Hydrilla Monitoring Report 2017

Eradication response

Prepared for MPI

November 2017

Prepared by:
Dr D.E. Hofstra

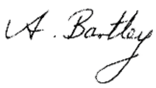
For any information regarding this report please contact:

Dr D E Hofstra
Scientist
Aquatic Plants
+64-7-859 1812
Deborah.Hofstra@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
PO Box 11115
Hamilton 3251

Phone +64 7 856 7026

NIWA CLIENT REPORT No: 2017383HN
Report date: November 2017
NIWA Project: MPI17204

Quality Assurance Statement		
	Reviewed by:	Mary de Winton
	Formatting checked by:	Alison Bartley
	Approved for release by:	Paul Champion

Contents

Tables

Figures

Executive summary

MPI (Ministry for Primary Industries) commenced 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 in 2007. 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 (Tutira, Waikōpiro and Opouahi) in December 2008. A second release of grass carp was made in Lake Tutira in December 2014.

NIWA was engaged by MPI to undertake initial baseline surveys of flora, invertebrates and fish, and has completed a series of subsequent surveys to inform decision making.

In 2017, NIWA was contracted by MPI to carry out a vegetation and mussel survey at the baseline sites (reduced from the full survey) and a hydrilla survey on the shallow water plateau within Lake Tutira, to determine the status of the hydrilla and document any changes. In Lake Opouahi, NIWA was contracted to assess the vegetation in the grass carp exclusion cages and install a new cage with a benthic barrier. The survey was planned for April 2017, but was deferred until October 2017, due to a persistent algal bloom and poor water clarity in autumn that limited visibility and hence opportunity for divers to find hydrilla, and potentially posed a risk to diver health.

In Lake Tutira, plants were surveyed at the 13 of the 15 baseline sites. Two sites were not surveyed as permission from the owners was not granted. For the second time since the MPI response commenced (2016 and 2017), no hydrilla plants were recorded at any of the inspected sites, including absence of previously marked hydrilla plants on the plateau. The abundance of freshwater mussels does not appear to have been impacted by the severe algal bloom over the 2016-2017 summer period.

As the visibility in Lake Opouahi was poor only the tunnel cage and 10 of the 15 large circular cages were located by divers. As in previous years, charophyte establishment was limited, and in 2017 plants appeared to be in poor condition with leaves coated in biofilm. A tunnel shaped cage with a biodegradable hessian benthic barrier was installed at the north end of the lake. The purpose of the benthic barrier is to stabilise sediments and support charophyte regeneration within the cage. The cage will be used to assess the potential for charophyte establishment in comparison with the existing exclusion cage designs.

Based on the persistent algal blooms in Lake Tutira in recent years (where poor visibility compromises divers' ability to find hydrilla), the potential for further substantial blooms if similar weather conditions prevail and the desire to avoid health risks for divers, it is recommended that future surveys for the hydrilla eradication response are carried out in spring (October).

For spring 2018 the recommendation is that a vegetation and macroinvertebrate survey is undertaken in all three lakes (Tutira, Waikōpiro and Opouahi). This will:

- Confirm progress towards hydrilla eradication, particularly in Lake Tutira, for which there has now been two consecutive hydrilla-free years.
- Create a macroinvertebrate spring baseline, aligned with vegetation data against which future change can be assessed.

Monitoring information will be used to inform the timing and frequency of subsequent monitoring events, recognising MPIs intent to move toward biennially and then triennial monitoring as the hydrilla eradication response progresses.

1 Introduction

Hydrilla (*Hydrilla verticillata* (L.f.) Royle) is a submerged aquatic weed classified as a notifiable organism[1] that is only found in the Hawke's Bay, and has been targeted 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 weed beds, 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 have been installed at seven littoral zone sites, which historically contained native charophytes as opposed to hydrilla, to enable regeneration of charophytes protected from grass carp browsing and provide native biodiversity refugia during the hydrilla eradication response (Hofstra 2015). A feasibility assessment for similar exclusion 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 2013a).

Based on the findings from the flora and fauna survey in April 2014 (Hofstra 2014), NIWA recommended 500 juvenile grass carp to be stocked in Lake Tutira (December 2014) and that a reduced survey, including macrophytes (plants) in all three lakes and macroinvertebrate in Lake Tutira only, be undertaken in autumn 2015 (Hofstra 2015). Following the continued presence of individual hydrilla plants in Lake Tutira in 2015, MPI contracted NIWA to undertake a further reduced survey in autumn 2016. For the first time since the MPI response commenced, no hydrilla plants were recorded in any of the three lakes (Tutira, Waikōpiro and Opouahi) in 2016.

Based on the autumn 2016 monitoring results and the MPI goal to eradicate hydrilla from New Zealand, MPI contracted NIWA to undertake a reduced survey in autumn 2017. However, a persistent algal bloom and poor water clarity meant that the survey was deferred until spring (October 2017) when it was expected that the water clarity would have improved.

This report records and describes the findings from the five activities in the reduced survey listed below.

[1] Biosecurity Notifiable Organisms Order 2006

In Lake Tutira the survey included:

1. an assessment of aquatic vegetation at the baseline sites in Lake Tutira only
2. a search for hydrilla on the shallow water plateau, and
3. sampling for mussels in the shallow water of the baseline sites.

In Lake Opouahi activities included:

1. assessment of vegetation in exclusion cages, and
2. the installation of a new type of exclusion cage with a hessian benthic barrier to continue to foster the regeneration of charophytes.

2 Methods

2.1 Lake Tutira

2.1.1 Aquatic plant survey

The survey was undertaken in October 2017. Photographed landmarks and GPS co-ordinates were used to locate the survey sites in Lake Tutira (Figure 2-1) (Hofstra et al. 2008). The sites were the same as those surveyed in autumn each year since 2008, with the exception of two sites (T15 and T18) at the north end of the lake (Figure 2-1). These sites were omitted from survey in 2016 and 2017 because access permission was not forthcoming from the lake owners.

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 The plateau

SCUBA divers searched for hydrilla plants on the shallow water plateau (Figure 2-1, 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 and photographs were taken. Underwater scooters were also used to search the plateau for hydrilla.

2.1.3 Freshwater mussel sampling

Sample sites corresponded with the sites that were being assessed for aquatic vegetation (section 2.1.1).

Along each profile, mussels were sampled by a SCUBA diver from within the shallow water at approximately 1.5m water depth. This area has been described as zone one in previous surveys (Figure 2-2), and is the zone within which the majority of mussels have previously been recorded.

The area for sampling was defined by a quadrat (25 x 25 cm), that equated to the opening of the Wisconsin net (250 µm mesh). The quadrat, with net attached, was placed adjacent to the sediment and surface sediments with associated mussels were raked by hand into the net. This was done three times (3 different quadrats) and the samples were pooled into the net and removed to the water surface for sieving and sorting. On the boat, the sample was rinsed through a 5 mm mesh sieve, and the mussels were removed, their lengths measured and recorded. All mussels were then returned to the lake.

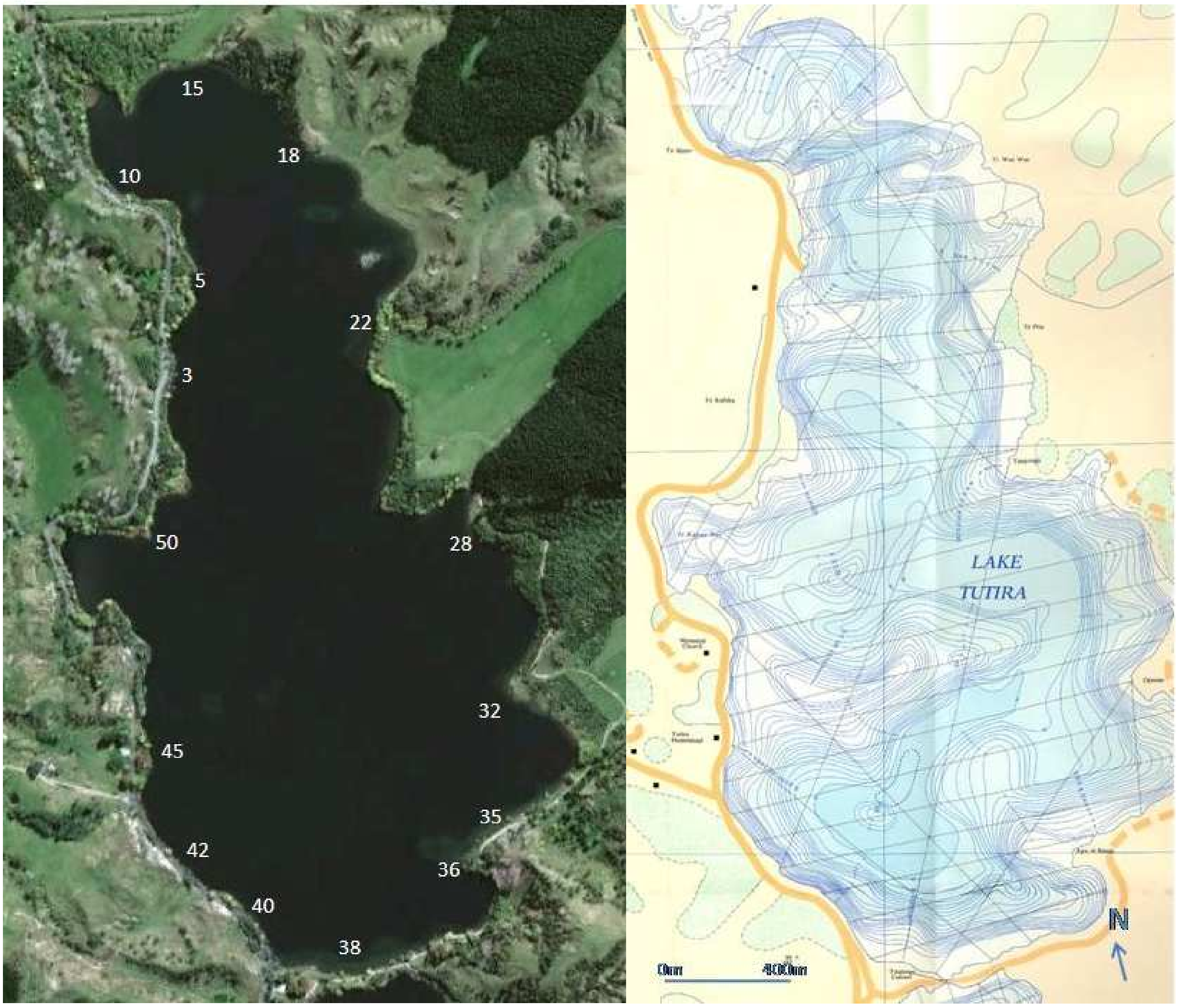


Figure 2-1: Lake Tutira showing survey sites (left) and a bathymetric map (Irwin 1978) showing the shallow water plateau (right). Sites 15 and 18 at the north end of the lake were not surveyed in 2016 and 2017.

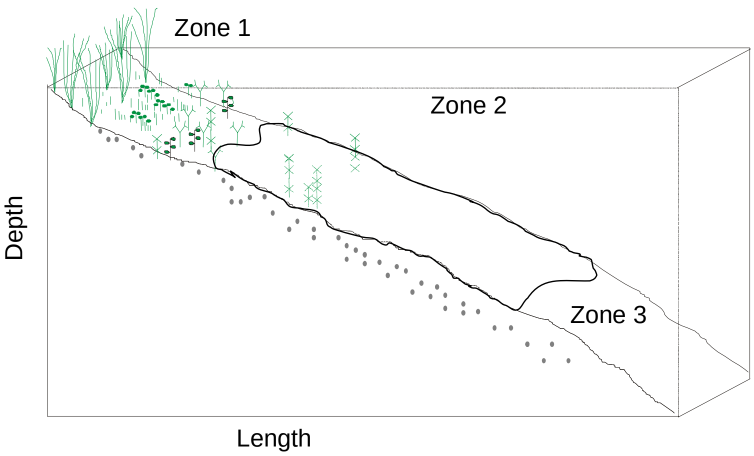


Figure 2-2: Diagrammatic plant profile showing the zone from which mussels were sampled. (Source M. de Winton).

2.2 Lake Opouahi

2.2.1 Exclusion cage assessment

In Lake Opouahi, SCUBA divers used GPS points to locate the cages sites, and subsequently searched for the exclusion cages to assess the vegetation response within them. A total of 15 large and 15 small submerged exclosure cages (at a total of six sites with five cages at each) were installed in February 2012 and a single tunnel cage was installed in April 2015 (Figure 2-3). At each site, photographs were taken of each cage that was located to compare with previous images for assessing charophyte emergence and growth, and to provide an estimate of localised changes (if any).

2.2.2 Exclusion cage installation

A tunnel cage (ca 1m wide by 2.6m long) was made on shore from semi rigid plastic mesh (green 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, Hofstra 2015). Hessian (18 oz, RJ Reid) was cut to fit inside the tunnel cage. SCUBA divers laid the hessian first and then, installed the cage over the hessian by lodging it into the sediment and securing with solid plastic warratah posts, at a depth of 2 to 3m at the north end of the lake, adjacent to (northeast of) the large cages (Figure 2-3).

2.2.3 Outflow assessment

In addition, following a report received by MPI that hydrilla may be present at the outflow of Lake Opouahi, an assessment of vegetation at the outflow was also undertaken.

Figure 2-3: Lake Opouahi showing the exclosure cage sites. Numbers refer to the baseline survey sites. The large and small asterisks represent the large and small exclosure cages respectively and the stars represents the tunnel cages.

3 Results and Discussion

3.1 Lake Tutira

No hydrilla plants or propagules (tubers and turions) were found in Lake Tutira.

The information gathered by the SCUBA divers from the monitoring sites in Lake Tutira is presented in Appendix A. General observations by the divers include, poor water clarity with visibility of approximately 1.5 m, the presence of shallow water plants at most sites (Figure 3-1), mussels at all sites, bullies were abundant with evident nest building (Figure 3-2), and holes (made by eels) were also frequently reported. Eels were seen in some of these holes. While koura were found in previous surveys, none were found during this survey.

Figure 3-1: Low growing native plants in shallow water in Lake Tutira. (Photo by M de Winton).

Figure 3-2: A bully attending to a nest of eggs. (Photo by M de Winton).

3.1.1 Aquatic plant survey

No hydrilla was found in Lake Tutira. Lake Tutira continues to support a range of low growing turf, and marginal emergent plants (e.g., *Typha orientalis*) (Table 3-1 and Appendix A), as outlined in the assessment of environmental effects (AEE) prior to the stocking of grass carp (Hofstra and Rowe 2008). The turf plant species occurred in water less than ca. 1 m deep at generally low cover values (5-25%), while the *T. orientalis* was in water less than 0.5 m deep (Table 3-1) and remained dense only where it was inaccessible to grass carp (i.e., shallow water). Aquatic plants found in deeper water (ca. 2.5 m) were charophyte germlings and milfoil (*Myriophyllum triphyllum*) which occurred down to approximately 5m. As in previous surveys since the removal of the hydrilla weed beds, milfoil was the most abundant submerged plant. Although milfoil was not recorded from all sites, the cover values are consistent with those seen in 2016 (Figure 3-3). Consistent plant cover values are particularly relevant given the high level of shading that submerged plants will have experienced during another summer with sustained algal blooms, conditions that can have an impact on submerged macrophytes over the longer term (Clayton and Edwards 2006).

Table 3-1: Lake Tutira vegetation summary.

Plant Species	No of Sites	Depth Range (m)	Height max. (m)	Height ave. (m)	Cover max	Cover median
Charophyte germlings (*Chara australis/C. globularis*)	3	1.3-5.8	0.08	0.08	1	1
Elatine gratioloides	1	0.6	-		1	1
Glossostigma diandrum	6	0-0.4			3	1
Lilaeopsis ruthiana	6	0-0.6			1	1
Myriophyllum triphyllum	10	0-5.3	0.4	0.15	5	1
No submerged macrophytes	1					
Potamogeton ochreatus	1	0.6			1	1
Ranunculus limosella	4	0.3-0.6	0.1	0.08	2	1
Ruppia polycarpa	1					
Stuckenia pectinata	1	1.1-1.3	0.15		1	1
Typha orientalis	4	0-0.5				

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.* Vegetation at two of the 15 survey sites (at the northern end of the lake) was not assessed as access was not granted by the owners.

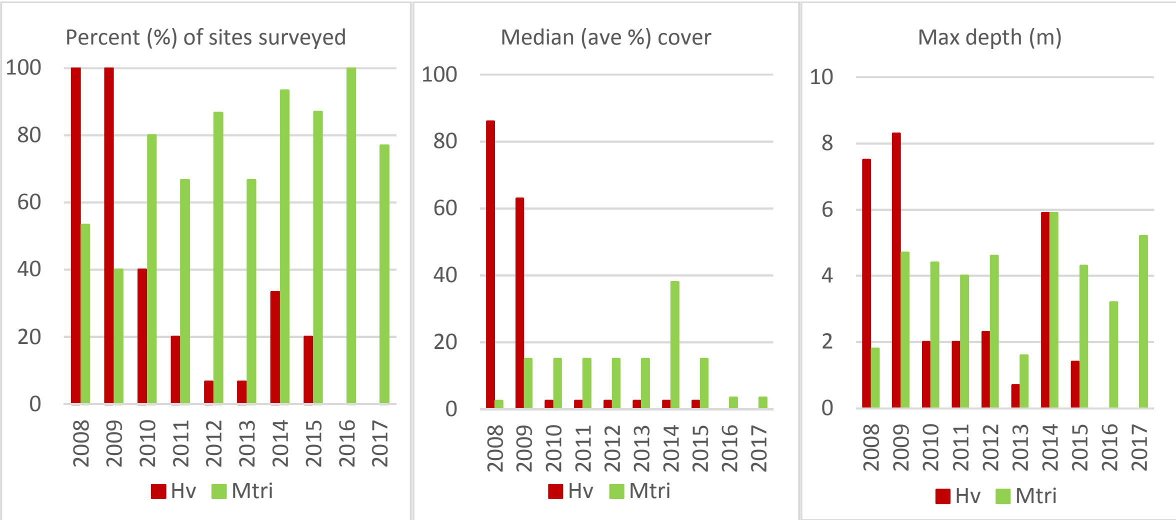


Figure 3-3: Hydrilla and milfoil abundance from 2008 to 2017. Hydrilla and milfoil are represented by the abbreviations Hv and Mtri respectively.

3.1.2 The plateau

No hydrilla was found on the plateau.

Of the twelve labelled markers (stakes) that were placed adjacent to hydrilla plants on the shallow water plateau in 2013, eight were found in 2017. This accounts for 67% of the stakes following a diver search time of over two hours (aided by scooters). Amongst those eight markers, only two still had the labels attached. The absence of labels on the markers means that it is now more difficult to track individual markers, however the absence of hydrilla also negates the need.

As this was only the second survey that no hydrilla was located in Lake Tutira, a further vegetation survey is recommended for October 2018.

3.1.3 Mussels

There is no indication that mussel numbers have been impacted by the recent severe algal blooms in the lake, with median mussel numbers similar to the previous highest yield in 2014 (Table 3-2).

The divers observed mussels at all sites that were surveyed (Figure 3-4), and as anticipated based on previous survey data, mussels were notably more abundant in shallow water (less than 1.5m deep) (Appendix A). There was wide variation between sites in the number of mussels recorded across all years that counts have been undertaken (Figure 3-4).

Initial information on mussel absence, presence or abundance was recorded by divers alongside the vegetation data in years 2008 to 2010. When juvenile mussels were first noted in the lake, amongst the macroinvertebrate samples, a decision was made to record the mussel data gathered by that method as well as the diver observations. Hence mussel numbers and lengths have been recorded from 2011 and 2012, respectively. During the present survey juvenile or young mussels (less than 30mm in length) were recorded from three sites, including the causeway site (T32, Figure 3-5), a site on the west (T50) and on the east shores of the lake (T22).

The causeway was the site from which the median number of mussels was collected, and mussels from most size classes (Figure 3-6). While young mussels were recorded from the lake in 2017, the distribution of mussels shows there are greater numbers of large older mussels, as illustrated by the site T32 sample, compared with 2012 when mussels under 10mm and those in the 61-70mm size class were equally abundant (Figure 3-6).

Mussels are recognised for their patchy distribution, variable abundance (Roper and Hickey 1994), and the periodic recruitment events (James 1985). Continued monitoring of mussels in Lake Tutira, including observations by the divers to assess any changes associated with the hydrilla eradication response and/or other changes occurring in the lake, provides a valuable opportunity to develop a better understanding of mussel population structure in general.

It is recommended that the next monitoring event for mussels is timed to occur with proposed macrophyte and macroinvertebrate surveys.

Table 3-2: Summary of mussel counts from 2011 to 2017.

Year	2011	2012	2013	2014	2015	2016	2017
Total	81	33	20	112	112	40	182
Mean	5.4	2.2	1.3	8.6	7.5	3.1	14
Median	2	1	1	9	6	2	10

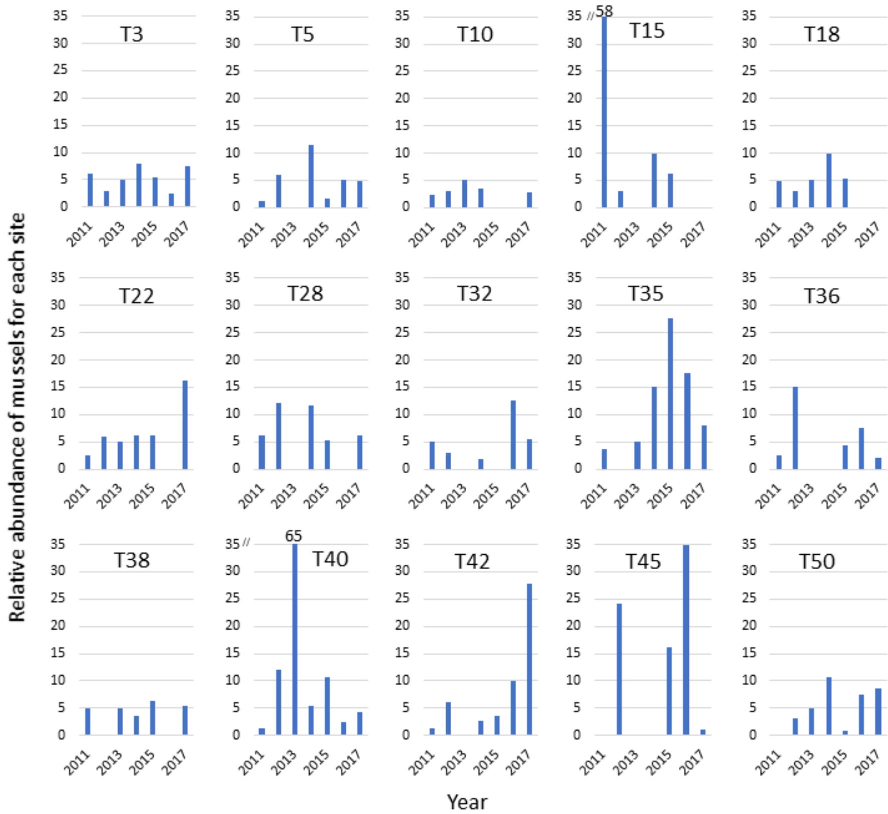


Figure 3-4: Relative abundance of mussels by year for each site in Lake Tutira. NB: sites T15 and T18 were not surveyed in 2016 nor in 2017.

Figure 3-5: Mussels sampled from the causeway (T32). The causeway was the site from which the median number of mussels was collected. The smallest mussel seen in this photo was 26mm long (Photo by Aleki Taumoepeau).

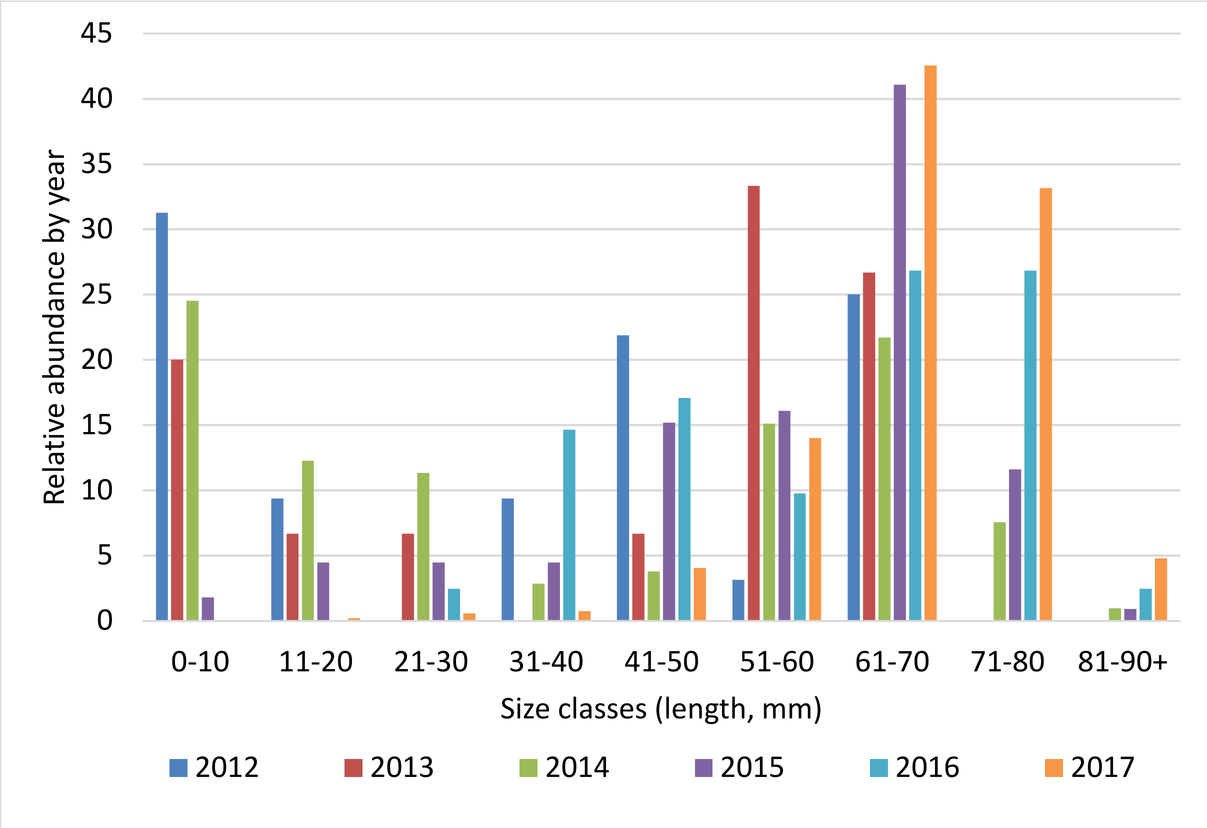


Figure 3-6: Relative abundance of mussels by size class across 6 years.

3.2 Lake Opouahi

No hydrilla was observed in Lake Opouahi, however the divers reported poor water clarity in the lake. A number of grass carp were seen cruising in the shallows along the southern shoreline during the survey, and three dabchicks were seen on the lake during the field work.

3.2.1 Exclusion cages

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 charophyte beds along with the hydrilla have been removed by the grass carp (Hofstra and Rowe 2008), and the only recent charophytes observed have been in the grass carp exclusion cages.

However, despite the GPS referencing of the cage sites, and that the divers are familiar with Lake Opouahi, once underwater, the cages themselves were difficult to locate due to the poor water clarity. Of the 15 large, circular cages within the lake, only 10 were found (at least 3 at each site), along with the one existing tunnel cage. Because of the time taken to locate these large cages under very low visibility, there was insufficient time to search for the small cages.

Plants were present in two of the large cages at the site closest to the jetty (Figure 2-3). The plants were charophytes (ca. 33% cover, most likely *Nitella* sp. aff. *cristata* (Figure 3-7) determined in 2016 at this site) in one cage and *Potamogeton crispus* in the other cage. No plants were observed in the other cages along the west and north shores of the lake, nor in the tunnel cage on the southern shore. In contrast, during the last two monitoring events (2015 and 2016) the amount of charophyte vegetation had increased to 100% cover in one cage at the north end of the lake. The continued growth of those plants supported the hypothesis that once a threshold density or size is reached the plants will persist, as opposed to small plants or germlings that appear to be highly susceptible to disturbance and a large portion or germlings have not survived longer than a year (Hofstra 2014, 2015). The single cage with charophytes adjacent to the jetty, still supports this hypothesis, as these plants have increased in area from 2016. In addition, it is possible that the vegetated cage at the northern site was one of the two cages that were not located under the low visibility conditions.

To improve substrate stability, and potentially improve local habitat for charophyte germlings whilst excluding grass carp, a new tunnel cage, with a hessian benthic barrier (Figure 3-8), was installed at the north end of the lake. This location was chosen, in part because of the past success reported from a cage at this site, and because the site was considered a minimal risk for the presence of hydrilla tubers (based on assessments prior to the release of grass carp) (Hofstra 2016).

As with the existing cages, the new cage with the benthic barrier will require monitoring for charophyte response, and to ensure that (in the unlikely event of regeneration from tubers) rapid hydrilla plant removal is possible.

It is recommended that the cages in Lake Opouahi are monitored in October 2018.

3.2.2 Outflow assessment

The only submerged macrophyte that was seen in the lake outside of the grass carp exclusion cages was *Ranunculus trichophyllus*. *Ranunculus trichophyllus* is considered a less palatable or non-desirable species for grass carp (Rowe and Schipper 1985) and plants show little evidence of having been browsed. This species was observed in patches along the southern shore line (Figure 3-9) and at the outflow. Amongst the *R. trichophyllus* at the outflow there were also a few stems of *Elodea canadensis* (Figure 3-10). *Elodea canadensis* is an introduced submerged weed in New Zealand, that has been recorded previously from Lake Opouahi. No *E. canadensis* has been recorded in the main body of the lake however, there are isolated plants by the bridge over the outflow, and there is currently a larger patch of *E. canadensis* in the outflow adjacent to the pest proof fence (Figure 3-10). The patch is small enough that physical removal is possible. If the plants were excavated, they should be allowed to dry out and compost on the adjacent shore within the pest proof fence. Composting the plants on site will ensure there is no risk of transferring aquatic life to another site. Any equipment, such as waders or rakes used in the process of excavating the *E. canadensis* should be thoroughly decontaminated (e.g., dried out, washed in salt water) before being used elsewhere.

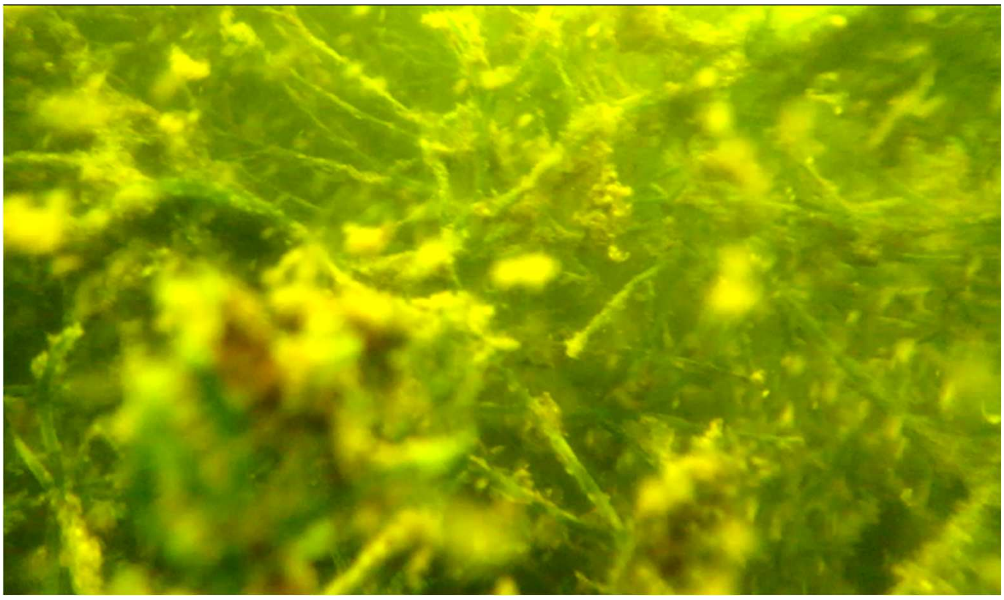


Figure 3-7: Charophytes in an exclusion cage near the jetty. The image shows charophytes (darker green) that are coated with epiphyton (pale yellow-green) (Photo by M de Winton).

Figure 3-8: Construction of the exclusion cage with the benthic barrier.

Figure 3-9: ***Ranunculus trichophyllus*** **in shallow water in Lake Opouahi (photo by M de Winton).**

Figure 3-10: Submerged vegetation at the outflow. *Ranunculus trichophyllus* with small shoots of *Elodea canadensis* (left) and *Elodea canadensis* adjacent to the pest proof fence (right).

4 Summary of progress and Recommendations

4.1 Progress towards hydrilla eradication

MPI is conducting an eradication response for hydrilla in Lakes Tutira, Waikōpiro and Opouahi. This report is one of a series that 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.

April 2011 and April 2013 were the first surveys in which no hydrilla plants or turions were detected in Lakes Opouahi and Waikōpiro, respectively (Hofstra 2011, 2013b) (Figure 4-1). Hydrilla has not been seen in these lakes in subsequent surveys up to and including 2016. Plant profiles were not surveyed in 2017.

April 2016 and October 2017 mark the first and second surveys, respectively, where divers were unable to find any hydrilla in Lake Tutira.

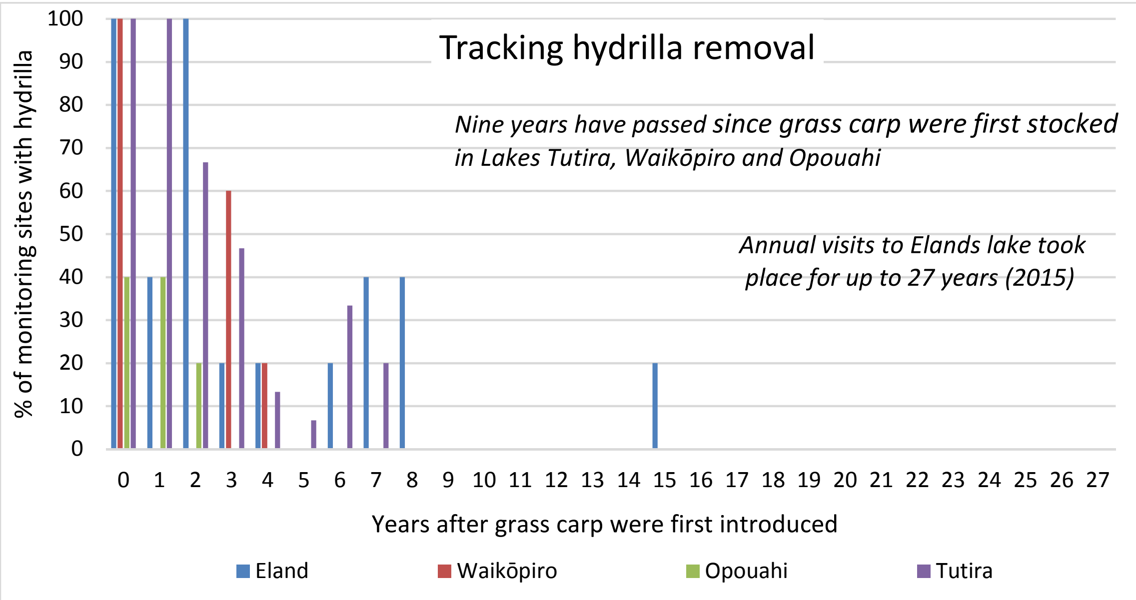


Figure 4-1: Portion of monitoring sites with hydrilla present since grass carp were first introduced. Data refer to plants and propagules. Lake Waikōpiro and Opouahi were not surveyed in 2017 (year 9).

4.2 Changing to spring monitoring

It is important to note that changing the survey to spring, whilst necessary for the response, is not the optimal time for assessing potential hydrilla recovery. The change to spring was, and remains necessary, because recurring events leading to poor water clarity in autumn, means reduced visibility, and reduced likelihood of divers finding plants. In addition, when contact recreation restrictions are in place for the lake it is also not considered safe for divers to be entering the water.

Given that improved water clarity and quality in the lake cannot be guaranteed, it is recommended that the survey dates are moved to spring because this change will provide better visibility in the lake (than autumn) for monitoring the hydrilla response.

The potential consequences of changing the monitoring season for assessing in lake flora and fauna are discussed below:

1) Hydrilla growth (re-growth) initiates primarily (but not exclusively) in spring, and is dependent on local conditions. It is possible that the spring survey dates (October) that are selected to take advantage of improved water clarity following winter, may precede the hydrilla spring growth period and/or new plants are likely to be small and difficult for divers to locate.

   This could be mitigated in the future by periodic tuber surveys (as were carried in Elands lake during the latter phases of that response) to assess the abundance and viability of the 'tuberbank'. Tuber surveys should primarily be focussed in Lake Tutira with some sampling in Lake Waikōpiro, because there are pre-response records for these two lakes (and 2012 records for Lake Tutira (Hofstra and Clayton 2012)). The need for a tuber survey should be informed by the findings of vegetation surveys and lake condition (e.g., further reduced visibility).

   In addition, sustained grass carp browsing pressure, which is required for hydrilla eradication, is also assessed by the abundance of other palatable native plants. Changes in the abundance of other submerged macrophytes will continue to be used as an indication of appropriate stocking density and browsing pressure to achieve the response goal of hydrilla eradication.

2) Seasonal trends in macroinvertebrate abundance are recognised (Talbot and Ward 1987, Rooke 1986), and in particular for phytophilous invertebrates associated with plants, numbers generally increase over the summer period (Cyr and Downing 1988, James et al. 1998). However, there are few lake littoral macroinvertebrate studies and fewer still that span several seasons that can be used to inform with certainty the consequences of making a seasonal change to the monitoring programme.

   Macroinvertebrate sampling was last undertaken in Lake Tutira in 2016 and in Lakes Waikōpiro and Opouahi in 2014, because the data had illustrated changes that were consistent with findings from Elands lake (Hofstra et al. 2008). These relatively homogenous data sets from the different lakes were attributed to changes in substrate or habitat (i.e., less submerged macrophytes with similar benthic habitats available at all depths) for macroinvertebrates with samples now dominated by mites, chironomids and snails (Hofstra 2014). It is well recognised that the macroinvertebrate diversity is a reflection of the variety or complexity of habitat present (Winterbourn and Lewis 1975, Cyr and Downing 1988, Sloey et al. 1996, James et al. 1998, Hansen et al. 2010). As the macrophyte abundance is unlikely to change significantly whilst grass carp are still in the lakes, season may have less influence on the macroinvertebrate data in these lakes than in other studies.

4.3 Recommendations

It is recommended that the next vegetation and macroinvertebrate survey is undertaken in spring 2018 in all three lakes. This will:

- confirm progress towards hydrilla eradication, particularly in Lake Tutira, for which there are now two consecutive, hydrilla-free years
- create a macroinvertebrate spring baseline at a time when the submerged vegetation is still expected to be limited but stable, and
- provide vegetation data to align with the spring macroinvertebrate data, against which future change can be assessed.

Monitoring information will be used to inform the timing and frequency of subsequent monitoring events, recognising MPIs intent to move toward biennially and then triennial monitoring as the hydrilla eradication response progresses.

5 Acknowledgements

The author would like to acknowledge the fantastic field team of Mary de Winton (NIWA), Aleki Taumoepeau (NIWA) and Joe Butterworth (JFB Environmental). Ian Gear (In Gear Global) is thanked for stakeholder communication and liaison, and co-ordinating the opportunity to present at the Maungaharuru-Tutira forum. Thank-you to all of those present at the forum for your questions and discussion. Thank-you also to the students from Guthrie Smith for visiting with our team and taking such a keen interest in the mahi and the lake.

6 References

Clayton, J.S. (1983) Sampling aquatic macrophyte communities. In: B. J. Biggs, J. S. Gifford and D. G. Smith (ed). Biological Methods for Water Quality Surveys. *Water and Soil Miscellaneous Publications,* 54.

Cyr, H., Downing, J.A. (1988) The abundance of phytophilous invertebrates on different species of submersed macrophytes. *Freshwater Biology,* 20: 365–374.

Hansen, J.P., Sagerman, J., Wikstrom, S.A. (2010) Effects of plant morphology on small-scale distribution of invertebrates. *Marine Biology,* 157: 2143–2155.

Hofstra, D.E. (2011) Hydrilla lakes flora and fauna survey and regional surveillance 2011. *NIWA Client Report* HAM2011-041.

Hofstra, D.E., Clayton, J.S., Champion, P.D., Smith, B.J., Smith, J.P. (2008) Hydrilla lakes baseline survey 2008 – Flora and Fauna. *NIWA Client Report* HAM2008-061.

Hofstra, D., Clayton, J. (2012) Hydrilla eradication response additional operations. *NIWA Client Report* HAM2012-039, NIWA Project MAF12205.

Hofstra, D.E. (2013a) Additional operations for the hydrilla eradication response February 2013. *Letter report to MPI.*

Hofstra, D.E. (2013b) Flora and fauna survey report for the hydrilla eradication response 2014. *NIWA Client Report* HAM2013-033.

Hofstra, D.E. (2014) Flora and fauna survey for the hydrilla eradication response. *NIWA Client Report* HAM2014-068.

Hofstra, D.E. (2015) Flora and fauna survey for the hydrilla eradication response. *NIWA Client Report* MPI15205.

Hofstra, D.E., Rowe, P.D. (2008) Assessment of Environmental Effects for the introduction of Grass carp to hydrilla affected lakes in Hawke's Bay. *NIWA Client Report* HAM2008-085 for MAF (MAF08208).

Hofstra, D.E., Smith, J.P. (2008) Hydrilla lakes baseline supplement 1: November 2008-January 2009. *NIWA Client Report* No. HAM2008-191.

Innes, J., Whaley, K., Owen, K. (1999) Abundance and distribution of waterbirds of the Rotorua lakes, 1985-1996. *Conservation Advisory Science Notes*, No. 236, Department of Conservation, Wellington.

James, M. (1985) Distribution, biomass and production of the freshwater mussel *Hyridella menziesi* (Gray), in Lake Taupo, New Zealand. *Freshwater Biology*, 15: 307-314.

James, M.R., Weatherhead, M., Stanger, C., Graynoth, E. (1998) Macroinvertebrate distribution in the littoral zone of Lake Coleridge, South Island, New Zealand – effects of habitat stability, wind exposure and macrophytes. *New Zealand Journal of Marine and Freshwater Research,* 32: 287–305.

MAF (2008) Operational Plan, *Hydrilla verticillata* Eradication Project (March 2008). *MAF Biosecurity New Zealand.*

Rooke, B.J. (1986) Seasonal aspects of the invertebrate fauna of three species of plants and rock surfaces in a small stream. *Hydrobiologia,* 134: 81-87.

Roper, D.S., Hickey, C.W. (1994) Population structure, shell morphology, age and condition of the freshwater mussel *Hyridella menziesi* (Unionacea: Hyriidae) from seven lake and river sites in the Waikato River system. *Hydrobiologia,* 284: 205–217.

Rowe, D.K., Schipper, C.M. (1985) An Assessment of the Impact of Grass Carp (*Ctenopharyngodon idella*) in New Zealand Waters. *Fisheries Environmental Report*, No 58.

Sloey, D., Schenck, T., Narf, R. (1996) Distribution of aquatic invertebrates within a dense bed of Eurasian Milfoil (*Myriophyllum spicatum* L). *Journal of Freshwater Ecology,* 12(2): 303–313.

Talbot, J.M., Ward, J.C. (1987) Macroinvertebrates associated with aquatic macrophytes in Lake Alexandrina, New Zealand. *New Zealand Journal of Freshwater Research*, 21: 199–213.

Winterbourn, M.J., Lewis, M.H. (1975) Littoral fauna. In: V. H. Jolly and J. M. A. Brown (ed). *New Zealand Lakes.* Auckland University Press/Oxford University Press: 271–280.

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, woody debris and branches. Max dive depth 8.8m; Maximum vegetation cover was 1%; Mussels (down to 2.1m), bullies present and an eel hole; Visibility ca 1.5m.	*Myriophyllum triphyllum* *Elatine gratioloides* *Typha orientalis*	0-2.3 0.6	0.1(0.1) -	1(1) 1(1)
5. South of the old boat ramp. Max depth of dive 8.1m; Visibility 1.5m; Mussels and bullies present. One eel at 6.5m.	No submerged macrophytes			
10. Steep site, with bare sediment. Total vegetation cover 1%; Visibility 1.2m. Mussels and bullies present.	*Typha orientalis* (floating sudd, undercut) *Ranunculus limosella*	0 0.3	-	1(1)
15. North end beach. Not surveyed.				
18. North-eastern shore. Not surveyed.				
22. Next to the fenceline south of the island. Max depth of dive 8.2m; Total vegetation cover 10%; Visibility 1.5m; Mussels and bullies present. Dead mussels at 2.6m. Large eel holes at 3m.	*Myriophyllum triphyllum* *Ranunculus limosella* *Ruppia polycarpa*	1-3.7 1.1	0.2(0.1) 0.1(0.08)	2(1) 1(1)
28. By four waratahs in the lake. Max depth of dive 8.5m; Visibility 1.5 m; Eel holes. Mussels at 1.6m.	*Myriophyllum triphyllum* Charophyte germlings	1.2-1.6 1.3	0.08(0.08)	1(1) 1(1)
32. Pa site, seat and lookout. Max depth of dive 8.1 m; Total vegetation cover 5%; Visibility 1 m; Mussels and bullies present in the shallows. Eel holes present; No koura located, despite targeted searching.	*Lilaeopsis ruthiana* *Glossostigma diandrum* *Ranunculus limosella* *Myriophyllum triphyllum*	0-0.2 0-0.3 0.5 1-2.1	0.15(0.1)	1(1) 3(2) 2(1) 2(1)
35. At camp ground by the picnic table and large willows.	*Myriophyllum triphyllum* *Stuckenia pectinata*	0.2-1.8 1.1-1.3	0.4(0.2) 0.15	4(2) 1(1)

Site No & Comments	Plant Species	Depth Range (m)*	Height (m) max (ave)	Cover max (ave)
Max depth of dive 8.1 m; Total vegetation cover 40%; Visibility 1m; Mussels present.	*Potamogeton ochreatus*	0.6		1(1)
	Glossostigma diandrum	0-0.2		1(1)
	Lilaeopsis ruthiana	0-0.2		1(1)
36. Rat point. Steep profile. Max depth of dive 9.1 m; Total vegetation cover 1%; thermocline at 6m, below which the water was clearer. Mussels present mostly shallower than 1.5m, but also at 3m. Low mound-forming plant community was very shallow.	*Glossostigma diandrum*	0-0.3		2(1)
	Lilaeopsis ruthiana	0-0.2		1(1)
38. Causeway Max depth of dive 7.3 m; Visibility 1.5m; Mussels and bullies present.	*Lilaeopsis ruthiana*	0-0.4		1(1)
	Glossostigma diandrum	0-0.1		1(1)
	Myriophyllum triphyllum	0.6-3.3	0.25(0.2)	5(2)
	Chara australis/globularis (germlings)	1.5-2.5		1(1)
40. Southwest shore. Max depth of dive 8.1m; Mussels present in the shallows (2.6m) as well as dead mussels at 4.7m.	*Myriophyllum triphyllum*	2.9		
	Lilaeopsis ruthiana	0.4		1(1)
	Glossostigma diandrum	0.4		1(1)
	Charophyte germlings	5.8		
42. Max depth of dive 8.2 m; Total vegetation cover <1%.; Mussels and bullies present. Bully nests on submerged wood. A small sponge was also observed.	*Myriophyllum triphyllum*	0.4-5.2	0.15(0.08)	2(1)
	Ranunculus limosella	0.3-0.6		2(1)
	Lilaeopsis ruthiana	0.3-0.6		1(1)
	Glossostigma diandrum	0.3-0.6		1(1)
45. Willows, shed over road. Max depth 7 m; Total vegetation cover 3%; Visibility 1.5m; Wood, branches and logs in the shallow. Mussels and bullies present.	*Typha orientalis*			
	Myriophyllum triphyllum			1(1)
50. Typha point. Max depth 8 m; Visibility 1.5m; Mussels (at 1.3m) and bullies present. Eel holes (active). *T. orientalis* and *Bolboschoenus fluviatilis* on a shallow bank.	*Typha orientalis*	0.5		
	Bolboschoenus fluviatilis	0.5		
	Myriophyllum triphyllum	5.2-5.3	0.1(0.1)	1(1)

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