053   | 5394859    | T5-4 | iv  | 1.2     | 13.40  | 4.38    | bottom   | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5548.jpg |
| 497       |         |          | 2174017   | 5394771    | T5-5 |     | 0.0     | 13.80  | 4.42    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 497       | 16/2/10 | 13:15:02 | 2174019   | 5394773    | T5-5 | i   | 0.9     | 13.80  | 4.42    | bottom   | muddySAND        | 1              | Myriophyllum     | 30-50     | v     | 10-20         | IMG_5549.jpg |
| 497       | 16/2/10 | 13:15:27 | 2174021   | 5394772    | T5-5 | ii  | 0.9     | 13.80  | 4.42    | bottom   | muddySAND        | 1              | Myriophyllum     | 30-50     | v     | 10-20         | IMG_5550.jpg |
| 497       | 16/2/10 | 13:15:41 | 2174022   | 5394772    | T5-5 | iii | 0.9     | 13.80  | 4.42    | bottom   | muddySAND        | 1              | Myriophyllum     | 50-80     | v     | 50-80         | IMG_5551.jpg |
| 497       | 16/2/10 | 13:16:15 | 2174026   | 5394774    | T5-5 | iv  | 0.9     | 13.80  | 4.42    | bottom   | muddySAND        | 1              | Myriophyllum     | 30-50     | v     | 20-50         | IMG_5552.jpg |

# Appendix 1

| WAY-POINT | DATE    | TIME     | NZMG EAST | NZMG NORTH | SITE | Rep | Depth m | Temp C | Sal_ppt | Sechi_cm | Substrate        | cm_to_Sulphide | Species          | Height_cm | Stage | Percent Cover | Photo Number |
|-----------|---------|----------|-----------|------------|------|-----|---------|--------|---------|----------|------------------|----------------|------------------|-----------|-------|---------------|--------------|
| 492       |         |          | 2173090   | 5396803    | T6-1 |     | 0.0     | 14.40  | 3.49    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 492       | 16/2/10 | 12:39:01 | 2173092   | 5396804    | T6-1 | i   | 0.6     | 14.40  | 3.49    | bottom   | gravelSAND       | 0              | nil              | 0         | nil   | 0             | IMG_5512.jpg |
| 492       | 16/2/10 | 12:39:27 | 2173093   | 5396804    | T6-1 | ii  | 0.6     | 14.40  | 3.49    | bottom   | gravelSAND       | 0              | nil              | 0         | nil   | 0             | IMG_5513.jpg |
| 492       | 16/2/10 | 12:39:41 | 2173093   | 5396804    | T6-1 | iii | 0.6     | 14.40  | 3.49    | bottom   | gravelSAND       | 0              | nil              | 0         | nil   | 0             | IMG_5514.jpg |
| 492       | 16/2/10 | 12:40:01 | 2173093   | 5396804    | T6-1 | iv  | 0.6     | 14.40  | 3.49    | bottom   | gravelSAND       | 0              | nil              | 0         | nil   | 0             | IMG_5515.jpg |
| 493       |         |          | 2173085   | 5396617    | T6-2 |     | 0.0     | 14.00  | 3.81    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 493       | 16/2/10 | 12:42:09 | 2173075   | 5396607    | T6-2 | i   | 0.7     | 14.00  | 3.81    | bottom   | muddygravel/SAND | 1              | Ruppia polycarpa | 30-50     | v     | 50-80         | IMG_5516.jpg |
| 493       | 16/2/10 | 12:42:59 | 2173076   | 5396609    | T6-2 | ii  | 0.7     | 14.00  | 3.81    | bottom   | muddygravel/SAND | 1              | nil              | 0         | nil   | 0             | IMG_5517.jpg |
| 493       | 16/2/10 | 12:43:23 | 2173079   | 5396610    | T6-2 | iii | 0.7     | 14.00  | 3.81    | bottom   | muddygravel/SAND | 1              | nil              | 0         | nil   | 0             | IMG_5518.jpg |
| 493       | 16/2/10 | 12:43:40 | 2173083   | 5396609    | T6-2 | iv  | 0.7     | 14.00  | 3.81    | bottom   | muddygravel/SAND | 1              | Ruppia polycarpa | 15-30     | n/a   | 10-20         | IMG_5519.jpg |
| 494       |         |          | 2173087   | 5396013    | T6-3 |     | 0.0     | 13.40  | 4.31    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 494       | 16/2/10 | 12:47:26 | 2173079   | 5395993    | T6-3 | i   | 1.2     | 13.40  | 4.31    | bottom   | muddygravel/SAND | 2              | Ruppia polycarpa | 15-30     | v     | 20-50         | IMG_5520.jpg |
| 494       | 16/2/10 | 12:47:55 | 2173088   | 5395992    | T6-3 | ii  | 1.2     | 13.40  | 4.31    | bottom   | muddygravel/SAND | 2              | Ruppia polycarpa | 30-50     | PFI   | 80-100        | IMG_5521.jpg |
| 494       | 16/2/10 | 12:49:04 | 2173093   | 5395983    | T6-3 | iii | 1.2     | 13.40  | 4.31    | bottom   | muddygravel/SAND | 2              | Ruppia polycarpa | 15-30     | PFI   | 20-50         | IMG_5522.jpg |
| 494       | 16/2/10 | 12:49:38 | 2173096   | 5395975    | T6-3 | iv  | 1.2     | 13.40  | 4.31    | bottom   | muddygravel/SAND | 2              | Ruppia polycarpa | 30-50     | PFI   | 80-100        | IMG_5523.jpg |
| 495       |         |          | 2173102   | 5395536    | T6-4 |     | 0.0     | 13.30  | 4.41    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 495       | 16/2/10 | 12:51:58 | 2173098   | 5395542    | T6-4 | i   | 1.5     | 13.30  | 4.41    | 1.25     | muddygravel/SAND | 0              | nil              | 0         | nil   | 0             | IMG_5524.jpg |
| 495       | 16/2/10 | 12:52:23 | 2173103   | 5395536    | T6-4 | ii  | 1.5     | 13.30  | 4.41    | 1.25     | muddygravel/SAND | 0              | Ruppia megacarpa | 30-50     | v     | 20-50         | IMG_5525.jpg |
| 495       | 16/2/10 | 12:53:01 | 2173111   | 5395527    | T6-4 | iii | 1.5     | 13.30  | 4.41    | 1.25     | muddygravel/SAND | 0              | Ruppia megacarpa | 30-50     | v     | 10-20         | IMG_5526.jpg |
| 495       | 16/2/10 | 12:54:15 | 2173112   | 5395526    | T6-4 | iv  | 1.5     | 13.30  | 4.41    | 1.25     | muddysandGRAVEL  | 0              | nil              | 0         | nil   | 0             | IMG_5527.jpg |
| 496       |         |          | 2173134   | 5395398    | T6-5 |     | 0.0     | 13.60  | 4.38    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 496       | 16/2/10 | 12:55:55 | 2173128   | 5395400    | T6-5 | i   | 0.5     | 13.60  | 4.38    | bottom   | muddysandGRAVEL  | 1              | Ruppia polycarpa | 30-50     | v     | 10-20         | IMG_5528.jpg |
| 496       | 16/2/10 | 12:56:42 | 2173133   | 5395397    | T6-5 | ii  | 0.5     | 13.60  | 4.38    | bottom   | muddysandGRAVEL  | 1              | nil              | 0         | nil   | 0             | IMG_5529.jpg |
| 496       | 16/2/10 | 12:57:02 | 2173136   | 5395397    | T6-5 | iii | 0.5     | 13.60  | 4.38    | bottom   | muddysandGRAVEL  | 1              | nil              | 0         | nil   | 0             | IMG_5530.jpg |
| 496       | 16/2/10 | 12:57:16 | 2173139   | 5395397    | T6-5 | iv  | 0.5     | 13.60  | 4.38    | bottom   | muddysandGRAVEL  | 1              | Ruppia polycarpa | 15-30     | v     | 10-20         | IMG_5531.jpg |
| 491       |         |          | 2172004   | 5397069    | T7-1 |     | 0.0     | 14.70  | 3.89    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 491       | 16/2/10 | 12:05:50 | 2172003   | 5397075    | T7-1 | i   | 0.5     | 14.70  | 3.89    | bottom   | sand/GRAVEL      | >5             | nil              | 0         | nil   | 0             | IMG_5503.jpg |
| 491       | 16/2/10 | 12:06:17 | 2172003   | 5397075    | T7-1 | ii  | 0.5     | 14.70  | 3.89    | bottom   | sand/GRAVEL      | >5             | nil              | 0         | nil   | 0             | IMG_5504.jpg |
| 491       | 16/2/10 | 12:06:33 | 2172004   | 5397074    | T7-1 | iii | 0.5     | 14.70  | 3.89    | bottom   | sand/GRAVEL      | >5             | nil              | 0         | nil   | 0             | IMG_5505.jpg |
| 491       | 16/2/10 | 12:06:55 | 2172007   | 5397073    | T7-1 | iv  | 0.5     | 14.70  | 3.89    | bottom   | sand/GRAVEL      | >5             | nil              | 0         | nil   | 0             | IMG_5506.jpg |

# Appendix 1

| WAY-POINT | DATE    | TIME     | NZMG EAST | NZMG NORTH | SITE | Rep | Depth m | Temp C | Sal_ppt | Sechi_cm | Substrate        | cm_to_Sulphide | Species          | Height_cm | Stage | Percent Cover | Photo Number |
|-----------|---------|----------|-----------|------------|------|-----|---------|--------|---------|----------|------------------|----------------|------------------|-----------|-------|---------------|--------------|
| 490       |         |          | 2172017   | 5396657    | T7-2 |     | 0.0     | 13.80  | 3.99    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 490       | 16/2/10 | 12:01:42 | 2172010   | 5396652    | T7-2 | i   | 1.1     | 13.80  | 3.99    | bottom   | muddysand/GRAVEL | 1              | nil              | 0         | nil   | 0             | IMG_5499.jpg |
| 490       | 16/2/10 | 12:02:15 | 2172016   | 5396639    | T7-2 | ii  | 1.1     | 13.80  | 3.99    | bottom   | muddysand/GRAVEL | 1              | nil              | 0         | nil   | 0             | IMG_5500.jpg |
| 490       | 16/2/10 | 12:02:45 | 2172018   | 5396626    | T7-2 | iii | 1.1     | 13.80  | 3.99    | bottom   | muddysand/GRAVEL | 1              | nil              | 0         | nil   | 0             | IMG_5501.jpg |
| 490       | 16/2/10 | 12:03:03 | 2172013   | 5396620    | T7-2 | iv  | 1.1     | 13.80  | 3.99    | bottom   | muddysand/GRAVEL | 1              | nil              | 0         | nil   | 0             | IMG_5502.jpg |
| 488       |         |          | 2172050   | 5395872    | T7-3 |     | 0.0     | 13.40  | 4.40    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 488       | 16/2/10 | 11:56:52 | 2172015   | 5395863    | T7-3 | i   | 1.3     | 13.40  | 4.40    | bottom   | muddySAND        | 1              | Ruppia megacarpa | 5-15      | v     | 1-5           | IMG_5495.jpg |
| 488       | 16/2/10 | 11:57:14 | 2172011   | 5395863    | T7-3 | ii  | 1.3     | 13.40  | 4.40    | bottom   | muddySAND        | 1              | Ruppia megacarpa | 5-15      | v     | 1-5           | IMG_5496.jpg |
| 488       | 16/2/10 | 11:58:02 | 2172001   | 5395872    | T7-3 | iii | 1.3     | 13.40  | 4.40    | bottom   | sand/GRAVEL      | 0              | nil              | 0         | nil   | 0             | IMG_5497.jpg |
| 488       | 16/2/10 | 11:58:20 | 2171997   | 5395869    | T7-3 | iv  | 1.3     | 13.40  | 4.40    | bottom   | muddysand/GRAVEL | 0              | nil              | 0         | nil   | 0             | IMG_5498.jpg |
| 487       |         |          | 2172047   | 5395297    | T7-4 |     | 0.0     | 13.30  | 4.31    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 487       | 16/2/10 | 11:52:33 | 2172045   | 5395294    | T7-4 | i   | 1.2     | 13.30  | 4.31    | bottom   | muddySAND        | 1              | Ruppia megacarpa | 30-50     | F     | 20-50         | IMG_5491.jpg |
| 487       | 16/2/10 | 11:53:01 | 2172046   | 5395298    | T7-4 | ii  | 1.2     | 13.30  | 4.31    | bottom   | muddySAND        | 1              | Ruppia megacarpa | 30-50     | F     | 50-80         | IMG_5492.jpg |
| 487       | 16/2/10 | 11:53:30 | 2172046   | 5395293    | T7-4 | iii | 1.2     | 13.30  | 4.31    | bottom   | muddySAND        | 1              | Ruppia megacarpa | 30-50     | F     | 80-100        | IMG_5493.jpg |
| 487       | 16/2/10 | 11:54:02 | 2172052   | 5395300    | T7-4 | iv  | 1.2     | 13.30  | 4.31    | bottom   | muddySAND        | 1              | Ruppia megacarpa | 15-30     | F     | 20-50         | IMG_5494.jpg |
| 486       |         |          | 2172012   | 5394838    | T7-5 |     | 0.0     | 13.60  | 4.38    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 486       | 16/2/10 | 11:48:01 | 2172004   | 5394835    | T7-5 | i   | 1.4     | 13.50  | 4.34    | 1.2      | muddySAND        | 0              | Ruppia megacarpa | 30-50     | v     | 50-80         | IMG_5487.jpg |
| 486       | 16/2/10 | 11:48:50 | 2172007   | 5394815    | T7-5 | ii  | 1.4     | 13.50  | 4.34    | 1.2      | muddySAND        | 0              | Ruppia megacarpa | 15-30     | v     | 5-10          | IMG_5488.jpg |
| 486       | 16/2/10 | 11:49:14 | 2172007   | 5394810    | T7-5 | iii | 1.4     | 13.50  | 4.34    | 1.2      | muddySAND        | 0              | nil              | 0         | nil   | 0             | IMG_5489.jpg |
| 486       | 16/2/10 | 11:49:39 | 2172005   | 5394817    | T7-5 | iv  | 1.4     | 13.50  | 4.34    | 1.2      | muddySAND        | 0              | nil              | 0         | nil   | 0             | IMG_5490.jpg |
| 485       |         |          | 2172010   | 5394041    | T7-6 |     | 0.0     | 13.70  | 4.38    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 485       | 16/2/10 | 11:42:29 | 2172010   | 5394042    | T7-6 | i   | 1.4     | 13.80  | 4.38    | 1.25     | muddySAND        | 0              | Ruppia megacarpa | 50-80     | F     | 80-100        | IMG_5483.jpg |
| 485       | 16/2/10 | 11:44:01 | 2172005   | 5394031    | T7-6 | ii  | 1.4     | 13.80  | 4.38    | 1.25     | muddySAND        | 0              | Ruppia megacarpa | 50-80     | F     | 80-100        | IMG_5484.jpg |
| 485       | 16/2/10 | 11:44:29 | 2172009   | 5394037    | T7-6 | iii | 1.4     | 13.80  | 4.38    | 1.25     | muddySAND        | 0              | Ruppia megacarpa | 50-80     | F     | 80-100        | IMG_5485.jpg |
| 485       | 16/2/10 | 11:44:49 | 2172017   | 5394043    | T7-6 | iv  | 1.4     | 13.80  | 4.38    | 1.25     | muddySAND        | 0              | Ruppia megacarpa | 50-80     | F     | 80-100        | IMG_5486.jpg |
| 484       |         |          | 2172000   | 5393900    | T7-7 |     | 0.0     | 13.20  | 4.38    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 484       | 16/2/10 | 11:39:15 | 2172000   | 5393893    | T7-7 | i   | 0.6     | 13.30  | 4.38    | bottom   | sand/GRAVEL      | 0              | Ruppia polycarpa | 15-30     | v     | 50-80         | IMG_5479.jpg |
| 484       | 16/2/10 | 11:39:55 | 2172000   | 5393893    | T7-7 | ii  | 0.6     | 13.30  | 4.38    | bottom   | sand/GRAVEL      | 0              | Ruppia polycarpa | 15-30     | v     | 50-80         | IMG_5480.jpg |
| 484       | 16/2/10 | 11:40:13 | 2172001   | 5393893    | T7-7 | iii | 0.6     | 13.30  | 4.38    | bottom   | sand/GRAVEL      | 0              | Ruppia polycarpa | 15-30     | v     | 80-100        | IMG_5481.jpg |
| 484       | 16/2/10 | 11:40:32 | 2172002   | 5393893    | T7-7 | iv  | 0.6     | 13.30  | 4.38    | bottom   | sand/GRAVEL      | 0              | Ruppia polycarpa | 15-30     | v     | 80-100        | IMG_5482.jpg |

# Appendix 1

| WAY-POINT | DATE    | TIME     | NZMG EAST | NZMG NORTH | SITE | Rep | Depth m | Temp C | Sal ppt | Secchi cm | Substrate        | cm_to_Sulphide | Species          | Height cm | Stage | Percent Cover | Photo Number |
|-----------|---------|----------|-----------|------------|------|-----|---------|--------|---------|-----------|------------------|----------------|------------------|-----------|-------|---------------|--------------|
| 476       |         |          | 2171028   | 5396501    | T8-1 | n/a | 0.0     | 13.50  | 4.07    | n/a       | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 476       | 16/2/10 | 10:37:02 | 2171033   | 5396493    | T8-1 | i   | 0.9     | 13.50  | 4.08    | bottom    | muddysand/GRAVEL | 1              | nil              | 0         | nil   | 0             | IMG_5433.jpg |
| 476       | 16/2/10 | 10:37:19 | 2171035   | 5396493    | T8-1 | ii  | 0.9     | 13.50  | 4.08    | bottom    | muddysand/GRAVEL | 1              | nil              | 0         | nil   | 0             | IMG_5434.jpg |
| 476       | 16/2/10 | 10:37:41 | 2171036   | 5396492    | T8-1 | iii | 0.9     | 13.50  | 4.08    | bottom    | muddysand/GRAVEL | 1              | nil              | 0         | nil   | 0             | IMG_5435.jpg |
| 476       | 16/2/10 | 10:37:56 | 2171037   | 5396492    | T8-1 | iv  | 0.9     | 13.50  | 4.08    | bottom    | muddysand/GRAVEL | 1              | nil              | 0         | nil   | 0             | IMG_5436.jpg |
| 477       |         |          | 2171042   | 5396368    | T8-2 | n/a | 0.0     | 13.70  | 4.16    | n/a       | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 477       | 16/2/10 | 10:40:14 | 2171036   | 5396339    | T8-2 | i   | 1.1     | 13.70  | 4.07    | bottom    | muddySAND        | 1              | Ruppia polycarpa | 15-30     | v     | 20-50         | IMG_5437.jpg |
| 477       | 16/2/10 | 10:41:13 | 2171039   | 5396352    | T8-2 | ii  | 1.1     | 13.70  | 4.07    | bottom    | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5438.jpg |
| 477       | 16/2/10 | 10:41:33 | 2171040   | 5396351    | T8-2 | iii | 1.1     | 13.70  | 4.07    | bottom    | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5439.jpg |
| 477       | 16/2/10 | 10:41:47 | 2171040   | 5396351    | T8-2 | iv  | 1.1     | 13.70  | 4.07    | bottom    | muddySAND        | 1              | Ruppia polycarpa | 15-30     | v     | 50-80         | IMG_5440.jpg |
| 478       |         |          | 2171049   | 5396071    | T8-3 | n/a | 0.0     | 13.40  | 4.09    | n/a       | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 478       | 16/2/10 | 10:43:48 | 2171045   | 5396018    | T8-3 | i   | 1.6     | 13.40  | 4.08    | 1.4       | muddySAND        | 0              | nil              | 0         | nil   | 0             | IMG_5441.jpg |
| 478       | 16/2/10 | 10:44:24 | 2171035   | 5396014    | T8-3 | ii  | 1.6     | 13.40  | 4.08    | 1.4       | muddySAND        | 0              | nil              | 0         | nil   | 0             | IMG_5442.jpg |
| 478       | 16/2/10 | 10:44:53 | 2171031   | 5396016    | T8-3 | iii | 1.6     | 13.40  | 4.08    | 1.4       | muddySAND        | 0              | nil              | 0         | nil   | 0             | IMG_5443.jpg |
| 478       | 16/2/10 | 10:45:15 | 2171032   | 5396018    | T8-3 | iv  | 1.6     | 13.40  | 4.08    | 1.4       | muddySAND        | 0              | nil              | 0         | nil   | 0             | IMG_5444.jpg |
| 480       |         |          | 2171048   | 5395470    | T8-4 | n/a | 0.0     | 13.40  | 4.17    | n/a       | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 480       | 16/2/10 | 10:49:13 | 2171051   | 5395475    | T8-4 | i   | 1.6     | 13.40  | 4.17    | 1.4       | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5445.jpg |
| 480       | 16/2/10 | 10:49:37 | 2171049   | 5395481    | T8-4 | ii  | 1.6     | 13.40  | 4.17    | 1.4       | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5446.jpg |
| 480       | 16/2/10 | 10:50:05 | 2171046   | 5395486    | T8-4 | iii | 1.6     | 13.40  | 4.17    | 1.4       | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5447.jpg |
| 480       | 16/2/10 | 10:50:25 | 2171048   | 5395492    | T8-4 | iv  | 1.6     | 13.40  | 4.17    | 1.4       | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5448.jpg |
| 482       |         |          | 2171120   | 5394893    | T8-5 |     | 0.0     | 13.90  | 4.33    | n/a       | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 482       | 16/2/10 | 10:53:12 | 2171090   | 5394854    | T8-5 | i   | 1.3     | 13.90  | 4.35    | bottom    | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5449.jpg |
| 482       | 16/2/10 | 10:53:38 | 2171094   | 5394850    | T8-5 | ii  | 1.3     | 13.90  | 4.35    | bottom    | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5450.jpg |
| 482       | 16/2/10 | 10:53:56 | 2171097   | 5394850    | T8-5 | iii | 1.3     | 13.90  | 4.35    | bottom    | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5451.jpg |
| 482       | 16/2/10 | 10:54:24 | 2171101   | 5394842    | T8-5 | iv  | 1.3     | 13.90  | 4.35    | bottom    | muddySAND        | 1              | nil              | 0         | nil   | 0             | IMG_5452.jpg |
| 483       |         |          | 2171195   | 5394495    | T8-6 |     | 0.0     | 13.50  | 4.31    | n/a       | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 483       | 16/2/10 | 10:57:39 | 2171193   | 5394496    | T8-6 | i   | 0.6     | 13.50  | 4.32    | bottom    | sand/GRAVEL      | 1              | Enteromorpha     | 15-30     | v     | 20-50         | IMG_5454.jpg |
| 483       | 16/2/10 | 10:59:40 | 2171194   | 5394487    | T8-6 | ii  | 0.6     | 13.50  | 4.32    | bottom    | sand/GRAVEL      | 1              | Enteromorpha     | 15-30     | v     | 20-50         | IMG_5455.jpg |
| 483       | 16/2/10 | 10:59:57 | 2171196   | 5394486    | T8-6 | iii | 0.6     | 13.50  | 4.32    | bottom    | sand/GRAVEL      | 1              | Enteromorpha     | 15-30     | v     | 20-50         | IMG_5456.jpg |
| 483       | 16/2/10 | 11:00:21 | 2171197   | 5394486    | T8-6 | iv  | 0.6     | 13.50  | 4.32    | bottom    | sand/GRAVEL      | 1              | nil              | 0         | nil   | 0             | IMG_5457.jpg |



# Appendix 1

| WAY-POINT | DATE    | TIME     | NZMG EAST | NZMG NORTH | SITE | Rep | Depth m | Temp C | Sal_ppt | Sechi_cm | Substrate   | cm_to_Sulphide | Species          | Height_cm | Stage | Percent Cover | Photo Number |
|-----------|---------|----------|-----------|------------|------|-----|---------|--------|---------|----------|-------------|----------------|------------------|-----------|-------|---------------|--------------|
| 516       |         |          | 2170958   | 5393126    | T8-7 |     | 0.0     | 13.60  | 4.43    | n/a      | n/a         | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 516       | 16/2/10 | 11:05:52 | 2170949   | 5393120    | T8-7 | i   | 0.6     | 13.50  | 4.43    | bottom   | sandyGRAVEL | 1              | nil              | 0         | nil   | 0             | IMG_5461.jpg |
| 516       | 16/2/10 | 11:06:09 | 2170951   | 5393121    | T8-7 | ii  | 0.6     | 13.50  | 4.43    | bottom   | sandyGRAVEL | 1              | nil              | 0         | nil   | 0             | IMG_5462.jpg |
| 516       | 16/2/10 | 11:06:23 | 2170951   | 5393121    | T8-7 | iii | 0.6     | 13.50  | 4.43    | bottom   | sandyGRAVEL | 1              | Ruppia megacarpa | 5-15      | v     | 20-50         | IMG_5463.jpg |
| 516       | 16/2/10 | 11:08:13 | 2170956   | 5393124    | T8-7 | iv  | 0.6     | 13.50  | 4.43    | bottom   | sandyGRAVEL | 1              | Ruppia megacarpa | 30-50     | v     | 80-100        | IMG_5464.jpg |
| 515       |         |          | 2170989   | 5393047    | T8-8 |     | 0.0     | 13.20  | 4.43    | n/a      | n/a         | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 515       | 16/2/10 | 11:18:44 | 2170978   | 5393036    | T8-8 | i   | 1.1     | 13.20  | 4.43    | bottom   | sandyMUD    | 0              | Ruppia megacarpa | 80-100    | AF    | 80-100        | IMG_5465.jpg |
| 515       | 16/2/10 | 11:19:25 | 2170971   | 5393029    | T8-8 | ii  | 1.1     | 13.20  | 4.43    | bottom   | sandyMUD    | 0              | Ruppia megacarpa | 50-80     | AF    | 80-100        | IMG_5466.jpg |
| 515       | 16/2/10 | 11:19:57 | 2170975   | 5393018    | T8-8 | iii | 1.1     | 13.20  | 4.43    | bottom   | sandyMUD    | 0              | Enteromorpha     | 30-50     | v     | 20-50         | IMG_5467.jpg |
| 515       | 16/2/10 | 11:21:31 | 2170992   | 5393037    | T8-8 | iv  | 1.1     | 13.20  | 4.43    | bottom   | sandyMUD    | 0              | Enteromorpha     | 30-50     | v     | 20-50         | IMG_5468.jpg |
| 514       |         |          | 2171015   | 5392974    | T8-9 |     | 0.0     | 13.30  | 4.45    | n/a      | n/a         | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 514       | 16/2/10 | 11:24:24 | 2171015   | 5392967    | T8-9 | i   | 0.6     | 13.30  | 4.45    | bottom   | sandyGRAVEL | 0              | Enteromorpha     | 30-50     | v     | 20-50         | IMG_5469.jpg |
| 514       | 16/2/10 | 11:25:15 | 2171016   | 5392967    | T8-9 | ii  | 0.6     | 13.30  | 4.45    | bottom   | sandyGRAVEL | 0              | Enteromorpha     | 50-80     | v     | 80-100        | IMG_5470.jpg |
| 514       | 16/2/10 | 11:25:42 | 2171015   | 5392967    | T8-9 | iii | 0.6     | 13.30  | 4.45    | bottom   | sandyGRAVEL | 0              | Enteromorpha     | 30-50     | v     | 50-80         | IMG_5471.jpg |
| 514       | 16/2/10 | 11:26:14 | 2171015   | 5392967    | T8-9 | iv  | 0.6     | 13.30  | 4.45    | bottom   | sandyGRAVEL | 0              | Enteromorpha     | 50-80     | v     | 80-100        | IMG_5473.jpg |
| 523       |         |          | 2170021   | 5396268    | T9-1 |     | 0.0     | 13.50  | 4.00    | n/a      | n/a         | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 523       | 16/2/10 | 9:57:59  | 2170036   | 5396247    | T9-1 | i   | 1.0     | 13.50  | 4.00    | bottom   | sand/GRAVEL | 3              | nil              | 0         | nil   | 0             | IMG_5404.jpg |
| 523       | 16/2/10 | 9:58:19  | 2170037   | 5396245    | T9-1 | ii  | 1.0     | 13.50  | 4.00    | bottom   | sand/GRAVEL | 3              | Ruppia polycarpa | 5-15      | v     | 1-5           | IMG_5405.jpg |
| 523       | 16/2/10 | 9:59:04  | 2170037   | 5396244    | T9-1 | iii | 1.0     | 13.50  | 4.00    | bottom   | sand/GRAVEL | 3              | nil              | 0         | nil   | 0             | IMG_5406.jpg |
| 523       | 16/2/10 | 9:59:42  | 2170039   | 5396244    | T9-1 | iv  | 1.0     | 13.50  | 4.00    | bottom   | sand/GRAVEL | 1              | Enteromorpha     | 5-15      | v     | 1-5           | IMG_5407.jpg |
| 522       |         |          | 2169973   | 5395831    | T9-2 |     | 0.0     | 13.40  | 4.12    | n/a      | n/a         | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 522       | 16/2/10 | 10:02:50 | 2169962   | 5395825    | T9-2 | i   | 1.4     | 13.40  | 4.13    | bottom   | muddySAND   | 2              | nil              | 0         | nil   | 0             | IMG_5409.jpg |
| 522       | 16/2/10 | 10:03:30 | 2169966   | 5395814    | T9-2 | ii  | 1.4     | 13.40  | 4.13    | bottom   | muddySAND   | 2              | nil              | 0         | nil   | 0             | IMG_5410.jpg |
| 522       | 16/2/10 | 10:03:48 | 2169968   | 5395810    | T9-2 | iii | 1.4     | 13.40  | 4.13    | bottom   | muddySAND   | 2              | nil              | 0         | nil   | 0             | IMG_5411.jpg |
| 522       | 16/2/10 | 10:04:07 | 2169970   | 5395805    | T9-2 | iv  | 1.4     | 13.40  | 4.13    | bottom   | muddySAND   | 2              | nil              | 0         | nil   | 0             | IMG_5412.jpg |
| 521       |         |          | 2169946   | 5395338    | T9-3 |     | 0.0     | 13.30  | 4.31    | n/a      | n/a         | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 521       | 16/2/10 | 10:07:10 | 2169927   | 5395332    | T9-3 | i   | 0.8     | 13.30  | 4.31    | 0.4      | sandGRAVEL  | 1              | Myriophyllum     | 15-30     | v     | 1-5           | IMG_5413.jpg |
| 521       | 16/2/10 | 10:08:03 | 2169926   | 5395334    | T9-3 | ii  | 0.8     | 13.30  | 4.31    | 0.4      | sandGRAVEL  | 3              | nil              | 0         | nil   | 0             | IMG_5414.jpg |
| 521       | 16/2/10 | 10:09:39 | 2169923   | 5395334    | T9-3 | iii | 0.8     | 13.30  | 4.31    | 0.4      | sandGRAVEL  | 3              | nil              | 0         | nil   | 0             | IMG_5415.jpg |
| 521       | 16/2/10 | 10:10:03 | 2169924   | 5395334    | T9-3 | iv  | 0.8     | 13.30  | 4.31    | 0.4      | sandGRAVEL  | 3              | Myriophyllum     | 15-30     | v     | 1-5           | IMG_5416.jpg |

# Appendix 1

| WAY-POINT | DATE    | TIME     | NZMG EAST | NZMG NORTH | SITE  | Rep | Depth m | Temp C | Sal_ppt | Sechi_cm | Substrate        | cm_to_Sulphide | Species          | Height_cm | Stage | Percent Cover | Photo Number |
|-----------|---------|----------|-----------|------------|-------|-----|---------|--------|---------|----------|------------------|----------------|------------------|-----------|-------|---------------|--------------|
| 520       |         |          | 2169832   | 5395189    | T9-4  |     | 0.0     | 13.20  | 4.33    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 520       | 16/2/10 | 10:13:01 | 2169840   | 5395171    | T9-4  | i   | 1.0     | 13.20  | 4.33    | 0.5      | sandyMUD         | 0              | Myriophyllum     | 80-100    | v     | 50-80         | IMG_5417.jpg |
| 520       | 16/2/10 | 10:13:45 | 2169856   | 5395173    | T9-4  | ii  | 0.8     | 15.03  | 2.99    | 0.65     | sandyMUD         | 1              | Ruppia megacarpa | 80-100    | v     | 5-10          | IMG_5418.jpg |
| 520       | 16/2/10 | 10:13:45 | 2169856   | 5395173    | T9-4  | ii  | 0.8     | 15.03  | 2.99    | 0.65     | sandyMUD         | 1              | Myriophyllum     | 80-100    | v     | 80-100        | IMG_5418.jpg |
| 520       | 16/2/10 | 10:15:03 | 2169883   | 5395175    | T9-4  | iii | 0.8     | 15.03  | 2.99    | 0.65     | sandyMUD         | 1              | Myriophyllum     | 80-100    | v     | 50-80         | IMG_5419.jpg |
| 520       | 16/2/10 | 10:15:54 | 2169902   | 5395177    | T9-4  | iv  | 0.8     | 15.03  | 2.99    | 0.65     | sandyMUD         | 1              | Myriophyllum     | 80-100    | v     | 50-80         | IMG_5420.jpg |
| 518       |         |          | 2169946   | 5394950    | T9-5  |     | 0.0     | 13.30  | 4.39    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 518       | 16/2/10 | 10:21:05 | 2169934   | 5394944    | T9-5  | i   | 1.0     | 13.40  | 4.38    | 0.8      | sandyMUD         | 0              | Myriophyllum     | 15-30     | v     | 5-10          | IMG_5422.jpg |
| 518       | 16/2/10 | 10:21:05 | 2169934   | 5394944    | T9-5  | i   | 1.0     | 13.40  | 4.38    | 0.8      | sandyMUD         | 0              | Ruppia megacarpa | 5-15      | v     | 50-80         | IMG_5422.jpg |
| 518       | 16/2/10 | 10:21:31 | 2169929   | 5394947    | T9-5  | ii  | 1.0     | 13.40  | 4.38    | 0.8      | sandyMUD         | 0              | Myriophyllum     | 30-50     | v     | 20-50         | IMG_5423.jpg |
| 518       | 16/2/10 | 10:23:38 | 2169925   | 5394943    | T9-5  | iii | 1.0     | 13.40  | 4.38    | 0.8      | sandyMUD         | 0              | Myriophyllum     | 50-80     | v     | 50-80         | IMG_5425.jpg |
| 518       | 16/2/10 | 10:24:23 | 2169944   | 5394933    | T9-5  | iv  | 1.0     | 13.40  | 4.38    | 0.8      | sandyMUD         | 0              | Ruppia megacarpa | 15-30     | v     | 5-10          | IMG_5426.jpg |
| 519       |         |          | 2170245   | 5394350    | T9-6  |     | 0.0     | 13.40  | 4.37    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 519       | 16/2/10 | 10:28:38 | 2170231   | 5394361    | T9-6  | i   | 1.0     | 13.40  | 4.38    | 0.8      | sandyMUD         | 0              | Ruppia megacarpa | 30-50     | PF    | 50-80         | IMG_5427.jpg |
| 519       | 16/2/10 | 10:28:38 | 2170231   | 5394361    | T9-6  | i   | 1.0     | 13.40  | 4.38    | 0.8      | sandyMUD         | 0              | Myriophyllum     | 30-50     | v     | 1-5           | IMG_5427.jpg |
| 519       | 16/2/10 | 10:30:50 | 2170224   | 5394376    | T9-6  | ii  | 1.0     | 13.40  | 4.38    | 0.8      | sandyMUD         | 0              | Myriophyllum     | 80-100    | v     | 10-20         | IMG_5428.jpg |
| 519       | 16/2/10 | 10:31:16 | 2170229   | 5394377    | T9-6  | iii | 1.0     | 13.40  | 4.38    | 0.8      | sandyMUD         | 0              | Myriophyllum     | 80-100    | v     | 50-80         | IMG_5429.jpg |
| 519       | 16/2/10 | 10:31:42 | 2170233   | 5394382    | T9-6  | iv  | 1.0     | 13.40  | 4.38    | 0.8      | sandyMUD         | 0              | Myriophyllum     | 30-50     | v     | 50-80         | IMG_5430.jpg |
| 517       |         |          | 2170280   | 5392766    | T9-7  |     | 0.0     | 13.50  | 4.57    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 517       | 16/2/10 | 11:29:38 | 2170276   | 5392760    | T9-7  | i   | 1.0     | 13.50  | 4.55    | bottom   | muddygravel/SAND | 0              | Ruppia megacarpa | 80-100    | PF    | 80-100        | IMG_5474.jpg |
| 517       | 15/2/10 | 10:30:30 | 2170285   | 5392749    | T9-7  | ii  | 1.0     | 13.50  | 4.55    | bottom   | muddygravel/SAND | 0              | Ruppia megacarpa | 80-100    | PF    | 80-100        | IMG_5475.jpg |
| 517       | 16/2/10 | 11:30:30 | 2170285   | 5392749    | T9-7  | ii  | 1.0     | 13.50  | 4.55    | bottom   | muddygravel/SAND | 0              | Myriophyllum     | 5-15      | v     | 1-5           | IMG_5475.jpg |
| 517       | 16/2/10 | 11:31:05 | 2170288   | 5392742    | T9-7  | iii | 1.0     | 13.50  | 4.55    | bottom   | muddygravel/SAND | 0              | Ruppia megacarpa | 80-100    | PF    | 80-100        | IMG_5476.jpg |
| 517       | 16/2/10 | 11:31:33 | 2170285   | 5392743    | T9-7  | iv  | 1.0     | 13.50  | 4.55    | bottom   | muddygravel/SAND | 0              | Ruppia megacarpa | 80-100    | PF    | 80-100        | IMG_5477.jpg |
| 524       |         |          | 2169042   | 5396141    | T10-1 |     | 0.0     | 13.80  | 3.50    | n/a      | n/a              | n/a            | n/a              | n/a       | n/a   | n/a           |              |
| 524       | 16/2/10 | 9:41:32  | 2169026   | 5396141    | T10-1 | i   | 1.0     | 13.70  | 4.08    | bottom   | sand/GRAVEL      | 1              | nil              | 0         | nil   | 0             | IMG_5390.jpg |
| 524       | 16/2/10 | 9:41:51  | 2169026   | 5396141    | T10-1 | ii  | 1.0     | 13.70  | 4.08    | bottom   | sand/GRAVEL      | 1              | nil              | 0         | nil   | 0             | IMG_5391.jpg |
| 524       | 16/2/10 | 9:42:08  | 2169026   | 5396140    | T10-1 | iii | 1.0     | 13.70  | 4.08    | bottom   | sand/GRAVEL      | 1              | nil              | 0         | nil   | 0             | IMG_5392.jpg |
| 524       | 16/2/10 | 9:42:28  | 2169025   | 5396139    | T10-1 | iv  | 1.0     | 13.70  | 4.08    | bottom   | sand/GRAVEL      | 1              | nil              | 0         | nil   | 0             | IMG_5393.jpg |

# Appendix 1

| WAY-POINT | DATE    | TIME    | NZMG EAST | NZMG NORTH | SITE  | Rep | Depth m | Temp C | Sal_ ppt | Sechi_ cm | Substrate   | cm_to_Sulphide | Species          | Height_ cm | Stage | Percent Cover | Photo Number |
|-----------|---------|---------|-----------|------------|-------|-----|---------|--------|----------|-----------|-------------|----------------|------------------|------------|-------|---------------|--------------|
| 525       |         |         | 2169028   | 5395949    | T10-2 |     | 0.0     | 13.70  | 3.55     | n/a       | n/a         | n/a            | n/a              | n/a        | n/a   | n/a           |              |
| 525       | 16/2/10 | 9:46:11 | 2169015   | 5395925    | T10-2 | i   | 1.0     | 13.30  | 3.51     | bottom    | muddySAND   | 2              | Myriophyllum     | 30-50      | v     | 10-20         | IMG_5397.jpg |
| 525       | 16/2/10 | 9:45:41 | 2169010   | 5395931    | T10-2 | ii  | 1.0     | 13.30  | 3.51     | bottom    | muddySAND   | 1              | Myriophyllum     | 30-50      | v     | 5-10          | IMG_5396.jpg |
| 525       | 16/2/10 | 9:45:41 | 2169010   | 5395931    | T10-2 | ii  | 1.0     | 13.30  | 3.51     | bottom    | muddySAND   | 1              | Ruppia polycarpa | 15-30      | v     | 5-10          | IMG_5396.jpg |
| 525       | 16/2/10 | 9:46:49 | 2169022   | 5395918    | T10-2 | iii | 1.0     | 13.30  | 3.51     | bottom    | muddySAND   | 1              | Myriophyllum     | 30-50      | v     | 1-5           | IMG_5398.jpg |
| 525       | 16/2/10 | 9:47:29 | 2169030   | 5395910    | T10-2 | iii | 1.0     | 13.30  | 3.51     | bottom    | muddySAND   | 1              | Ruppia polycarpa | 5-15       | v     | 1-5           | IMG_5399.jpg |
| 526       |         |         | 2169050   | 5395759    | T10-3 |     | 0.0     | 13.20  | 3.55     | n/a       | n/a         | n/a            | n/a              | n/a        | n/a   | n/a           |              |
| 526       | 16/2/10 | 9:51:05 | 2169031   | 5395751    | T10-3 | i   | 1.0     | 13.40  | 3.56     | bottom    | sand/GRAVEL | 2              | nil              | 0          | nil   | 0             | IMG_5400.jpg |
| 526       | 16/2/10 | 9:51:16 | 2169031   | 5395751    | T10-3 | ii  | 1.0     | 13.40  | 3.56     | bottom    | sand/GRAVEL | 2              | nil              | 0          | nil   | 0             | IMG_5401.jpg |
| 526       | 16/2/10 | 9:51:25 | 2169031   | 5395751    | T10-3 | iii | 1.0     | 13.40  | 3.56     | bottom    | sand/GRAVEL | 4.00           | nil              | 0          | nil   | 0             | IMG_5402.jpg |
| 526       | 16/2/10 | 9:51:36 | 2169032   | 5395751    | T10-3 | iv  | 1.0     | 13.40  | 3.56     | bottom    | sand/GRAVEL | >5             | nil              | 0          | nil   | 0             | IMG_5403.jpg |