Flora and fauna survey for the Hydrilla eradication response 2015

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Executive summary

MPI (Ministry for Primary Industries) is undertaking a biosecurity response to manage and eradicate the submerged weed hydrilla (*Hydrilla verticillata* (L.f.) Royle) from the Hawke's Bay, and hence from New Zealand. The tools for the hydrilla eradication response included an initial application of the aquatic herbicide endothall (Aquathol® K), and introduction of the herbivorous fish grass carp (*Ctenopharyngodon idella*) into the affected lakes in December 2008. A second release of grass carp was made in December 2014.

In autumn 2015, NIWA was contracted by MPI to carry out a vegetation survey at the baseline sites in the hydrilla affected lakes Tutira, Waikōpiro and Opouahi, and an invertebrate survey in Lake Tutira to determine the status of the hydrilla and document any changes in the flora and fauna.

Plants and macroinvertebrates were surveyed at the 15 sites established in 2008 and inspected in subsequent surveys in Lake Tutira. Plants were surveyed at the five sites, established in 2008, in each of the smaller lakes, Waikōpiro and Opouahi. No hydrilla weed beds were recorded in any of the three lakes (Tutira, Waikōpiro and Opouahi). Small hydrilla plants were recorded at three sites in Lake Tutira, (this is a decrease from the five sites in 2014) and on the shallow water plateau in Lake Tutira. The presence of hydrilla at some sites indicates a need to continue to monitor the browsing pressure of the grass carp, to inform future stocking requirements for the hydrilla eradication response. No further grass carp are required at this time.

In all three lakes, shallow water turf plants and/or marginal emergent plants were present. In Lake Waikōpiro three species were recorded in shallow water. In Lake Tutira the native aquatic plant *Myriophyllum triphyllum,* that had expanded its distribution and cover following removal of the hydrilla, remains the most abundant aquatic plant. The number of macroinvertebrate taxa recorded from Lake Tutira was the same as that obtained before the hydrilla weed beds were removed. Eels, mussels and koura were also observed by the SCUBA divers in Lake Tutira.

In Lake Opouahi, vegetation in the grass carp exclusion cages was monitored. Two cages had charophytes, but only one cage had established plants. With the exception of this one cage, no large scale (entire cage) colonisation has taken place. Factors described as potentially contributing to the lack of charophyte establishment within the cages (ie., demise of young charophytes), include localised sediment movement resulting in oospore (seed) burial, sediment disturbance and/or low light climate. Germling (charophyte seedling) presence in different surveys coupled with photographic records indicate that localised sediment movement has not been the primary cause of the empty exclosure cages.

Localised sediment disturbance by bullies seeking shelter from predation, or as a consequence of their preference for hard surfaces for spawning in lakes was discussed as a potential contributor to the limited establishment of charophytes. There is no direct evidence to support interference by bullies, however any potential impacts on young plants in the cages could be mitigated by reducing the edge effect of the cage. A larger tunnel cage was installed on the south-eastern littoral zone. Oospore counts from sediment cores from this site, sampled in April 2015, are consistent with published numbers from 1996. Light loggers were secured to the cage prior to installation to monitor the light climate over the coming year.

Based on the autumn 2015 monitoring results and the MPI goal to eradicate hydrilla from New Zealand, it is recommended that a further flora and fauna survey takes place in autumn 2016. The survey should include an assessment of aquatic vegetation and macroinvertebrates in Lake Tutira and the vegetation only in Lakes Waikōpiro and Opouahi at the established survey sites. Additional activities should include, an assessment of hydrilla on the shallow water plateau in Lake Tutira, and the vegetation within the exclusion cages in Lake Opouahi.

1 Introduction

Hydrilla (*Hydrilla verticillata* (L.f.) Royle) is an alien submerged aquatic weed that is only found in the Hawke's Bay, and has been identified as a pest for eradication as a National Interest Pest Response (NIPR).

MPI (Ministry for Primary Industries) developed a plan to manage and eliminate hydrilla in Lakes Tutira, Waikōpiro and Opouahi and to achieve the goal of eradication from New Zealand (MAF 2008). The tools to achieve eradication include stocking the herbivorous fish grass carp (*Ctenopharyngodon idella*) for sustained grazing pressure on the hydrilla, in conjunction with the aquatic herbicide endothall (Aquathol K). Endothall was applied at select sites in Lakes Tutira and Waikōpiro that posed a high risk of plant transfer. In May 2008, before the introduction of grass carp and the use of endothall (December 2008), a comprehensive baseline survey of the flora and fauna in the hydrilla affected lakes was undertaken (Hofstra et al. 2008), with an additional fish survey in spring 2008 (Hofstra and Smith 2008).

To document changes in the lakes, monitoring of flora and fauna within all three lakes at the established baseline sites has been undertaken annually, in autumn, since the grass carp were released. To date, the most significant change has been the removal of the hydrilla weed beds (by autumn 2010) and subsequent to the reduction in hydrilla, a further fish survey was undertaken in spring 2011 (Smith and Rowe 2011). Additional operations to the hydrilla eradication response have included the installation and monitoring of grass carp exclusion cages in Lake Opouahi. Cages were installed at six littoral zone sites, which historically contained native charophytes as opposed to hydrilla, to enable regeneration of charophytes in the absence of grass carp browsing and provide native biodiversity refugia during the hydrilla eradication response. A feasibility assessment for similar exclosure cages in Lake Tutira was also carried out along with an assessment of obstructions to grass carp grazing in Lake Tutira and marking of hydrilla plants on the shallow water plateau in Lake Tutira (Hofstra and Clayton 2012, Hofstra 2013a).

Based on the findings from the flora and fauna survey in April 2014 (Hofstra 2014) it was recommended that additional grass carp were stocked in Lake Tutira and a reduced survey was undertaken in autumn 2015. The reduced survey was to include an assessment of vegetation and macroinvertebrates in Lake Tutira following the introduction of further grass carp (December 2014), and the vegetation in Lakes Waikōpiro and Opouahi. In addition, the exclosure cages within Lake Opouahi were to be assessed for the presence/absence of charophytes, an estimate of oospores (charophyte seed) was to be undertaken to inform future decision making on the use of exclusion cages, and the potential installation of a larger tunnel shaped exclosure cage in the lake.

This report records and describes the findings from the three lakes:

- Lake Tutira - Aquatic vegetation and macroinvertebrate survey, including monitoring of hydrilla on the plateau.
- Lake Waikōpiro – Aquatic vegetation survey.
- Lake Opouahi - Aquatic vegetation survey, exclosure cage and oospore assessment, and installation of a tunnel cage.

2 Methods

2.1 Lake Tutira

2.1.1 Aquatic Plant Survey

The sites selected in Lake Tutira (Figure 1) were the same as those surveyed in autumn each year since 2008. GPS co-ordinates and photographed landmarks were used to locate each site (Hofstra et al. 2008).

At each site, vegetation was recorded by a SCUBA diver along the profile (ca. 2 m wide) down the gradient to the maximum depth of historic plant growth (ca 8 m). Observations were recorded while diving through the profile. Data recorded included plant species present, their depth range, height (maximum and average) and cover (maximum and average). The scale used for plant cover was a modified Braun-Blanquet scale where 1 represents 1–5% cover, 2 was 6–25%, 3 was 26–50%, 4 was 51–75%, 5 was 76–95% and 6 was 96–100% cover (Clayton 1983). The presence of aquatic fauna including koura, mussels, fish and eels and a general description of the site, such as visibility, length and maximum depth of the profile were also recorded (Clayton 1983).

2.1.2 Plateau plants in Lake Tutira

SCUBA divers assessed hydrilla plants on the shallow water plateau (Figure 1, bathymetric map) that had previously been marked (February and April 2013, Hofstra 2013 a, b). The plant markers were located, presence/absence of hydrilla was recorded along with descriptive notes on plant size (height and branching) and photographs were taken.

2.1.3 Invertebrate Sampling

Sample sites corresponded with the aquatic plant profile sites used in the 2008 baseline survey (Hofstra et al. 2008) as these represented a variety of the habitat types known to be present in the lake (Figure 1).

Along each profile, macroinvertebrate communities were sampled by a SCUBA diver from three zones defined by existing or historic vegetation characteristics (i.e., turf community, macrophyte community where the dense hydrilla beds had previously occurred (ca. 4 m water depth), and bare sediment at a water depth below which plants had occurred (Figure 2)).

Zone 1. Shallow water/Turf community

The shallow water zone at the lake margin is comprised of a turf plant community, willow trees either standing or felled extending into the lake, tall emergent vegetation and/or bare sediment. This zone was sampled at less than 1.5 m water depth. The area for sampling was defined by a quadrat (25 x 25 cm), any plants present were aggressively raked with hands to dislodge organisms and these were scooped into the Wisconsin nets (500 µm mesh). This included organisms in the top 1cm of sediment and those that had fallen from the plants. This was done three times (in 3 different quadrats) and the samples were pooled into the net and removed to the water surface for sieving and sorting. A description of plant cover in each quadrat was also recorded along with mussel presence or absence.

Zone 2. Macrophyte Community

Dense hydrilla weed beds previously occupied this area. During this survey, plants were absent or sparse at some sites, with *M. triphyllum* present at most Lake Tutira sites. The quadrat procedure (as described for zone 1) was used to sample from the range of habitats present (ie., plants or bare sediment), and a core (8.5 cm diameter by 10 cm depth) was used to sample benthic macroinvertebrates in order to enable comparison with previous sampling events from this zone.

Zone 3. Benthic Community

Benthic macroinvertebrates were sampled beyond the deeper margins of the weed bed (where there were no plants) at greater than 6 m water depth in all lakes. The area for sampling was defined by a quadrat (25 x 25 cm), where the top 1 cm of sediment was scooped into a Wisconsin net (500 µm mesh). This was repeated three times (in 3 different quadrats), and the samples were pooled into the bottom of the Wisconsin net which was then secured off before surfacing.

Invertebrate Identification

Onshore, the macroinvertebrate samples were washed out of the Wisconsin net (or core), sieved (500 µm) and placed in sorting trays marked with grids (ca. 6 cm x 6 cm). Water from a wash bottle was used to evenly spread the sample across the tray. Using the fixed count method (Stark et al. 2001), and systematically working from one grid in the tray to another, macroinvertebrates were picked out using forceps, counted and placed in glass Petri dishes. After 200 macroinvertebrates were counted the grid count was completed, the number of grids counted was noted, and then the sample was scanned for rare taxa. When fewer than 200 macroinvertebrates were present in a grid, successive grids were also counted. Where fewer than 200 macroinvertebrates were present in the tray, the entire sample was counted. Macroinvertebrates were identified using Winterbourn et al. (2006) and numbers recorded. The lengths of any mussels present in the sample were recorded. Following identification and counting samples were released back into the lake.

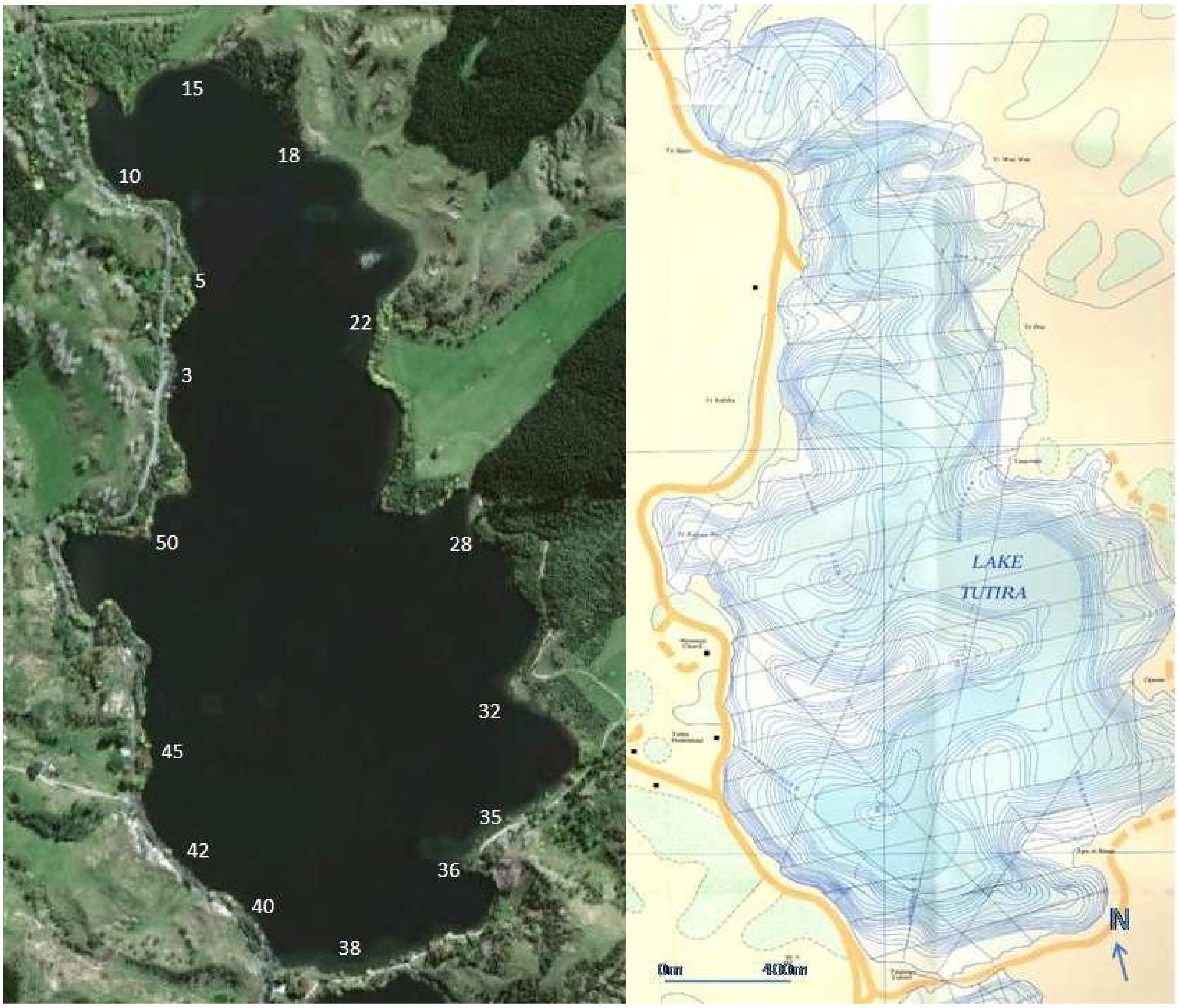

Figure 1: **Lake Tutira showing macrophyte and invertebrate sample sites (left) and a bathymetric map (Irwin 1978) showing the shallow water plateau in the southern part of the lake (right).**

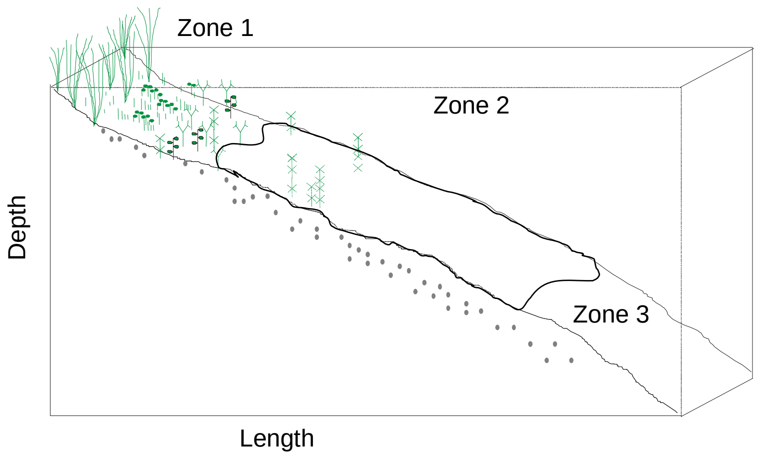

Figure 2: **Diagrammatic plant profile showing the zones from which invertebrates were sampled within the lakes.** (Source M. de Winton).

2.2 Lake Waikōpiro

2.2.1 Aquatic plant survey in Lake Waikōpiro

Five sites in Lake Waikōpiro were surveyed for aquatic vegetation (Figure 3). These were the same sites as those surveyed in autumn each year since 2008. The sites were located by GPS co-ordinates and photographed landmarks (Hofstra et al. 2008).

The aquatic plant survey method is described above (see Section 2.1.1).

Figure 3: **Lake Waikōpiro showing macrophyte survey sites.**

2.3 Lake Opouahi

2.3.1 Aquatic plant survey in Lake Opouahi

Five sites in Lake Opouahi were surveyed for aquatic vegetation (Figure 4). These were the same sites as those surveyed in autumn each year since 2008. The sites were located by GPS co-ordinates and photographed landmarks (Hofstra et al. 2008).

Aquatic plant survey method is described above (see Section 2.1.1).

2.3.2 Exclosure cages and oospore assessment

SCUBA divers assessed the presence/absence of vegetation in submerged exclosure cages (15 large and 15 small cages at a total of six sites with five cages at each) that were installed in Lake Opouahi in February 2012 (Figure 4). Photographs were taken of each cage to compare with previous images and provide an estimate of localised changes in sediment level (if any), and hence the potential for burial of charophyte oospores.

Sediment cores (8.5 cm diameter and 10 cm deep) were used to sample the seedbank and provide an estimate of charophyte oospores at a site of interest. The site was selected based on the presence of historic charophyte beds (as opposed to hydrilla), and that germlings (charophyte seedlings) had been recorded in the adjacent small exclosure cages, indicating that this area of shoreline may be the most suitable for installation of a larger tunnel shaped exclosure cage. The cores were removed at half metre intervals along a depth gradient from 1 to 3.5m water depth adjacent to site 7 (Figure 4). There were a total for 30 cores, five from each half metre water depth interval. The SCUBA divers brought the cores to shore where they were carefully packed into a chillibin for transport. The cores were taken to NIWA's research facility at Ruakura, where they were uncapped and carefully placed into an outdoor tank (water depth of ca 70cm and covered with 80% shade cloth) for subsequent monitoring for charophyte germination.

An additional set of sediment cores, one core from each metre interval from 1 to 5m at the same site, were sieved (250 and 500 µm) and viable charophyte oospores counted under a stereomicroscope in the laboratory. Viability of the oospores was inferred by the firmness of the oospore, the intact nature of the seed coat and condition of the starch reserves (ie., if the oospore was punctured by the forceps) (de Winton and Clayton 1996).

A tunnel cage (ca 1m wide by 2.6m long) was made on shore from semi rigid plastic mesh (orange safety fencing with 50mm by 50mm mesh). These were the same materials and methods used to make the cages that were previously installed in the lake (Hofstra and Clayton 2012). SCUBA divers installed the cage by lodging it into the sediment and securing with solid plastic warratah posts, at a depth of 2 to 4m at the location now referred to as site 8 (Figures 4 and 13). Light loggers (Hobo) were secured to the upper surface of the tunnel cage to record light levels over the coming year.

Figure 4: Lake Opouahi showing macrophyte survey and exclosure cage sites. Numbers with solid markers refer to the survey sites. Numbers with the large and small hexagons represent the large and small exclosure cages sites respectively. The large tunnel cage is at site 8.

3 Results and Discussion

3.1 Lake Tutira

Information gathered by the SCUBA divers from Lake Tutira is presented in Appendix A. The divers reported good water clarity with visibility of 5m. Mussels and eels were regularly sighted and a juvenile koura was found by a diver under a rock on the eastern shore. The boat crew reported herons and black swans on the eastern side of the lake.

3.1.1 Aquatic plants

Hydrilla was found at three of the 15 monitoring sites in Lake Tutira (Table 1 and Appendix A1). The plants were generally small in stature ca 10cm high (Table 1), usually with multiple branches and evidence of browsed shoots. Plants found at the monitoring sites were excavated, no new tubers were found, and there was no indication of tuber formation occurring (Figure 5). The number of sites at which hydrilla was found, the size of the plants and the depth range (Figure 6) of the hydrilla has decreased since 2014. As in previous years the hydrilla was found amongst milfoil, however the milfoil was also smaller in stature this year (max height 30cm, Table 1) compared with 2014 when the maximum height was 50cm (Hofstra 2014).

Lake Tutira continues to support a range of low growing turf, and marginal plants (eg., *Typha orientalis*) (Table 1 and Appendix A1). The turf plant species occurred in water less than ca 1.4 m deep at generally low cover values, while the *T. orientalis* was in water less than 0.4m deep (Table 1) and remains dense where it was inaccessible to grass carp.

Due to the continued presence of hydrilla at some sites in Lake Tutira, monitoring of the aquatic vegetation in April 2016 is recommended. No further grass carp are required at this time.

Table 1: Lake Tutira vegetation summary.

Plant Species	No. of sites	Depth range (m)	Height (m)		Cover	
			max	ave	max	median
Chara australis	8	0.5-4.2	0.1	<0.1	2	1
Chara globularis	6	0.2-4	0.1	<0.1	1	1
Elatine gratioloides	2	0.2-0.6			3	2
Elodea canadensis	2	0.5-1.2	0.1	0.1	2	1
Glossostigma elatinoides	9	0-1.1			5	2
Hydrilla verticillata	3	0.8-1, 1.4	0.1	<0.1	1	1
Lilaeopsis novae-zealandiae	8	0-1.4			5	1
Myriophyllum triphyllum	13	0-4.3	0.3	0.1	6	2
Nitella hyalina	8	0.1-5	0.1	<0.1	2	1
Potamogeton cheesemanii	1	0.4			1	1
Potamogeton crispus	1	0.4			1	1
Ranunculus limosella	5	0.1-0.8			3	1
Ruppia polycarpa	4	0.5-2.1	0.1	0.1	2	1
Typha orientalis	7	0-0.4	3	2	6	5
Nostoc spp.	4				4	3

NB: Cover data 1=1–5%, 2=6–25%, 3=26–50%, 4=51–75%, 5=76–95%, 6=96–100%. Marginal plants include *Bidens frondosa, Carex maorica, Cyperus eragrostis, Eleocharis acuta, Lotus pedunculatus, Lycopus europaeus, Persicaria decipiens* and *Symphyotrichum subulatum.* At one site, no submerged macrophytes were recorded.

Figure 5: **Hydrilla plants from site 28 in Lake Tutira.** The plants shown here illustrate the small stature of the hydrilla and the production of new shoots from horizontal stem or rhizomes (Photo by P Champion).

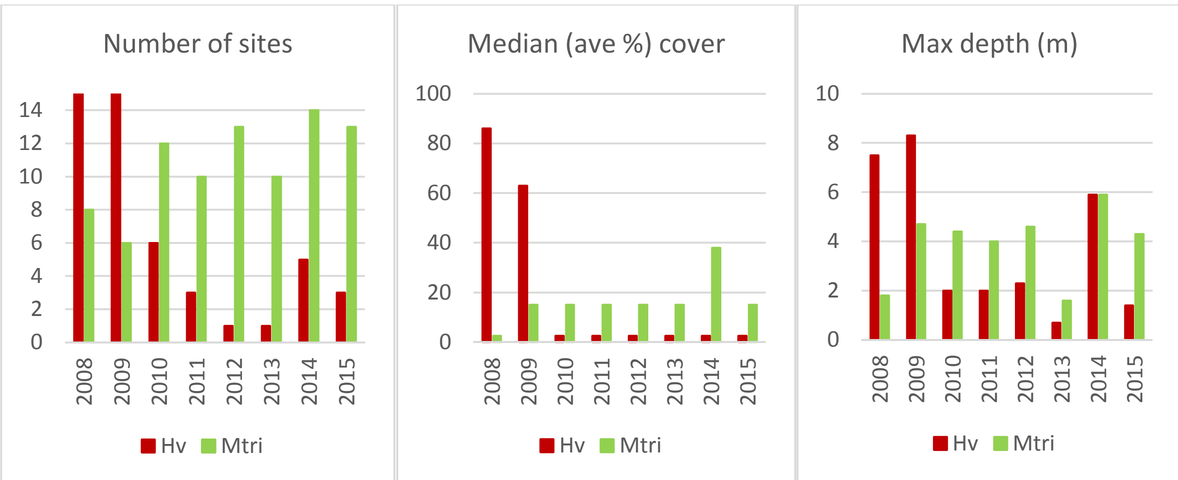

Figure 6: **Hydrilla and milfoil abundance from 2008 to 2015.**

3.1.2 The plateau

The hydrilla markers (stakes) that were placed adjacent to hydrilla plants on the shallow water plateau in February and April 2013 were located and assessed (Figures 7 and 8).

As in 2014, half of the stakes had adjacent hydrilla plants. The hydrilla had browsed shoots, but new shoots were observed on the plants having arisen from the root crown (the base of the plant) or as new plants on horizontal stems or rhizomes (Figure 5). Although the site data (section 3.1.1) may indicate that the December release of grass carp is having an impact on the overall abundance of the hydrilla, no such change was evident on the plateau. Further monitoring of the plateau is recommended for April 2016. The hydrilla plants that have been marked should be located and (if still present) assessed for browsing damage. Any new or additional plants that are identified on the plateau should be assessed for browsing damage, and excavated to assess tuber production.

Figure 7: A stake marking hydrilla on the plateau. In this image hydrilla is not readily discernible amongst the native milfoil (Photo by A Taumoepeau).

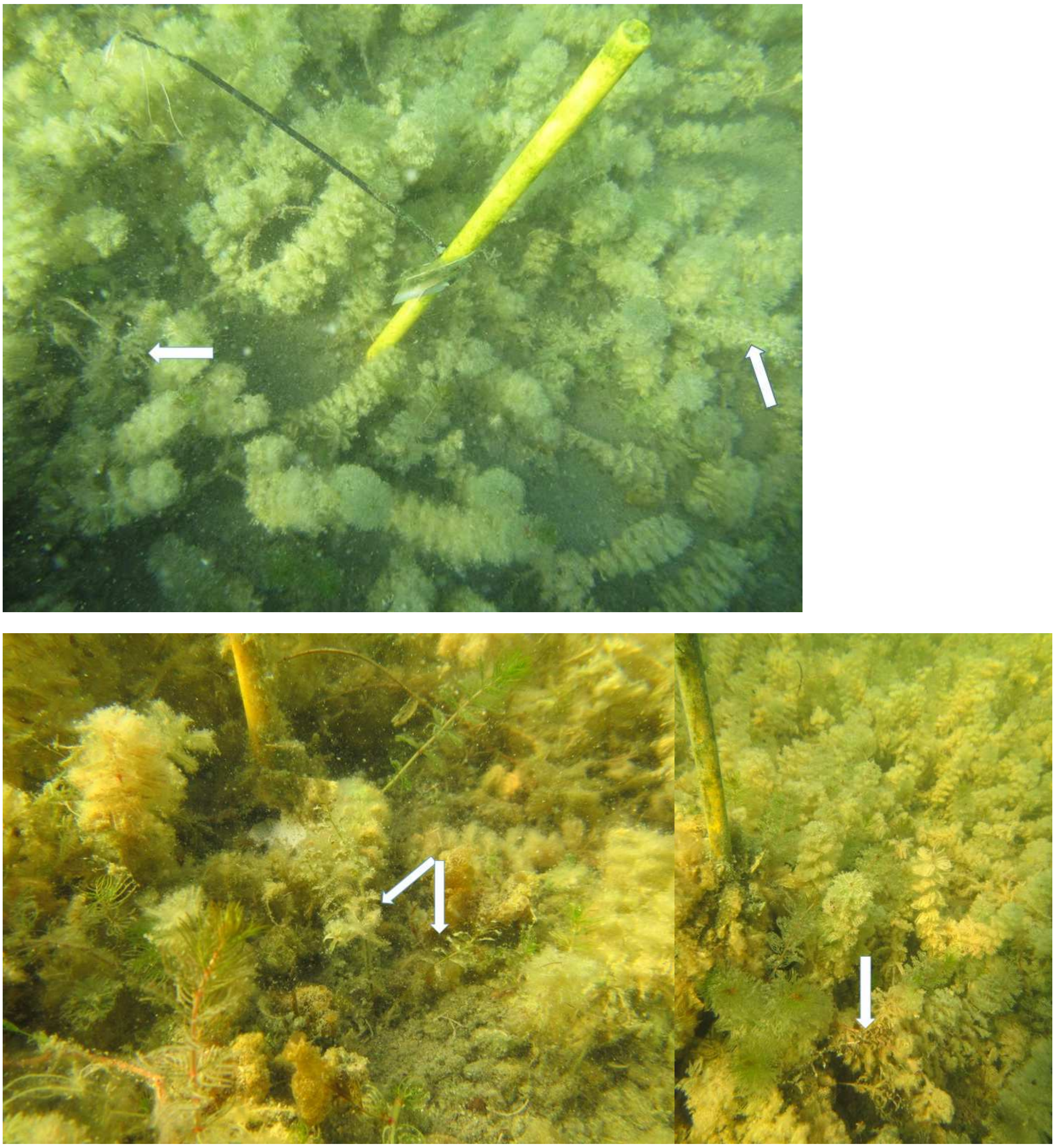

Figure 8: Stakes that have been wiped clean so that the marker tags can be recorded with the hydrilla. Hydrilla plants have been identified adjacent to the stakes (white arrows). Photos by A Taumoepeau (top) and M de Winton (bottom).

3.1.2 Invertebrates

The total number of taxa recorded from Lake Tutira was the same as that obtained before the hydrilla weed beds were removed by the grass carp (Table 2), and the taxa recorded in this current survey were also present in previous surveys (Figure 9, Appendix A2).

Samples from the shallow water (zone 1) in general had higher macro-invertebrate diversity than the deeper water samples (zone 3), although this trend is not as pronounced as it was in 2008 and 2009, prior to the removal of the hydrilla weed beds (Table 2). The most abundant macroinvertebrates were chironomids, snails and mites. In particular, chironomids and snails dominated the samples from zones one and two, compared with chironomids and mites in the zone three samples (Appendix A2).

Mussels were recorded in the macro-invertebrate samples from all but two sites (T10 and T32), however diver's observations confirm mussels were present at these sites. The number of mussels in 2015 was the same as that in 2014, and juvenile mussels (under 20mm in size) were recorded from four sites (Figure 10). The largest number of mussels recorded from any one site was at the campground site (T35), which is also the only site at which new piles of empty mussel shells were recorded in 2015. In 2013, several piles of mussel shells were found on the shore of Lake Tutira and thought to be a likely consequence of rat predation (Hofstra 2013b). Although the methodology for macro-invertebrate monitoring was not developed specifically for mussels, the data at this time do not indicate an impact on mussel numbers due to predation. Mussels are recognised for their patchy distribution, variable abundance of mussels (Roper and Hickey 1994), and the periodic recruitment of juveniles (James 1985). Continued monitoring of mussels in Lake Tutira, including observations by the divers, to assess any changes associated with the hydrilla eradication response or potentially predation, provides a valuable opportunity to develop a better understanding of mussel population structure in general.

The monitoring of macroinvertebrates at the baseline sites and methods in Lake Tutira, is recommended to align with the next vegetation survey in the lake, April 2016, to assess changes in the fauna during the hydrilla eradication response.

Table 2: Number of taxa per zone in Lake Tutira.

Year	2008	2009	2010	2011	2012	2013	2014	2015
Total	19	14	18	20	16	16	19	19
Zone 1	16	14	15	18	16	16	18	19
Zone 2	16	14	15	14	15	14	17	18
Zone 3	6	3	10	8	11	9	15	15

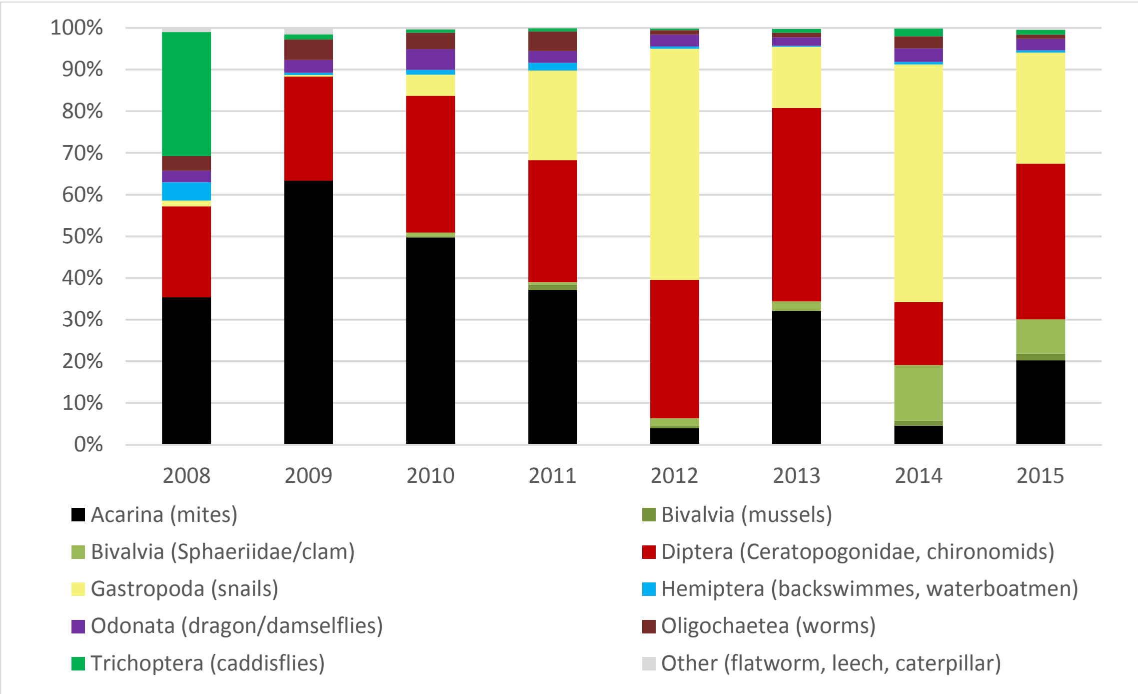

Figure 9: **The relative abundance of macroinvertebrate taxa from 2008 to 2015 autumn surveys.**

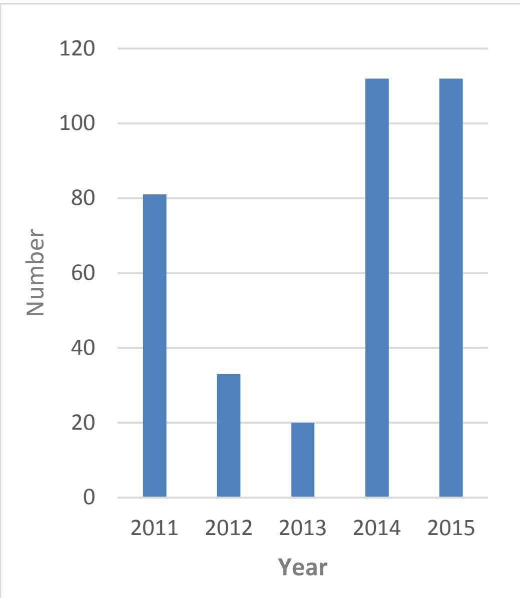

Figure 10: **Mussel summary.** The number of mussels recorded from 2011 to 2015 amongst macroinvertebrate samples (left), and a juvenile mussel from the causeway site, T38 (right) (Photo by P Champion).

3.2 Lake Waikōpiro

Information gathered by the SCUBA divers from Lake Waikōpiro is presented in Appendix B. In summary the divers reported poor water clarity with visibility of 0.3 to 0.5m. The divers observed bullies in the lake and the boat crew reported a little shag, blue heron and pukeko, two dabchicks and seven scaup on the lake.

The marginal emergent flora included 16 species (Table 3), of all which have previously been recorded from Lake Waikōpiro. Three species, *Glossostigma elatinoides, Lilaeopsis novae-zealandiae,* and *Lycopus europaeus* extended into the water to a depth of ca 10cm, at low cover values (maximum 25%).

No hydrilla was found in Lake Waikōpiro. However, high rainfall events (as occurred in April 2012) can result in water flooding the causeway between Lakes Waikōpiro and Tutira and allow the movement of grass carp (Hofstra 2012). Given the evidence of insufficient browsing pressure in Lake Tutira in 2014 and the subsequent introduction of additional grass carp into that lake in December 2014, a focus on aquatic vegetation in Lake Waikōpiro as a means of determining that grass carp grazing pressure is being maintained in that lake is essential to the hydrilla eradication response.

It is recommended that Lake Waikōpiro vegetation is monitored in conjunction with vegetation surveys of Lake Tutira in the future.

Table 3: List of marginal aquatic plants from Lake Waikōpiro.

No. of Sites (max 5)	Plant Species
1	*Alnus glutinosa* (seedling)
1	*Carex maorica*
1	*Carex secta*
2	*Carex virgata*
2	*Cyperus ustulatus*
4	*Eleocharis acuta*
5	*Glossostigma elatinoides*
1	*Juncus bufonis*
1	*Lilaeopsis novae-zealandiae*
2	*Ludwigia palustris*
5	*Lycopus europaeus*
3	*Myosotis laxa*
4	*Paspalum distichum*
1	*Persicaria decipiens*
1	*Persicaria hydropiper*
4	*Symphyotrichum subulatum*

3.3 Lake Opouahi

Information gathered by the SCUBA divers from Lake Opouahi is presented in Appendix C. In summary the divers reported good water clarity with visibility of ca 4m. Eel holes in the lake sediment were evident and smelt were observed in the lake. The boat crew reported four dabchicks on the lake.

3.3.1 Aquatic plants

No hydrilla was observed in Lake Opouahi.

In contrast to Lakes Tutira and Waikōpiro, Lake Opouahi did not have an extensive shallow water turf plant community prior to the release of grass carp, rather significant areas of charophytes were present amongst the hydrilla (Hofstra et al. 2008). As anticipated, the charophytes beds along with the hydrilla have been removed by the grass carp (Hofstra and Rowe 2008), and charophytes now only occur at very low abundance (Table 4) as occasional germlings (seedlings). In contrast *Ranunculus trichophyllus* still occurs in relatively deep water (ca 2m) where it is accessible to the grass carp (Table 4) but shows no evidence of being browsed. It is considered a less palatable or non-desirable species for grass carp (Rowe and Schipper 1985).

Table 4: Lake Opouahi vegetation summary.

No. of sites	Plant Species	Depth Range (m)	Height (m)		Cover	
			max	ave	max	media
1	*Chara australis*	4-4.5	0.05		1	1
1	*Chara globularis* (on firm sand)	4.5	0.05		1	1
2	*Ranunculus trichophyllus* (fragments in deeper water to 3.2m)	0.4-2.1	0.5	0.4	5	4
1	*Typha orientalis* (grazed)					
1	No submerged plants					

NB: For % Cover data 1=1–5%, 2=6–25%, 3=26–50%, 4=51–75%, 5=76–95%, 6=96–100%.

3.3.2 Exclosure cages

Amongst the 15 small grass carp exclosure cages, one cage contained a charophyte germling, and three had *R. trichophyllus* adjacent to, and enveloping the cages. Similarly, amongst the 15 large exclosure cages, the majority were empty, however one cage had a small *Potamogeton crispus* plant, and another contained *Chara australis* up to 50cm tall and with 75% cover (Figure 11). Numerous bullies were also observed amongst the *C. australis.*

In 2014, charophytes were only recorded from one of the small exclusion cages and two of the large cages (Hofstra 2014). In April 2013, charophytes were present in 10 of the 15 small exclusion cages at two of the sites, while none of the larger (and deeper) exclusion cages had any plants (Hofstra 2103b). This was an increase on numbers from February 2013 where 8 cages had plants (Hofstra 2013a), and in contrast to April 2012 when two large cages had small (germling) charophytes. With the recent exception of one large cage in April 2015, no large scale (entire cage) colonisation has taken place. Rather there has been a change in the presence and absence of charophytes between cages over time, indicating that charophytes are germinating, but the young plants have not persisted. There have however, consistently been more young charophytes recorded from cages along the south-eastern shoreline. A number of factors were described as potentially contributing to the lack of charophytes establishing within the cages (demise of young charophytes), including localised sediment movement or creep, sediment disturbance (eg., by fish), which may result in oospore burial, and/or low light climate (Hofstra 2014).

Photographic records indicate that there has been localised sediment movement at some sites. A comparison of images from 2015 with images from previous monitoring events illustrates that there can be small scale/localised sediment movement. The result is an increased sediment level (ca 5cm) on the outside of the cage on the upper side of the slope and on the interior of the cage on the lower side of the slope. The relevance of local changes in sediment level for charophyte germination has been described previously, and a relationship of declining emergence with increasing burial depth was established (Dugdale et al. 2001). For example, *Chara australis* emerged from burial depths of at least 50-75 mm, while *Chara globularis* oospores were able to emerge from the maximum tested depth of 100 mm. However the authors describe the upper portion of the sediment (top 50mm) as the most "ecologically active" seedbank (Dugdale et al. 2001). With respect to Lake Opouahi, consistent germination indicates that burial depth to date, has not been the primary cause of the empty exclosure cages. However it is possible that sediment movement at some sites, may have resulted in a reduction of charophyte oospores in the upper portion of the sediment. Littoral zone sediment cores were used to estimate the seed bank potential from a historically charophyte rich site within the lake. Sediment cores removed from the site on the southern shoreline (site 7), were placed in a cultivation tank to monitor germination. To date (15 May 2015), no charophyte germlings have been observed. However longer emergence times were not unexpected (de Winton et al. 2000) and the cores will continue to be monitored throughout the year. Additional cores that were sieved to remove the oospores for counting, indicate that large numbers of charophytes oospores are present (Figure 12). Oospores of *Chara globularis* were the most abundant, while *Chara australis* and *Nitella hyalina* oospores were also present (Figure 12). The thousands of charophyte oospores counted from this one site, corresponds well with earlier records from Lake Opouahi (de Winton and Clayton 1996). Data from the cores demonstrate that there is a viable seed bank, which can be expected to provide a means to restore vegetation within the lake (de Winton et al. 2000, Rodrigo et al. 2010).

Localised sediment disturbance by fish was also considered as a potential factor contributing to the limited establishment of young charophytes. Eel holes for example, have been recorded in and around cages on several occasions, however the frequency of disturbance does not indicate that they are likely to have a significant impact on charophyte establishment. In addition the limited number of small eels recorded from the lake (Hofstra et al. 2008) indicate that there is unlikely to be significant disturbance from smaller eels seeking refuge from predation (eg., by shags). In other lake based research (Rattray et al. 1991, Rattray et al. 1994) koura have caused significant damage to native plants until they were excluded by fine (1 cm diameter) wire mesh. Given that koura are considered scare in Lake Opouahi, with only two recorded from an inlet stream during the baseline survey (Hofstra et al. 2008), they too are unlikely to be a significant factor contributing to the displacement of charophyte germlings. By contrast, the preference of bullies for hard surfaces for spawning in lakes has been documented (Rowe et al. 2001), and bullies are likely to utilise the cage structure as a refuge from predation. In addition bullies have had significant detrimental impacts on the establishment of potted plants in revegetation studies (de Winton pers comm) and "effectively cleaned out" unprotected containers with plant shoots in a lake based nutrient study (Rattray et al 1991). For example, in Lake Taupo it is reported that "male bullies prepared and guarded a nest on any solid substrate which was raised above the bottom" (Stephens 1982). Further, that the "male cleaned a patch of substrate 50-200cm^2 by scuffing with the pelvic fins, which were frequently damaged by this behaviour" (Stephens 1982). Although there is no direct evidence to support disturbance by bullies with the Lake Opouahi cages, any potential impacts may be mitigated by reducing the edge effect of the cage. For example, if indeed it is the area around the hard substrate (ie., the cage wall) that the bullies primarily disturb, a larger cage with great internal space will have less edge effect.

The tunnel cage installed on the south-eastern littoral zone (site 8) is made from the same materials as the previous exclosure cages, but covers a larger area (ca 1 by 2.6m), and is anchored across a water depth that is likely to be high in charophyte oospores (Figure 12 and 13). The tunnel cage has a low profile to minimise potential impact from people either in kayaks (or visually), but is considered tall enough to enable charophytes to thrive and fruit. Light loggers were attached to the upper surface of the exclusion cage at the mid-point (ca 1.3m) to record the light environment and provide an indication as to whether local light levels may be limiting charophyte establishment.

It is recommended that the vegetation in Lake Opouahi is monitored in April 2016, including the presence or absence of plants within the grass carp exclusion cages. Any hydrilla, if present, within a cage should be removed by hand-weeding with care taken to ensure below ground plant parts are excavated, or alternatively the cage should be moved to enable grass carp access. The presence or absence of charophytes in the exclusion cages and associated monitoring data (eg., light level, sediment level changes) should be used to inform decisions to improve the utility of the cages as refugia for native biodiversity, during the hydrilla eradication response.

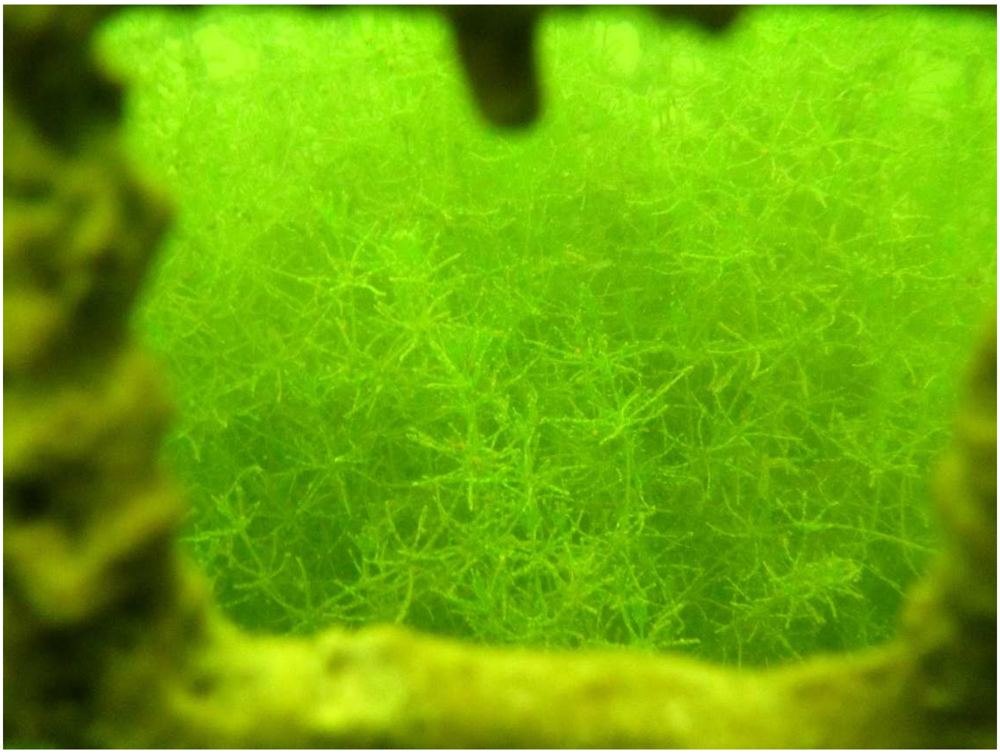

Figure 11: A view through the mesh of a large exclosure cage with *Chara australis* in Lake Opouahi. (Photo by M de Winton).

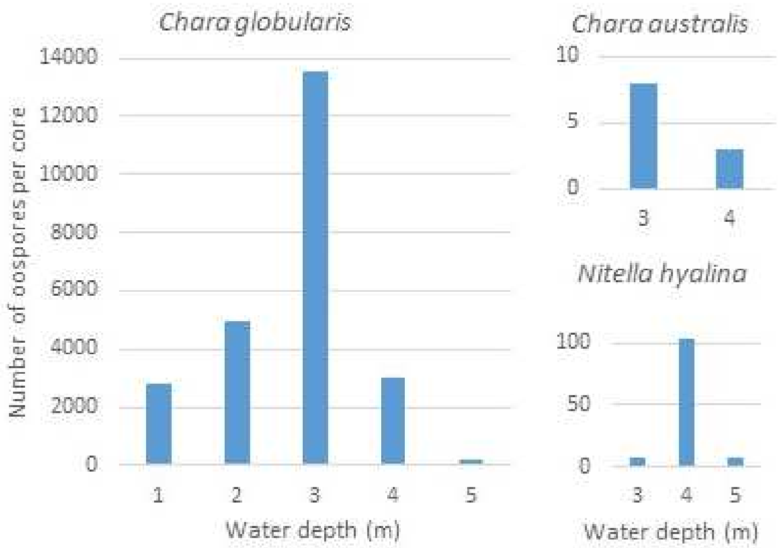

Figure 12: Charophytes oospore counts from Lake Opouahi core samples.

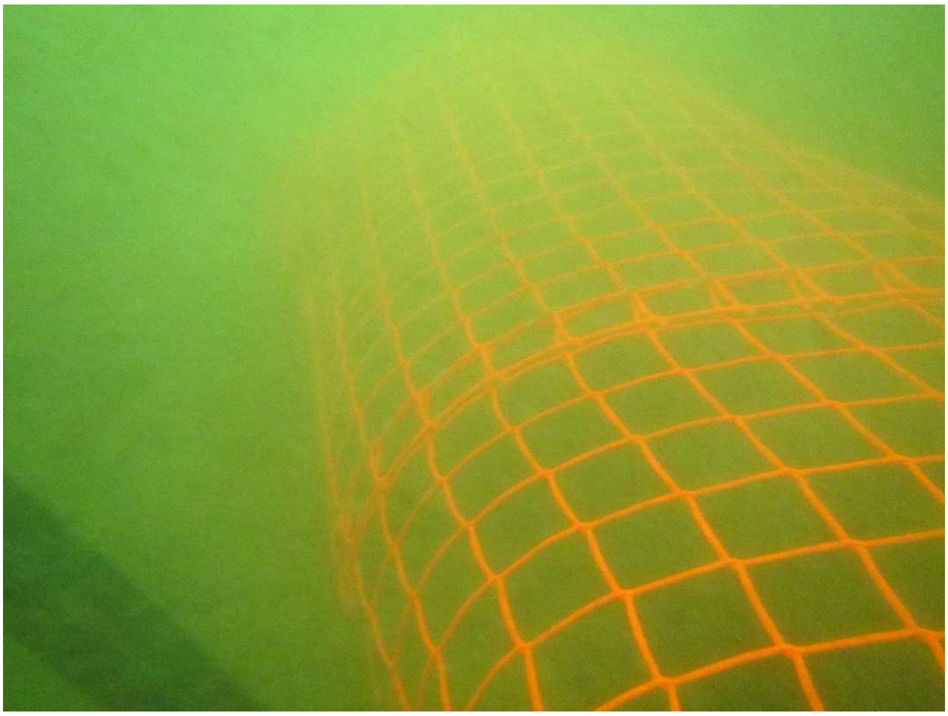

Figure 13: The tunnel cage installed in Lake Opouahi. The cage was made by Natasha Grainger (DOC), (Photo by A Wright-Stow).

4 Recommendations

MPI is conducting an eradication response for hydrilla in Lakes Tutira, Waikōpiro and Opouahi. This report documents the changes that are occurring in these lakes, following the initial use of endothall and release of grass carp in December 2008. The hydrilla weed beds were removed by the grass carp by April 2010. The effects of hydrilla removal on lake ecology are in line with predictions in the assessment of environmental effects (Hofstra and Rowe 2008), and increased browsing pressure has been noted in Lake Tutira following the second release of grass carp in December 2014.

Based on the autumn 2015 monitoring results the following recommendations are made:

1. The next autumn flora and fauna survey, recommended for autumn 2016, is to include an assessment of aquatic vegetation and macroinvertebrates at the baseline survey sites in Lake Tutira and vegetation only in Lakes Waikōpiro and Opouahi.

2. (a) In Lake Tutira monitoring should also include a focussed investigation of milfoil beds (if they persist) for hidden hydrilla plants on the shallow water plateau in Lake Tutira. In particular, the hydrilla plants that have been marked should be located and (if still present) assessed for browsing damage. Any new or additional hydrilla plants are assessed for browsing damage and excavated to assess tuber production.

   (b) As part of the macroinvertebrate monitoring methods in Lake Tutira, mussel data are collected so that a picture of potential mussel recruitment, and mortality can be developed within the lake.

3. In Lake Waikōpiro the focus on plants will provide evidence of any similar decline in browsing pressure as was observed in Lake Tutira in April 2014, prior to the subsequent release of grass carp in December 2014 in that lake.

4. In Lake Opouahi, during the vegetation assessment, the submerged grass carp exclosure cages are assessed for charophyte regeneration. Any hydrilla or elodea plants (if present) are documented, excavated and removed. Charophyte regeneration and associated monitoring data (eg., light level, sediment level changes) should be used to inform decisions to improve the utility of the cages as refugia for native biodiversity, during the hydrilla eradication response.

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Appendix A Lake Tutira Data

Table A1: Lake Tutira Aquatic Vegetation.

Site No & Comments	Plant Species	Depth Range (m)*	Height (m) max (ave)	Cover max (ave)
3. Raupo & willows, woody debris to 3m. Max dive depth 9.5m; Total vegetation cover was 6-25%; mussels were present. Blue-green algae at depth.	*Typha orientalis*	0-0.2	3(2)	5(3)
	Lilaeopsis novae-zealandiae	0-0.1		2(1)
	Elatine gratioloides	0.2-0.6		3(2)
	Glossostigma elatinoides	0.2-0.6		3(2)
	Nitella hyalina	0.2-2.8	<0.1	2(1)
	Myriophyllum triphyllum	0.2-2.5	0.1(0.1)	2(1)
5. South of the old boat ramp. Overhanging willows; Max depth of dive 7.5m; Visibility 5m; mussels present. Soft sediments.	No submerged plants.			
10. Steep site, Typha overhanging. Max depth of dive 8.5 m; Total vegetation cover 6-25%; Visibility 5m. Mussels present.	*Typha orientalis*	0-0.3	3(2.2)	5(5)
	Myriophyllum triphyllum	1.2-4	0.3(0.15)	5(2)
15. North end beach. Max depth of dive 8 m; Total vegetation cover 26-50%; Visibility 5; Mussels present, and dense at 0.2m.	*Potamogeton cheesemanii*	0.4		1(1)
	Ranunculus limosella	0.4-0.8		1(1)
	Lilaeopsis novae-zealandiae	0.2-1		1(1)
	Myriophyllum triphyllum	0.2-4	0.3(0.1)	6(2)
	Chara globularis	0.2		1(1)
18. North-eastern shore. Max depth of dive 10.9m; total vegetation cover 26-50%; Visibility 5m; Mussels present.	*Nitella hyalina*	0.1-2.3	<0.1	1(1)
	Chara globularis	0.6-3.5	0.1(0.1)	1(1)
	Myriophyllum triphyllum	0.6-3.8	0.2(0.1)	5(3)
	Chara australis	4.2	<0.1	1(1)
	Lilaeopsis novae-zealandiae	0.2-1.4		2(1)
	Glossostigma elatinoides	0.2-1.1		2(1)
	Elodea canadensis	0.8	0.1	1(1)
	Ranunculus limosella			2(1)
22. Next to the fenceline near the island. Max depth of dive 8m; Total vegetation cover 26-50%; Visibility 5m; Mussels present; eel holes at ca 5m depths and two eels.	*Glossostigma elatinoides*	0.1		2(1)
	Myriophyllum triphyllum	0.1-1.9	0.2(0.1)	6(2)
	Chara australis	1.2-1.5		2(1)
	Nitella hyalina	1.2-1.5		2(1)
	Chara australis	1.2-1.5		1(1)
	Hydrilla verticillata	1.4	<0.1	1(1)
	Scattered nostoc			4(3)

Site No & Comments	Plant Species	Depth Range (m)*	Height (m) max (ave)	Cover max (ave)
28. By four warratahs in the lake. Max depth of dive 8.5 m; Length of profile 25–100 m; Visibility 5 m; Total vegetation cover 26-50%; Eel holes. Mussels were present.	*Glossostigma elatinoides*	0-0.3		2(1)
	Ranunculus limosella	0.1-0.2		2(1)
	Lilaeopsis novae-zealandiae	0-0.3		5(3)
	Myriophyllum triphyllum	0.6-3.1	0.2(0.2)	1(1)
	Chara globularis	1.0	<0.1	1(1)
	Chara australis	1.0-1.9	<0.1	1(1)
	Nitella hyalina	0.8-1.4		1(1)
	Hydrilla verticillata	0.8-1	0.1	1(1)
	Ruppia polycarpa	0.8-1		1(1)
	Nostoc			
32. Pa site, seat and lookout. Max depth of dive 8.5 m; Total vegetation cover 26-50%; Visibility 5 m; Mussels and eel holes present and a juvenile koura found under a rock in the shallows.	*Glossostigma elatinoides*	0-0.5		5(3)
	Myriophyllum triphyllum	0.5-3.1	0.3(0.1)	4(2)
	Lilaeopsis novae-zealandiae	0-1.1		3
	Nitella hyalina	0.5-1.7		1(1)
	Ruppia polycarpa	0.5-0.8	0.1(0.1)	2(1)
35. At camp ground by the picnic table and large willows. Max depth of dive 8.1 m; Total vegetation cover 26-50%; Visibility 4m; Mussels present, and one eel was observed. *M. triphyllum* was partially defoliated. A drift island (ca 5 by 3m) primarily of *T. orientalis* was beached on the shore. On the island there was a pile of mussel shells with teeth marks.	*Typha orientalis*	0.4	3(3)	5(5)
	Myriophyllum triphyllum	0.1-4.3	0.2	6(3)
	Lilaeopsis novae-zealandiae	0.5-1.1		2(1)
	Nitella hyalina	0.5-4.8	0.1(0.1)	1(1)
	Elodea canadensis	0.5-1.2		2(1)
	Glossostigma elatinoides	0.1-0.5		2(1)
	Chara globularis	4		1(1)
	Chara australis	3.1		1(1)
	Ranunculus limosella	0.3-0.8		2(1)
	Ruppia polycarpa	0.5-0.5		1(1)
36. Rat point. Steep profile. Max depth of dive 8.5m; Total vegetation cover 1-5%; Visibility 5m; Mussels present.	*Glossostigma elatinoides*	0.2-0.2		1(1)
38. Causeway Max depth of dive 8.1 m; Total vegetation cover 51-75%; Visibility 5m; Mussels present, and three eels were observed.	*Typha orientalis*	0-0.1	2.5(2)	5(4)
	Myriophyllum triphyllum	0-3.7	0.3(0.1)	6(4)
	Ruppia polycarpa	0.5-2.1		1(1)
	Nitella hyalina	0.5-3.7		1(1)
	Chara australis	0.5-2.1		1(1)
	Hydrilla verticillata	1.0	(0.1)	1(1)
	Chara globularis	1.0		1(1)

Site No & Comments	Plant Species	Depth Range (m)*	Height (m) max (ave)	Cover max (ave)
	Lilaeopsis novae-zealandiae	1.0		1(1)
40. Southwest shore. Max depth of dive 10 m; Length of profile <25m; Total vegetation cover 26-50%; Visibility 5m; Mussels present, and two eels observed. Marginal vegetation included willow, *T. orientalis, Carex maorica, Eleocharis acuta, Persicaria decipiens, Lycopus europaeus, Symphyotrichum subulatum, Bidens frondosa, Cyperus eragrostis, Lotus pedunculatus.*	*Glossostigma elatinoides* *Lilaeopsis novae-zealandiae* *Ranunculus limosella* *Myriophyllum triphyllum* *Chara australis* *Nitella hyalina*	0-0.4 0-0.5 0.2-0.6 0.5-2.6 1-1.4 0.6-5.0	 0.2(0.1) 0.1(<0.1) <0.1	3(2) 2(1) 3(2) 5(3) 1(1) 1(1)
42. Max depth of dive 9 m; Total vegetation cover 26-50%. Mussels present. There was a lot of woody debris. Typha seedlings (6-25%) were present in the shallow water.	*Typha orientalis* *Glossostigma elatinoides* *Myriophyllum triphyllum* *Chara australis*	0-0.1 0-0.9 0.5-4 1.7	3(2) 0.2(0.1) 	5(4) 2(1) 4(2) 1(1)
45. Willows, shed over road. Max depth 7.8 m; Total vegetation cover 1-5%; Visibility 4m; Wood, branches and logs in the shallow. Mussels present from ca 0.4 to 1.7m. Nostoc widespread.	*Myriophyllum triphyllum*	0.4-1	0.15(0.1)	2(1)
50. Typha point. Max depth 7.8 m; Vegetation cover 1-5%; Visibility 5m; Mussels present. Nostoc widespread in the shallow. *C.globularis* plant hidden in an old *T. orientalis* stem (remnant stumps from having been grazed).	*Typha orientalis* *Myriophyllum triphyllum* *Chara globularis* *Potamogeton crispus* *Elatine gratioloides*	0-0.3 0-1.5 0.5 0.4 0.5	3(2.5) 0.1(0.1) <0.1 	6(5) 1(1) 1(1) 1(1) 2(2)
NB: For % Cover data 1=1–5%, 2=6–25%, 3=26–50%, 4=51–75%, 5=76–95%, 6=96–100%.				

Table A2: Lake Tutira Invertebrate Data (Fixed 200 count).

Site	Invertebrates	Zone 1	Zone 2 (core)	Zone 3
3	Description	1.3 to 1.5m, bare sediment, woody debris and milfoil	Ca 3 to 6m	Sampled at 8m.
	Mites (Acarina)		(3)	45
	Leech (Hurdinea)			
	Mussels (Bivalvia)	6		
	Midge (Chironomidae)		32(15)	154
	Ceratopogonidae	45		
	Waterboatmen (*Sigara*)		2	
	Backswimmer	3		
	Snail (*Glyptophysa*)	2		
	Snail (Gyraulus)	1		
	Snail (Lymnaea)	2		
	Snail (*Physa*)	18		
	Snail (*Potamopyrgus*)	54	24(4)	
	Clam (Sphaeriidae)	46	6(2)	6
	Dragonfly (*Hemicordulia*)	18	12(1)	3
	Damselfly (*Xanthocnemis*)	16		
	Stone caddis (*Oecetis*)	2	1	
	Stick caddis (*Triplectides*)	3		
5	Description			
	Leech (Hurdinea)		2	
	Mussels (Bivalvia)	2		
	Midge (Chironomidae)	22	24(31)	146
	Ceratopogonidae			
	Waterboatmen (*Sigara*)		3	
	Snail (*Physa*)	1	2	
	Snail (*Potamopyrgus*)	24	8(2)	4
	Clam (Sphaeriidae)	58	8(2)	
	Dragonfly (*Hemicordulia*)	5	4	
	Damselfly (*Xanthocnemis*)		3	
	Stone caddis (*Oecetis*)	2		
	Stick caddis (*Triplectides*)	2		
10	Description	1.2 to 1.5m, bare sediment and 20 to 35% milfoil cover.		
	Mites (Acarina)	168		
	Midge (Chironomidae)	148	22(24)	5
	Backswimmer			2
	Snail (Lymnaea)		(1)	
	Snail (*Physa*)		3	
	Snail (*Potamopyrgus*)	13	62(9)	13
	Clam (Sphaeriidae)	5		22
	Dragonfly (*Hemicordulia*)	4	2(3)	
	Damselfly (*Xanthocnemis*)		(1)	
15	Description	1.3m bare, half counted		
	Mussels (Bivalvia)	3	4	
	Midge (Chironomidae)	213	21(2)	46
	Ceratopogonidae	2		
	Worm (Oligochaeta)	4		
	Backswimmer		1	
	Snail (*Potamopyrgus*)	9	44(14)	12
	Clam (Sphaeriidae)	13	13(26)	10
	Dragonfly (*Hemicordulia*)	4		
	Damselfly (*Xanthocnemis*)	1		
	Stone caddis (*Oecetis*)	2		

Site	Invertebrates	Zone 1	Zone 2 (core)	Zone 3
18	Description	1.2 to 1.3m with 10 to 60% milfoil and <5% turf plants. 3 of 16		
	Mites (Acarina)			21
	Mussels (Bivalvia)	6		
	Midge (Chironomidae)	12	41(6)	196
	Ceratopogonidae	2	(1)	
	Worm (Oligochaeta)	4	(18)	
	Waterboatmen (*Sigara*)	10		
	Snail (*Glyptophysa*)			1
	Snail (Lymnaea)	7		
	Snail (*Potamopyrgus*)	134	24(1)	12
	Clam (Sphaeriidae)	27		5
	Dragonfly (*Hemicordulia*)	5	3	3
	Damselfly (*Xanthocnemis*)	4	1	
	Stone caddis (*Oecetis*)	2		
	Case caddis (*Paroxyethira*)	1		
	Stick caddis (*Triplectides*)	5		
22	Description	1.1 to 1.3m, bare sediment and 40 to 75% milfoil, <5% *Nitella*.		
	Leech (Hurdinea)	5	4	
	Mussels (Bivalvia)	6		1
	Midge (Chironomidae)	12	13(1)	78
	Ceratopogonidae		2	
	Waterboatmen (*Sigara*)	4		
	Backswimmer	2		
	Snail (Gyraulus)		1	1
	Snail (*Potamopyrgus*)	152	190(7)	94
	Clam (Sphaeriidae)	17	15(3)	21
	Dragonfly (*Hemicordulia*)	7	1	2
	Damselfly (*Xanthocnemis*)	3		
	Stone caddis (*Oecetis*)	1	3	15
	Case caddis (*Paroxyethira*)		1	1
	Stick caddis (*Triplectides*)	2		
28	Description			
	Mites (Acarina)			140
	Leech (Hurdinea)	1	2	
	Mussels (Bivalvia)	6		
	Midge (Chironomidae)	34	10(7)	29
	Ceratopogonidae		(1)	
	Waterboatmen (*Sigara*)		1	
	Backswimmer	4		
	Snail (*Potamopyrgus*)	143	88(1)	3
	Clam (Sphaeriidae)	13	6(1)	
	Dragonfly (*Hemicordulia*)	12	1	1
	Damselfly (*Xanthocnemis*)	1		
	Stone caddis (*Oecetis*)	1		
	Case caddis (*Paroxyethira*)	1	1	
32	1.3m, 0 to 30%milfoil	1.3m, 0 to 30%milfoil		
	Midge (Chironomidae)	57	119(4)	99
	Snail (*Potamopyrgus*)	156	12	24
	Clam (Sphaeriidae)	14	1	
	Dragonfly (*Hemicordulia*)	1		1
	Stone caddis (*Oecetis*)	15	4	
	Stick caddis (*Triplectides*)	3	1	

Site	Invertebrates	Zone 1	Zone 2 (core)	Zone 3
35	Description	1.1 to 1.4m, 30 to 75% milfoil, ca 5% *Nitella*. Abundant mussels.		
	Mites (Acarina)		3(3)	53
	Leech (Hurdinea)	3		
	Mussels (Bivalvia)	31		
	Midge (Chironomidae)	9	43(15)	145
	Ceratopogonidae		(1)	
	Worm (Oligochaeta)		(3)	
	Waterboatmen (*Sigara*)	4		
	Snail (Gyraulus)		1	
	Snail (*Potamopyrgus*)	172	134(13)	11
	Clam (Sphaeriidae)	5	116	3
	Dragonfly (*Hemicordulia*)	11	5(1)	1
	Damselfly (*Xanthocnemis*)	3		
	Stone caddis (*Oecetis*)	1	1	
	Stick caddis (*Triplectides*)	1		
36	Description	1.1m woody detritus and bare sediment.		
	Mites (Acarina)		65(5)	35
	Mussels (Bivalvia)	3		2
	Midge (Chironomidae)	12	30(3)	
	Snail (*Potamopyrgus*)	182	105(12)	18
	Clam (Sphaeriidae)	13	57(19)	28
	Dragonfly (*Hemicordulia*)	1	1	2
38	Description			
	Mites (Acarina)			93
	Leech (Hurdinea)		25	
	Mussels (Bivalvia)	7		
	Midge (Chironomidae)	156	63(25)	177
	Waterboatmen (*Sigara*)	6		
	Backswimmer		1	
	Snail (Gyraulus)	1		
	Snail (Lymnaea)	1		
	Snail (*Physa*)		2	
	Snail (*Potamopyrgus*)	12	55(4)	
	Clam (Sphaeriidae)		61	3
	Dragonfly (*Hemicordulia*)	12	6	1
	Damselfly (*Xanthocnemis*)	3		
	Stone caddis (*Oecetis*)	1	12	1
40	Description	0.8 to 1.4m, bare sediment or up to 40% milfoil.		
	Mites (Acarina)		231	25
	Mussels (Bivalvia)	12		
	Midge (Chironomidae)	123	122(22)	11
	Ceratopogonidae		1	1
	Worm (Oligochaeta)		3(1)	1
	Snail (Lymnaea)		(1)	
	Snail (*Physa*)			1
	Snail (*Potamopyrgus*)	62	(6)	9
	Clam (Sphaeriidae)		(2)	8
	Dragonfly (*Hemicordulia*)	8	3	9
	Damselfly (*Xanthocnemis*)	7		1
	Stone caddis (*Oecetis*)		1	
	Case caddis (*Paroxyethira*)			1

Site	Invertebrates	Zone 1	Zone 2 (core)	Zone 3
42	Description	0.9 to 1.3m, bare sediment, up to 50% turf plants		
	Mites (Acarina)		186(10)	139
	Leech (Hurdinea)		1	
	Mussels (Bivalvia)	4		
	Midge (Chironomidae)	26	16(69)	54
	Backswimmer	2		
	Snail (*Potamopyrgus*)	14	27(9)	2
	Clam (Sphaeriidae)		33(4)	4
	Dragonfly (*Hemicordulia*)	2	8	1
	Damselfly (*Xanthocnemis*)	2	2	
	Stone caddis (*Oecetis*)		(1)	
45	Description	1.3m bare sediment, mussels and woody debris		
	Mites (Acarina)			209
	Mussels (Bivalvia)	18		
	Midge (Chironomidae)	54	92(63)	196
	Ceratopogonidae	2		
	Snail (*Potamopyrgus*)	18	32(1)	4
	Clam (Sphaeriidae)	1	25	
	Dragonfly (*Hemicordulia*)	3		
	Damselfly (*Xanthocnemis*)	1		
	Stone caddis (*Oecetis*)	2	4	
	Stick caddis (*Triplectides*)	1		
50	Description	1.1 to 1.3m, bare sediment; 70% milfoil;100% milfoil.		
	Mites (Acarina)	73		275
	Mussels (Bivalvia)	1		
	Midge (Chironomidae)	30	10(6)	
	Ceratopogonidae			35
	Worm (Oligochaeta)	57		
	Waterboatmen (*Sigara*)		2	
	Snail (*Glyptophysa*)	14		
	Snail (*Physa*)	18		
	Snail (*Potamopyrgus*)		6	
	Clam (Sphaeriidae)	27		
	Dragonfly (*Hemicordulia*)	11	4	
	Damselfly (*Xanthocnemis*)	6	2	
	Stone caddis (*Oecetis*)	1		

Appendix B Lake Waikōpiro Data

Table B1: Lake Waikōpiro Aquatic Vegetation

Site No & Comments	Plant Species	Depth Range (m)	Cover, max (ave)
1. Causeway, by silver birch. Tall submerged macrophytes absent, marginal emergent species present.	*Glossostigma elatinoides* *Symphyotrichum subulatum* *Lycopus europaeus* *Eleocharis acuta* *Paspalum distichum*		
3. Causeway Tall submerged macrophytes absent.	*Ludwigia palustris* *Glossostigma elatinoides* *Eleocharis acuta* *Juncus bufonis* *Myosotis laxa* *Lycopus europaeus* *Carex virgata* *Cyperus ustulatus*		
4. South east. Tall submerged macrophytes absent.	*Glossostigma elatinoides* *Lilaeopsis novae-zealandiae* *Ludwigia palustris* *Lycopus europaeus* *Persicaria decipiens* *Myosotis laxa* *Persicaria hydropiper* *Eleocharis acuta* *Alnus glutinosa* (seedling) *Symphyotrichum subulatum* *Paspalum distichum* *Carex maorica*	0-0.1 0-0.05 0	4(2) 1(1) 4(2)
5. South side. Tall submerged macrophytes absent.	*Glossostigma elatinoides* *Carex secta* *Carex virgata* *Cyperus ustulatus* *Lycopus europaeus* *Symphyotrichum subulatum* *Paspalum distichum* *Myosotis laxa*	0-0.1	1(1)
7. South end Roadside. No tall submerged macrophytes.	*Glossostigma elatinoides* *Symphyotrichum subulatum* *Lycopus europaeus* *Eleocharis acuta* *Paspalum distichum*		
NB: For % Cover data 1=1–5%, 2=6–25%, 3=26–50%, 4=51–75%, 5=76–95%, 6=96–100%.			

Appendix C Lake Opouahi Data

Table C1: Lake Opouahi Aquatic Vegetation.

Site No & Comments	Plant Species	Depth Range (m)	Height (m) max (ave)	Cover max (ave)
1. Left side of the jetty. Max depth 7.6 m; Vegetation 1-5%.	*Ranunculus trichophyllus* Fragments of *R. trichophyllus* in deeper water (ca 3.2m)	1.2-2.1	0.5(0.5)	5(5)
3. North west side. Max depth of dive 8 m.	*Typha orientalis* (grazed)			
5. North east side. Max depth of dive 8 m.	*Chara australis* *Chara globularis* (on firm sand)	4-4.5 4.5	0.05 0.05	1(1) 1(1)
7. South end. Max depth of dive 7.6 m.	No submerged plants			
9. South end. Max depth of dive 8.4 m; Total vegetation cover 1-5%.	*Ranunculus trichophyllus*.	0.4-1, 1.7	0.3(0.3)	3(2)
NB: For % Cover data 1=1–5%, 2=6–25%, 3=26–50%, 4=51–75%, 5=76–95%, 6=96–100%.				