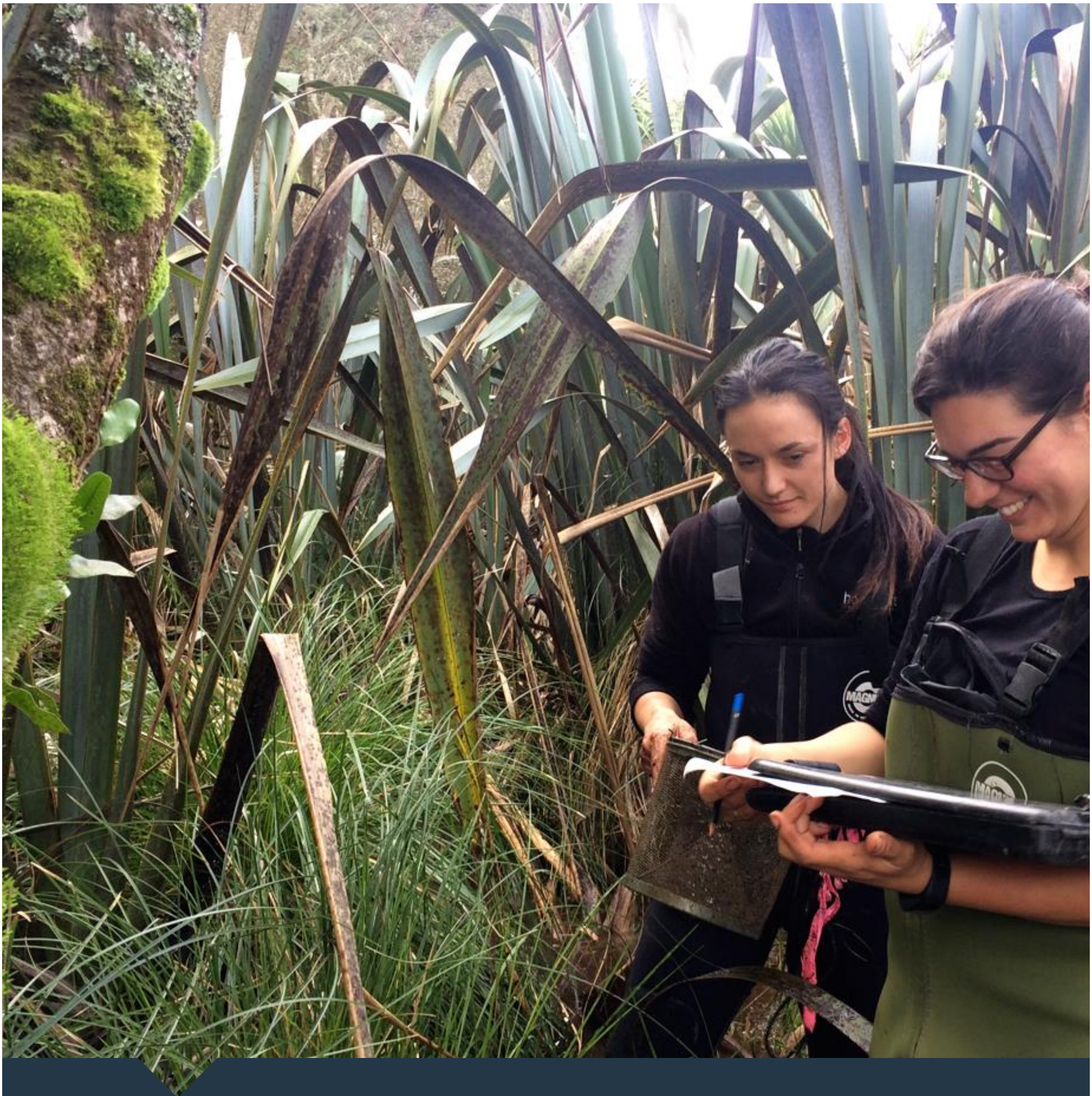

Lake Namunamu – Hornwort Eradication – Short communication

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Short Communication

From	**Dr Daniel Clements, Paul Champion, Mary de Winton (NIWA)**
To	Elizabeth Daly- Horizons Regional Council
CC	Logan Brown - Horizons Regional Council
Date	5 February 2020
Title	Lake Namunamu - Hornwort eradication - Short communication
NIWA Project No.	ELF20209

1. Introduction

The introduced submerged freshwater perennial plant *Ceratophyllum demersum* (hornwort), has recently been found in Lake Namunamu. Horizons Regional Council (HRC) are considering an attempt to eradicate hornwort at this site. The successful eradication of hornwort in New Zealand to date has been achieved in relatively small, shallow lakes, or those with shallow water weed beds. The feasibility of hornwort eradication in Lake Namunamu is more uncertain as the lake is larger (14.55 ha) (BVAR 2019) and deeper (19.1 m) (Burton 2017), compared to previous eradication attempts for this species.

This short communication incorporates NIWA aquatic plant specialist knowledge (authors of this report) and information from aquatic plant management experts in the USA ([1.]Dr Kurt Getsinger, Research Biologist, U.S. Army Engineer Research and Development Centre-teleconference: 5/12/2019; [2] Dr Lars Anderson, U.S. Department of Agriculture, Agricultural Research Service-meeting 4-5/11/2019) to indicate the feasibility of success for an eradication attempt at Lake Namunamu. This information will support decision making by HRC for the potential eradication attempt of hornwort in Lake Namunamu. The feasibility of eradication is indicated, with uncertainties and assumptions discussed.

2. Background

Lake Namunamu

Lake Namunamu is a ca. 14.55 ha lake in Rangitikei District, Manawatu-Whanganui Region. It is estimated to have a waterbody volume of 1,031,128 m^3 (BVAR 2019), with a maximum depth of 19.1 m (Burton 2017). It has three main arms that extend from the deeper central area of the lake, two main arms to the north and one to the south (Figure 1).

In 2016, Lake Namunamu was characterised as being in moderate ecological condition with a LakeSPI Index (overall measure of a lake's ecological condition) of 31% (Burton 2017). At this time, Lake Namunamu had the sixth highest LakeSPI Index, out of the 22 lakes assessed in the Manawatu-Wanganui Region. Elodea (*Elodea canadensis*) was the only invasive species recorded along the survey transects at this time, growing to 3 m tall to a maximum depth of 5.5 m. Native charophytes (*Chara australis* and *Nitella* sp. aff. *cristata*) meadows (>75% cover) and pondweed (*Potamogeton ochreatus*) was recorded to a maximum depth of 6.4 m. Native milfoil (*Myriophyllum triphyllum*) was also recorded at the lake forming a dense stand at one of the more sheltered sites (Burton 2017).

More recent surveillance work in Lake Namunamu by Bay of Plenty Regional Council (BOPRC) in 2019, found the dominant species growing in the littoral zone of the lake was the exotic species elodea (*E. canadensis*) with median cover values of ca. 60% for each sector of the lake (Figure 2, Sectors 1-14; Table 1). 11 out of the 14 sectors recorded 60% elodea cover, however values of 20% (Sector 4), 90% (Sector 5) and 95% (Sector 1) were recorded. Other submerged species that recorded lower covers included the invasive species hornwort (*C. demersum*) and curled pond weed (*Potamogeton crispus*), as well as native species *Chara corallina* (currently described as *Chara australis*) and pondweed (*P. ochreatus*) (Table 1).

Hornwort was reported during the BOPRC surveys in 2019 growing in every sector of the lake (Figure 2, Sectors 1-14; Table 1), to a maximum depth of 5.9 m. 12 out of 14 sectors recorded cover values of ≤ 5%. Sector 4 and Sector 5 recorded the highest cover values, 70% and 10% cover respectively (Table 1). Therefore, hornwort is widely distributed in the littoral zone at Lake Namunamu but currently at relative low covers.

Species description

Hornwort propagates through asexual reproduction, whereby stem fragments are the primary method of reproduction and spread, both within and between waterways. Hornwort is monoecious and although flowers are produced, in New Zealand there is no evidence that viable seed is formed (Coffey and Clayton 1988). Human mediated dispersal, either knowingly or by accident, is therefore recognised as the main vector of spread of this weed between catchments (e.g. boat traffic, eel fishing nets) (Cooke et al. 2005; Bickel 2015). Once within catchments the primary mode of dispersal is by hydrochory, the dispersal of propagules by water currents (Johansson and Nilsson 1993). The plant regularly grows with the base of the stem buried in sandy and silty sediments, anchored by modified leaves, but does not form 'true roots'. It is regarded as a brittle, poorly attached plant that is prone to dislodgement by water currents, wave action and other disturbance events. It can grow in water depths of up to 10 m and reach lengths of 5 to 6 m in New Zealand. It can form extremely dense canopies, frequently growing as monospecific stands and outcompeting diverse native submerged plant communities (Coffey and Clayton 1988).

Previous eradication efforts for hornwort

In previous New Zealand studies, applications of the herbicides endothall (dipotassium endothall) or diquat (diquat dibromide), as well as the herbivorous fish grass carp (*Ctenopharyngodon idella*) have been shown to eradicate hornwort. Use of endothall requires compliance with the NZ Environmental Protection Authority (EPA) permit and a Resource Management Act (RMA) consent for all regions. Diquat application has no EPA controls and is a permitted activity by some regional councils, but resource consent may be required. Statutory approvals are required for the release of grass carp.

Hornwort was eradicated from Centennial Lake (1.6 ha; 2 m average depth), Timaru (South Canterbury, SI), using endothall with a total water body treatment of 5 ppm (parts per million). Hornwort was of low cover (ca. 15%) prior to treatment but widespread throughout the lake (similar situation present at Lake Namunamu). Post-treatment scuba inspections were used to assess underwater vegetation. There were no traces of hornwort in any of the post treatment inspections (from 1 month to 2 years after treatment). Other species present in Centennial Lake such as elodea (*E. canadensis*) and curled pond weed (*P. crispus*) were not affected by endothall and no impacts on waterfowl or fish were observed (Wells and Champion 2010). Both elodea (*E. canadensis*) and curled pond weed (*P. crispus*) have also been recorded in Lake Namunamu (BOPRC surveys in 2019).

Low dose endothall applications have also been trialled in Lake Otamatearoa, a 4 m deep, 10 ha lake dominated by hornwort (surface-reaching beds, up to 100% cover and 3 m tall) in the North Island. A spring application (September 2009) resulted in 0.15 ppm endothall (33 times less than maximum label rate of 5 ppm) that reduced the extensive beds of hornwort to scattered fragments within two months. Off-target impacts were minimal with 35 other recorded macrophyte species showing no signs of damage. Dissolved oxygen levels remained above 76% saturation in surface water column and above 61% close to the bottom of the lake. Water clarity and nutrient levels were not adversely affected. However, recovery of hornwort was rapid with weed beds returning after six months. Two years later the weed nuisance had returned and in winter (June 2011), three applications were applied over two weeks to maintain endothall levels above 1.5 ppm for three weeks. Weed beds were reduced to decaying fragments within seven days and nine weeks later only the odd viable fragment was found buried within the bottom detritus. Six months later a few scattered plants mostly less than 0.5 m tall were found. It is likely repeated low dose applications, or a higher rate would have been required to eradicate hornwort in this lake (Wells et al. 2014). Eradication of hornwort has not currently been achieved in this lake and egeria (*E. densa*) has subsequently been detected (authors pers. obs.), which is not controlled using endothall (Hofstra et al. 2015).

Endothall has also been used to eradicate the invasive submerged weed lagarosiphon (*Lagarosiphon major*) in several sites within New Zealand (Wells and Champion 2010; Champion and Wells 2014; Wells et al. 2014).

The herbicide diquat was used to successfully eradicated hornwort from sites in Motueka (Tasman District, SI) in flowing water with a short contact time (Wells and Champion 2010), but this is the only known occasion where eradication of hornwort has been achieved with this herbicide. Diquat provided ineffective control of hornwort in Centennial Lake, Timaru.

Diquat is rapidly deactivated by organic matter or clays so is of limited use in turbid water and within sediments. In 2016, through-water visibility at Lake Namunamu estimated by divers ranged from ca. 0.5-2 m and a secchi disc measurement of 2.17 m was recorded (Burton 2017). Turbidity levels would need to be considered at Lake Namunamu if diquat treatment was considered. Conversely, endothall is not deactivated by turbid water conditions, making eradication more feasible in these situations (Hofstra et al. 2001). Further, if long contact times (weeks) for endothall can be achieved where the effects of dissipation are minimal (such as total water body treatments) and when biodegradation rates are slow, such as when temperatures are cool (at 16°C, endothall persisted for weeks and was an effective treatment) (Wells and Champion 2010), eradication likelihood is increased. Neither herbicide damages charophytes, the most important deep-water native vegetation. Consecutive herbicide treatments will likely be required to eradicate hornwort from Lake Namunamu.

Grass carp (*C. idella*) have been used to eradicate hornwort, from two small Northland lakes (Champion and Wells 2014). Grass carp are non-selective and difficulty in removing fish post-eradication is recognised. Lake Roto-otuauru (16.1 ha) and Lake Heather (12.5 ha) (Northland) were completely dominated by hornwort (*C. demersum*) and egeria (*E. densa*) and eradication using grass carp was enacted to protect surrounding high-value regional lakes in 2009 and 2010, respectively. Annual monitoring of submerged vegetation transects across these lakes were undertaken, with the last fragments of the target species found in 2011 (Lake Roto-otuauru) and 2014 (Heather) (Champion and Wells 2014). Hornwort is now considered eradicated from both lakes and removal of grass carp is recommended.

3. <u>Feasibility of hornwort eradication at Lake Namunamu</u>

Eradication can be defined as the elimination of every individual of a species from a geographic area that is sufficiently isolated to prevent reinvasion (Newsom 1978; Myers et al. 1998; Clements 2017). The National Policy Statement for Pest Management outlines that the intermediate outcome of "eradication" is to reduce the infestation level of an organism, being spread by the subject, to zero levels in an area in the short to medium term (New Zealand Government 2015).

Management of submerged weeds is regarded as more problematic than for terrestrial plants (Champion et al. 2019). Eradication of aquatic organisms is more difficult due to factors including; their early detection and delimitation being more difficult in the aquatic environment, than for a terrestrial site, and the restrictions around the use of eradication tools and effective deployment of those tools in the aquatic environment (Simberloff 2014).

For an eradication attempt of hornwort at Lake Namunamu to be effective, the following assumptions need to be met and limitations addressed. Often, individual sites may be eradicated, but achievement of the lake-wide eradication goal is hindered by not meeting the assumptions described below:

<u>Assumption 1:</u> All stages required for eradication are met. The eradication response programme needs to include delimitation of hornwort within the lake, assessment of management options, containment of hornwort (i.e. minimise dispersal of propagules within the lake), control of hornwort, and follow-up monitoring, until extirpation occurs over the entire infested area (Champion et al. 2019).
Limitations: Subsequent and often ongoing discovery of surviving propagules.

<u>Assumption 2:</u> Both effective detection and control techniques are available to be implemented at a whole of lake scale.
Limitations: Failure to detect regrowth; inadequate access to eradication tools (legislation, limited importation and manufacture); underestimation of the time required to eradicate all propagules, including recognising unsuitable environmental conditions preventing requisite control effort (water inflows, dilution, water levels, weather).

<u>Assumption 3:</u> Effective management of potential pathways of spread and reintroduction has been undertaken and reintroduction prevented.
Limitations: Spread by weed fragmentation and water dispersal; inability to prevent high risk activities (i.e. contaminated eel fishing nets, contaminated vessel transfers, illegal fish liberations).

<u>Assumption 4:</u> Sufficient resources available to undertake the programme, backed by legislation.
Limitations: Limited or inflexible budget; timely access to required resourcing; inadequate level of experience and effort of individuals charged with implementing eradication programmes (Howell 2012).

If the above assumptions cannot be sufficiently addressed, it is likely a *Progressive Containment* programme is more appropriate, in which the intermediate outcome for the programme is to contain or reduce the geographic distribution of the subject over time (New Zealand Government 2015). Should progress be made to the point where eradication is assessed as attainable, then a review of the programme could change the species-led goal to *Eradication* (Champion et al. 2019).

Aspects informing feasibility of eradication

Essential components in planning a successful eradication programme were identified by Simberloff (2014). These included ensuring there were sufficient resources to undertake a programme, that actions were backed by efficient legislation, that tools targeting vulnerable life stages of the weed were available and that the likelihood of reinvasion from outside of the eradication zone had been evaluated. This is a critical point for an eradication attempt at Lake Namunamu. Understanding the risk and managing potential pathways of spread and the likelihood of reintroduction to the lake following any control work is critical to initiating the decision to target eradication. Any eradication attempt would be regarded as site-based eradication, as hornwort is relatively widespread in the North Island. For example, hornwort was recorded as present in nine of 22 lakes surveyed for LakeSPI in the Manawatu-Wanganui Region in 2016, including Lake Ngaruru which is less than 1 km from Lake Namunamu (Burton 2017).

Determining the efficacy of eradication is dependent on: (1) the 'delimitation criterion' being the requirement to detect the full extent of an incursion initially and until extirpation occurs over the entire infested area (Panetta and Lawes 2005; Panetta 2009); (2) the 'extinction criterion', being the rate of decrease in population numbers of a given species (3) the 'containment criterion' being the extent to which an eradication programme prevents the spread of the target species (Zamora et al. 1989; Panetta and Lawes 2005; Clements 2017). Therefore, both effective detection and control techniques must be available to achieve eradication at the site. Effective techniques would need to be identified and prioritised prior to an eradication attempt at Lake Namunamu.

It is recognised that eradication feasibility is influenced not only by biological factors, including both site and species factors, but also socio-political, economic and operational factors (Panetta et al. 2011; Dodd et al. 2015). As weed density falls in an eradication programme, costs of finding and killing each remaining weed increases (Zamora et al. 1989). Eradicating the last 1% of a target population can cost more than destroying the first 99% (Myers et al. 1998; Simberloff 2003; Simberloff 2014). The resources required to achieve eradication are initially far greater than that required for conventional ongoing control and management (Dodd et al. 2015), however over the longer term eliminating the pest (eradication) compared to employing long-term control strategies is a cost-effective management strategy (Dahlsten and Garcia 1989; Clements 2017).

Studies have attempted to estimate extirpation probability and determine if an eradication programme should be attempted, this needs to be considered in conjunction with other important variables including the perceived risk of a species, the cost of intervening (Panetta 2009; Dodd et al. 2015) and the long-term costs of not intervening, including economic, environmental and social impacts. For invasive species that spread quickly, like hornwort, it has been suggested that eradication attempts should often proceed even with uncertain prospects for success, as the costs of not intervening outweigh the cost of intervening (Simberloff 2003; Clements 2017).

4. Management options for hornwort in Lake Namunamu

Based on the above information, NIWA advise that *Progressive Containment* of hornwort in Lake Namunamu, leading to *Eradication*, is likely the best management strategy to control and minimise the impacts posed by this invasive species at this lake. We certainly suggest that it is worthwhile to attempt to eliminate hornwort from Lake Namunamu and believe HRC can gain a lot of knowledge from these attempts, that can be used more broadly within the region if successful. Further, this attempt would contribute to waterway managers knowledge for future biosecurity threats in New Zealand lakes.

If management using herbicide is deemed appropriate at Lake Namunamu, there is a potential to do whole of lake treatments or partial lake herbicide treatments (i.e. contain herbicide to one arm of the lake at a time) or spot treatments to control hornwort. Currently, hornwort is growing to a depth of ca. 6 m in Lake Namunamu (BOPRC surveys in 2019). Data supplied to HRC (by Ian Henderson, Massey University) between 2011-2018 shows thermocline depth at Lake Namunamu to be at ca. 6 m quite consistently in early March over this monitoring period. If herbicide is to be utilised as a control technique, this may allow for herbicide treatments to be held in areas where the target weed is present, as herbicide is not likely to disperse to deeper areas during this time, potentially allowing for extended contact times with the target weed. At 6 m depth at Lake Namunamu this equates to <5.5 ha of the waterbody with a cumulative volume of <650,000 m^3 (HRC data).

The use of barrier curtains (silt curtains or bubble curtains) are probably useful to limit water exchange with partial lake herbicide treatments and increase herbicide exposure periods, which in turn increases herbicide efficacy on the target plant. However, the effectiveness of these techniques would require verification which could be conducted using herbicide tracer dye studies and/or herbicide water sample monitoring.

There are various options to control hornwort in Lake Namunamu, including trialling selected management strategies in one arm of the lake (e.g. the north east arm initially), which may allow for results to be further optimised before treating the entire lake. One of the knowledge gaps for applying herbicide in lake situations is how to effectively conduct spot treatments of target submerged invasive plants in larger lake environs and particularly how to use endothall in this situation.

5. Recommendations

To minimise the impacts posed by hornwort at Lake Namunamu, a *Progressive Containment* programme is recommended where the intermediate outcome for the programme is to contain and reduce the distribution of the weed within the lake. Should progress be made where eradication is assessed as attainable, then a review of the programme could change the species-led goal to *Eradication*.

Identifying appropriate control and detection techniques that will be utilised, and the implementation of those tools, should be further evaluated prior to making the decision to enact a management programme for hornwort at Lake Namunamu.

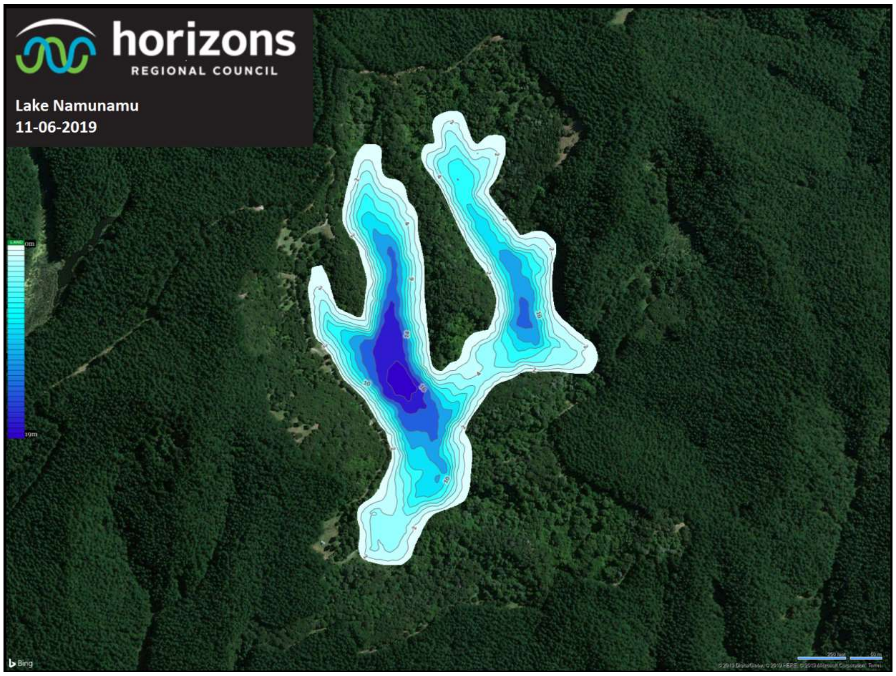

Figure 1: Bathymetry map of Lake Namunamu. (Source: BVAR: Biobase Vegetation Analysis Report – 13.6.19, Rangitikei Manawatu-Wanganui. Data collected by David Brown on 10.6.19; provided to NIWA by HRC).

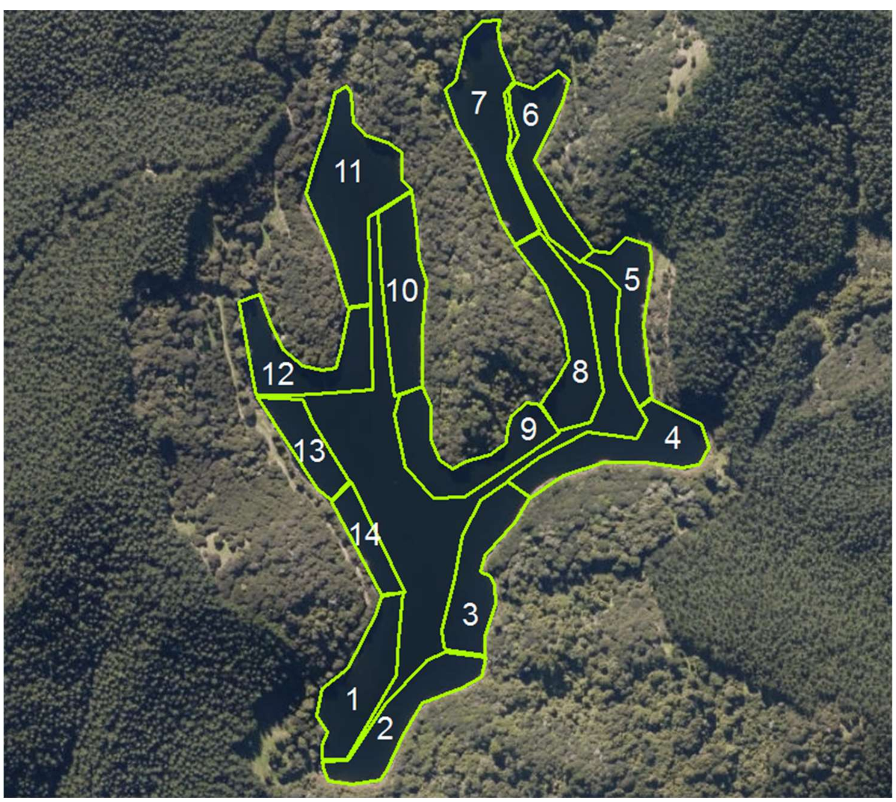

Figure 2: Bay of Plenty Regional Council (BOPRC) surveillance for hornwort (*C. demersum*) at Lake Namunamu in 2019*,* indicating each sector searched (provided to NIWA by HRC).

Table 1: Bay of Plenty Regional Council (BOPRC) submerged weed surveillance results for Lake Namunamu in 2019, indicating each sector searched (sector numbers align with values in Figure 2) (Table modified from original data provided to NIWA by HRC). Note: *Chara corallina* currently described as *Chara australis*.

Sector number	Area of sector (ha)	Invasive plant cover	Native plant cover	Notes for *Ceratophyllum demersum*
1	0.65	*Elodea canadensis(95%)* *Ceratophyllum demersum(5%)* *Potamogeton crispus*	*Chara corallina(5%)* *Potamogeton ochreatus*	1-5m depth. 1 large plant found off boat ramp
2	0.64	*Elodea canadensis(60%)* *Ceratophyllum demersum(5%)* *Potamogeton crispus(5%)*	*Chara corallina(20%)* *Potamogeton ochreatus*	3-5.5m depth. Mostly small plants
3	0.67	*Elodea canadensis(60%)* *Ceratophyllum demersum(5%)* *Potamogeton crispus(5%)*	*Chara corallina(20%)* *Potamogeton ochreatus*	3-5.5m depth. Mostly small plants
4	0.7	*Elodea canadensis(20%)* *Ceratophyllum demersum(70%)* *Potamogeton crispus(5%)*	*Chara corallina* *Potamogeton ochreatus*	0-2m depth. Mostly small plants
5	0.5	*Elodea canadensis(90%)* *Ceratophyllum demersum(10%)* *Potamogeton crispus(1%)*	*Chara corallina* *Potamogeton ochreatus*	0-2m depth. Mostly small plants
6	0.55	*Elodea canadensis(60%)* *Ceratophyllum demersum (?)* *Potamogeton crispus(10%)*	*Chara corallina(30%)* *Potamogeton ochreatus*	2-4m depth. Scattered plants (10) mostly small
7	0.7	*Elodea canadensis(60%)* *Ceratophyllum demersum(5%)* *Potamogeton crispus(5%)*	*Chara corallina(30%)* *Potamogeton ochreatus*	2-5.9m depth. Scattered plants mostly small, one large plant
8	0.5	*Elodea canadensis(60%)* *Ceratophyllum demersum(5%)* *Potamogeton crispus(5%)*	*Chara corallina(30%)* *Potamogeton ochreatus*	2-5.9m depth. Scattered plants mostly small, one large plant
9	0.54	*Elodea canadensis(60%)* *Ceratophyllum demersum(5%)* *Potamogeton crispus(5%)*	*Chara corallina(30%)* *Potamogeton ochreatus*	(7) found 2-5.9m depth. Scattered plants mostly small, one large plant
10	0.6	*Elodea canadensis(60%)* *Ceratophyllum demersum(5%)* *Potamogeton crispus(5%)*	*Chara corallina(30%)* *Potamogeton ochreatus*	2-5.9m depth. Scattered plants mostly small, one large plant
11	0.7	*Elodea canadensis(60%)* *Ceratophyllum demersum(5%)* *Potamogeton crispus(5%)*	*Chara corallina(30%)* *Potamogeton ochreatus*	Hornwort plant found 3.5m depth
12	0.7	*Elodea canadensis(60%)* *Ceratophyllum demersum(1%)* *Potamogeton crispus(9%)*	*Chara corallina(30%)* *Potamogeton ochreatus*	Hornwort plant found 3.5m in depth
13	0.4	*Elodea canadensis(60%)* *Ceratophyllum demersum(1%)* *Potamogeton crispus(5%)*	*Chara corallina(30%)* *Potamogeton ochreatus(4%)*	Hornwort plants (2) found 3.5m depth
14	0.4	*Elodea canadensis(60%)* *Ceratophyllum demersum(5%)* *Potamogeton crispus(5%)*	*Chara corallina(30%)* *Potamogeton ochreatus*	Hornwort plants (many) found 3-5m depth
Total	8.25			

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