# Assessment of 47 Lakes in the Manawatu-Whanganui Region using LakeSPI

June 2021

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## using LakeSPI

*Prepared for Horizons Regional Council*

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# Executive summary

Horizons Regional Council contracted NIWA to report on the ecological condition of 47 lakes in the Manawatū-Whanganui region using LakeSPI (Submerged Plant Indicators). LakeSPI is a bioassessment method that uses the degree of development by native submerged plants, and level of impact by non-native, invasive weeds to indicate a lakes ecological condition. Lakes were assessed over five main survey occasions between November 2015 and December 2020. New or repeat surveys carried out for inclusion into this report included: Alice, Dudding, Centennial (Hokowhitu) Lagoon, Namunamu, Pauri, Pukepuke Lagoon, Virginia (Rotokawau), Waipu and Wiritoa.

Of the two lakes surveyed for the first time in 2020, Centennial Lagoon was categorised in excellent condition, and Lake Virginia in moderate condition. Of the seven lakes resurveyed, Pukepuke Lagoon improved moving from moderate to high condition, while lakes Namunamu and Alice remained in moderate condition, and lakes Pauri and Wiritoa in poor condition. Lake Waipu improved from being classified as non-vegetated to moderate condition.

LakeSPI indices for lakes in the Manawatū-Whanganui Region ranged from 0% (heavily impacted lakes) to 97% (pristine, unimpacted lakes). Lakes were categorised into five categories according to the value of the most recent LakeSPI Index and compared with 310 lakes nationally.

Excellent: 11 lakes in the Manawatū-Whanganui Region had a LakeSPI Index >75% that classified them to be in excellent ecological condition according to LakeSPI. This included lakes Hukanui Swamp, Otamataraha, Herbert, Ohinetonga Lagoon, Twin Lakes, Centennial Lagoon, Waipakuranui, Mahangaiti, Green Pond Wetland, Te Paata Wetland and Meremere. These water bodies had substantial native vegetation with no or very little impact from invasive weed species. A slightly higher proportion of Manawatū-Whanganui lakes fall into this excellent category compared with lakes nationally.

High: Six lakes had a LakeSPI Index >50-75% that classified them to be in high ecological condition. This included lakes Karere Lagoon, Rotorua, Ram Hills Dam, Pukepuke Lagoon, Omanuka Lagoon and Rotokauwau. High status lakes are under-represented in the region compared to lakes nationally.

Moderate: 16 lakes were categorised in moderate condition with LakeSPI indices of >20-50%. This included lakes: Kaitoke, Rotoataha, Heaton, Huia Road, Christies, Otamangakau, Virginia, Waipu, Saddle Road, Namunamu, Voss Lagoon, Alice, Bernard, Koputara, Maungarataiti, Maungaratanui. All of these lakes reflected differing degrees of impact from invasive weeds and/or restricted development of native plant communities. A higher proportion of Manawatū-Whanganui lakes fall into this moderate category compared with lakes nationally.

Poor: Eight lakes with LakeSPI indices <20% were categorised in poor condition according to LakeSPI, with all lakes being heavily impacted by hornwort (*Ceratophyllum demersum*) or egeria (*Egeria densa*). These included lakes: Koitiata, Dudding, Omanu, Pauri, Kohata, Ngaruru, Kopureherehere, William and Wiritoa. In the case of lakes Koitiata, Dudding, Pauri, Ngaruru, Kopureherehere and William, both the presence of weed and poor water clarity contributes to their poor condition. A higher proportion of Manawatū-Whanganui lakes fall into this poor category compared with lakes nationally.

Non-vegetated: Five lakes scored a LakeSPI Index of 0% due to the lack of any significant submerged vegetation. These included lakes: Pounamu, Papaitonga, Poroa, Westmere and the Manawatū Gorge Dam. A lower proportion of the region's lakes are non-vegetated compared to lakes nationally.

Influences impacting on ecological condition included the presence of the regions worst submerged weed species, hornwort and egeria, that are currently present in 43% of the vegetated lakes surveyed. These weeds have quickly spread through lakes in the region with six new lakes reported to have been invaded by hornwort in the last seven years (since 2013). Hornwort and egeria are ranked as New Zealand's worst submerged weed species and it is likely that we will see a reduction in the condition of the region's lakes, as recently recorded for Lake Ngaruru, if these weed species continue to invade new water bodies and impact on existing submerged vegetation.

Poor water clarity and prevalence of planktonic and epiphytic algal blooms were also noted from most lakes, indicating eutrophication. Prolonged effects of these impacts are likely to lead to further deterioration of submerged vegetation.

It is recommended that a schedule for LakeSPI monitoring be developed with priorities and timing for re-surveys based on perceived lake value, stability and known threats to the lakes. It is also recommended that lake-specific weed management plans be considered for the Manawatū - Whanganui Region to improve ecological condition and achieve better outcomes for recreational users.

It is intended that this report will be used to help inform lakes prioritisation work that is occurring as part of a larger Horizons project.

# 1 Introduction

## 1.1 Background

The Manawatū-Whanganui Region has approximately 226 lakes greater than 1 ha in size (Freshwater Ecosystems of New Zealand geo-database). Lake types in the region include seven geomorphic formation types: volcanic, riverine, landslide, wetland-formed, beach-lagoons, dune lakes, and man-made reservoirs. Horizons Regional Council have a duty to monitor, report and make information available about the state of the freshwater environment and must also plan and regulate to protect water resources with minimised or mitigated impacts to the natural environment.

Amongst the threats to lakes in the region are land use changes and agricultural intensification which can result in increased nutrient loads to water bodes. The introduction of alien aquatic invaders such as weeds or algae puts further pressure on vulnerable native ecosystems.

Lake surveys using LakeSPI (Submerged Plant Indicators), a biomonitoring method used to assess ecological condition of lakes, were initiated in 2015. Since that time (to 2020), LakeSPI surveys have been undertaken for 47 lakes in the region, with many being monitored on more than one occasion so that changes over time can be identified.

This report provides LakeSPI results for each lake (Section 3), accompanied by a brief description of vegetation character, and discussion of impacts or threats that may be facing these lakes. Finally, recommendations are provided on priorities and schedules for future LakeSPI monitoring of lakes based on their apparent stability, value, and perceived threats (Section 4). It is intended that the results from this work will be used to help inform lakes prioritisation work that is occurring as part of a larger Horizons project.

## 1.2 Study lakes

Forty-seven lakes located within the Manawatū-Whanganui Region have been assessed for this report (Figure 1). Lakes resurveyed or surveyed for the first time in December 2020 include: Alice, Dudding, Centennial (Hokowhitu) Lagoon, Namunamu, Pauri, Pukepuke Lagoon, Virginia (Rotokawau) and Wiritoa. A re-survey of Lake Waipu carried out under a separate project in January 2020 has also been included.

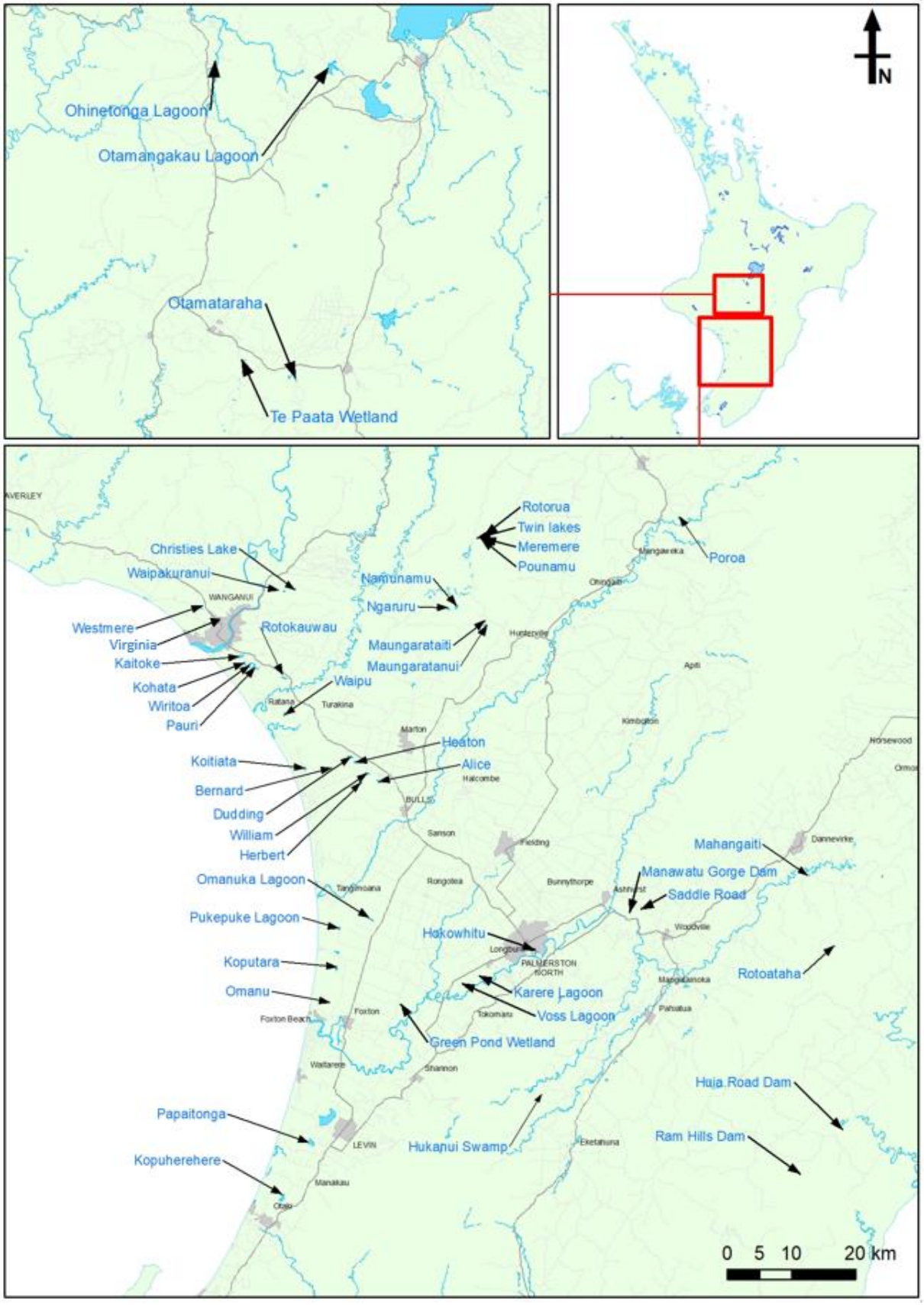



**Figure 1: Map showing location of the 47 Manawatū-Whanganui lakes surveyed using LakeSPI.**

**Table 1: Lake identification number and map co-ordinates of 47 lakes surveyed for this report (data supplied by Horizons Regional Council).**

| Lake name | FENZ # | Ecotype # | Easting (NZMG) | Easting (NZMG) |
|---|---|---|---|---|
| Alice | 13456 | 814 | 2708701.752 | 6116461.844 |
| Bernard | 13438 | 800 | 2704793.11 | 6118672.285 |
| Centennial Lagoon | 5363 | 1009 | 2733325 | 6089800 |
| Christie's (Rotokura) | 19140 | 775 | 2695553.494 | 6146459.684 |
| Dudding | 13447 | 798 | 2704403.588 | 6120292.037 |
| Green Pond Wetland | 877 | 17746 | 2712108 | 6081766 |
| Heaton | 13446 | 801 | 2705153.234 | 6119492.02 |
| Herbert | 17363 | 805 | 2705922.323 | 6116342.513 |
| Huia Road Dam | 5610 | n/a | 2781187 | 6062082 |
| Hukanui Swamp | 54966* | 17856 | 2733800.199 | 6067899.821 |
| Kaitoke | 18936 | 409 | 2687131.269 | 6136054.426 |
| Karere Lagoon | 4509 | 952 | 2724339 | 6086143 |
| Kohata | 17214 | 417 | 2687710.824 | 6134954.391 |
| Koitiata | 16901 | 879 | 2697144.551 | 6118534.218 |
| Kopureherehere | 847 | 1043 | 2693572.076 | 6051957.914 |
| Koputara | 5008 | 18439 | 2702067.919 | 6087238.758 |
| Mahangaiti | 31749 | 1443 | 2775846.057 | 6101816.632 |
| Manawatū Gorge Dam | 5492 | n/a | 2747871 | 6095964 |
| Maungarataiti | 20094 | n/a | 2724964.279 | 6141180.803 |
| Maungaratanui | 20096 | n/a | 2725374.04 | 6140840.78 |
| Meremere | 20240* | 748 | 2724924 | 6154472 |
| Namunamu | 19624 | 733 | 2720856.386 | 6143731.368 |
| Ngaruru | 19621 | 16368 | 2719566.667 | 6143441.886 |
| Ohinetonga Lagoon | 21313 | 3135 | 2717234.289 | 6242451.787 |
| Omanu | 4380 | 892 | 2700987.481 | 6081669.773 |

| Lake name | FENZ # | Ecotype # | Easting (NZMG) | Easting (NZMG) |
|---|---|---|---|---|
| Omanuka Lagoon | 5306 | 915 | 2707567.965 | 6094916.636 |
| Otamangakau | 21383 | 1097 | 2737665.539 | 6241325.535 |
| Otamataraha | 20673 | 17825 | 2731361.984 | 6187382.027 |
| Papaitonga | 1974 | 1071 | 2698196.634 | 6060072.947 |
| Pauri | 18933 | 421 | 2689410.337 | 6134243.932 |
| Poroa | 17286 | n/a | 2755707.939 | 6157583.833 |
| Pounamu | 20239 | n/a | 2724677 | 6154424 |
| Pukepuke Lagoon | 5042 | 18462 | 2702458.714 | 6093577.631 |
| Ram Hills Dam | 5446 | n/a | 2774628 | 6055132 |
| Rotoataha | 5955 | 1502 | 2779883.672 | 6090751.846 |
| Rotokauwau | 17014 | 769 | 2693957 | 6132620 |
| Rotorua | 55000* | 748 | 2725214 | 6154876 |
| Saddle Road | 55003* | n/a | 2749661 | 6096456 |
| Te Paata Wetland | 20693 | 18540 | 2722515 | 6190705 |
| Twin lake | 55002* | 552 | 2724064 | 6154442 |
| Virginia (Rotokawau) | 18957 | 293 | 2683857 | 6141544 |
| Voss (Rotane) Lagoon | 4506 | 946 | 2721727 | 6084923 |
| Waipakuranui | 19103 | 767 | 2693925 | 6146194 |
| Waipu | 16939 | 873 | 2694007.348 | 6126883.66 |
| Westmere | 18951 | 385 | 2680964.733 | 6143675.599 |
| William | 13437 | 807 | 2706942.438 | 6117761.963 |
| Wiritoa | 18934 | 418 | 2688600.597 | 6134664.137 |

*Lake number designated by NIWA.

## 1.3 Changes in lake vegetation

Lakes in the Manawatū-Whanganui Region have been significantly affected by changes both in water quality and through the introduction of invasive aquatic plants over the last 50+ years.

In a pristine state, lakes in the Manawatū-Whanganui Region would have once contained a diverse range of native plant species down to a depth determined by water clarity (Figure 2). For many of these relatively shallow lakes plant growth would have occurred across the entire lake bottom at some stage during their development and maturation. By 1949, Cunningham et al. (1953) described dune lakes of the region as generally having a sparse to low density of submerged vegetation, comprising scattered beds of charophytes (*Chara* species) and pondweeds (*Potamogeton* species).

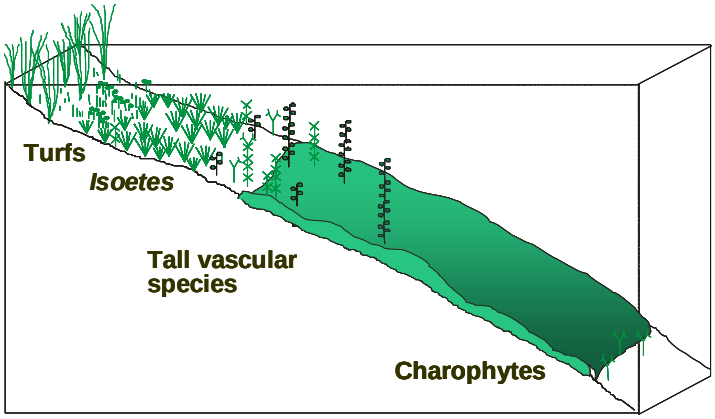



**Figure 2: Depth profile illustrating the main components of native lake vegetation.**

Kelly (1978) reported that the only invasive submerged species in the 12 lakes he had sampled were the curled pondweed (*Potamogeton crispus*), water buttercup (*Ranunculus trichophyllus*) and eelgrass (*Vallisneria australis* - in Lake Wiritoa only). However, he did report the presence of hornwort (*Ceratophyllum demersum*), egeria (*Egeria densa*), lagarosiphon (*Lagarosiphon major*) and elodea (*Elodea canadensis*) present within rivers and drains in the Manawatū area.

With the introduction of invasive 'oxygen weed' species (family Hydrocharitaceae) likely to have occurred during the 1980's and 1990's, native plants in invaded lakes would have been displaced by the impacts from tall mono-specific weed beds (Figure 3). Most of the regions lakes now remain in various stages of this state and remain vulnerable to further change.

As well as displacing other submerged plants, dense invasive weed growth can restrict the movement of water, cause flooding, block irrigation and drinking water intakes, destroy habitats for native fish and wildlife, decrease water quality and can restrict recreational activities such as boating, fishing and swimming.

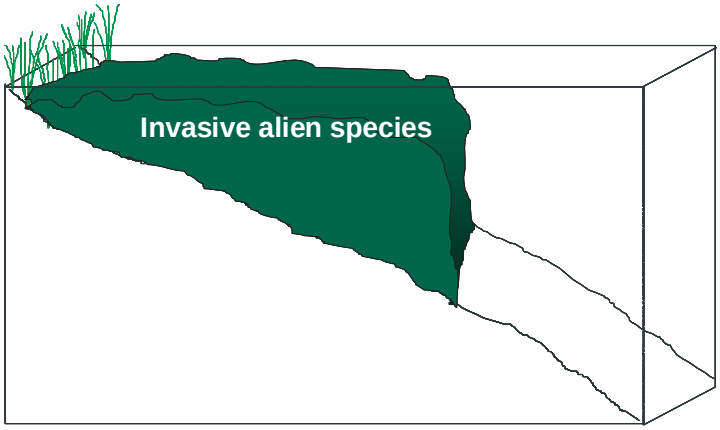



**Figure 3: Depth profile illustrating the potential impact of invasive species.**

Further degradation of shallow lakes may occur where submerged vegetation is lost completely (Figure 4) and the lake becomes turbid and dominated by planktonic (usually cyanobacteria) algal blooms. A few Manawatū-Whanganui lakes are in this non-vegetated condition.

Although invasive species are not favourable in terms of overall lake condition, the presence of any submerged plants in a lake is preferable to none, in that they can help mitigate many of the symptoms of eutrophication (e.g., lock-up nutrients, maintain water clarity, compete with phytoplankton).

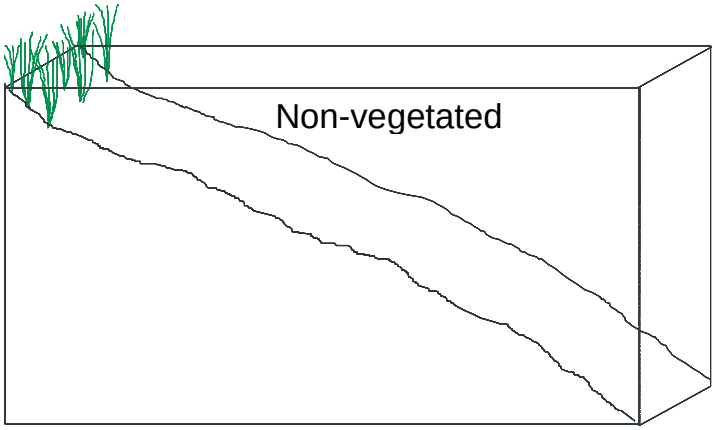



**Figure 4: Depth profile illustrating a non-vegetated lake.**

## 1.4 Plants as indicators of lake condition

Submerged plants have a number of advantages that favour their use as indicators of lake condition. For example, they are predominantly rooted or anchored to the bed of lakes. They are also macroscopic and perennial in nature, and together these features make them easy to observe, sample and identify. This contrasts with many other biota that can be highly mobile (e.g., fish) or difficult to sample, measure or identify (e.g., plankton).

Submerged plants also effectively integrate the range of environmental conditions supporting plant growth over an extended period of time prior to survey. This contrasts with other physio-chemical methods (e.g., water chemistry and Secchi disc), which may change markedly over short time periods and require frequent measurements throughout the year.

In lakes where the littoral zone (lake margin to maximum plant depth) represents a large proportion of the lake area (e.g., small shallow dune or peat lakes), the open water (or lake centre) condition can have quite different water quality and ecological condition compared to the littoral zone. Given the importance of the littoral zone to the overall ecological state and recreational value of many lakes it is important to monitor the ecological well-being and biological functioning of the littoral zone where submerged plants tend to dominate.

Increased sediment and nutrient loading from catchment activities, and displacement of native vegetation by invasive alien plant species are major influences on lake ecology and condition. The submerged plant indicators used in LakeSPI provide an effective means of assessing these impacts.

# 2 Study methods

## 2.1 LakeSPI

LakeSPI is a management tool that uses Submerged Plant Indicators (SPI) for assessing the ecological condition of New Zealand lakes and for monitoring changes in lakes. Key features of aquatic vegetation structure and composition are used to generate three LakeSPI indices:

- 'Native Condition Index' – This captures the native character of vegetation in a lake based on diversity and extent of indigenous plant communities. A higher score means healthier, deeper, diverse submerged vegetation.
- 'Invasive Impact Index' – This captures the invasive character of vegetation in a lake based on the degree of impact by invasive weed species. A higher score means more impact from exotic species, which is often undesirable.
- 'LakeSPI Index' – This is a synthesis of components from both the native condition and invasive impact condition of a lake and provides an overall indication of lake condition. The higher the score the better the condition.

Key assumptions of the LakeSPI method are that native plant species and high plant diversity represents healthier lakes or better lake condition, while invasive plants are ranked for undesirability based on their displacement potential and degree of measured ecological impact (Clayton and Edwards 2006).

Because lakes have differing physical characteristics that can influence the extent and type of submerged vegetation, each of the LakeSPI indices are expressed in this report as a percentage of a lake's maximum scoring potential. Scoring potential reflects the maximum depth of the lake to normalise the results from very different types of lakes. A lake scoring full points for all LakeSPI indicator criteria would result in a LakeSPI Index of 100%, a Native Condition Index of 100% and an Invasive Impact Index of 0%.

A complete description of measured characteristics is given in the technical report and user manual at www.lakespi.niwa.co.nz/about. The LakeSPI method is supported by a web-reporting service found at www.lakespi.niwa.co.nz, where scores for lakes assessed to date can be searched and displayed. This secure and freely-accessible data repository allows agencies to compare lake scores with other lakes regionally and nationally as required.

## 2.2 Field surveys

The LakeSPI method (Clayton and Edwards 2006) was applied to 3-5 LakeSPI baseline sites selected within each of the 47 Horizons lakes. Baseline sites were selected to be representative of maximal vegetation development and situated away from local influences such as streams.

At each site, scientific divers recorded relevant vegetation characteristics on data sheets. A full description of the vegetation features that are assessed for the LakeSPI method can be found in the technical report and user manual on the web-reporting pages (www.lakespi.niwa.co.nz), but includes measures of diversity from the presence of key plant communities, the depth extent of vegetation and the extent that invasive weeds are represented.

Observations were then entered into the NIWA LakeSPI database which is used to calculate LakeSPI indices for each lake. Additionally, an inventory of all submerged plant species encountered was also made (Appendix A).

While casual observations were recorded of emergent and free-floating aquatic plant species encountered at LakeSPI sites within the lakes, these records do not form part of this report.

All equipment and boats were decontaminated between sites according to NIWA's standard operating procedures to prevent the spread of freshwater invasive species (Burton 2019). These precautions equal or exceed the Check, Clean, Dry protocols (MPI 2017).

## 2.3 LakeSPI status

For ease of reporting results, five lake condition categories are used to provide a description of a lakes status at the time of a survey. These categories are allocated according to the LakeSPI Index score:

| **Score** | = | **LakeSPI Category** |
|---|---|---|
| >75% | = | Excellent |
| >50-75% | = | High |
| >20-50% | = | Moderate |
| >0-20% | = | Poor |
| 0% | = | Non-vegetated |

## 2.4 LakeSPI change

Changes in LakeSPI indices can be assessed over multiple surveys to provide an indication of current stability in lake condition and the direction of any change. Guidelines (Figure 5) based on expert judgement suggest a scale of probabilities for determining the ecological significance of change in lake condition, using averaged LakeSPI indices over repeated surveys. These guidelines have considered variation by different observers and the response of LakeSPI scores to major ecological events in lakes. The significance for the various levels of change are:

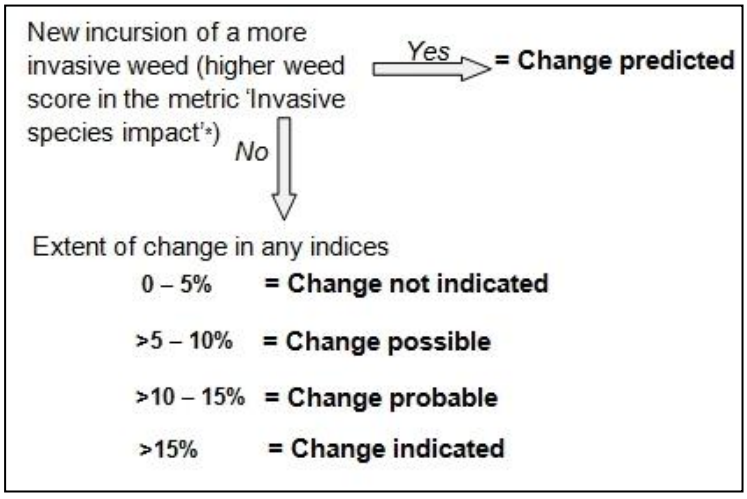



**Figure 5: Guidelines assessing the significance of change in LakeSPI Indices over multiple surveys of a lake.**

In addition, the likelihood of a statistically significant change in LakeSPI scores over time is based on analysis of the direction and magnitude of change in indices across the surveyed sites. A paired t-test (GraphPad InStat) was used to compare site results between surveys at the significance level $p < 0.05$.

# 3 LakeSPI report cards

Table 2 presents LakeSPI results for each lake in order of their LakeSPI Index scores, with the indices presented as a percentage of maximum scoring potential. In the following section the lakes are discussed in alphabetical order.

**Table 2: Summary of current LakeSPI indices,** for 47 Horizons lakes in order of their overall lake condition.

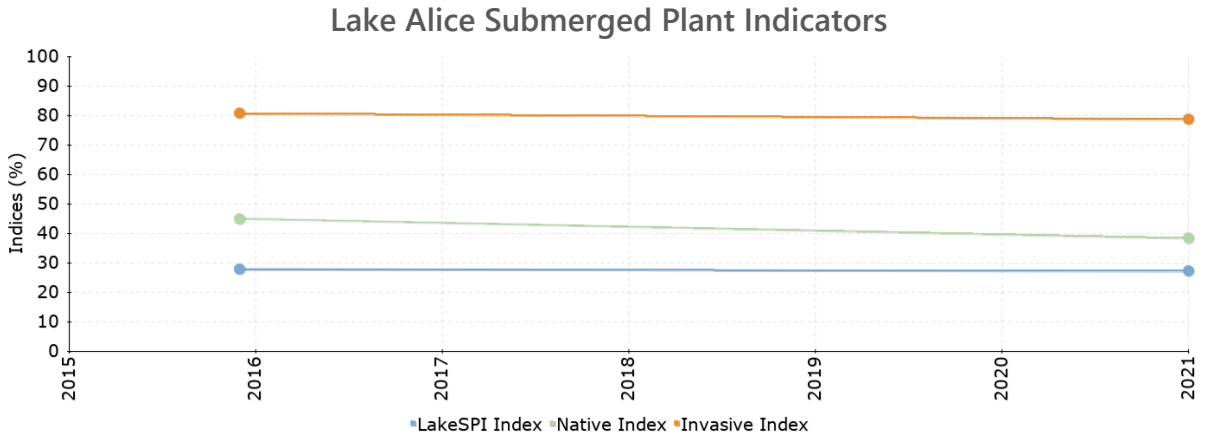
| Lake | Most Recent LakeSPI Survey | LakeSPI Index (%) | Native Condition Index (%) | Invasive Impact Index (%) | Overall Condition |
|---|---|---|---|---|---|
| Hukanui Swamp | 05/12/2017 | 97 | 93 | 0 | |
| Otamataraha | 03/12/2019 | 94 | 86 | 0 | |
| Herbert | 06/12/2017 | 94 | 85 | 0 | |
| Ohinetonga Lagoon | 03/12/2017 | 91 | 80 | 0 | |
| Twin lakes | 13/11/2018 | 90 | 77 | 0 | |
| Centennial Lagoon | 02/12/2020 | 90 | 77 | 0 | Excellent |
| Waipakuranui | 05/12/2019 | 83 | 65 | 0 | |
| Mahangaiti | 05/12/2017 | 81 | 70 | 11 | |
| Te Paata Wetland | 03/12/2019 | 78 | 56 | 0 | |
| Green Pond Wetland | 15/11/2018 | 78 | 70 | 16 | |
| Meremere | 13/11/2018 | 77 | 54 | 0 | |
| Karere Lagoon | 12/11/2018 | 64 | 67 | 34 | |
| Rotorua (Rangitikei) | 13/11/2018 | 56 | 47 | 30 | |
| Ram Hills Dam | 15/11/2018 | 55 | 57 | 44 | |
| Pukepuke Lagoon | 04/12/2020 | 53 | 69 | 51 | High |
| Omanuka Lagoon | 24/11/2016 | 52 | 61 | 49 | |
| Rotokauwau | 05/12/2019 | 52 | 67 | 56 | |
| Kaitoke | 04/12/2017 | 46 | 47 | 54 | |
| Rotoataha | 05/12/2017 | 44 | 38 | 47 | |
| Heaton | 06/12/2017 | 43 | 39 | 29 | Moderate |
| Huia Road Dam | 15/11/2018 | 42 | 26 | 44 | |
| Christies | 04/12/2017 | 40 | 71 | 73 | |

| Lake | Most Recent LakeSPI Survey | LakeSPI Index (%) | Native Condition Index (%) | Invasive Impact Index (%) | Overall Condition |
|---|---|---|---|---|---|
| Otamangakau | 02/12/2009 | 38 | 50 | 72 | |
| Virginia | 30/11/2020 | 36 | 36 | 58 | |
| Waipu | 10/02/2020 | 34 | 28 | 68 | |
| Saddle Road | 14/11/2018 | 32 | 32 | 72 | |
| Namunamu | 02/12/2020 | 29 | 37 | 79 | |
| Voss Lagoon | 12/11/2018 | 28 | 32 | 74 | Moderate |
| Alice | 03/12/2020 | 27 | 38 | 79 | |
| Bernard | 12/11/2015 | 27 | 40 | 79 | |
| Koputara | 24/11/2016 | 25 | 32 | 81 | |
| Maungaratiti | 22/11/2016 | 22 | 28 | 86 | |
| Maungaratanui | 22/11/2016 | 22 | 20 | 86 | |
| Koitiata | 12/11/2015 | 19 | 39 | 93 | |
| Dudding | 03/12/2020 | 18 | 11 | 87 | |
| Omanu | 24/11/2016 | 17 | 25 | 89 | |
| Pauri | 01/12/2020 | 16 | 20 | 96 | |
| Kohata | 10/11/2015 | 16 | 21 | 94 | Poor |
| Ngaruru | 04/12/2019 | 14 | 16 | 95 | |
| Kopureherehere | 06/12/2017 | 11 | 3 | 87 | |
| William | 11/11/2015 | 11 | 0 | 93 | |
| Wiritoa | 01/12/2020 | 9 | 5 | 97 | |
| Manawatū Gorge Dam | 14/11/2018 | 0 | 0 | 0 | |
| Papaitonga | 12/11/2015 | 0 | 0 | 0 | |
| Poroa | 22/11/2016 | 0 | 0 | 0 | Non-vegetated |
| Pounamu | 13/11/2018 | 0 | 0 | 0 | |
| Westmere | 25/11/2016 | 0 | 0 | 0 | |

## 3.1 Lake Alice

### 3.1.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 24th equal |
| Lake maximum depth: | 2.3m (2020) |
| Max depth of vegetation: | 2.3 m |




| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2020 | Moderate | 27% | 38% | 79% |
| November 2015 | Moderate | 28% | 45% | 81% |

**Figure 6: LakeSPI results for Lake Alice.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Alice is categorised as being in moderate ecological condition with a LakeSPI Index of 27% (Figure 6).

A mixed community of submerged vegetation extended across the bottom of Lake Alice to the lakes maximum observed depth of 2.3 m (December 2020) (Figure 7).

Invasive weed species egeria (*Egeria densa*) (Figure 8) and elodea (*Elodea canadensis*) formed clumps of near surface reaching weed (tops removed by swans) at all LakeSPI sites, extending across the lake bottom. An introduced pondweed *Potamogeton crispus*, was also recorded.

Two native submerged plant species were recorded in Lake Alice. A native milfoil species *Myriophyllum triphyllum* was the most abundant of these with its flowering stems forming surface reaching (Figure 7 and Figure 9) bands along the lake margins growing down to a maximum depth of 2.3 m. A native pondweed *Potamogeton ochreatus* was also present. Moderate to high covers of these native species contributed to a Native Condition Index of 38% (Figure 6).

At the time of survey, through-water visibility was low and estimated by divers to be <1 m. No freshwater mussels were observed.

*Historic vegetation notes:* Egeria and elodea were not recorded from within Lake Alice during a spot survey of submerged vegetation carried out by NIWA in March 2003 (Champion and Wells 2003). Kelly (1978) surveyed this lake in February 1978 finding the native pondweeds (*Potamogeton ochreatus*, *Potamogeton cheesemanii*) and the introduced pondweed (*Potamogeton crispus*) to be common throughout. Other submerged species noted during this early survey were *Ranunculus fluitans* (now *Ranunculus trichophyllus*), *Ottelia ovalifolia*, an unidentified Myriophyllum species, and only one fragment of charophyte noted as "probably *Nitella hookeri*".

### 3.1.2 Discussion

A high Invasive Impact Index of 79% (Figure 6) reflects the major impact the invasive weeds egeria and to a lesser extent elodea are having on the submerged vegetation in Lake Alice. Despite this, native plants still persisted at all profile sites resulting in a moderate Native Condition Index of 40%.

Water levels were lower during the 2020 survey with the maximum observed depth being 2.3 m compared to 3.2 m recorded in 2015.

The submerged vegetation was similar in 2015, with slightly lower LakeSPI scores possibly reflecting the shallower nature of this water body in 2020.

Lake Alice still remains at risk of invasion from hornwort (*Ceratophyllum demersum*), with contaminated boat traffic representing the greatest threat.

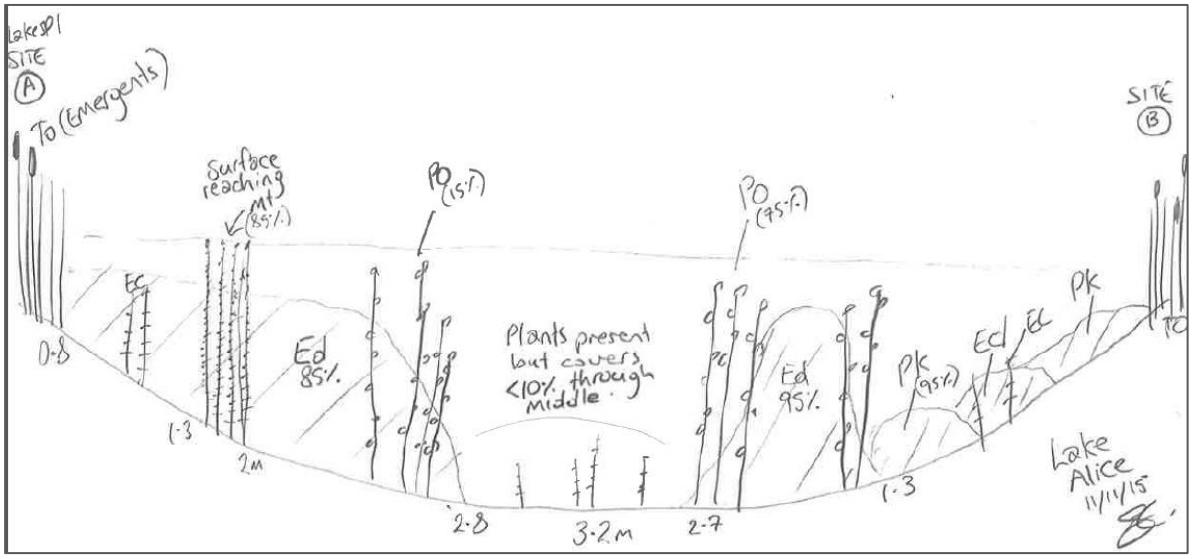



**Figure 7: Profile sketch showing submerged plants growing across the bottom of Lake Alice in 2015.**

**Figure 8: Egeria in Lake Alice (Photo, 2020).**

**Figure 9: The red flowers of *Myriophyllum triphyllum* were visible on the surface of Lake Alice (Photo, 2015).**

## 3.2 Lake Bernard

### 3.2.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 24th equal |
| Lake maximum depth: | 6.7 m |
| Max depth of vegetation: | c. 5 m |

Lake Bernard Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2015 | Moderate | 27% | 40% | 79% |

**Figure 10: LakeSPI results for Lake Bernard.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Bernard is categorised as being in moderate ecological condition with a LakeSPI Index of 27% (Figure 10).

Two native charophyte species, *Nitella* sp. aff. *cristata* and *Chara australis* (Figure 11) formed near complete covers at all sites, with charophyte meadows (>75% cover) recorded from three of the four LakeSPI sites to a maximum depth of 1.8 m. Other native species recorded from this lake included *Potamogeton ochreatus*, a turf plant *Glossostigma diandrum*, water buttercup *Ranunculus amphitrichus* (one plant) and an unidentified moss species (most likely *Drepanocladus aduncus*).

Hornwort (*Ceratophyllum demersum*) was present at all surveyed sites growing down to c. 3.2 m depth, with occasional shoots still found anchored in sediment below 5.5 m. Beds were variable in cover, forming a closed cover at only two of the four sites forming beds up to 2.2 m tall. Hornwort plants were etiolated, presumably as a result of low light levels, with whorls of leaves widely spaced along stems (Figure 12). *Potamogeton crispus* was also present at low covers.

A thick covering of algae was noted by divers on plants from the lake edge down to 1.5 m depth.

*Historic vegetation notes:* No hornwort was recorded from Lake Bernard when visited by NIWA in March 2003 (Champion and Wells 2003). Native species present were similar to those described above.

### 3.2.2 Discussion

The extent of native vegetation still present in Lake Bernard and lower covers of hornwort at some sites contributed to the lake being categorised in moderate condition with a LakeSPI Index of 27% (Figure 10).

A Native Condition Index of 40% (Figure 10) reflected the extent and cover of native plants in the lake and charophyte meadows (>75% cover) were recorded from most sites.

Charophyte meadows are particularly sensitive to invasive displacement and reduced water clarity (Clayton and Edwards 2006), so should the conditions observed in Lake Bernard continue long-term, we could expect to see these native communities disappear in the future.

The extent of native vegetation still present in Lake Bernard and lower covers of hornwort at some sites contributed to the lake being categorised in moderate condition (Figure 10).

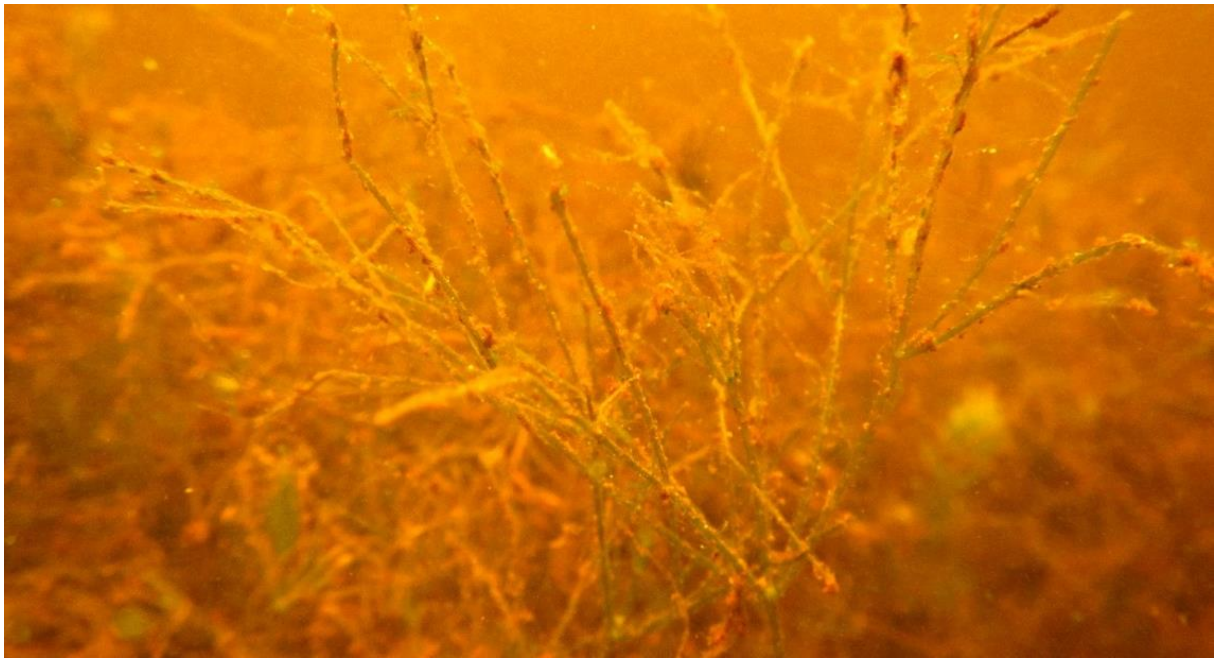


**Figure 11: Charophytes growing in Lake Bernard covered in algae.**

**Figure 12: Hornwort growing in Lake Bernard showing etiolated stems.**

## 3.3 Centennial (Hokowhitu) Lagoon

### 3.3.1 Results

| | |
|---|---|
| Lake condition: | Excellent |
| Lake ranking: | 5th equal |
| Lake maximum depth: | 2.5 m |
| Max depth of vegetation: | 2.5 m |

Centennial (Hokowhitu) Lagoon Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2020 | Excellent | 90% | 77% | 0% |

**Figure 13: LakeSPI results for Centennial Lagoon.** LakeSPI indices expressed as a percentage of lake maximum potential.

Centennial Lagoon is categorised as being in excellent condition with a LakeSPI Index of 90% (Figure 13).

Native submerged vegetation extended across the bottom of Centennial Lagoon to the lakes maximum observed depth of 2.5 m.

Two native charophyte species (*Nitella* sp. aff. *cristata* and *Chara australis*) and a native pondweed *Potamogeton ochreatus* (Figure 14) were recorded from the lake. *Nitella* sp. aff. *cristata* was the most abundant of these species and it formed meadows (>75% cover) at three of the four LakeSPI sites extending across the bottom. *Potamogeton ochreatus* was also recorded from all four sites forming low to moderate covers across the shallow bottom to a maximum depth of c. 1.5 m.

No invasive species were recorded from within the lake.

At the time of the survey, water clarity was very poor with through-water visibility estimated by divers as only 0.5 m. No freshwater mussels or crayfish (koura) were observed.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out in March 2003 (Champion and Wells 2003) recorded the presence of the invasive species egeria (*Egeria densa*), *Elodea canadensis* and *Potamogeton crispus*. Egeria was described at the time of the 2003 survey as being surface reaching.

### 3.3.2 Discussion

Centennial Lagoon is categorised as being in excellent condition, representative of those lakes in the Manawatū-Whanganui Region that maintain a well-developed native plant community in the absence of any invasive weed species (Table 3). This is reflected in a high LakeSPI Index of 90% and Native Condition Index of 77% (Figure 13).While historic notes of the vegetation recorded the

presence of three invasive species (*Egeria densa*, *Elodea canadensis*, *Potamogeton crispus*) in March 2003 (Champion and Wells 2003), none of these were observed from the four sites surveyed in 2020. Extreme fluctuations in water level are likely to account for their disappearance since that time.

The re/introduction of invasive weed species (i.e., egeria) into Centennial Lagoon remains a major threat to current lake condition. This lakes very public and central location, and its popularity for recreational use means that aquarium liberations, contaminated small boats, fishing nets and other recreational equipment likely represent the greatest threat.

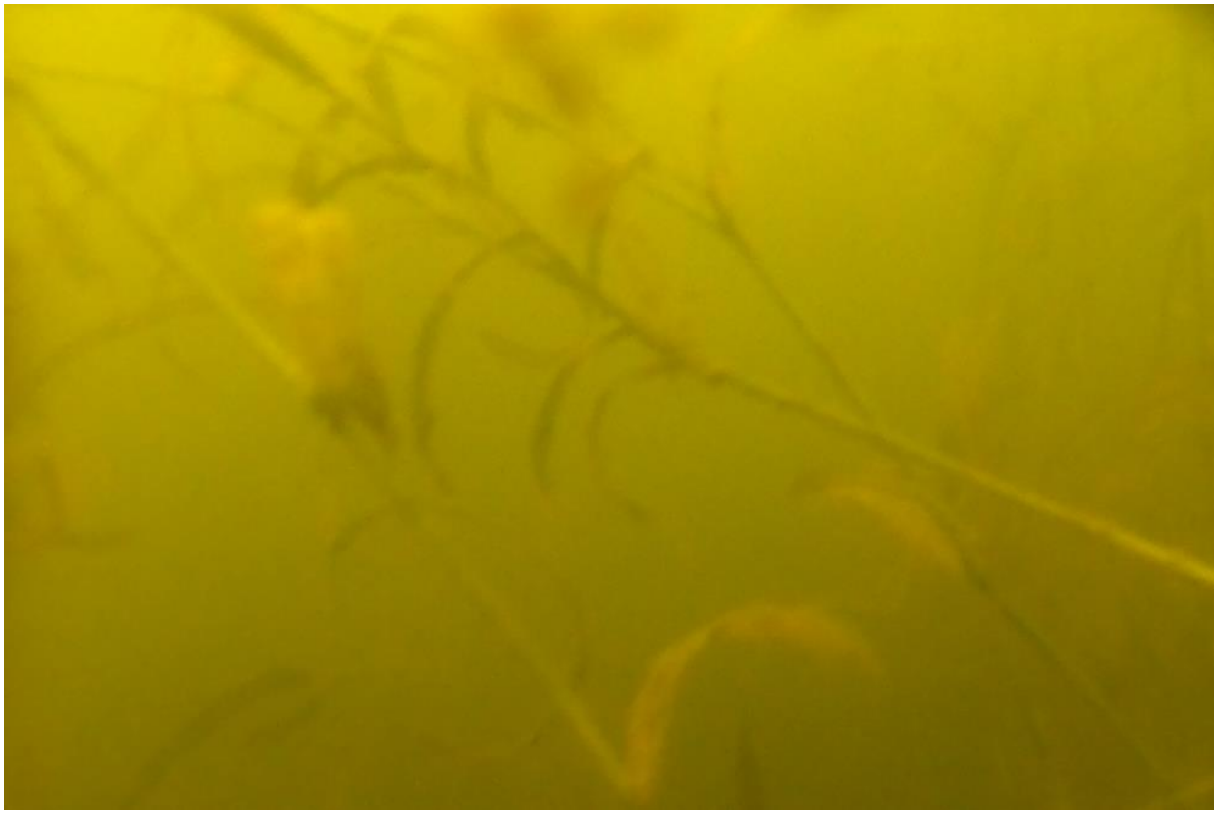


**Figure 14: Pondweeds growing in Centennial Lagoon.**

## 3.4 Christies Lake (Rotokura)

### 3.4.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 22nd |
| Lake maximum depth: | 3.7 m |
| Max depth of vegetation: | 3.7 m |

**Christies Lake Submerged Plant Indicators**

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2017 | Moderate | 40% | 71% | 73% |

**Figure 15: LakeSPI results for Christies Lake.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Christies Lake is categorised as being in moderate ecological condition with a LakeSPI Index of 40% (Figure 15).

A well-developed mixed community of native and invasive submerged species formed a dense cover of vegetation across the entire lake bottom to its maximum depth of 3.7 m.

Three native charophyte species (*Nitella* sp. aff. *cristata*, *Nitella pseudoflabellata*, *Chara australis*) were present in the lake with charophyte meadows (≥75 % cover) recorded at all five LakeSPI sites, extending from the shallows to a maximum depth of 3.6 m. Native pondweeds *Potamogeton ochreatus* (Figure 16), formed moderate to high cover clumps over the profile at four sites down to an average depth of 2.8 m. Occasional plants of *Myriophyllum triphyllum*, were also recorded from two sites.

Egeria (*Egeria densa*) was the only invasive species observed in the lake and surface reaching weed beds around the lake margin were flowering at the time of the recent survey (Figure 17). Egeria was present at all five sites and formed dense patches up to 2.8 m tall across the lake bottom (Figure 18).

At the time of the survey, good water clarity was observed in the lake with through-water visibility estimated by divers to be c. 4 m. Some algae was noted covering plants. No freshwater mussels were observed in the lake, but divers did observe perch (*Perca fluviatilis*) swimming in the lake.

### 3.4.2 Discussion

Despite egeria being established in Christies Lake, the extent and cover of native plants and charophyte meadows contributed to a high Native Condition Index of 71%, and moderate LakeSPI Index of 40% (Figure 15).

An Invasive Impact Index of 73% is less than what could be expected for this weed species, reflecting a limited level of impact that egeria is currently having on other vegetation in the lake. If the current findings reflect an early stage of invasion by egeria then we could expect to see a significant reduction in lake condition and LakeSPI scores in the future as the weed continues to spread. Another scenario could be that egeria has been present in the lake for some time but that the current environmental conditions are preventing it from forming high covers, but this is less likely.

Christies lake remains at risk of further invasion from hornwort (*Ceratophyllum demersum*), with contaminated boat traffic or fishing nets representing the greatest threat. It is advisable that the landowners be notified to exercise discretion in allowing access to the lake for users of equipment that may be contaminated by hornwort.

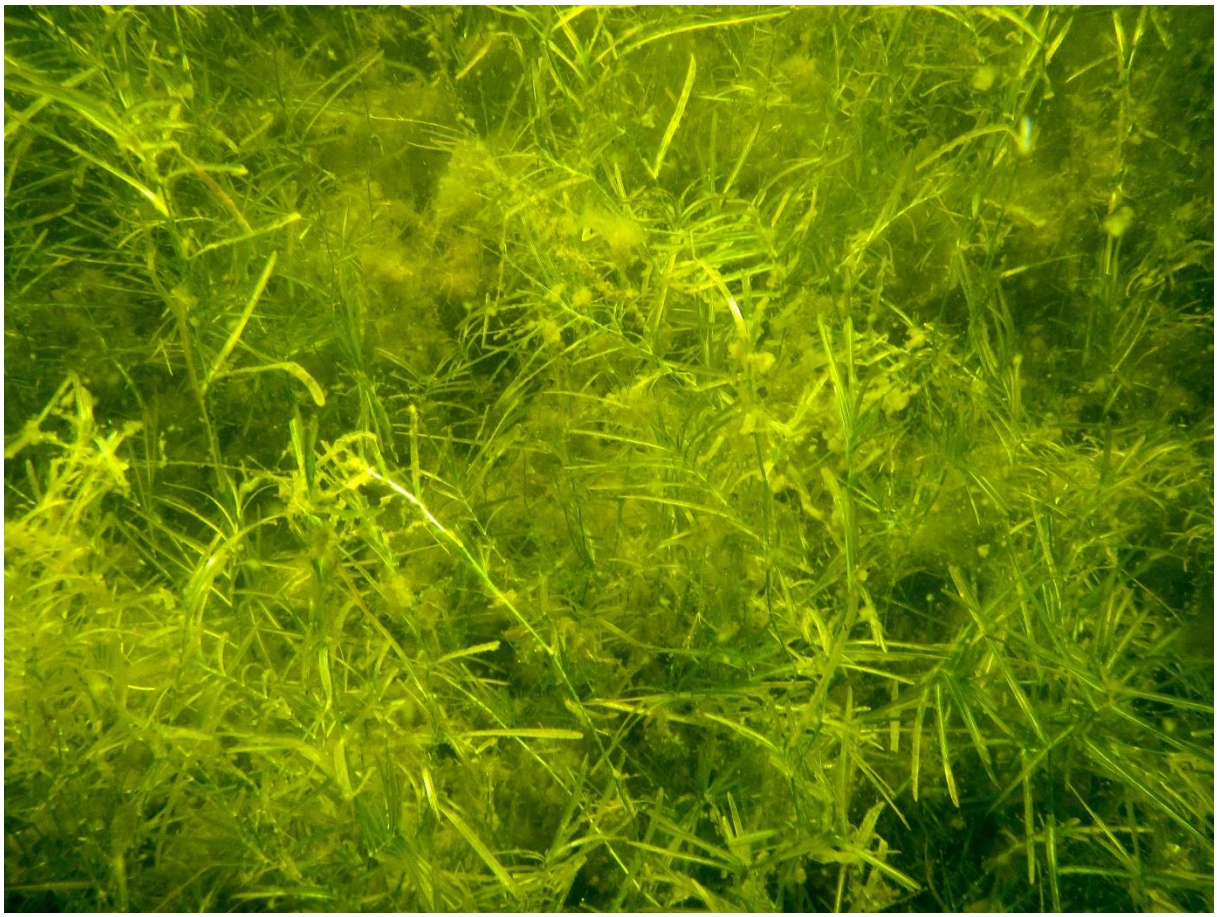


**Figure 16: Native pondweeds (*Potamogeton ochreatus*) growing amongst charophytes in Christies Lake.**

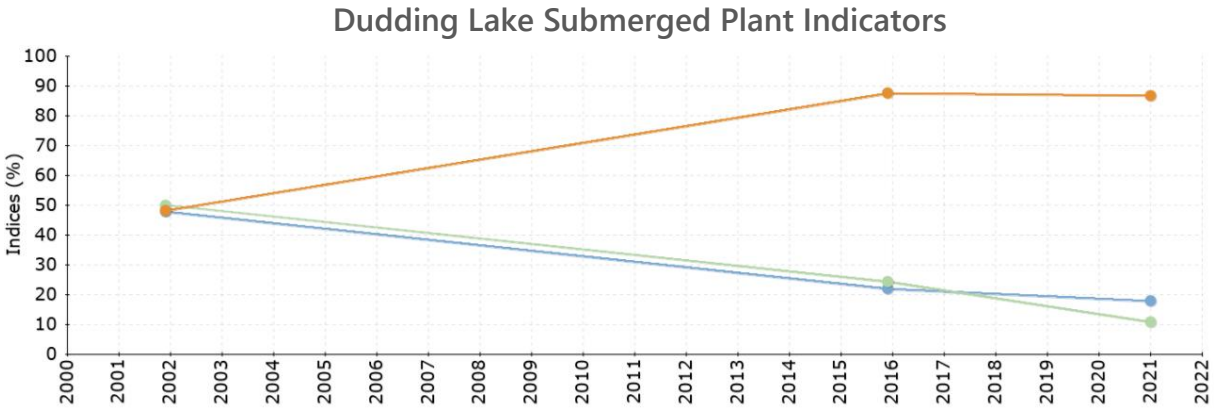
**Figure 17:** **Egeria was surface reaching and flowering around the margins of Christies Lake.**

**Figure 18:** **Egeria formed high cover patches across the bottom of Christies Lake.**

## 3.5 Dudding Lake

### 3.5.1 Results

| | |
|---|---|
| Lake condition: | Poor |
| Lake ranking: | 35th |
| Lake maximum depth: | 12.8 m |
| Max depth of vegetation: | c. 6 m |




| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2020 | Poor | 18% | 11% | 87% |
| November 2015 | Moderate | 22% | 24% | 87% |
| November 2001 | Moderate | 48% | 50% | 48% |

*Note: 2001 survey based on only 2 sites. 2020 survey based on topside observations.

**Figure 19: LakeSPI results for Dudding Lake.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Dudding Lake is categorised as being in poor ecological condition with a LakeSPI Index of 18% (Figure 19).

Egeria (*Egeria densa*) (Figure 20) dominated the submerged vegetation in Dudding Lake forming surface reaching weed beds around the lake margins exceeding 3 m in height, and extending down to a maximum depth of between 5.4 - 7 m at all five sites. Other introduced weeds included *Elodea canadensis* and the introduced pondweed *Potamogeton crispus*. *Ranunculus trichophyllus* was not observed during the 2020 survey.

Native vegetation consisted of the pondweed *Potamogeton ochreatus*, two charophyte species (*Nitella* sp. aff. *cristata*, *Chara australis*) and a turf forming species *Glossostigma diandrum*. Charophytes were recorded growing beyond the depth range of egeria (c. 5 - 6 m) at one site.

At the time of the 2020 survey, a phytoplankton bloom prevented divers from being able to enter the water. Freshwater mussels and sponges (recorded in 2015) were not observed using the topside monitoring methods in 2020.

*Historic vegetation notes:* When the submerged vegetation was surveyed in November 2001 (Edwards and Clayton 2002) it was described as "predominantly native and dominated by pondweeds and charophytes". Elodea was recorded for the first time during this survey although noted as common down to 3 m but forming only an open cover allowing other native plants to coexist. Species composition was similar to that observed by Kelly (1978) with vegetation recorded as growing down to a maximum depth of 5 m in 1977 and 6.5 m in 2001.

### 3.5.2 Discussion

A thick phytoplankton bloom present in Dudding Lake during the December 2020 survey, and during a prior visit in December 2017 (Burton 2020), prevented divers from being able to have any contact with the water. Instead a grapnel, drop camera and hydroacoustic data were used during the recent 2020 survey to confirm the presence of submerged plants, and collect the necessary data required for assessment by LakeSPI.

Previously sitting just above the threshold between the moderate and poor scoring categories, a LakeSPI Index of 18% in 2020 (Figure 19) has resulted in Dudding Lake now being categorised in poor condition. A significant reduction in the Native Condition Index from 24% in 2015 to 11% in 2020 reflects the absence of deeper water charophytes from four of the five sites since 2015, and loss of all charophyte meadows (> 75% cover).

The predominantly South Island charophyte species *Nitella masonae*, that was recorded from Dudding Lake during the 2015 survey, was not observed during the 2020 survey. This species had previously been recorded from within the Taranaki Region (Wood and Mason 1977), but no further North Island records had been found since.

Over the longer term, the LakeSPI Index has more than halved from 48% in 2001 (Figure 19) showing a marked increase in the Invasive Impact Index prior to the 2015 survey driven by the invasion of egeria in the lake. Other invasive weeds (*Elodea canadensis* and *Potamogeton crispus*) recorded from the lake are having little impact in comparison to the egeria.

A high risk of hornwort (*Ceratophyllum demersum*) introduction to Dudding Lake remains a major threat to current lake condition due to the popularity of this waterbody for recreational use and its close proximity to water bodies that contain this plant (e.g., Lake Wiritoa). Should hornwort get into Dudding Lake, it would likely occupy a deeper depth range than egeria, with the potential to displace all remaining deeper water charophytes currently co-existing with egeria.

Of noticeable concern during both the December 2017 and 2020 visits, were the exposed banks around the margin of the lake (Figure 21). In these areas, all marginal vegetation that would serve as buffer zones for nutrient interception had been removed and it is likely that the exposed sediments from the banks are directly contributing to an influx of nutrients entering the lake resulting in increased algae blooms in the lake.

**Figure 20:** ***Egeria densa*** **growing up towards the surface in Dudding Lake in 2015.**

**Figure 21: Exposed banks around Lake Dudding in December 2017.**

## 3.6 Green Pond Wetland

### 3.6.1 Results

| | |
|---|---|
| Lake condition: | Excellent |
| Lake ranking: | 9th equal |
| Lake maximum depth: | 1.8 m |
| Max depth of vegetation: | 0.9 m |

**Green Pond Wetland Submerged Plant Indicators**

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2018 | Excellent | 78% | 70% | 16% |

**Figure 22: LakeSPI results for Green Pond Wetland.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Green Pond Wetland is categorised as being in excellent ecological condition with a LakeSPI Index of 78% (Figure 22).

A narrow band of submerged plants, in most areas < 5 m wide, grew around the margin of the lake (Figure 23). Plants were surface reaching close to the lake margin and extended across the shallow lake bottom to a maximum depth of 0.9 m. The native pondweed *Potamogeton cheesemanii*, and milfoil *Myriophyllum propinquum* (Figure 24) were the most prevalent species present forming moderate to high covers up to 0.7 m tall at all five LakeSPI sites. Another native pondweed *Potamogeton ochreatus*, and an introduced submerged marginal species *Ludwigia palustris*, were also present.

Invasive species included the introduced pondweed *Potamogeton crispus*, and water buttercup *Ranunculus trichophyllus*. These species formed only low to moderate covers and were not recorded from all sites.

At the time of the survey, the water was very brown with through-water visibility estimated by divers as < 1 m. The lake had a firm sandy bottom but c. 80% of the lake was void of vegetation. No freshwater mussels were observed.

### 3.6.2 Discussion

The Green Pond Wetland lake generated an excellent LakeSPI Index of 77%, but it sits close to the threshold between the excellent and high condition category (75%). A diverse native plant community around the margins of this shallow pond, with little impact from introduced species contributed to this high score. None of the worst submerged weeds species were present.

With a maximum depth of just 1.8 m deep, Green Pond Wetland is close to the limit of being able to apply a LakeSPI assessment.

Water bodies less than one meter in depth, are not generally recommended for assessment using LakeSPI based on limitations in the methods metrics to detect change over time at shallow depths. The shallow nature of this waterbody makes it particularly vulnerable to change over a short time frame (e.g., vulnerability to drought).

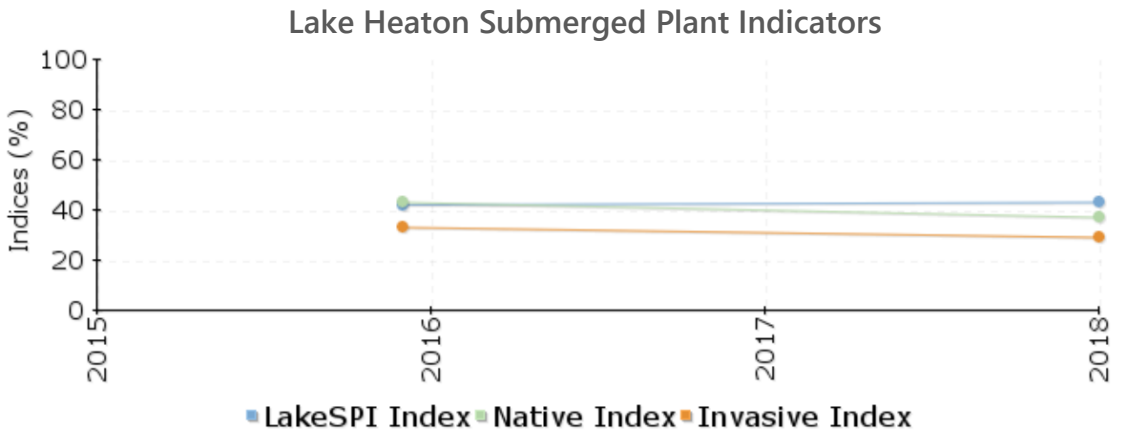
**Figure 23: Submerged plants formed high covers around the margins of Green Pond Wetland.** Oval floating leaves of *Potamogeton cheesemanii* visible on right.

**Figure 24: Native submerged plants *Potamogeton cheesemanii* and *Myriophyllum propinquum* growing just below the surface in Green Pond Wetland.**

## 3.7 Lake Heaton

### 3.7.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 20th |
| Lake maximum depth: | 4.2 m |
| Max depth of vegetation: | 1.9 m |




| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2017 | Moderate | 43% | 37% | 29% |
| November 2015 | Moderate | 42% | 43% | 33% |

**Figure 25: LakeSPI results for Lake Heaton.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Heaton is categorised as being in moderate ecological condition with a LakeSPI Index of 43% (Figure 25).

Two native species were recorded from within Lake Heaton. Native charophyte *Nitella* sp. aff. *cristata*, was recorded from three of the four LakeSPI sites, forming a meadow (>75% cover) at one site (northern side). Native pondweed *Potamogeton ochreatus,* was recorded from two of the four sites down to a maximum depth of 1.6 m (Figure 26). A native callitriche species, *Callitriche petriei*, recorded from one site during the 2015 survey was not observed in 2017.

*Potamogeton crispus* was the only introduced species recorded from the lake growing at relatively low covers to a maximum depth of 1.5 m.

At the time of the most recent survey water clarity was very poor with the through-water visibility <0.3m for divers. High densities of freshwater mussels (*Echyridella menziesii*) were recorded from within the lake.

*Historic vegetation notes:* Kelly (1978) surveyed Lake Heaton in March 1978 finding only a "bed of *Potamogeton crispus* at the east end". However, it was noted that had the lake been surveyed earlier in the summer before water temperature and algal population rose, that more species would probably have been present. Lake Heaton was also spot surveyed by Champion and Wells (2003) who recorded similar species to that recorded during the recent surveys.

Submerged vegetation was not specifically recorded in 1949 by Cunningham et al. (1953), but scattered beds of Typha and live mussels were observed.

### 3.7.2 Discussion

A moderate LakeSPI Index of 43%, reflects a lake that has maintained a native plant community in areas favourable for macrophyte growth (not too steep or shaded), with only limited impact from the invasive weed species *Potamogeton crispus*.

A reduction in the Native Condition Index from 43 % in 2015, to 37 % in 2017 (Figure 25) resulted from a small decline in native diversity and ratio scores, and the absence of a charophyte meadow from one of the four sites during the recent survey. A corresponding small reduction in the invasive impact scores over the same period, counteracted an overall change in LakeSPI Index. However, care must be taken when interpreting any reduction in LakeSPI scores for the recent survey. Poor water clarity made surveying the vegetation difficult and it is possible that some covers and presence/absence of native species may have been missed or underestimated.

The proximity of hornwort (*Ceratophyllum demersum*) in adjacent Lake Bernard, raises concern over the risk of its spread into this lake, with contaminated eel nets and small boats likely to represent the greatest threat. Should this occur, we could expect to see a significant decline in lake condition in the future.

**Figure 26: Native pondweed *Potamogeton ochreatus* formed high covers in Lake Heaton (2015).**

## 3.8 Lake Herbert

### 3.8.1 Results

| | |
|---|---|
| Lake condition: | Excellent |
| Lake ranking: | 2nd equal |
| Lake maximum depth: | 3.4 m |
| Max depth of vegetation: | 2.5 m |

Lake Herbert Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2017 | Excellent | 94% | 85% | 0% |

**Figure 27: LakeSPI results for Lake Herbert.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Herbert is categorised as being in excellent ecological condition with a LakeSPI Index of 94% (Figure 27).

Native milfoil *Myriophyllum propinquum* was surface reaching at depths < c. 1 m at all four sites around the main basin of this lake. Sprawling emergents, *Ludwigia palustris* and *Persicaria decipiens*, and free-floating species *Azolla pinnata* and *Ricciocarpus natans*, were also recorded growing in this surface reaching mat near the margin (Figure 28).

A native charophyte species, *Nitella* sp. aff. *cristata* formed meadows (>75% cover) beyond the milfoils extending down to c. 1.5 m. The native pondweed *Potamogeton ochreatus*, was recorded growing amongst the charophytes at all four LakeSPI sites extending down to a maximum depth of 2.5 m.

No submerged invasive species were recorded from within the lake.

At the time of the survey, water clarity was very poor with through-water visibility estimated by divers as only 0.2 m. The water appeared to be peat stained and was very dark in colour. Plants appeared clean and were not covered in algae. No freshwater mussels were observed.

### 3.8.2 Discussion

Lake Herbert is one of the best examples of a shallow lake in the Manawatū-Whanganui Region (Table 3) that maintains a well-developed native plant community in the absence of any invasive submerged weed species. This is reflected in a high LakeSPI Index of 94% and a Native Condition Index of 85% (Figure 27).

While threats from additional weed species appear minimal on account of restricted public access into Lake Herbert, it is advisable that the land owners be notified to exercise discretion in allowing access to the lake for users of equipment that may be contaminated with invasive species (e.g., boats used for duck shooting, fishing nets).

**Figure 28: Dense mat of submerged and sprawling emergent species in the shallows of Lake Herbert.** *Ludwigia palustris* with big leaves and growing above the water surface.

## 3.9 Huia Road Dam

### 3.9.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 21st |
| Lake maximum depth: | 6.1 m |
| Max depth of vegetation: | 2.6 m |

Huia Road Dam Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2018 | Moderate | 42% | 26% | 44% |

**Figure 29: LakeSPI results for Huia Road Dam.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Huia Road Dam is categorised as being in moderate ecological condition with a LakeSPI Index of 42% (Figure 29).

A native turf plant *Glossostigma elatinoides* (Figure 30), was the only native species recorded in the lake. It formed moderate to near complete covers at all five LakeSPI sites and extended down the profile to a maximum depth of 1.4 m.

Two invasive species were present in the dam. Swamp lily *Otellia ovalifolia* (Figure 31), was recorded from four of the five sites. It formed low to moderate covers and extended down to a maximum depth of 1.6 m. The introduced pondweed *Potamogeton crispus* was also present at all five sites.

At the time of recent survey, through-water visibility was poor and estimated by divers to be c. 1 m. Total vegetation covers at each site were estimated to be c. 20-60% and profiles were short (c. <5 m). Freshwater sponges were common. No freshwater mussels were observed.

### 3.9.2 Discussion

While the Huia Road Dam was dominated by invasive species *Ottelia ovalifolia* and *Potamogeton crispus*, a moderate LakeSPI Index of 42% (Figure 29) reflects the more benign nature of these two invasive species, in comparison to other submerged weeds in the region (e.g., hornwort and egeria). A Native Condition Index of 26% resulting from high covers of the turf forming species *Glossostigma elatinoides* at all five LakeSPI sites also contributed positively to the overall LakeSPI Index.

The discovery of swamp lily *Ottelia ovalifolia* in the Huia Road Dam, is the first time this species has been recorded from a LakeSPI survey in this region. Swamp lily is common in some local areas (particularly in Northland) where it is known to prefer fertile ponds and small farm lakes such as this dam.

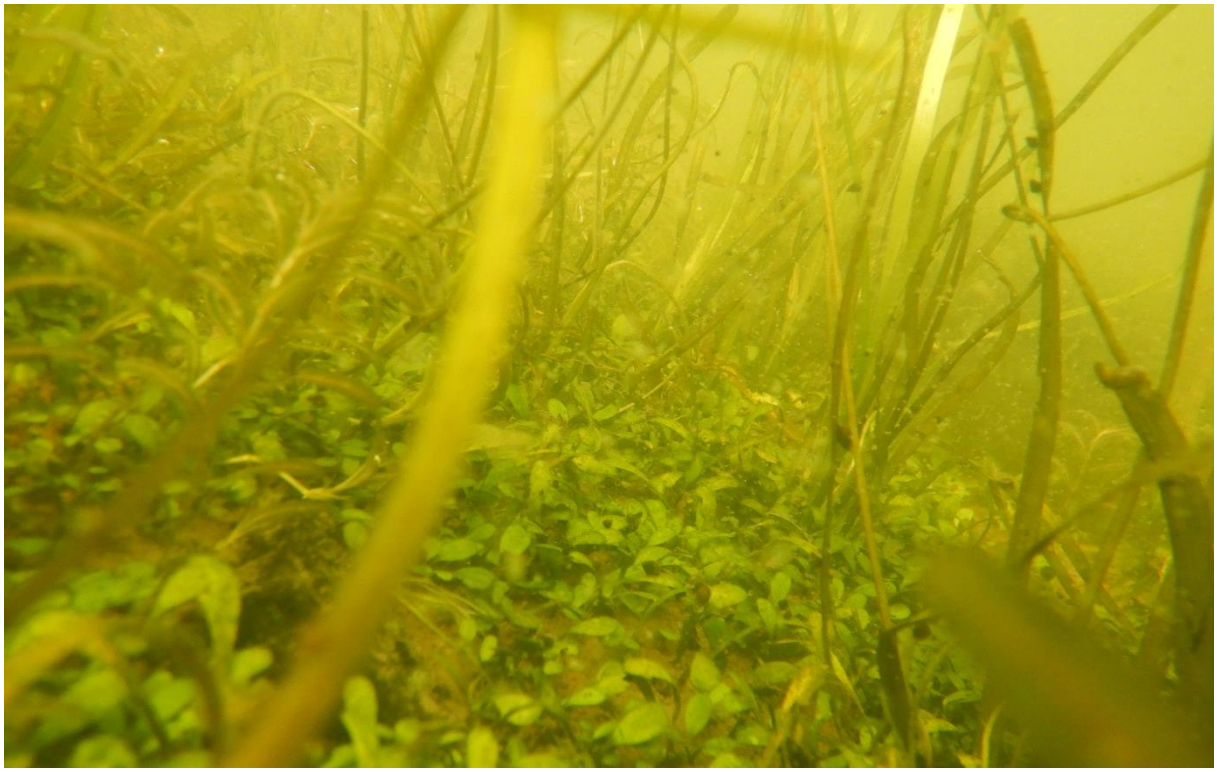


**Figure 30: Turf plant *Glossostigma elatinoides* formed high covers around the edge of the Huia Road Dam.** Seen here growing below invasive plants *Potamogeton crispus* (left) and *Ottelia ovalifolia* (background) .

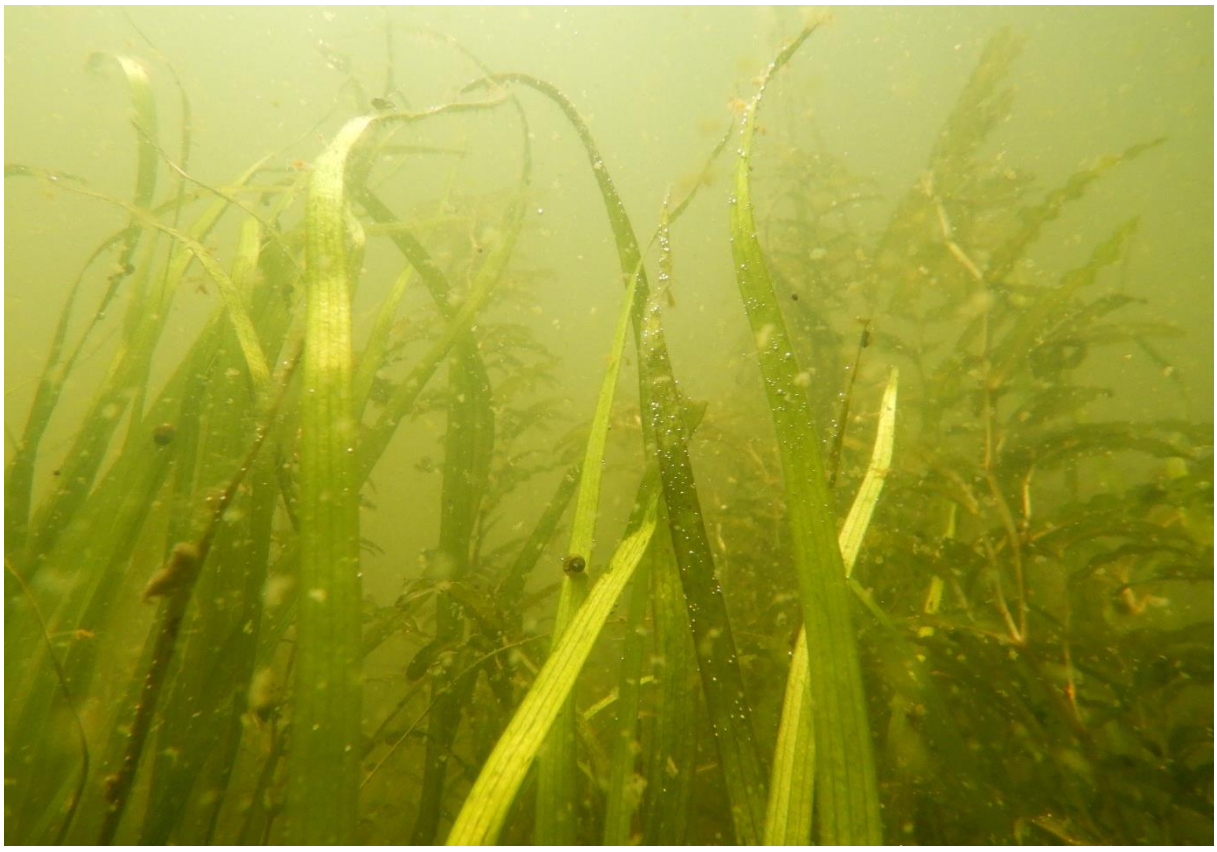


**Figure 31: Strap like leaves of *Ottelia ovalifolia* growing to the surface in the Huia Road Dam.** Introduced pondweed *Potamogeton crispus* visible on far right.

## 3.10 Hukanui Swamp

### 3.10.1 Results

| | |
|---|---|
| Lake condition: | Excellent |
| Lake ranking: | 1st |
| Lake maximum depth: | 1.4 m |
| Max depth of vegetation: | 1.4 m |

**Hukanui Swamp Submerged Plant Indicators**

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2017 | Excellent | 97% | 93% | 0% |

**Figure 32: LakeSPI results for Hukanui Swamp.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Hukanui Swamp is categorised as being in excellent ecological condition with a LakeSPI Index of 97% (Figure 32).

Native milfoil, pondweed and charophyte species formed a dense mat of vegetation across the bottom of the Hukanui Swamp down to a maximum observed depth of 1.4 m. Emergent stems of *Myriophyllum propinquum* were visible over much of the lake surface (Figure 33) growing over a shallow, c. 0.7 m deep, gravel bar in the lake centre. *Potamogeton ochreatus* also formed moderate covers over this zone, growing amongst the milfoils. In deeper areas closer to the lake margin, *Nitella* sp. aff. *cristata* formed meadows (>75% cover) at all four LakeSPI sites extending across the bottom.

While an introduced sprawling grass, *Glyceria maxima*, grew in large patches around the margins, no submerged invasive weed species were observed growing in the waterbody.

Good water clarity was noted during the recent survey. No freshwater mussels were observed.

### 3.10.2 Discussion

Hukanui Swamp is currently ranked the highest of 47 lakes assessed for this report (Table 3) and is categorised as being in excellent condition with a LakeSPI Index of 97% (Figure 32). This high score reflects a waterbody that while very shallow, remains in a near pristine state with a well-developed native plant community extending across the bottom, with no impact from invasive weed species.

With a maximum depth of just 1.4 m deep, Hukanui Swamp is close to the limit of being able to apply a LakeSPI assessment. Water bodies less than one meter in depth, are not generally recommended for assessment using LakeSPI based on limitations in the methods metrics to detect change over time at shallow depths. The shallow nature of this waterbody makes it particularly vulnerable to change over a short time frame (e.g., vulnerability to drought).

**Figure 33: Surface reaching mats of *Myriophyllum propinquum* in Hukanui Swamp.**

## 3.11 Lake Kaitoke

### 3.11.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 18th |
| Lake maximum depth: | 1.4 m |
| Max depth of vegetation: | 1.3 m |

Lake Kaitoke Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2017 | Moderate | 46% | 47% | 54% |

**Figure 34: LakeSPI results for Lake Kaitoke.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Kaitoke is categorised as being in moderate ecological condition with a LakeSPI Index of 46% (Figure 34).

A mixed community of native and invasive submerged vegetation formed moderate covers across the bottom of the lake down to its maximum recorded depth of 1.4 m (at time of recent survey).

A native milfoil (*Myriophyllum triphyllum*) (Figure 35) and pondweed (*Stuckenia pectinata*) were the most prominent native species in the lake present at all five LakeSPI sites. Low covers of *Potamogeton ochreatus* were also recorded from two sites.

Invasive species included *Potamogeton crispus* and elodea (*Elodea canadensis*). *Potamogeton crispus* formed moderate to high covers at all sites, while elodea was present at only low covers (< 5% cover) from four of the five sites and was very low growing (≤ 0.2 m).

At the time of the survey water clarity was poor with the through-water visibility estimated by divers to be near zero (c. 0.2 m). A Secchi disk measurement of 0.4 m was recorded from the lake centre. Freshwater mussels (*Echyridella menziesii*) were observed from two sites.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out by NIWA in March 2003 (Champion and Wells 2003) recorded no elodea in the lake. All other species described above were recorded with the addition of *Callitriche stagnalis, Callitriche petriei, Glossostigma elatinoides, Lilaeopsis novae-zelandiae, Limosella australis* and *Ranunculus amphitrichus*.

### 3.11.2 Discussion

A mixed cover of native and invasive submerged plants growing across the shallow bottom of Lake Kaitoke is reflected in a Native Condition Index of 47% and an Invasive Impact Index of 54% (Figure 34).

While *Potamogeton crispus* was the dominant invasive species recorded in the lake at the time of the survey (December), if the survey had been undertaken later in the season it is possible that elodea covers could have been higher. However, this would have had only a small impact on overall LakeSPI scores, since elodea was already present at most sites and the shallow depth of this lake means that invasive impact values from *Potamogeton crispus* were already high. It is also possible that wave action generated over the large shallow littoral zone helps prevent surface reaching weed beds of elodea from forming.

The proximity of hornwort (*Ceratophyllum demersum*) in Lake Wiritoa raises particular concern over the risk of spread into Lake Kaitoke, with contaminated boat traffic representing the greatest threat.

With a maximum depth of just 1.4 m deep, care must be taken when interpreting results for Lake Kaitoke as water bodies less than one meter in depth are not generally recommended for assessment using LakeSPI. It is possible that small impacts could result in big ecological changes over a short period of time (e.g., seasonal storms, drought).

**Figure 35: Native milfoils *Myriophyllum triphyllum,* formed moderate covers across the bottom of Lake Kaitoke.**

## 3.12 Karere Lagoon

### 3.12.1 Results

| | |
|---|---|
| Lake condition: | High |
| Lake ranking: | 12th |
| Lake maximum depth: | 3.4 m |
| Max depth of vegetation: | 2.5 m |

Karere Lagoon Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2018 | High | 64% | 67% | 34% |

**Figure 36: LakeSPI results for Karere Lagoon.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Karere Lagoon is categorised as being in moderate ecological condition with a LakeSPI Index of 64% (Figure 36).

Native charophyte species *Nitella* sp. aff. *cristata*, formed meadows (> 75% cover) extending across the bottom of the lagoon at all four LakeSPI sites, to a maximum depth of 2.5 m (Figure 37). A native pondweed *Potamogeton ochreatus*, formed variable low to moderate covers, up to 1 m tall over the same 0.1 – 2.5 m depth range. Native milfoils *Myriophyllum propinquum* and *Myriophyllum triphyllum* were also recorded at two of the four sites close to the lake margin (c. < 0.8 m).

The introduced pondweed *Potamogeton crispus* was the only invasive species recorded from the lagoon. It grew amongst native species growing up to 0.9 m in height, and down to a maximum depth of 1.4 m

Three native free-floating species were present. Accumulations of the native fern *Azolla rubra* (Figure 38) formed extensive floating mats over much of the lagoon surface, particularly along the northern side and at each end of the oxbow. An aquatic liverwort *Riccia fluitans*, (Figure 39) and common duck weed *Lemna disperma* were also present recorded from all four sites.

At the time of recent survey, through-water visibility was poor and estimated by divers to be c. 0.5 m. Total submerged plant covers over the bottom of the lagoon were estimated to be c. 70-80%. No freshwater mussels were observed.

*Historic vegetation notes:* No submerged vegetation was recorded during a spot survey carried out in the lagoon by NIWA in March 2003 (Champion and Wells 2003). Free-floating *Riccia fluitans, Lemna disperma* and *Landoltia punctata* were present. Note: an error in lake names cited in the 2003 report resulted in the submerged plant observations for lakes Karere and Karere South (Voss Lagoon) being listed around the wrong way - but are corrected here.

### 3.12.2 Discussion

A high LakeSPI Index of 64% (Figure 36) reflects a lake that has maintained a well-developed native plant community extending across the bottom of the lagoon with only limited impact from the invasive weed species *Potamogeton crispus*.

Extensive floating mats of *Azolla rubra* covering large areas of the lagoon surface did not appear to be having an impact on the submerged vegetation at the time of the recent survey (early summer). It is possible that the absence of submerged plants noted during a spot visit to the lake in late summer March 2003 (Champion and Wells 2003), may have resulted from prolonged shading by azolla mats over the summer months. Azolla is common in shallow eutrophic water bodies such as this, often dying back in winter, which could provide an opportunity for charophytes to recover from seed banks.

The floating crystalwort *Riccia fluitans,* (Figure 39) was an interesting find in the lagoon. It is one of the few true aquatic liverworts in New Zealand and was common at all sites.

While threats from additional weed species appear minimal on account of restricted public access into the Karere Lagoon, it is advisable that the land owners be notified to exercise discretion in allowing access to the lake for users of equipment that may be contaminated with invasive species (e.g., boats used for duck shooting, eel fishing nets).

**Figure 37: Charophyte meadows extended over the bottom of Karere Lagoon.** Note, free-floating *Azolla rubra* accumulating on the lagoon surface.

**Figure 38: Free-floating species *Azolla rubra* in Karere Lagoon.** Smaller green leaves are *Lemna disperma*.

**Figure 39: Floating crystalwort (*Riccia fluitans*) formed bright green balls in Karere Lagoon.** Seen here with other free-floating species *Azolla rubra* and *Lemna disperma*.

## 3.13 Lake Kohata

### 3.13.1 Results

| | |
|---|---|
| Lake condition: | Poor |
| Lake ranking: | 37th equal |
| Lake maximum depth: | 14.8 m |
| Max depth of vegetation: | 5 m |

Lake Kohata Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2015 | Poor | 16% | 21% | 94% |

*Note: 2015 survey based on only 3 sites.

**Figure 40: LakeSPI results for Lake Kohata.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Kohata is categorised as being in poor ecological condition with a LakeSPI Index of 16% (Figure 40).

Hornwort (*Ceratophyllum demersum*) was present at all three LakeSPI baseline sites forming a weed bed down to a maximum depth of 5 m. Other introduced plants included the water buttercup *Ranunculus trichophyllus* and pondweed *Potamogeton crispus*. Both species formed lower covers in shallower water than hornwort.

Native plants included the milfoils *Myriophyllum triphyllum* and *Myriophyllum propinquum*, pondweeds *Potamogeton cheesemanii* and *Potamogeton ochreatus*, a turf plant *Glossostigma elatinoides*, and charophyte species *Nitella* sp. aff. *cristata*.

At the time of this recent survey, the water was noted as very dark in colour, with the underwater visibility estimated to be 0.5 m by divers. No freshwater mussels were observed.

*Historic vegetation notes:* Hornwort was not recorded from Lake Kohata during a spot survey of submerged vegetation carried out by NIWA in March 2003 (Champion and Wells 2003). Kelly (1978) surveyed this lake in February 1978 and made comment of its “fairly clear water”. Kelly noted that the most common plants at the time were *Potamogeton crispus* and *Myriophyllum propinquum*, often accompanied by either *Potamogeton ochreatus* or *Potamogeton cheesemanii*, and growing deeper than this community was a bed of *Nitella* sp. aff. *cristata* to a maximum depth of 5 m.

### 3.13.2 Discussion

Hornwort was the dominant submerged plant species in Lake Kohata generating a high Invasive Impact Index of 94% (Figure 40). A Native Condition Index of 21% (Figure 40), reflects some native submerged plants still present despite the lakes degraded condition.

## 3.14 Lake Koitiata

### 3.14.1 Results

| | |
|---|---|
| Lake condition: | Poor |
| Lake ranking: | 34th |
| Lake maximum depth: | 2.9 m |
| Max depth of vegetation: | 2.9 m |

Lake Koitiata Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2015 | Poor | 19% | 39% | 93% |

**Figure 41: LakeSPI results for Lake Koitiata.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Koitiata is categorised as being in poor ecological condition with a LakeSPI Index of 19% (Figure 41).

Hornwort (*Ceratophyllum demersum*) formed a near complete cover (Figure 42) up to 2.4 m tall across the entire lakebed to its maximum depth of 2.9 m. The invasive weeds *Egeria densa*, *Elodea canadensis* and the introduced pondweed *Potamogeton crispus* were also present but were having little impact compared to hornwort.

Two native plants were also present in Lake Koitiata. A charophyte species *Chara globularis* (Figure 43) formed meadows (>75% cover) at two of the four LakeSPI sites down to a maximum depth of 1.8 m. A native milfoil *Myriophyllum triphyllum* was also present contributing to a Native Condition Index of 39% (Figure 41).

At the time of survey, the water in Lake Koitiata was very clear with little or no obvious signs of phytoplankton blooms or epiphytic algae on the plants. Through-water visibility estimated by divers was c. 3 m, making it one of the clearest lakes surveyed. Emergent beds of *Typha orientalis* encircled the lake with no obvious access points for entry. No freshwater mussels were observed during this survey.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out in March 2003 (Champion and Wells 2003) recorded the presence of invasive species egeria and *Potamogeton crispus* but not the invasive weeds elodea or hornwort.

### 3.14.2 Discussion

Hornwort dominated the submerged vegetation in Lake Koitiata generating a high Invasive Impact Index of 93% (Figure 41).

As the hornwort has now likely reached habitat saturation, we can expect to see only small changes in the LakeSPI scores in the future unless the lake become devegetated. Lakes like Koitiata that are dominated by hornwort (or Egeria) can often have good water quality, however, when native diversity is compromised and vegetation is made up of monospecific and vegetatively reproducing invasive species, lakes are more vulnerable to 'flipping'.

**Figure 42: Hornwort forming a complete cover across the bottom in Lake Koitiata.**

**Figure 43: Native charophyte species (*Chara globularis*) growing in Lake Koitiata.**

## 3.15 Lake Kopureherehere

### 3.15.1 Results

| | |
|---|---|
| Lake condition: | Poor |
| Lake ranking: | 40th equal |
| Lake maximum depth: | 11.7 m |
| Max depth of vegetation: | 3.2 m |

Lake Kopureherehere Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2017 | Poor | 11% | 3% | 87% |

**Figure 44: LakeSPI results for Lake Kopureherehere.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Kopureherehere is categorised as being in poor ecological condition with a LakeSPI Index of 11% (Figure 44).

Hornwort (*Ceratophyllum demersum*) dominated the vegetation in Lake Kopureherehere but was present at only low to moderate covers (≤50 %) (Figure 45). It was relatively short growing (≤1 m) in height and extended from the lake margin down to a maximum depth of 3.2 m. Hornwort plants were etiolated with the whorls of leaves widely spaced along stems (Figure 45).

One plant of a native charophyte species *Nitella* sp. aff. *cristata*, was also observed.

At the time of the survey the through-water visibility estimated by divers was c. 1.5 m. A Secchi disk measurement of 1.15 m was recorded from the lake centre. No freshwater mussels were observed.

*Historic vegetation notes:* Hornwort was recorded in Lake Kopureherehere during a visit to the lake in 1997 (Champion and Wells 2003).

### 3.15.2 Discussion

Lake Kopureherehere has one of the lowest LakeSPI Indices (11%) of any of the vegetated lakes in the Manawatū-Whanganui Region (Table 3) reflecting the presence of only hornwort in the lake.

As the hornwort has been present in the lake for more than twenty years, we can expect to see only small changes in the LakeSPI scores in the future unless the lake become devegetated.

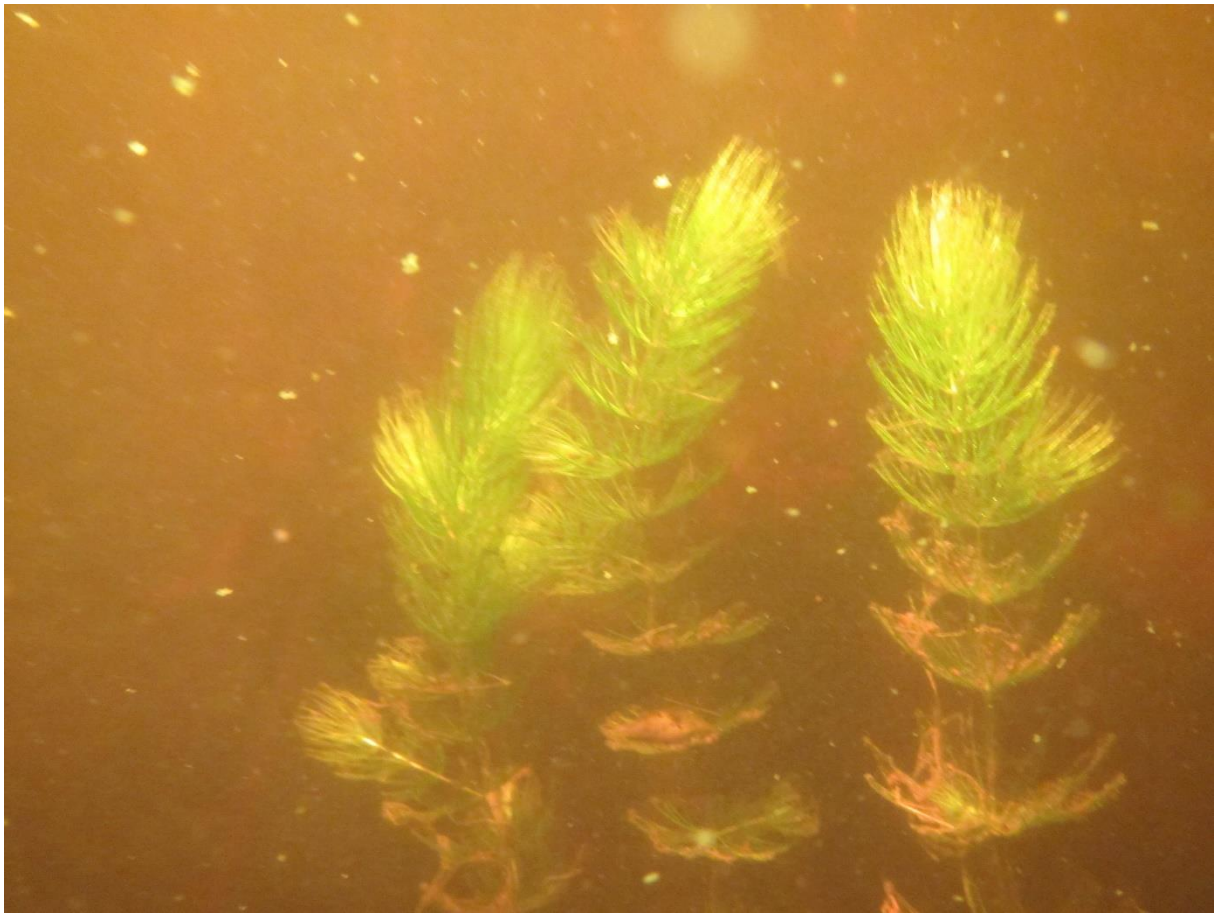


**Figure 45: Hornwort growing in Lake Kopureherehere.**

## 3.16 Lake Koputara

### 3.16.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 31st |
| Lake maximum depth: | 1 m |
| Max depth of vegetation: | 1 m |

Lake Koputara Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2016 | Moderate | 25% | 32% | 81% |

**Figure 46: LakeSPI results for Lake Koputara.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Koputara is categorised as being in moderate ecological condition with a LakeSPI Index of 25% (Figure 46).

Submerged vegetation (Figure 47) extended across the bottom of Lake Koputara to the lake's maximum depth of 1 m (at time of recent survey).

The introduced pondweed *Potamogeton crispus*, was the most abundant submerged plant in the lake and it formed moderate to high covers extending across the lake bottom at all four LakeSPI sites. Hornwort (*Ceratophyllum demersum*) was recorded forming small clumps of weed across all profiles, and occasional plants of elodea (*Elodea canadensis*) were present.

Native submerged plants included the native pondweed *Stuckenia pectinata*, forming low to moderate covers at all sites, and small patches of *Ruppia polycarpa* and a charophyte species (*Chara globularis*) (Figure 48).

In water visibility was poor, with through-water visibility estimated by divers to be c. 0.5 m. A Secchi disk measurement of 0.8 m was recorded from the lake. High densities of freshwater mussels (*Echyridella menziesii*) were observed, particularly on sand bars running through the lake centre. Lake sediments consisted of a hard iron sand base over much of the lake bottom.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out by NIWA in March 2003 (Champion and Wells 2003) recorded the presence of hornwort, *Potamogeton crispus*, and *Ruppia polycarpa*. At the time of this survey the lake was also noted as being nearly dry following a prolonged drought.

### 3.16.2 Discussion

A moderate LakeSPI Index of 25% (Figure 46) reflects a lake that maintains a well-developed submerged plant community but is dominated by introduced species (Invasive Impact Index, 81%). While introduced species are not favourable in terms of overall lake condition, the presence of any submerged plants in a lake is preferable to none, in that they can help mitigate many of the symptoms of eutrophication (e.g., lock-up nutrient, maintain water clarity, compete with phytoplankton). Care should also be taken when interpreting LakeSPI scores for this lake however as its shallow nature (c. 1 m depth) could make it particularly vulnerable to change over a short time frame.

High densities of large freshwater mussels were observed within Lake Koputara with many measuring c. 100 mm in length. Examination of the shells suggests that these larger mussels (Figure 48) could be more than 50 years old (Sue Clearwater, NIWA, pers. comm.). The mussel shells in general were noted to be in good condition with no signs of erosion or deformities, suggesting that environmental factors for mussel populations in the lake were good.

At the time of the current survey (November 2016), excavation work had recently been carried out at the lakes north western end to extend the area of open water.

**Figure 47: A handful of submerged vegetation comprising of a mix of native and introduced pondweed species growing across the bottom of Koputara.**

**Figure 48: Plant species and mussel from within Lake Koputara.** From left to Right: native species: *Chara globularis* and *Ruppia polycarpa*; and invasive species: *Potamogeton crispus*, *Elodea canadensis*, and *Ceratophyllum demersum*.

## 3.17 Lake Mahangaiti

### 3.17.1 Results

| | |
|---|---|
| Lake condition: | Excellent |
| Lake ranking: | 8th |
| Lake maximum depth: | 1.1 m |
| Max depth of vegetation: | c. 1 m |

Lake Mahangaiti Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2017 | Excellent | 81% | 70% | 11% |

**Figure 49: LakeSPI results for Lake Mahangaiti.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Mahangaiti is categorised as being in excellent ecological condition with a LakeSPI Index of 81% (Figure 49).

Native pondweed *Stuckenia pectinata*, was the most abundant submerged plant in the lake. It formed high covers at all sites extending across the bottom to a maximum depth of c. 0.9 m (Figure 50). Native milfoils, *Myriophyllum triphyllum*, formed low to moderate covers at four of the five LakeSPI sites, and occasional plants of *Potamogeton ochreatus* were recorded from one site. Two native free-floating species, *Azolla rubra* and *Lemna disperma*, were observed at all sites near the lake margin.

The introduced pondweed *Potamogeton crispus*, was the only invasive weed species recorded in the lake forming low covers (<10 plants) at three of the five sites.

At the time of the survey, water clarity was poor with through-water visibility estimated by divers to be c. 0.4 m. A Secchi disk measurement of 1 m was recorded from the lake centre. No freshwater mussels were observed.

### 3.17.2 Discussion

A high Native Condition Index (70%) reflects the presence of native pondweeds extending over the bottom of the lake with little impact from *Potamogeton crispus*, which generated a low Invasive Impact Index of 11% (Figure 49).

With a maximum depth of just 1.1 m deep, care must be taken when interpreting results for Lake Mahangaiti as water bodies less than one meter in depth, are not generally recommended for assessment using LakeSPI. Seemingly small impacts have the potential to cause big ecological changes over a short period of time (e.g., vulnerability to drought).

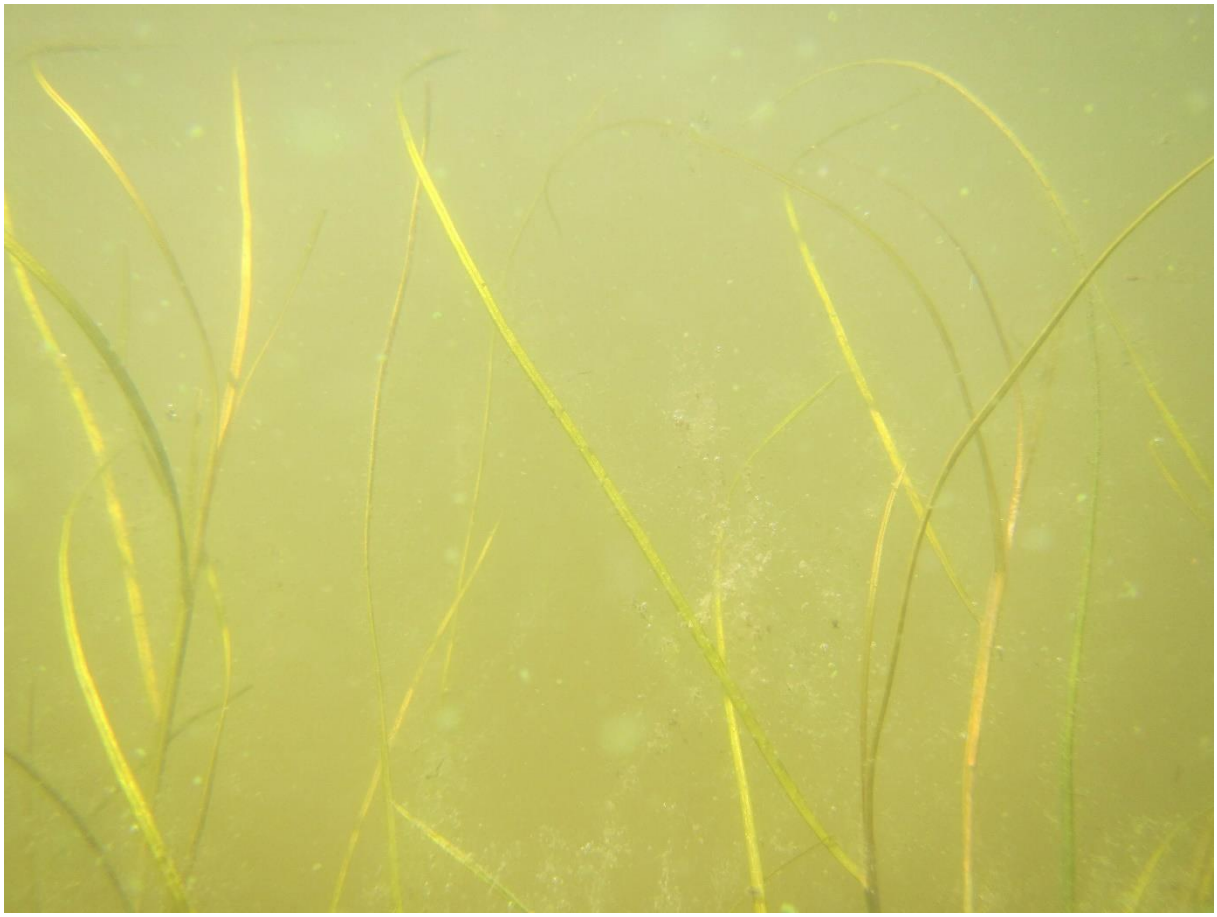


**Figure 50: Native pondweed *Stuckenia pectinata* formed high covers across the bottom of Lake Mahangaiti.**

## 3.18 Manawatū Gorge Dam

### 3.18.1 Results

Lake condition: Non-vegetated

Lake ranking: 43rd equal

Lake maximum depth: ?

Max depth of vegetation: 0

Manawatū Gorge Dam Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2018 | Non-vegetated | 0% | 0% | 0% |

*Note: Very soft sediments meant the lake could only be observed from the edge.

**Figure 51: LakeSPI results for Manawatū Gorge**. LakeSPI Indices expressed as a percentage of lake maximum potential.

Manawatū Gorge Dam is categorised as being non-vegetated with a LakeSPI Index of 0% (Figure 51).

No submerged vegetation was observed from the lake edge at three sites.

Access was restricted to the lake margin due the very soft, sludgy clay-like mud surrounding the lake. The water was very brown in colour and clumps of filamentous algae were common around the margin (Figure 52).

### 3.18.2 Discussion

Poor water quality and the softness of the lake bottom make this lake unsuitable for submerged plant growth. The landowner described the bottom sediments to be like 'quicksand' and estimated the maximum lake depth to be < 2 m (J. Bolton, pers. comm.).

**Figure 52: Manawatū Gorge Dam showing soft sludgy sediments and clumps of algae on the lake margin.**

## 3.19 Lake Maungarataiti

### 3.19.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 32nd equal |
| Lake maximum depth: | 10 m |
| Max depth of vegetation: | 5.5 m |

Lake Maungaratiti Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2016 | Moderate | 22% | 28% | 86% |

**Figure 53: LakeSPI results for Lake Maungarataiti.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Maungarataiti is categorised as being in moderate ecological condition with a LakeSPI Index of 22% (Figure 53).

Egeria (*Egeria densa*) formed a dense band of weed around the lake margin, in places exceeding 3 m in height, and growing down to a maximum depth of 5.5 m. Occasional plants of the introduced *Ludwigia palustris* and starwort *Callitriche stagnalis* were also noted.

Native charophytes (*Nitella* sp. aff. *cristata*, *Chara australis*) were present at all five LakeSPI sites, forming high cover patches in shallow water (<1.5 m), and at four sites, extended into deeper water recorded at the outer edge of egeria weed beds (c. 5 m). Charophyte meadows (> 75% cover) were recorded at two of the five sites in water < 1 m deep. The native pondweed *Potamogeton ochreatus* was also observed at two sites.

At the time of survey, the water was very green and there was no underwater visibility in the upper 1-2 m of water. Below this the through water visibility improved slightly and was estimated by divers to be up to c. 3 m, but with very low light. A Secchi disk measurement of 0.72 m was recorded from the lake centre. No freshwater mussels and were observed.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out by NIWA in March 2003 (Champion and Wells 2003) recorded only the presence of egeria.

### 3.19.2 Discussion

LakeSPI results show that lakes Maungarataiti and Maungaratanui are very similar in condition with a LakeSPI Index of 22% (Figure 53, Figure 55). The lakes are located close to each other (<300 m apart), have similar depths (c. 10 m) and are both dominated by egeria, while still supporting some healthy native charophyte communities.

This lake had poor water quality at the time of the survey (November 2016) resulting from an algae bloom present in the lake. In conversation with a neighbouring farmer, they noted that the colour of neighbouring Lake Maungaratanui had likely changed only a couple of days prior to this visit. This observation would also be consistent with the survey results for Lake Maungarataiti too, as despite there being zero through-water visibility in the top few meters of water, a healthy submerged plant community (Figure 54) was present in the lake down to c. 5.5 m.

Charophyte meadows (>75% cover) were recorded from two of the five LakeSPI sites in Lake Maungarataiti contributing positively to a Native Condition Index of 28% (Figure 53). Charophyte meadows are particularly sensitive to reduced water clarity so should the water quality conditions observed in Lake Maungarataiti continue long term, we could expect to see these communities disappear in the future.

**Figure 54: Submerged plants in Lake Maungarataiti consisted of the invasive weed egeria (top left) and native charophyte species (bottom right).**

## 3.20 Lake Maungaratanui

### 3.20.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 32nd equal |
| Lake maximum depth: | 9.8 m |
| Max depth of vegetation: | 5.5 m |

Maungaratanui Lake Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2016 | Moderate | 22% | 20% | 86% |

**Figure 55: LakeSPI results for Lake Maungaratanui.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Maungaratanui is categorised as being in moderate ecological condition with a LakeSPI Index of 22% (Figure 55).

Egeria (*Egeria densa*) formed a dense band of weed around the lake margin, in places exceeding 3 m in height, and growing down to a maximum depth of 5.5 m. Other introduced vegetation included one plant of elodea (*Elodea canadensis*) and occasional plants of *Ludwigia palustris*, and *Callitriche stagnalis*.

Native charophytes (*Nitella* sp. aff. *cristata* (Figure 56), *Chara australis*) were observed from two of the five LakeSPI sites, in shallow water (<2 m). The native pondweed *Potamogeton ochreatus* was also present at four of the baseline sites.

At the time of survey, the water was a yellow/green colour and smelled earthy. Underwater visibility in the littoral zone was zero. A Secchi disk measurement of 0.45 m was recorded from the lake centre. No freshwater mussels were observed.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out by NIWA in March 2003 (Champion and Wells 2003) recorded the presence of egeria, elodea, *Potamogeton ochreatus* and *Ludwigia palustris.*

### 3.20.2 Discussion

A thick algae bloom noted on the lake at the time of the recent survey (November 2016) made surveying the submerged plants in Lake Maungaratanui difficult. Due to safety concerns for the divers, the vegetation was surveyed using a combination of a grapnel and wading. A conversation with a farmer on the property noted that the colour of the lake had likely changed only a couple of days prior to this visit. This observation would be consistent with the survey results that found a healthy submerged plant community present in the lake extending down to a maximum depth of c. 5.5 m, despite there being very little light (zero through-water visibility) in the water. Should the water quality conditions observed in Lake Maungaratanui continue long term, then we could expect to see ad decline in lake condition and LakeSPI scores in the future.

A LakeSPI Index of 22% was recorded for Lake Maungaratanui (Figure 55). This lake is in close proximity to Lake Maungarataiti (<300 m apart) and both lakes have similar depths (c. 10 m) and are both dominated by egeria while still supporting some native plant communities. Lake Maungaratanui had a slightly lower Native Condition Index (20 %) than Lake Maungarataiti (28 %), reflecting a lower distribution of charophytes in the lake, however it is possible that some charophyte communities may have been missed using the grapnel survey technique.

**Figure 56: Native charophyte *Nitella* sp. aff. *cristata*, was recorded from two sites in Maungaratanui.**

## 3.21 Lake Meremere

### 3.21.1 Results

| | |
|---|---|
| Lake condition: | Excellent |
| Lake ranking: | 11th |
| Lake maximum depth: | 5.7 m |
| Max depth of vegetation: | 3.4 m |

Lake Meremere Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2018 | Excellent | 77% | 54% | 0% |

**Figure 57: LakeSPI results for Lake Meremere.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Meremere is categorised as being in excellent ecological condition with a LakeSPI Index of 77% (Figure 57).

The native pondweed *Potamogeton ochreatus* was the only submerged plant recorded in the lake. It formed moderate to high covers up to 1.2 m tall and extended down to a maximum depth of 3.4 m at all four LakeSPI sites.

Free-floating native species *Azolla rubra* and *Lemna disperma* were also recorded at all four sites (Figure 58). Accumulations of azolla at the northern end of the lake formed a floating mat covering approximately one third of the lake surface.

At the time of this recent survey, good through-water visibility was noted by divers (c. 2 m). No freshwater mussels were observed.

*Historic vegetation notes:* A spot survey was not carried out for this lake in 2003 (Champion and Wells 2003).

### 3.21.2 Discussion

Lake Meremere sits just above the cusp of the high and excellent condition categories with a LakeSPI Index of 77% (Figure 57). This high score reflects the presence of only native pondweeds in Lake Meremere and the absence of any invasive species.

While threats from additional weed species appear minimal on account of the remoteness of the lake, it is advisable that the land owners continue to exercise discretion in allowing access to the lake for users of equipment that may be contaminated with invasive species (e.g., boats used for duck shooting, eel fishing nets).

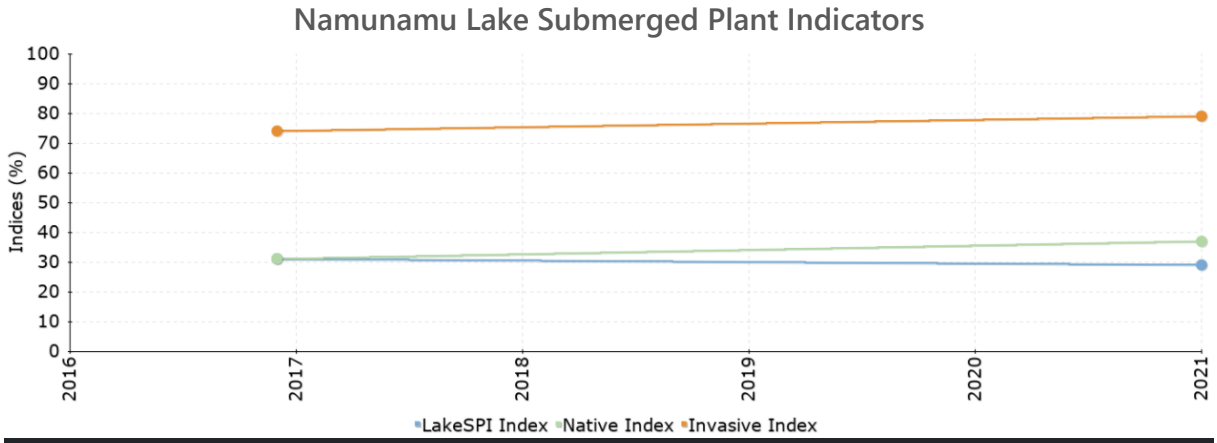
*Note:* Discussions with the farmer indicated that he believes the names of Lake Meremere and neighbouring lake Waiwahi are reversed and labelled incorrectly on the LINZ map.

**Figure 58: Native free-floating *Azolla rubra* was present at all sites surveyed in Lake Meremere.**

## 3.22 Lake Namunamu

### 3.22.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 27th |
| Lake maximum depth: | 19.1 m |
| Max depth of vegetation: | 6.4 m |




| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2020 | Moderate | 29% | 37% | 79% |
| November 2016 | Moderate | 31% | 31% | 74% |

**Figure 59: LakeSPI results for Lake Namunamu.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Namunamu is categorised as being in moderate ecological condition with a LakeSPI Index of 29% (Figure 59).

Two invasive weed species were recorded from Lake Namunamu (Figure 60). Elodea (*Elodea canadensis*) formed a dense band of weed around the lake, growing up to 3 m tall and down to a maximum depth of 5.3 m at all five LakeSPI sites. Hornwort (*Ceratophyllum demersum*) was recorded for the first time during a LakeSPI survey and was present from three of the five sites. At two of these sites, hornwort formed large clumps of weed throughout the elodea down to a maximum depth of 6.8 m. At the third site, occasional hornwort fragments were recorded lying on top of other vegetation.

Native plants included two charophytes (*Chara australis*, *Nitella* sp. aff. *cristata*) (Figure 61) a pondweed *Potamogeton ochreatus*) and milfoil *Myriophyllum triphyllum* (Figure 62).

Charophytes were present at all five sites and formed meadows (>75% cover) at four sites extending beyond the elodea weed beds to a maximum depth of 6.8 m. Flowering stems of the native milfoil *Myriophyllum triphyllum* were also observed elsewhere in the lake but not at a LakeSPI site.

At the time of the survey, good water clarity was noted by the divers with the through-water visibility estimated to be > 3 m. No freshwater mussels were observed.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out by NIWA in March 2003 (Champion and Wells 2003) recorded elodea extending down to a maximum depth of 6.5 m, and native species *Potamogeton ochreatus* and *Chara australis* present down to 8 m depth.

### 3.22.2 Discussion

Hornwort (*Ceratophyllum demersum*) was first discovered in Lake Namunamu in May 2019 (Horizons Regional Council, Agenda Report for Environment-Committee, 14 August 2019), and during the December 2020 survey it was recorded from three of the five LakeSPI sites (Figure 60).

While the LakeSPI Index shows no significant change between the 2016 and 2020 timeframe (Figure 59), an increase in the Invasive Impact Index from 74% in 2016 to 79% in 2020 reflects the early stages of invasion by hornwort in this lake. It is expected that the Invasive Impact scores for Lake Namunamu with increase significantly as hornwort continues to spread and expand its reach around the lake, particularly into deeper water where it has the potential to displace all remaining native vegetation. Currently elodea (*Elodea canadensis*) forms a band of weed around the lake margin extending down to a maximum depth of 5.3 m, thus allowing charophytes to grow beyond this depth to a maximum depth of 6.8 m. During the 2020 survey hornwort was recorded growing down to 6.4 m and 6.8 m at two of the sites. It is likely that hornwort will displace all remaining native vegetation, in particular the deeper growing charophytes within the next few years.

**Figure 60: Hornwort (foreground) and Elodea growing in Lake Namunamu.**

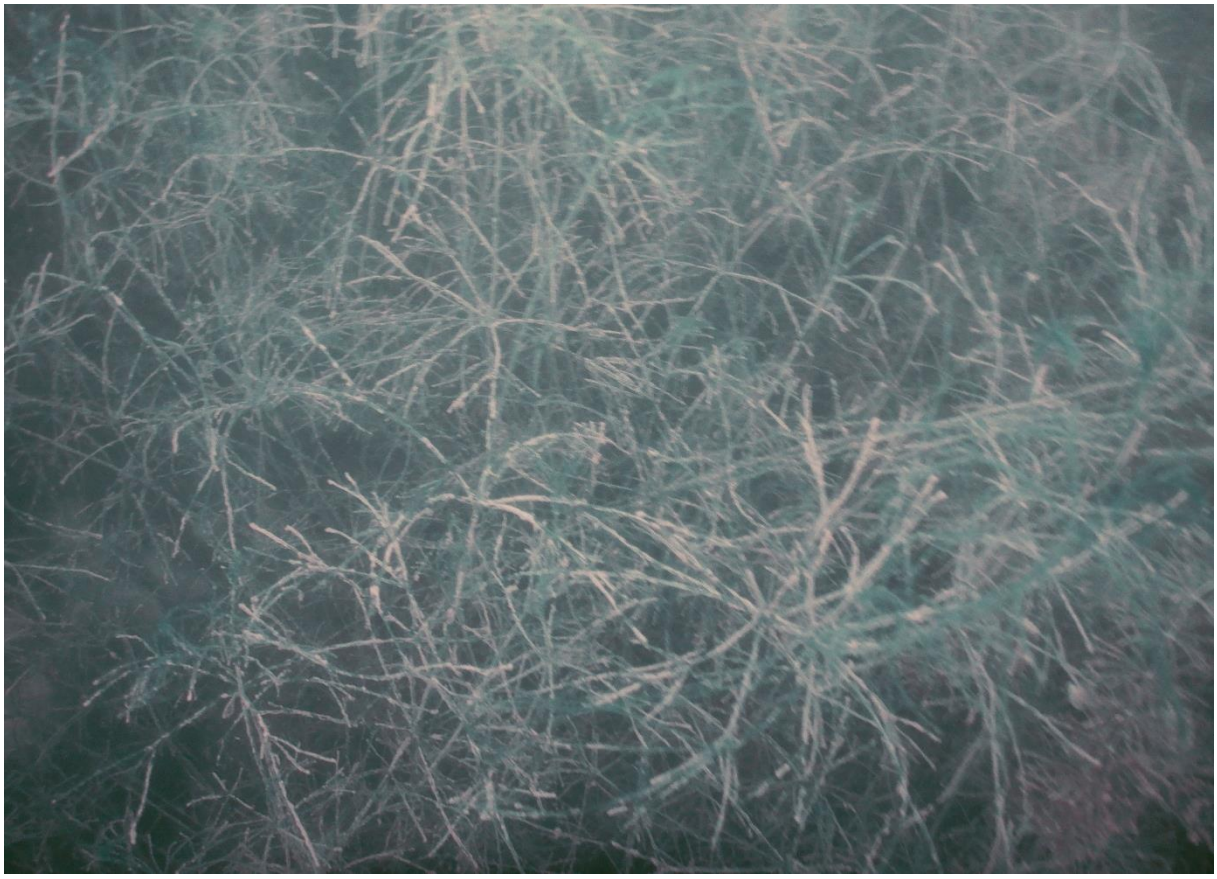


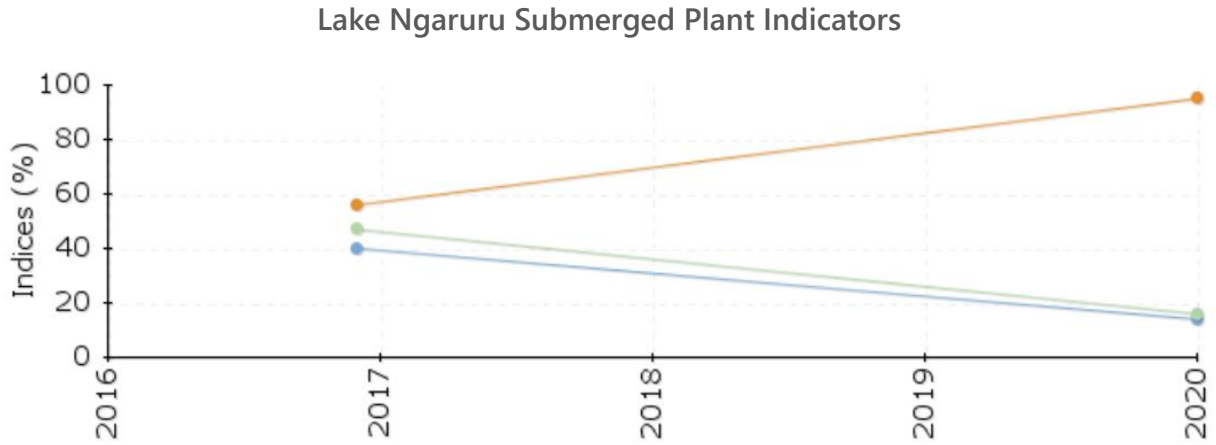
**Figure 61: Native charophytes (*Nitella* sp. aff. *cristata*) in Lake Namunamu .**

**Figure 62: Native milfoils (*Myriophyllum triphyllum*) flowering in Lake Namunamu.**

## 3.23 Lake Ngaruru

### 3.23.1 Results

| | |
|---|---|
| Lake condition: | Poor |
| Lake ranking: | 39th |
| Stability: | Declining |
| Lake maximum depth: | 11.3 m |
| Max depth of vegetation: | 5.9 m |




| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2019 | Poor | 14% | 16% | 95% |
| November 2016 | Moderate | 40% | 47% | 56% |

**Figure 63: LakeSPI results for Lake Ngaruru.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Ngaruru is categorised as being in poor ecological condition with a LakeSPI Index of 14% (Figure 63).

Hornwort (*Ceratophyllum demersum*) dominated the submerged vegetation at all four LakeSPI sites. It formed dense surface reaching weed beds around the lake margin extending from the outer edge of emergents (c. 1.1 m) down to a maximum depth of 5.9 m. Egeria (*Egeria densa*), elodea (*Elodea canadensis*) and the introduced pondweed *Potamogeton crispus* were also recorded. Egeria was observed at three of the four sites, forming low to moderate covers on the shallower edge of hornwort growth. Elodea was recorded from one site and *P. crispus* from two sites.

Two native charophytes (*Chara australis* and *Nitella* sp. aff. *cristata*) were recorded from two of the four LakeSPI sites growing on the inside edge of the emergents, between 1.1 – 2.5 m deep. *Chara australis* was tall growing, up to 1.7 m high, and formed a meadow (> 75% cover) at one site. Native pondweeds *Potamogeton ochreatus* (Figure 64) and *Potamogeton cheesemanii* were also recorded forming low covers at one and two sites respectively.

A thick band of emergent species, mainly *Typha orientalis*, grew around the lake margin. Free-floating native species, *Azolla rubra* and *Lemna disperma* were observed near the edges of emergent growth.

At the time of the survey a dense algae bloom was obvious in the lake and water clarity was poor. A Secchi disk measurement of 1 m was recorded from the lake. Divers estimated the through-water visibility to range between 0.5 - 1.5 m. No freshwater mussels were observed.

*Historic vegetation notes:* Elodea was the only invasive weed species recorded from within Lake Ngaruru during a spot survey of submerged vegetation carried out by NIWA in March 2003 (Champion and Wells 2003). Other submerged plants recorded at this time included *Potamogeton ochreatus*, *Chara australis* and *Ludwigia palustris*.

### 3.23.2 Discussion

The ecological condition of Lake Ngaruru has significantly declined between the 2016 and 2019 LakeSPI surveys, evidenced by a large reduction in the LakeSPI Index from 40% to 14% (Figure 63). A significant increase in the Invasive Impact Index (now 95%), and corresponding decrease in the Native Condition Index, reflects the spread and domination of hornwort, New Zealand's worst submerged weed species, and the lake is now classified in poor condition.

In 2016, Lake Ngaruru still maintained a well-developed native plant community consisting mainly of charophytes (meadows present at all sites) and pondweeds with little to no impacts from invasive weed species. Only single plants of hornwort were found at two of the four LakeSPI sites, and a floating fragment was found at a third. Three years after this survey, hornwort has largely replaced all native vegetation, forming a dense tall band of weed around the lake margin, extending down to a maximum depth of 5.9 m. While Egeria and elodea were also present in 2019, they were having little impact in comparison to hornwort.

The speed at which hornwort has invaded Lake Ngaruru from its discovery in 2016, to the complete domination of all LakeSPI sites in 2019, is an unfortunate reminder of the devastating impact hornwort can have on lake ecosystems over a relatively short time frame (c. 3 years). It is unlikely that we will see further large changes in LakeSPI scores in the future, as hornwort now occupies the majority of its potential habitat in Lake Ngaruru.

During the 2019 survey, a decrease in water clarity was also noted, with Secchi depth measurements declining from 2.48 m in November 2016, to only 1 m in December 2019.

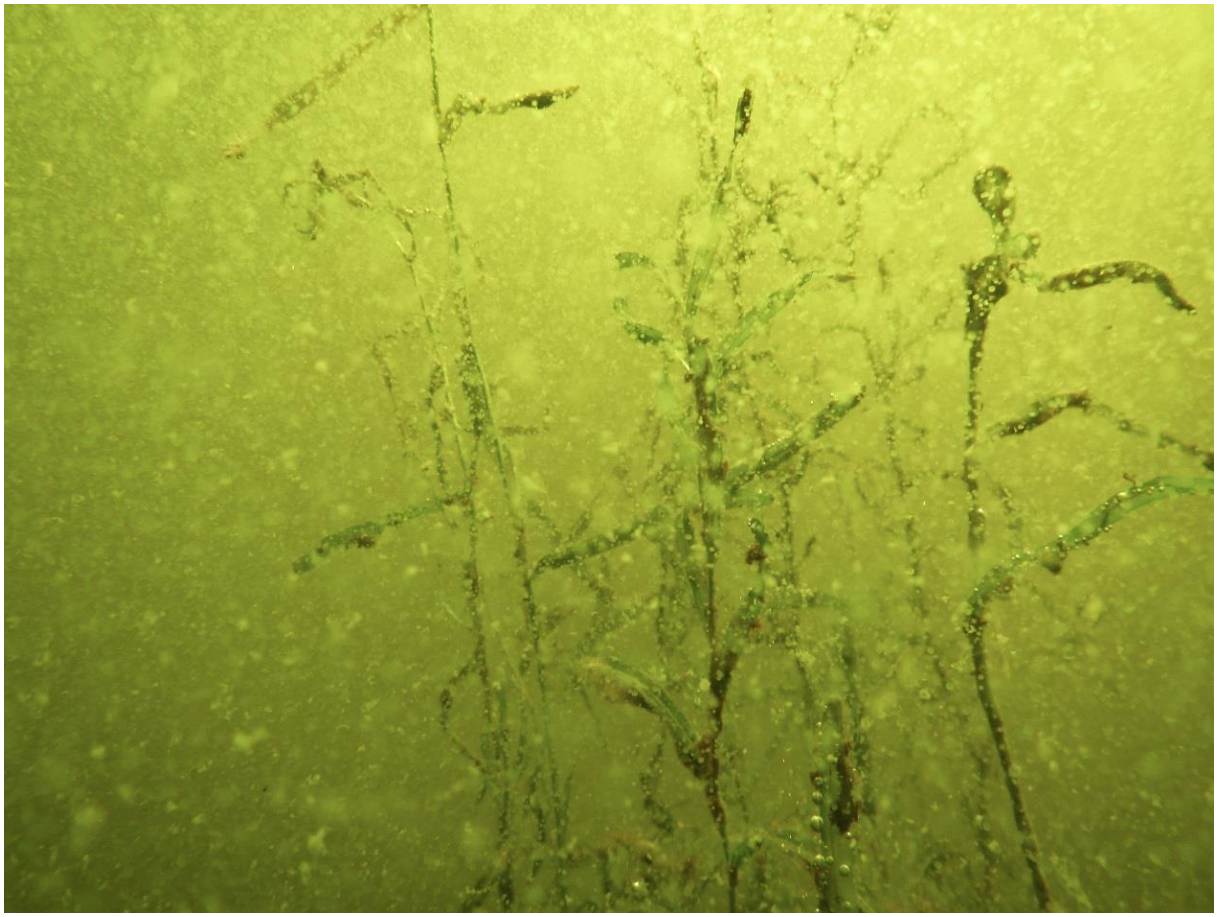


**Figure 64: Native pondweeds (*Potamogeton ochreatus*) growing in Lake Ngaruru in 2016.** Note: Algae bloom obvious in water.

## 3.24 Ohinetonga Lagoon

### 3.24.1 Results

| | |
|---|---|
| Lake condition: | Excellent |
| Lake ranking: | 4th |
| Lake maximum depth: | 3.8 m |
| Max depth of vegetation: | 2.7 m |

**Ohinetonga Lagoon Submerged Plant Indicators**

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2017 | Excellent | 91% | 80% | 0% |

**Figure 65: LakeSPI results for Ohinetonga Lagoon.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Ohinetonga Lagoon is categorised as being in excellent ecological condition with a LakeSPI Index of 91% (Figure 65).

Charophyte species *Nitella* sp. aff. *cristata*, formed dense meadows (> 75% cover) at all five LakeSPI sites extending across the bottom (Figure 66) to a maximum depth of 2.7 m. The native pondweed *Potamogeton ochreatus*, was the only other submerged plant growing in the lagoon and it formed tall patches, up to 2.4 m tall, from a depth of c. 1 – 2.7 m at all sites (Figure 67).

No invasive species were recorded from within the lagoon.

At the time of the survey, good water clarity was noted in the lagoon with through-water visibility estimated by divers to be > 3 m. No freshwater mussels were observed.

*Historic vegetation notes:* The only submerged plant species recorded during a spot survey by NIWA in March 2003 (Champion and Wells 2003) was *Potamogeton ochreatus*. *Ludwigia palustris* was recorded on the margins and a floating lily, *Nymphaea alba*, was also observed.

### 3.24.2 Discussion

Ohinetonga Lagoon provides an excellent example of a small but un-impacted lake system that has retained a well-developed native submerged plant community in the absence of any invasive species.

A Native Condition Index of 80% (Figure 65) reflects the extent and cover of native plants in the lake with charophyte meadows extending over much of the bottom.

Ohinetonga Lagoon remains at considerable risk from invasion by submerged weed species that have the potential to have a big impact in this lake system.

While the lake is accessible to the public via a walking track, the lagoons remote location and absence of any obvious access points for small boats, provide it with some protection.

**Figure 66: A native charophyte *Nitella* sp. aff. *cristata*, formed meadows in Ohinetonga Lagoon.**

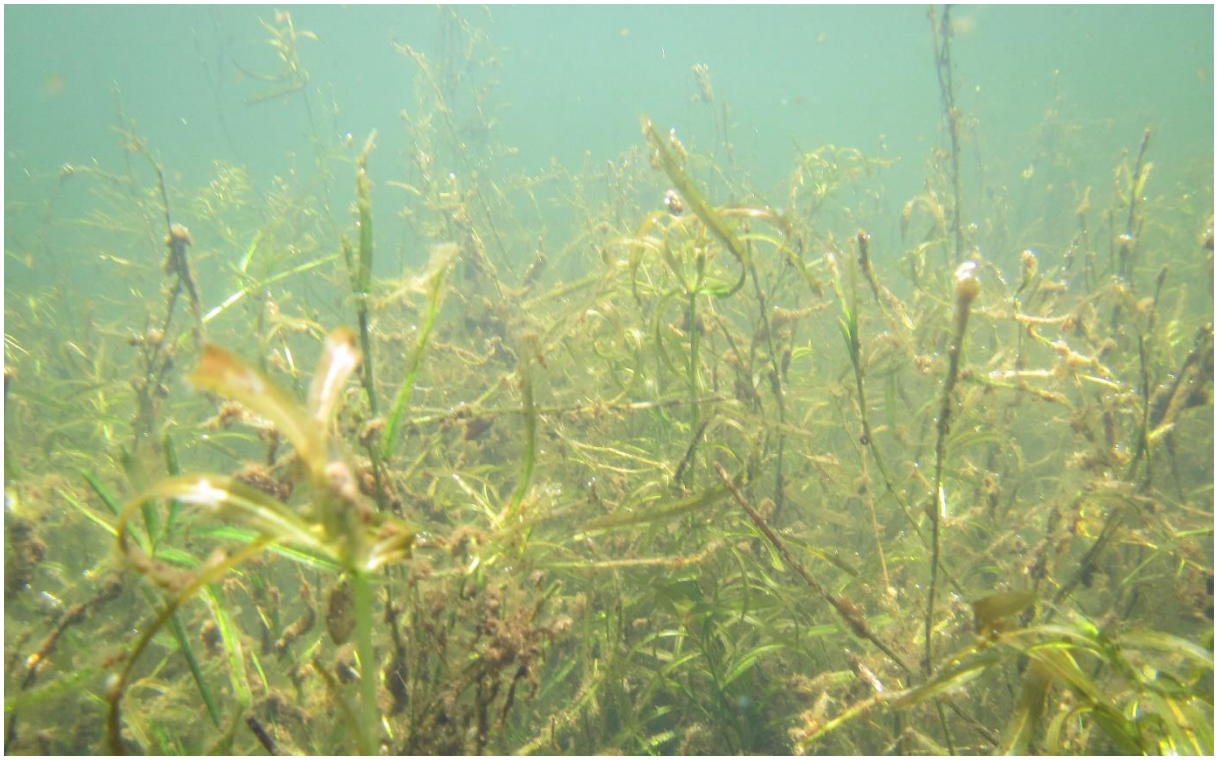


**Figure 67: Native pondweeds (*Potamogeton ochreatus*) formed clumps throughout the Ohinetonga Lagoon.**

## 3.25 Lake Omanu

### 3.25.1 Results

| | |
|---|---|
| Lake condition: | Poor |
| Lake ranking: | 36th |
| Lake maximum depth: | 1.2 m |
| Max depth of vegetation: | 1.2 m |

**Lake Omanu Submerged Plant Indicators**

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2016 | Poor | 17% | 25% | 89% |

**Figure 68: LakeSPI results for Lake Omanu.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Omanu is categorised as being in poor ecological condition with a LakeSPI Index of 17% (Figure 68).

Hornwort (*Ceratophyllum demersum*) dominated the submerged vegetation in Lake Omanu forming a dense weed bed over the entire lake surface down to the lake's maximum depth of 1.2 m. Plants were surface reaching but had been topped by waterfowl browsing. Other invasive species included *Potamogeton crispus* and low covers of *Elodea canadensis.* Floating fragments of *Lagarosiphon major* were also observed on the lake.

The native pondweed *Stuckenia pectinata* was the only submerged native species recorded in Lake Omanu. It formed low to moderate covers in patches throughout the hornwort at all four LakeSPI baseline sites.

At the time of this recent survey, the water was noted as very dark in colour, with little visibility. A Secchi disk reading was 0.3 m. No freshwater mussels were observed.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out by NIWA in March 2003 (Champion and Wells 2003) recorded only the presence of hornwort.

### 3.25.2 Discussion

Lake Omanu is managed by Fish and Game for recreational shooting and a large number of black swan were present on the lake at the time of the recent visit. While the presence of hornwort is not favourable in terms of overall lake condition, the presence of any submerged plants in a lake is preferable to none. For Lake Omanu, the surface reaching beds of hornwort maybe attracting waterfowl to the lake, but monospecific beds of this weed are not beneficial for diversity or ecological stability of a vegetated lake.

## 3.26 Omanuka Lagoon

### 3.26.1 Results

| | |
|---|---|
| Lake condition: | High |
| Lake ranking: | 16th equal |
| Lake maximum depth: | 0.95 m |
| Max depth of vegetation: | 0.95 m |

Omanuka Lagoon Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2016 | High | 52% | 61% | 49% |

**Figure 69: LakeSPI results for Omanuka Lagoon.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Omanuka Lagoon is categorised in high ecological condition with a LakeSPI Index of 52% (Figure 69).

Lake vegetation consisted of a mixed community of native and invasive plant species, forming a mosaic of plants across the bottom down to the lagoons maximum recorded depth of 0.95 m (at time of recent survey). Total submerged plant covers over the lake bottom were recorded by divers to be c. 70-80%.

Native pondweeds (*Stuckenia pectinata, Potamogeton ochreatus*) were the most prevalent submerged species in the lagoon forming moderate covers, surface reaching in places, at all four LakeSPI sites. Other native submerged vegetation included two native milfoils (*Myriophyllum triphyllum* and *Myriophyllum propinquum*), *Ruppia polycarpa* and two charophyte species (*Chara globularis* and *Chara* sp. aff. *muellerii*) (Figure 70).

The introduced pondweed *Potamogeton crispus*, grew amongst native species in the lagoon growing up to 0.9 m in height at all LakeSPI sites. Other introduced species included water buttercup (*Ranunculus trichophyllus*), starwort (*Callitriche stagnalis*), *Ludwigia palustris* and the submerged form of the usually emergent water speedwell (*Veronica anagallis-aquatica*).

Three free-floating native species, *Ricciocarpos natans, Azolla rubra* and *Lemna disperma* (Figure 71), were also recorded from lagoon. A dense band of emergent species, mainly *Typha orientalis*, grew around the margin.

At the time of recent survey, through-water visibility was estimated to be c. 0.9 m. No freshwater mussels were observed.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out by NIWA in August 2002 (Champion and Wells 2003) recorded many of the same species recorded above including *Callitriche stagnalis*, *Myriophyllum triphyllum*, *Potamogeton ochreatus*, *Stuckenia pectinata*, and *Ludwigia palustris*. *Potamogeton crispus* was the only invasive submerged plant present.

### 3.26.2 Discussion

A high LakeSPI Index of 52% reflects the presence of a well-developed submerged plant community, comprising both native and introduced species, extending across the bottom of the lagoon. Furthermore, submerged plant records from a spot survey in the lake in 2002, suggest that the lake has remained in a similar condition over the last fifteen years (2002-2017).

The shallow nature of Omanuka Lagoon (<1 m) could make the lake particularly vulnerable to change over a short time frame (e.g., vulnerability to drought). However, periodic drying out of the lake bed may also be helping the lake to maintain its diverse submerged plant community by favouring seed-producing species (similar to Pukepuke Lagoon).

An exciting find in Omanuka lagoon was the discovery of the native charophyte species, *Chara* sp. aff. *muellerii* (Figure 70), for the first time in the North Island. This plant's threat status is categorised as data deficient (Townsend et al. 2008), and it is thought to be at risk (Paul Champion, NIWA, pers. comm.).

Another plant of interest was the near-threatened (At Risk: Declining – de Lange et al. 2020) aquatic liverwort, *Ricciocarpos natans* (Figure 71). This free-floating species was found growing amongst another free-floating native species in sheltered areas around the margin.

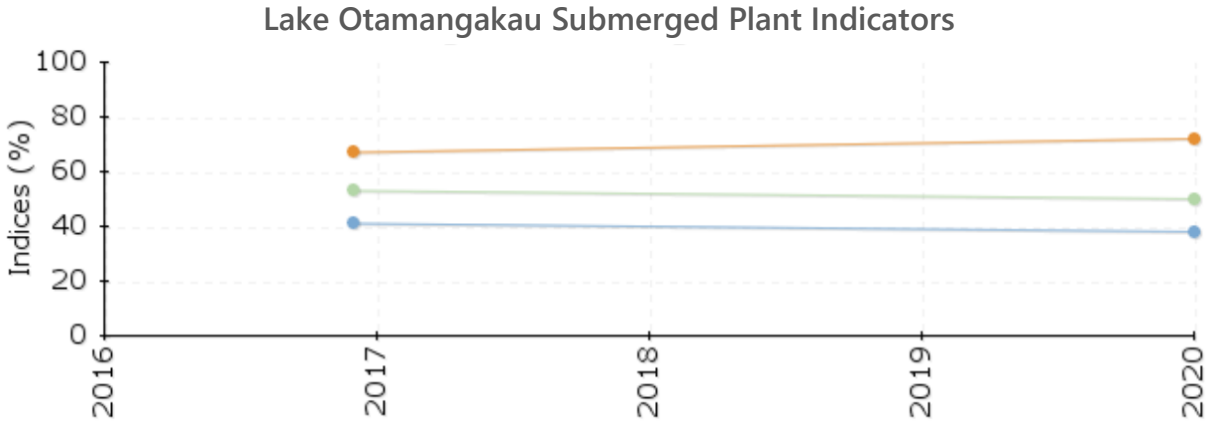
**Figure 70:** ***Chara* sp. aff. *muellerii* from Omanuka Lagoon.** Insert shows distinctive tips with two end cells.

**Figure 71:** ***Ricciocarpos natans*** **(bigger green leaves) growing amongst other free-floating species (*Azolla rubra* (reddish colour) and *Lemna disperma*) in the Omanuka Lagoon.**

## 3.27 Lake Otamangakau

### 3.27.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 23rd |
| Stability: | Stable |
| Lake maximum depth: | 10 m |
| Max depth of vegetation: | 7.7 m |




| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2019 | Moderate | 38% | 50% | 72% |
| November 2016 | Moderate | 41% | 53% | 67% |

**Figure 72: LakeSPI results for Lake Otamangakau.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Otamangakau is categorised as being in moderate ecological condition with a LakeSPI Index of 38% (Figure 72).

Lagarosiphon (*Lagarosiphon major*) (Figure 73) dominated the submerged vegetation in Lake Otamangakau forming dense surface-reaching weed beds, up to 3.8 m tall, extending from the shallows to c. 5 m deep (Figure 74). *Elodea canadensis* was present at lower covers growing deeper than lagarosiphon to a maximum depth of 5.9 m.

Two native charophytes, *Nitella* sp. aff. *cristata* and *Chara australis*, were recorded from the lake. *Nitella* sp. aff. *cristata* formed meadows (>75% cover) at all five LakeSPI sites, down to a maximum depth of 6.8 m (Figure 75). *Chara australis* was recorded from only one site forming high covers between 6.6 – 7.7 m. A native pondweed, *Potamogeton ochreatus*, was also recorded from all five baseline sites.

In shallower water, a diverse native low growing community extended down to a maximum depth of c. 1 m. This included *Glossostigma diandrum*, *Glossostigma elatinoides*, *Lilaeopsis ruthiana*, *Limosella lineata*, *Ranunculus limosella*, *Myriophyllum propinquum, Nitella hyalina* and *Nitella pseudoflabellata*. Submerged foliage emergent *Ranunculus flammula* were also present at one of the five LakeSPI sites.

A thick covering of epiphytic algae was noted covering the plants during both the 2015 and 2019 surveys (Figure 73 and Figure 75). At the time of the 2019 survey, through-water visibility was estimated by divers to be c. 3 - 5 m. No freshwater mussels or kōura were observed.

*Historic vegetation notes:* A survey in November 1982 (NIWA historic record), recorded many of the same species recorded above, with the addition of the native pondweed (*Potamogeton cheesemanii*). Lagarosiphon was present as well as two additional introduced species, *Potamogeton crispus* and *Ranunculus trichophyllus*. Dugdale and Wells (2001) also carried out a submerged plant survey at one site (near boat ramp) February 2001. They described *Glossostigma diandrum* and *Myriophyllum propinquum* growing in the shallows "before being overtopped by the tall growing species lagarosiphon, elodea, and *Potamogeton ochreatus*" (Dugdale and Wells 2001). *Juncus bulbosus* was also recorded at this time.

### 3.27.2 Discussion

Lake Otamangakau has remained in a relatively stable condition with only minor changes evidenced in the LakeSPI scores between the 2016 and 2019 timeframe (Figure 72). A LakeSPI Index of 38% reflects a lake that still maintains a well-developed deep water native plant community extending down to c. 7 m, close to the lakes maximum observed depth of 10 m, despite being impacted by the invasive weed lagarosiphon.

The initial selection of baseline LakeSPI sites in 2016 was difficult in Lake Otamangakau, with much of the lakebed being <5 m in depth. LakeSPI survey sites were therefore selected adjacent to areas of steeper topography that allowed for plant maximum depth to be recorded. Because of the lake's shallow nature, extensive areas of the lake are occupied by surface reaching weed beds (browsed by swans) and many swans were observed on the lake during both surveys.

Lake Otamangakau is particularly vulnerable to invasion by hornwort (*Ceratophyllum demersum*). Hornwort, already present in nearby lakes Rotoaira and Taupo, has the potential to displace all deeper growing native plant communities present in the lake by occupying a deeper depth range than lagarosiphon. Should hornwort or make its way into Lake Otamangakau we could expect to see a significant decline in LakeSPI scores in the future. There would also be considerable recreational impacts associated with invasion by these weed species because of the lake's popular trout fishery.

**Figure 73: Lagarosiphon dominated the vegetation in Lake Otamangakau.** Bottom photo shows diver moving through weed bed at a depth of c. 5 m during the 2019 survey.

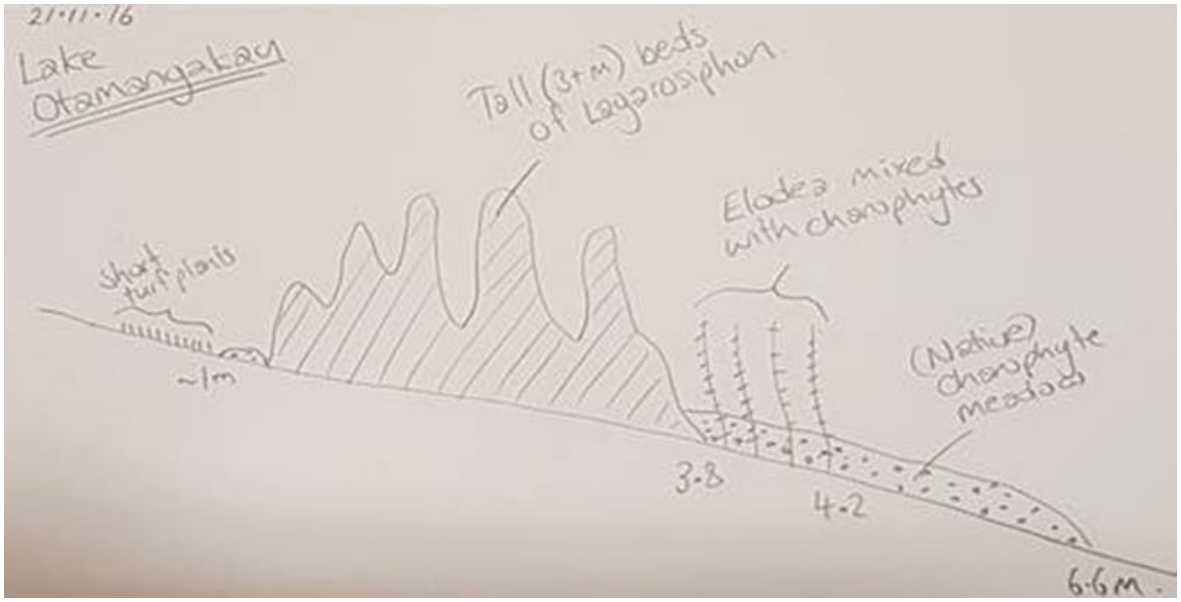


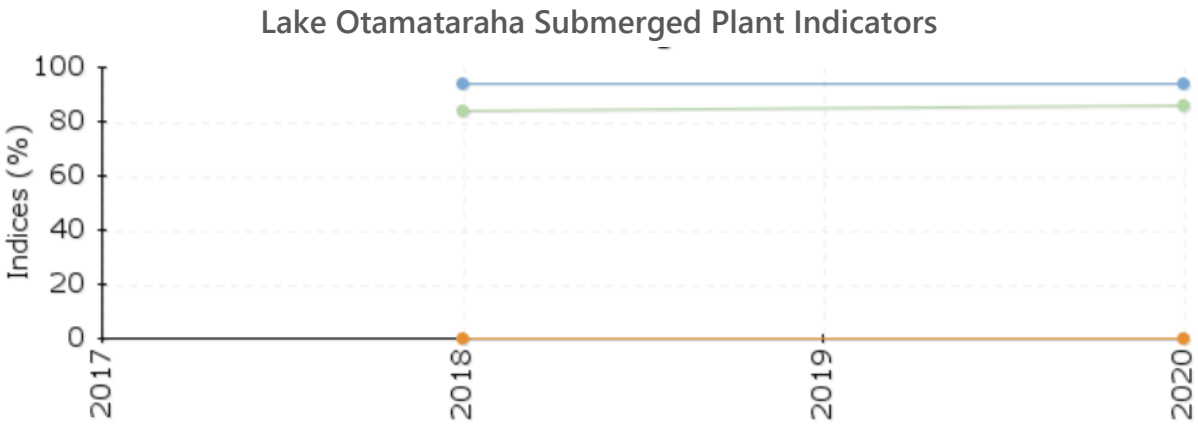

**Figure 74: Profile sketch by diver in 2016 showing submerged plants growing down profile in Lake Otamangakau**

**Figure 75: Native charophytes (*Nitella* sp. aff. *cristata*) growing in deeper water > 5 m in Lake Otamangakau.** (photo on left taken in 2015, photo on right in 2019)

## 3.28 Lake Otamataraha

### 3.28.1 Results

| | |
|---|---|
| Lake condition: | Excellent |
| Lake ranking: | 2nd equal |
| Stability: | Stable |
| Lake maximum depth: | 1.8 m |
| Max depth of vegetation: | 1.8 m |




| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2019 | Excellent | 94% | 86% | 0% |
| December 2017 | Excellent | 94% | 84% | 0% |

**Figure 76: LakeSPI results for Lake Otamataraha.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Otamataraha is categorised as being in excellent ecological condition with a LakeSPI Index of 94% (Figure 76).

A dense stand of emergent species (*Typha orientalis*) surrounds the entire lake margin growing down to c. 1 m in depth. Beyond this, native submerged vegetation extends over the lake bottom to the lakes maximum observed depth of 1.8 m. Native charophyte *Nitella* sp. aff. *cristata*, formed meadows (>75% cover) at all five sites, and the native pondweed *Potamogeton ochreatus* was also present from most sites, growing through the charophytes and reaching up to 1.2 m tall (Figure 77).

No invasive species were recorded from within the lake.

At the time of the survey, through-water visibility was estimated by divers as c. 1 m. No freshwater mussels or crayfish (koura) were observed.

*Historic vegetation notes:* The same submerged species as above were recorded during the 2015 LakeSPI survey and a during a spot survey of submerged of submerged vegetation carried out by NIWA in March 2003 (Champion and Wells 2003). Additional species observed in the lake include a milfoil, *Myriophyllum triphyllum*, observed in 2015 (but not at a LakeSPI site), and a native buttercup species, *Ranunculus amphitrichus* in 2003.

### 3.28.2 Discussion

Lake Otamataraha is one of best examples of a lake system in the Manawatū-Whanganui Region (Table 3) that, while shallow, maintains a well-developed native plant community in the absence of any invasive weed species. This is reflected in a high LakeSPI Index of 94% and a Native Condition Index of 86% with little to no change occurring between the 2017 and 2019 survey (Figure 76).

Due to the lakes shallow depth, care should continually be taken when interpreting results for Lake Otamataraha as seemingly small impacts have the potential to cause large ecological changes in condition over a short period of time (e.g., vulnerability to drought).

Although threats from additional weed species appear minimal on account of the lack of public access in to Lake Otamataraha, it is advisable that the land owners be notified to exercise discretion in allowing access to the lake for users of equipment that may be contaminated with invasive species (e.g., boats used for duck shooting, fishing nets).

While no koura were observed in the lake during the surveys, conversations with the landowner (Andy Sheret, pers. comm. 2015) indicate they are present.

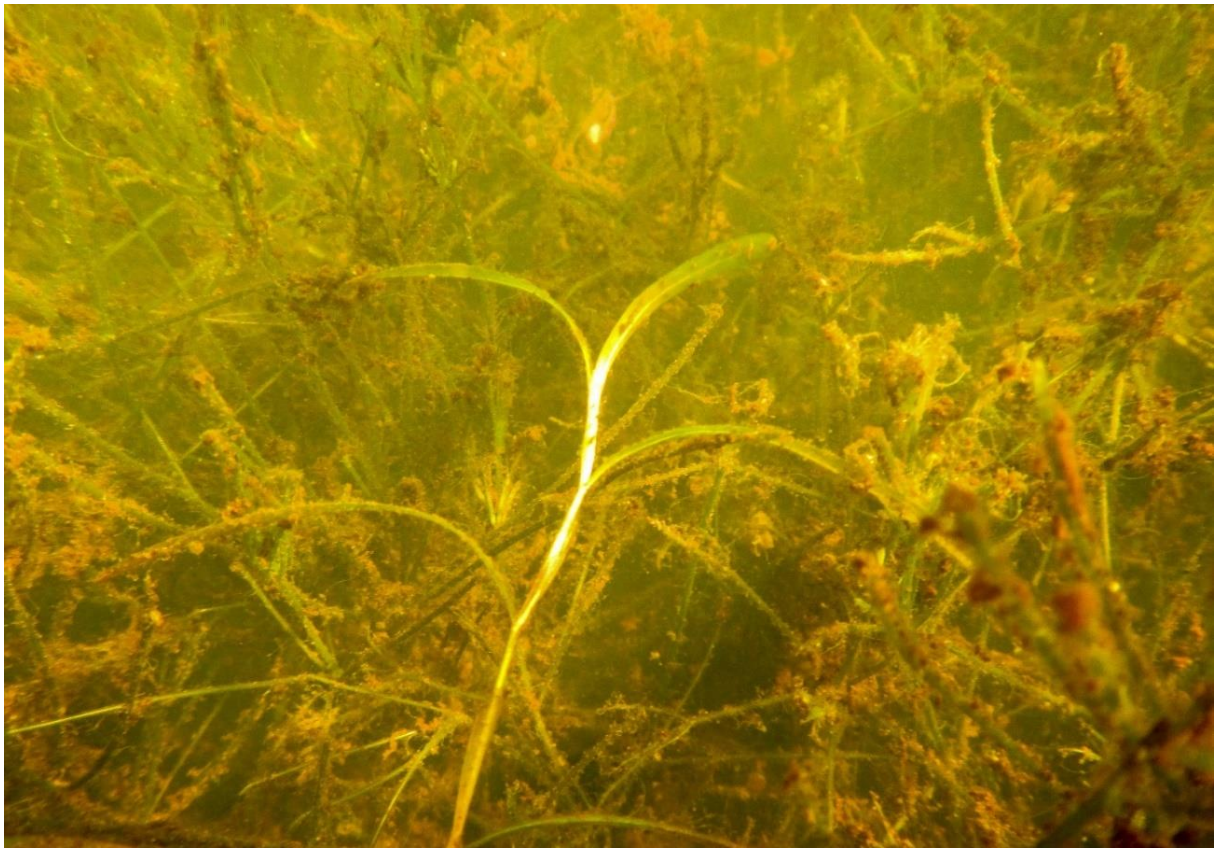


**Figure 77: *Nitella* sp. aff. *cristata* and *Potamogeton ochreatus* (centre) formed a complete cover across the bottom of Lake Otamataraha.**

## 3.29 Lake Papaitonga

### 3.29.1 Results

| | |
|---|---|
| Lake condition: | Non-vegetated |
| Lake ranking: | 43rd equal |
| Lake maximum depth: | 1 m |
| Max depth of vegetation: | 0 m |

**Lake Papaitonga Submerged Plant Indicators**

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2015 | Non-vegetated | 0% | 0% | 0% |

**Figure 78: LakeSPI results for Lake Papaitonga.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Papaitonga is categorised as being non-vegetated with no submerged vegetation observed during the survey (Figure 78).

This lake had extremely low water clarity (Figure 79) and bottom sediments consisted of a soft muddy sludge with no hard bottom. High covers of filamentous algae were also present in the lake.

*Historic vegetation notes:* In 1949 Cunningham et al. (1953) recorded pondweeds (species not identified) growing around the shallower edges of the lake. At this time the deepest point of the lake was at least 2 m depth.

### 3.29.2 Discussion

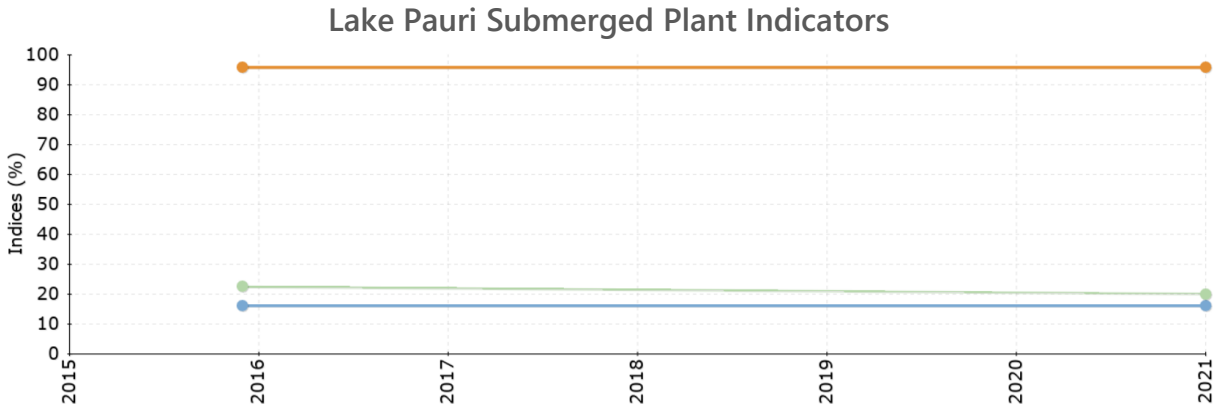
The water clarity observed in Lake Papaitonga was the lowest observed for any of the 47 lakes assessed in the region. Water quality and the soft sludgy mud bottom make this lake unsuitable for submerged plant growth.


**Figure 79: Clipboard on the surface of Lake Papaitonga shows the colour of water and range of visibility.**

## 3.30 Lake Pauri

### 3.30.1 Results

| | |
|---|---|
| Lake condition: | Poor |
| Lake ranking: | 37th equal |
| Lake maximum depth: | 14.9 m |
| Max depth of vegetation: | 6.4 m |




| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2020 | Poor | 16% | 20% | 95% |
| November 2015 | Poor | 16% | 22% | 96% |

**Figure 80: LakeSPI results for Lake Pauri.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Pauri is categorised as being in poor ecological condition with a LakeSPI Index of 16% (Figure 80).

Five invasive weed species were recorded from within Lake Pauri with the most invasive of these, hornwort (*Ceratophyllum demersum*) (Figure 81), dominating the submerged vegetation. Hornwort formed a dense band of weed around the lake margin, growing to more than 4 m in height and down to a maximum depth of 6.4 m. Other invasive species included *Egeria densa*, which formed clumps through the hornwort, and to a lesser extent *Elodea canadensis*, *Potamogeton crispus* and water buttercup *Ranunculus trichophyllus*.

Native vegetation in Lake Pauri included two native pondweeds (*Potamogeton ochreatus*, *Stuckenia pectinata*), a milfoil *Myriophyllum triphyllum*, three charophytes (*Nitella* sp. aff. *cristata*, *Chara australis*, *Chara globularis*), two turf plants (*Glossostigma elatinoides*, *Lilaeopsis novae-zelandiae*), and *Ruppia polycarpa*. Only low covers of native plants were recorded from 4 of the 5 sites.

Higher covers were observed from one site on the lakes Southern side, where native plants formed a mixed native community in shallower water <2 m deep.

A near-threatened (At Risk: Declining – de Lange et al. 2020) aquatic free-floating liverwort, *Ricciocarpos natans* (Figure 82) was also recorded from the lake. This free-floating species was observed growing amongst other free-floating native species, *Azolla rubra* and *Lemna disperma* in sheltered areas around the jetty close to the sailing club.

At the time of the survey, through-water visibility was poor and estimated by divers to be between 0.5 – 1.5 m. One large freshwater mussel and sponges were found in the shallows on the Southern side.

*Historic vegetation notes:* When Lake Pauri was surveyed by Kelly (1978), the introduced pondweed *Potamogeton crispus* was the dominant species and the invasive buttercup *Ranunculus trichophyllus* was also present. A diverse community of native submerged vegetation was present including the pondweeds *Potamogeton ochreatus*, *Potamogeton cheesemanii* and *Stuckenia pectinata*, milfoils *Myriophyllum triphyllum* and *Myriophyllum propinquum*, the charophytes *Chara australis* and *Nitella* sp. aff. *cristata* and *Ruppia megacarpa*. In January 2003, a spot survey of submerged vegetation carried out by NIWA (Champion and Wells 2003) recorded the presence of egeria and elodea but not hornwort. Hornwort was not found in the lake until 2013 (Gibbs and Champion 2013).

*Chara australis* was collected from the lake in 1956 (Wood and Mason 1977).

### 3.30.2 Discussion

Lake Pauri has remained in a relatively stable condition with only minor changes evidenced in the LakeSPI scores between the 2015 and 2020 timeframe (Figure 80).

An Invasive Impact Index of 96% (Figure 80) is one of the highest recorded for the 47 lakes in the Manawatū-Whanganui Region reflecting the high level of impact from these combined weed species on the overall condition of Lake Pauri. As hornwort has likely reached habitat saturation in the lake it is likely that this lake will remain categorised in poor condition.

An invasive filamentous green alga water net (*Hydrodictyon reticulatum*), recorded from one site in 2015, was not seen in 2020.

**Figure 81: Hornwort dominated the vegetation in Lake Pauri.**

**Figure 82: Native free-floating *Ricciocarpos natans* (bigger leaves) growing amongst *Lemna disperma***

## 3.31 Lake Poroa (Oporoa)

### 3.31.1 Results

| | |
|---|---|
| Lake condition: | Non-vegetated |
| Lake ranking: | 43rd equal |
| Lake maximum depth: | 2.2 m |
| Max depth of vegetation: | 0 m |

Lake Poroa Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2016 | Non-vegetated | 0% | 0% | 0% |

**Figure 83: LakeSPI results for Lake Poroa.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Poroa is categorised as being non-vegetated with no submerged vegetation recorded during the survey (Figure 83).

At the time of this recent survey, the water was noted to be a yellow-brown colour (Figure 84), with little underwater visibility. Secchi disk reading was 0.3 m. No freshwater mussels were observed.

*Historic vegetation notes:* Discussions with Robert Martin (Te Maru O Ruahine Trust) at the time of the recent survey alluded to the presence of native plant communities present in this lake in the past, however no written observations have been found. A group of students who visited the lake in March 2007 (Fowles et al. 2007) noted that the condition of the lake as being poor with an algal bloom and water discolouration.

### 3.31.2 Discussion

This lake had extremely low water clarity and bottom sediments were a soft sludge (Figure 85) making this lake unsuitable for submerged plant growth.

**Figure 84: The lake water appeared yellow in Lake Poroa at the time of the survey.**The browner water in the centre shows disturbance of the sediments by the boat prop.

**Figure 85: Lake Poroa had soft organic bottom sediments.**

## 3.32 Lake Pounamu

### 3.32.1 Results

| | |
|---|---|
| Lake condition: | Non-vegetated |
| Lake ranking: | 43rd equal |
| Lake maximum depth: | 15.1 m |
| Max depth of vegetation: | 0 m |

**Lake Pounamu Submerged Plant Indicators**

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2018 | Non-vegetated | 0% | 0% | 0% |

**Figure 86: LakeSPI results for Lake Pounamu.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Pounamu is categorised as being in a non-vegetated condition with a LakeSPI Index of 0% (Figure 86).

No submerged plants were present in the lake. At the time of the survey, a dense algae bloom was present, and the water was very green in colour (Figure 87).

*Historic vegetation notes:* A spot survey carried out by NIWA in March 2003 (Champion and Wells 2003) recorded native pondweeds (*Potamogeton ochreatus*) forming high covers up to 1.5 m high, and growing down to a maximum depth of 3.1 m. Through water visibility was low (c. 0.3 m) and many eels were observed at this time.

### 3.32.2 Discussion

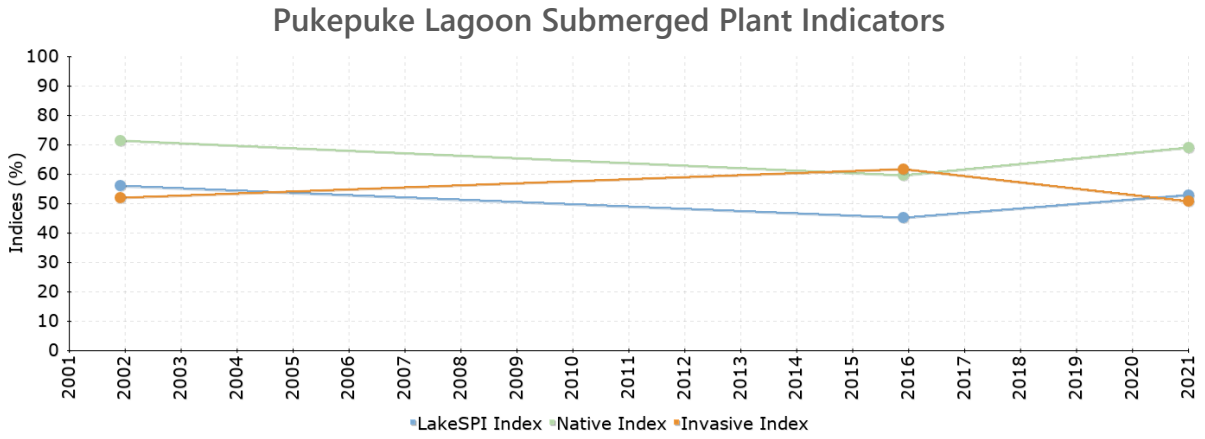
Submerged vegetation noted in the lagoon in 2003 (Champion and Wells 2003) was not present during the recent survey. Poor water quality noted at the time of the recent survey likely makes this lake unsuitable for submerged plant growth.

**Figure 87: Lake Pounamu was green during the 2018 survey.**

## 3.33 Pukepuke Lagoon

### 3.33.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 17th |
| Lake maximum depth: | 1.3 m |
| Max depth of vegetation: | 1.25 m |




| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2020 | High | 53% | 69% | 51% |
| November 2015 | Moderate | 45% | 60% | 62% |
| November 2001 | High | 56% | 71% | 52% |

*Note: 2001 survey based on only 1 site.

**Figure 88: LakeSPI results for Pukepuke Lagoon.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Pukepuke lagoon is categorised as being in high ecological condition with a LakeSPI Index of 53% (*Note: **2001 survey based on only 1 site.**

Figure 88).

A well-developed mixed community of native and invasive submerged vegetation formed high covers across the bottom of the lagoon down to its maximum recorded depth of 1.25 m.

In 2020, two small (< 10 cm) fragments of hornwort (*Ceratophyllum demersum*) were found floating amongst the marginal vegetation at one of the three LakeSPI sites (Figure 89). Other introduced species included the pondweed *Potamogeton crispus*, that formed moderate covers across the lagoon bottom at all three sites, and the water buttercup (*Ranunculus trichophyllus*), which was less common but present in shallower water to a maximum of 0.8 m depth.

Native vegetation was comprised of a mixed community (Figure 90) of *Stuckenia pectinata*, *Ruppia polycarpa* and *Chara globularis*, with the odd shoot of *Myriophyllum triphyllum*.

Water clarity was poor during the survey with through water visibility estimated by divers to be < 0.5 m. No freshwater mussels were observed.

*Historic vegetation notes:* In 1949, Cunningham et al. (1953) recorded a dense wide bed of *Typha orientalis* around the margins and noted that the depth of Pukepuke Lagoon was 0.8 m, similar to today. This report also noted submerged vegetation across the entire lakebed that was dominated by pondweeds (species not identified) and *Chara fibrosa* in shallow depths.

Kelly (1978) surveyed this lake in December 1977 and also recorded submerged vegetation growing across the entire bed of the lake. Kelly reported a Secchi measurement of "greater than 1.2 metres", which was presumably the deepest point in the lake. He also noted that "the macrophytes throughout the lake were covered with a brown fungal or algal growth and generally seemed unhealthy". By late summer the vegetation in the lagoon was recorded as having almost completely "decomposed'. Kelly reported that a three-year study by Gibbs (1973) noted a 'different group of species were dominant each summer".

A spot survey of the lagoon in November 2001 (Edwards and Clayton 2002), again described the submerged vegetation extending across the entire lake bottom. Vegetation was similarly comprised of a mixed community of *Stuckenia pectinata*, *Ruppia* sp., and *Chara globularis*.

### 3.33.2 Discussion

The LakeSPI Index for Pukepuke Lagoon has increased from 45% in 2015 to 53% in 2020 (Figure 88) on account of higher native ratios (and lower invasive ratios) being recorded for the submerged vegetation during the recent survey. While the introduced pondweed *Potamogeton crispus* was still present at all three sites in 2020, it was present at lower covers than previously observed in 2015. The recent LakeSPI scores for Pukepuke Lagoon are close to what were generated for the lagoon in 2001 (Figure 88) indicating that over the longer term (c. 19 years), the lagoon has remained relatively stable.

Hornwort, New Zealand's worst submerged invasive weed was first recorded in Pukepuke Lagoon in late 2010 (L. Brown, Horizons Regional Council, pers. comm.). While fragments of hornwort (*Ceratophyllum demersum*) seem to be persisting around the margins of Pukepuke Lagoon, found in 2015 and again during the recent 2020 survey, it does not appear to be having an impact on lake vegetation. The regular natural dewatering of Pukepuke Lagoon is likely its best defence against the invasion by hornwort, as it would limit hornwort establishment to places that would remain wetted year-round. Should hornwort continue to spread in the lagoon, it is likely that we will see a further reduction in LakeSPI scores in the future.

**Figure 89: Hornwort fragments found in Pukepuke Lagoon during the 2020 survey.**

**Figure 90: A mixed community of native species (mostly fertile *Chara globularis*) growing in Pukepuke Lagoon.**

## 3.34 Ram Hills Dam

### 3.34.1 Results

| | |
|---|---|
| Lake condition: | High |
| Lake ranking: | 14th |
| Lake maximum depth: | 4.4 m |
| Max depth of vegetation: | 1.8 m |

**Ram Hills Dam Submerged Plant Indicators**

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2018 | High | 55% | 57% | 44% |

**Figure 91: LakeSPI results for Ram Hills Dam.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Ram Hills Dam is categorised as being in high ecological condition with a LakeSPI Index of 55% (Figure 91).

Native vegetation consisted of three tall native vascular plants (*Potamogeton ochreatus*, *Potamogeton cheesemanii, Ruppia polycarpa*), three charophytes (*Nitella hyalina*, *Nitella pseudoflabellata, Chara australis*) and a turf forming species *Glossostigma diandrum*. Charophyte meadows (>75% cover) were present at two of the four LakeSPI sites.

The introduced pondweed *Potamogeton crispus* (Figure 92) was the only invasive species recorded from the lake. It formed variable covers at all four sites and extended now to a maximum depth of 1.5 m.

At the time of survey, underwater visibility was estimated by divers as between 0.3 – 1 m. No freshwater mussels or crayfish (koura) were also observed in the lake.

*Historic vegetation notes:* No historic records available. During the recent visit the landowner mentioned that the lake (Figure 93) had been created using shovels in the 1930's (Jeanie Fowler, pers. comm.).

### 3.34.2 Discussion

A high LakeSPI Index of 55% (Figure 91), reflects a lake that while small, maintains a diverse native plant community with only limited impact from the invasive species *Potamogeton crispus*.

While threats from additional weed species appear minimal on account of restricted public access, it is advisable that the land owners be notified to exercise discretion in allowing access to the lake for users of equipment that may be contaminated with invasive species (e.g., boats used for duck shooting, eel fishing nets).

Koura were not found in Ram Hills Dam but the landowner (Jeanie Fowler, pers. comm.) made comment that they used to be found in the surrounding streams and ponds.

**Figure 92: Introduced pondweed *Potamogeton crispus* in Ram Hills Dam.**

**Figure 93: Ram Hills Dam in the Waihoki Valley.**

## 3.35 Lake Rotoataha

### 3.35.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 19th |
| Lake maximum depth: | 12 m |
| Max depth of vegetation: | 4.3 m |

Lake Rotoataha Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2017 | Moderate | 44% | 38% | 47% |

**Figure 94: LakeSPI results for Lake Rotoataha.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Rotoataha is categorised as being in moderate ecological condition with a LakeSPI Index of 44% (Figure 94).

Native charophytes, *Chara globularis*, formed meadows (>75% cover) in shallower water extending down to a depth of c. 1 m. Native pondweeds, *Potamogeton ochreatus* and *Potamogeton cheesemanii*, were recorded at all five sites growing beyond the charophytes down to a maximum depth of 4.3 m. Pondweeds grew up to 3.6 m tall.

The introduced pondweed *Potamogeton crispus* was the only submerged invasive species observed in Lake Rotoataha. Covers varied between sites, extending down to a maximum depth of 3 m. Water cress (*Nasturtium sp*.) was recorded in the shallows at one site (southern side, near spring).

At the time of the survey water clarity decreased quickly with depth. Through-water visibility estimates from divers varied between sites (0.3 – 1.5 m), dropping quickly to near zero at a depth of c. 2 m. No freshwater mussels were observed.

A small side arm of the lake on the eastern side (used for boat access), contained clear spring-fed water. *Chara globularis*, *Potamogeton cheesemanii* and *Potamogeton crispus* were observed forming high covers in this shallow arm (Figure 95).

### 3.35.2 Discussion

Native and invasive pondweed species dominated the vegetation in Lake Rotoataha, with native charophyte species persisting in shallow waters despite poor water clarity at the time of the survey. Charophyte meadows are particularly sensitive to invasive displacement and reduced water clarity (Clayton and Edwards 2006), so should the water quality conditions observed in Lake Rotoataha worsen long-term, we could expect to see these native communities disappear in the future.

While threats from additional weed species appear minimal on account of the lack of public access in to Lake Rotoataha, it is advisable that the land owners be notified to exercise discretion in allowing access to the lake for users of equipment that may be contaminated with invasive species (e.g., boats used for duck shooting, fishing nets).

**Figure 95: Side arm of Lake Rotoataha. *Chara globularis* (shadow in centre) and *Potamogeton cheesemanii* (bottom right) visible through clear spring-fed water.** Emergent *Carex secta* in middle.

## 3.36 Lake Rotokauwau

### 3.36.1 Results

| | |
|---|---|
| Lake condition: | High |
| Lake ranking: | 16th equal |
| Lake maximum depth: | 1.8 m |
| Max depth of vegetation: | 1.8 m |

Lake Rotokauwau Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2019 | High | 52% | 67% | 56% |

**Figure 96: LakeSPI results for Lake Rotokauwau.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Rotokauwau is categorised as being in high condition with a LakeSPI Index of 52% (Figure 96).

A mixed community of native and introduced submerged vegetation formed high covers across the bottom of Lake Rotokauwau down to its maximum observed depth of 1.8 m.

Native vegetation consisted of four charophytes (*Chara australis*, *Chara globularis*, *Nitella* sp. aff. *cristata*, *Nitella stuartii*), three tall native vascular plants (*Potamogeton ochreatus*, *Stuckenia pectinata*, *Myriophyllum triphyllum* (Figure 97) and a turf forming species *Glossostigma elatinoides*. Charophyte meadows (>75% cover) were observed over much of the lake bottom at four of the five LakeSPI sites.

The introduced pondweed *Potamogeton crispus* (Figure 97) was the most prevalent introduced species in the lake. It formed high but variable covers across the bottom at all five sites. Egeria (*Egeria densa*) was recorded from one site forming small clumps, up to 0.6 m high, between 1.2 – 1.6 m depth.

Free-floating native species, *Azolla rubra* and *Lemna disperma* were also observed in the lake.

At the time of survey, underwater visibility was estimated by divers to be c. 1.5 m. A Secchi disk measurement of 1.4 m was recorded from the lake centre. No freshwater mussels or koura were also observed in the lake.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out in March 2003 (Champion and Wells 2003) recorded *Chara australis*, *Potamogeton crispus* and *Azolla rubra*.

### 3.36.2 Discussion

A well-developed mixed community of native and introduced species growing across the shallow bottom of Lake Rotokauwau is reflected in a high Native Condition Index of 67% and Invasive Impact Index of 56% (Figure 96).

The discovery of egeria in Lake Rotokauwau is concerning. Egeria, one of New Zealand's worst submerged plants species, has the potential to displace all existing native vegetation as it is capable of forming dense weed beds. At the time of the recent survey (December 2019), only small clumps of egeria were found at one site at the eastern end of the lake. If the current findings reflect an early stage of invasion by egeria then we could expect to see a significant reduction in lake condition and LakeSPI scores in the future as the weed continues to spread. Another scenario could be that egeria has been present in the lake for some time but that the current environmental conditions are preventing it from forming high covers, but this is less likely.

Lake Rotokauwau remains at risk of future invasion from hornwort (*Ceratophyllum demersum*), with contaminated boat traffic or fishing nets representing the greatest threat. It is advisable that the landowners be notified to exercise discretion in allowing access to the lake for users of equipment that may be contaminated by hornwort.

With a maximum depth of just 1.8 m deep, Lake Rotokauwau is close to the limit of being able to apply a LakeSPI assessment. Water bodies less than one meter in depth, are not generally recommended for assessment using LakeSPI based on limitations in the methods metrics to detect change over time at shallow depths. The shallow nature of this waterbody makes it particularly vulnerable to change over a short time frame (e.g., vulnerability to dewatering during drought).

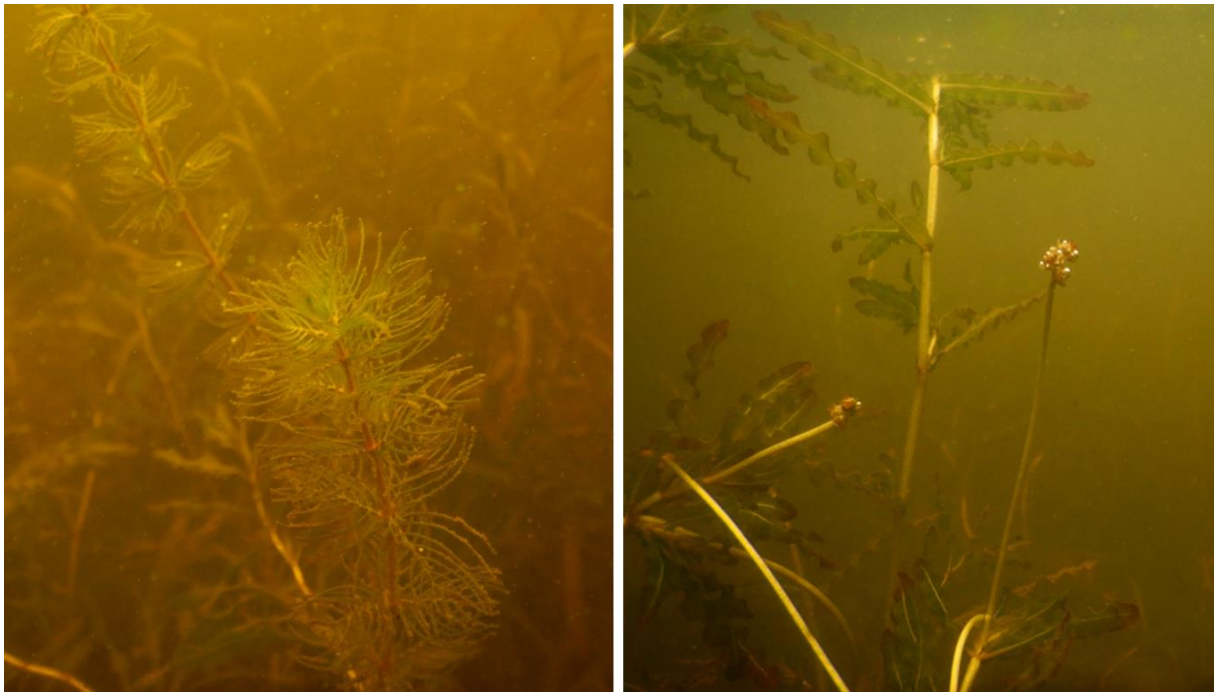


**Figure 97: Native milfoil *Myriophyllum triphyllum* (left) and the introduced pondweed *Potamogeton crispus* (right) in Lake Rotokauwau.**

## 3.37 Lake Rotorua (Rangitikei Valley)

### 3.37.1 Results

| | |
|---|---|
| Lake condition: | High |
| Lake ranking: | 13th |
| Lake maximum depth: | 8.7 m |
| Max depth of vegetation: | 3 m |

Lake Rotorua Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2018 | High | 56% | 47% | 30% |

**Figure 98: LakeSPI results for Lake Rotorua.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Rotorua is categorised as being in high ecological condition with a LakeSPI Index of 56% (Figure 98).

Native pondweed *Potamogeton ochreatus*, formed moderate to high covers at all five LakeSPI sites, growing up to 1.6 m tall and extending down a maximum depth of 3 m (Figure 99). A native charophyte *Chara australis*, was also present, generally at low covers in the shallows (< 1 m), but was meadow forming (> 75% cover) at one site (Figure 100). Other native species included two free-floating species *Azolla rubra* and *Lemna disperma*. Azolla formed a dense floating mat along the western margin of the lake.

Three invasive species were recorded from the lake: egeria (*Egeria densa*), elodea (*Elodea canadensis*) and the introduced pondweed *Potamogeton crispus*. Only one shoot of egeria was recorded from a LakeSPI site but further investigation located two localised areas close to maimai's at the southern end of the lake. Elodea was present at all five LakeSPI sites and formed low to moderate covers (< 25 %) extending down to a maximum depth of 1.4 m. An introduced pondweed *Potamogeton crispus* and submerged marginal species *Ludwigia palustris* were also present at one site.

At the time of recent survey, through-water visibility was good and estimated by divers to be c. 3.0+ m. A thick layer of filamentous algae (Figure 101) was noted covering most plants. No freshwater mussels were observed.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out by NIWA in March 2003 (Champion and Wells 2003) recorded the presence of *Potamogeton ochreatus*, two free-floating plants *Azolla rubra* and *Lemna disperma*, and a submerged marginal *Ludwigia palustris*. Records indicate that the pondweeds were not in good condition at the time of the visit, described as being "mostly died-off seedlings" extending down to a maximum depth of 1 m. Through-water visibility at the time of the 2003 survey was estimated at 0.8 m.

### 3.37.2 Discussion

A high LakeSPI Index of 56% (Figure 98) reflects the presence and extent of native species in the lake with only limited impact from invasive species. The native pondweed *Potamogeton ochreatus* was the most prevalent species recorded with plants appearing healthy at the time of the recent survey (early summer). As pondweeds are seed and turion (specialised asexual reproductive organs similar to tubers) producing species, should lake conditions become unfavourable for plant growth (e.g., due to water quality), they have the ability to recolonise once conditions for plant growth improve. This may explain observations from the visit (Champion and Wells 2003) in late summer, which noted that the pondweeds appeared to have died off with only seedlings persisting. A thick layer of filamentous algae covering the plants at the time of the recent survey likely indicates ongoing issues with water quality in the lake.

The discovery of egeria, one of New Zealand's worst submerged weed species during the recent survey is of concern for Lake Rotorua. This finding likely reflects an early stage of invasion given the plants localised distribution and location next to two maimai's at the time of the recent 2018 survey. Egeria is capable of forming dense surface reaching weed beds that in a lake of this depth (8.7 m), would result in it displacing all existing native vegetation. We can therefore expect to see a significant reduction in LakeSPI scores in the future as this weed continues to spread and impact on lake condition.

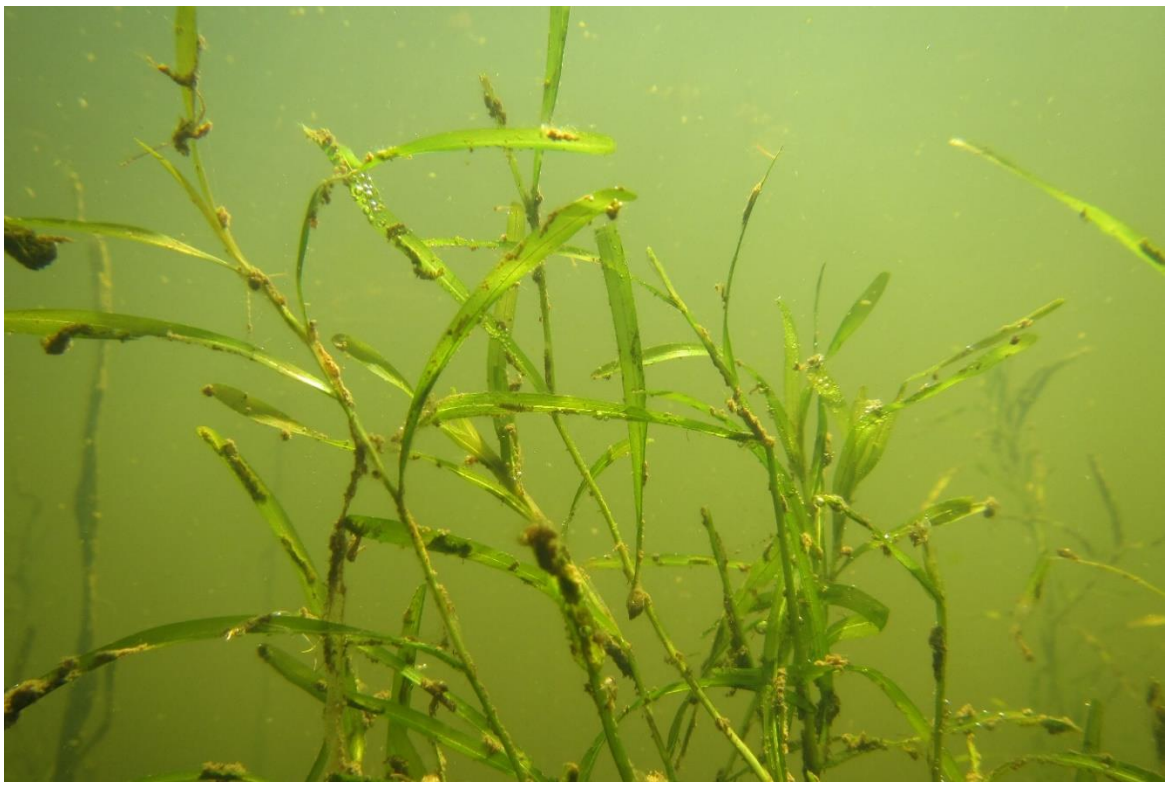


**Figure 99: Native pondweeds (*Potamogeton ochreatus*) in Lake Rotorua.**

**Figure 100: Native charophytes (*Chara australis*) growing in the shallows in Lake Rotorua.**

**Figure 101: A thick layer filamentous algae covered the plants in Lake Rotorua.**

## 3.38 Saddle Road Dam

### 3.38.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 26th |
| Lake maximum depth: | 3 m |
| Max depth of vegetation: | 1.7 |

Saddle Road Dam Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2018 | Moderate | 32% | 32% | 72% |

*Note: 2015 survey based on only 3 sites.

**Figure 102: LakeSPI results for Saddle Road Dam.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Saddle Road Dam is categorised as being in moderate ecological condition with a LakeSPI Index of 32% (Figure 102).

The invasive species *Elodea canadensis* (Figure 103) formed a narrow band of weed around the lake margin extending down to a maximum depth of 1.7 m. Elodea weed beds were low growing, ≤ 0.8 m in height, at all four sites. The introduced pondweed *Potamogeton crispus* was present at low to moderate covers at two of the four LakeSPI sites.

Four native species were recorded from within the dam. The pondweed *Potamogeton cheesemanii* was the most prolific native species present. It was surface reaching (Figure 104) in the shallows and extended down to a maximum depth of 1.2 m. Other native species included a native milfoil *Myriophyllum propinquum* and two native charophytes, *Chara australis* and *Nitella stuartii* (Figure 105). Native vegetation was most prevalent along the southern margin with less of a gradient.

At the time of the survey, through-water visibility was estimated by divers as c. 1 m. Small (< 5 mm) fingernail clams (*Sphaerium* sp., Sphaeriidae) and freshwater sponges (Figure 106) were common. The eastern arm of the lake was very shallow (c. 0.3 m deep) due to accumulated sediment.

### 3.38.2 Discussion

A high Invasive Impact Index of 72% (Figure 102) reflects the distribution and extent of the invasive weed elodea, and to a lesser extent, *Potamogeton crispus* in the lake. While introduced species are not favourable in terms of overall lake condition, their presence is preferable to a devegetated state, in that plants can help mitigate many of the symptoms of eutrophication (e.g., lock-up nutrients in the sediments, maintain water clarity, compete with phytoplankton).

Note: a smaller waterbody to the east of Saddle Road Dam was also investigated. It contained elodea to a depth of c. 1 m, with *Potamogeton crispus* observed in the shallows.

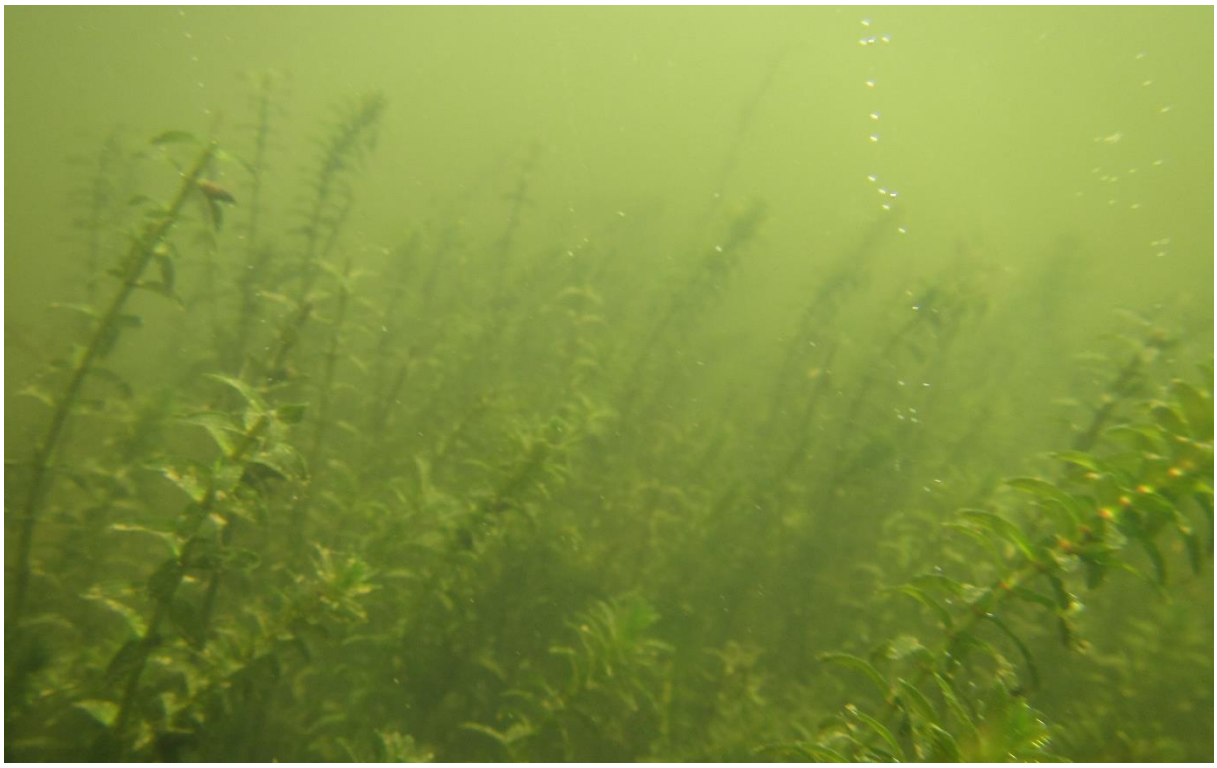


**Figure 103: Elodea formed a narrow band of weed around the Saddle Road Dam.**

**Figure 104: Surface floating leaves of the pondweed *Potamogeton cheesemanii* on the Saddle Road Dam.**

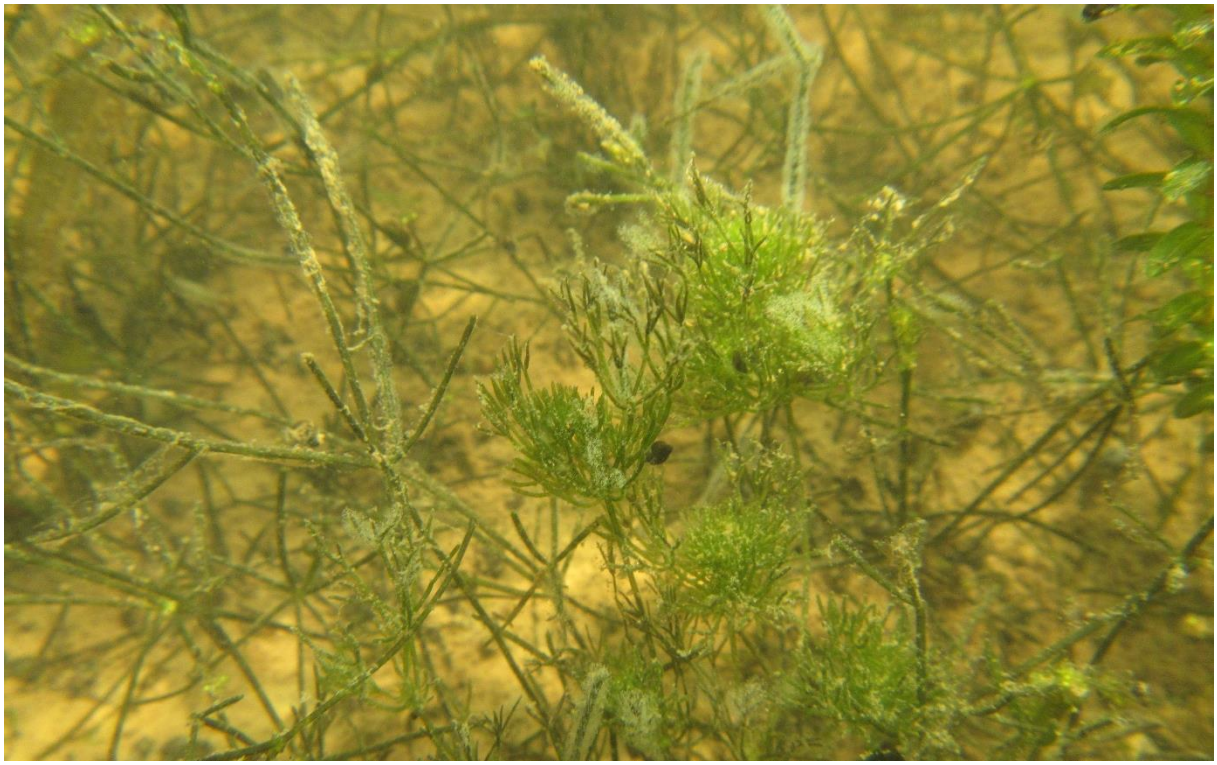


**Figure 105: Native charophytes *Chara australis* (background) and *Nitella stuartii* (middle front) were recorded on the southern side of the Saddle Road Dam.**

**Figure 106: Freshwater sponges (left) and fingernail clams (right) were common in the Saddle Road Dam.**

## 3.39 Te Paata Wetland

### 3.39.1 Results

| | |
|---|---|
| Lake condition: | Excellent |
| Lake ranking: | 9th equal |
| Lake maximum depth: | 6.2 m |
| Max depth of vegetation: | 2.3 m |

Te Paata Wetland Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2019 | Excellent | 78% | 56% | 0% |

**Figure 107: LakeSPI results for Te Paata Wetland.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Te Paata Wetland is categorised as being in excellent condition with a LakeSPI Index of 78% (Figure 107).

Two native charophyte species (*Nitella* sp. aff. *cristata* and *Chara australis*) were recorded from the lake. *Nitella* sp. aff. *cristata* (Figure 108) was the most abundant and it formed meadows (>75% cover) at all five LakeSPI sites extending from the shallows down to a maximum depth of 2.3 m. A native pondweed, *Potamogeton ochreatus,* was recorded forming low to moderate covers at three of the five sites.

At the time of the survey, the water was very dark in colour with through-water visibility estimated by divers to be < 1 m. A Secchi disk measurement of 0.95 m was recorded from the lake centre. No freshwater mussels were observed.

### 3.39.2 Discussion

The Te Paata Wetland lake sits just above the cusp of being classified in excellent condition with a LakeSPI Index of 78% and Native Condition Index of 56% (Figure 107). These high scores reflect the presence of native charophyte meadows (> 75% covers) and pondweeds around the lake and the absence of any introduced species.

While threats from invasive weed species appear minimal on account of restricted public access into the wetland, it is advisable that the land owners be notified to exercise discretion in allowing access to the lake for users of equipment that may be contaminated with invasive species (e.g., boats used for duck shooting, eel fishing nets).

**Figure 108: Native charophytes formed high covers around the margins of Te Paata Wetland Lake.**

## 3.40 Twin Lakes

### 3.40.1 Results

| | |
|---|---|
| Lake condition: | Excellent |
| Lake ranking: | 5th |
| Lake maximum depth: | 4.5 m |
| Max depth of vegetation: | 3.1 m |

**Twin Lake Submerged Plant Indicators**

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2018 | Excellent | 90% | 77% | 0% |

**Figure 109: LakeSPI results for Twin Lakes.** LakeSPI Indices expressed as a percentage of lake maximum potential.

The eastern basin of the Twin Lakes was categorised as being in excellent ecological condition with a LakeSPI Index of 90% (Figure 109).

A free-floating native fern, *Azolla rubra* (Figure 110), was present covering the surface of Twin Lakes at the time of the survey. Below, a native charophyte *Nitella* sp. aff. *cristata*, formed a meadow (>75% cover) across the lake bottom extending down to a maximum depth of 3.1 m. No other submerged plant species were observed. A small patch of water lilies (*Nymphaea* species) were recorded from one of the four LakeSPI sites.

At the time of the survey, through-water visibility was limited (< 1.5 m) with low light penetration through the floating mat of azolla. No freshwater mussels were observed from the lake.

*Note:* Twin Lakes were comprised of two small water bodies separated by an earth dam. Both lakes were surveyed but only the deeper, eastern basin was considered appropriate for a LakeSPI assessment with results included above. The western basin (Figure 111) of Twin Lakes was very shallow at the time of the survey (< 0.9 m deep) but contained the same composition of submerged plants as the deeper Eastern basin. Native charophyte *Nitella* sp. aff. *cristata*, formed high covers across the lake bottom, growing below a floating mat of *Azolla rubra*.

### 3.40.2 Discussion

Twin Lakes provide a good example of an un-impacted lake system that while very small, maintains a well-developed native submerged plant community in the absence of any invasive species.

A high Native Condition Index of 77% (Figure 109) reflected the presence of charophytes forming high covers over most of the lake bottom to 3.1 m, close to the lakes maximum depth of 4.5 m.

Shading from the accumulation of azolla on the surface did not appear to be having an impact on submerged plant growth at the time of the survey (early summer). Azolla is common in shallow eutrophic water bodies such as farm dams and often dies back in winter.

**Figure 110: Native charophytes (left) formed high covers across the bottom of Twin Lakes below a floating mat of *Azolla rubra* (right).**

**Figure 111: Twin lakes western basin showing the accumulation of Azolla on the lake surface.**

## 3.41 Lake Virginia (Rotokawau)

### 3.41.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 24th |
| Lake maximum depth: | 16 m |
| Max depth of vegetation: | 6.2 m |

Lake Virginia Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2020 | Moderate | 36% | 36% | 58% |

**Figure 112: LakeSPI results for Lake Virginia.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Virginia is categorised as being in moderate ecological condition with a LakeSPI Index of 36% (Figure 112).

The invasive weed species egeria (*Egeria densa*) was recorded from all four LakeSPI sites. It formed low to moderate covers at three sites, but at a fourth, it formed a dense weed bed more than 3 m in height, extending down to maximum depth of 6.2 m. An introduced water lily (*Nymphaea alba*) was also recorded.

Native vegetation consisted of the pondweed *Potamogeton ochreatus*, milfoil *Myriophyllum triphyllum* and two charophyte species (*Chara australis* and *Nitella* sp. aff. *cristata*) (Figure 113). Native covers were variable between sites. Both charophyte species formed meadows (>75% cover) at one site each, extending down to a maximum depth of 5.4 m.

At the time of the 2020 survey, a thick yellow/brown phytoplankton bloom (Figure 113) prevented divers from being able to enter the water. No freshwater mussels were observed using the topside monitoring methods used to carry out this investigation. High numbers of waterfowl were present.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out in March 2003 (Champion and Wells 2003) recorded a similar species list to that found during the 2020 survey. Egeria was recorded forming high covers down to a maximum depth of 7.2 m. Native milfoil *Myriophyllum triphyllum* formed high covers in the shallows (< 2 m), and charophyte *Nitella* sp. aff. *cristata* was recorded growing beyond the band of egeria at c. 7.2 m.

### 3.41.2 Discussion

A phytoplankton bloom in Lake Virginia during the December 2020 survey prevented divers from being able to enter the water. Instead remote techniques (grapnel, drop camera, hydroacoustic data) were used during the recent survey to confirm the presence of submerged plants, and collect the necessary data required for assessment by LakeSPI.

Despite the poor water quality encountered during the 2020 survey, and the long-term presence of egeria (for at least 17 years), the lake appears to have maintained a well-developed submerged native plant community. An Invasive Impact Index of 58% (Figure 112) is less than what could be expected for a lake impacted by egeria. It is most likely that the steep marginal zone noted in some areas around the lake, in combination with environmental conditions (e.g., water quality), prevent egeria from forming higher covers in otherwise suitable areas around the lake.

Lake Virginia remains at further risk of invasion from hornwort (*Ceratophyllum demersum*), with contaminated recreational gear likely representing the greatest threat.

**Figure 113: Native charophytes on a grapnel (Left); surface reaching milfoils (Right) in Lake Virginia (2020).** Spot small fragment of Egeria centre bottom on Right. Note: colour of water due to algae bloom.

## 3.42 Voss Lagoon (Karere South)

### 3.42.1 Results

| | |
|---|---|
| Lake condition: | Moderate |
| Lake ranking: | 28th |
| Lake maximum depth: | 1.9 m |
| Max depth of vegetation: | 1.9 m |

Voss Lagoon Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2018 | Moderate | 28% | 32% | 74% |

**Figure 114: LakeSPI results for Voss Lagoon.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Voss Lagoon is categorised as being in moderate ecological condition with a LakeSPI Index of 28% (Figure 114).

Submerged vegetation extended across the bottom of Voss Lagoon to the lake's maximum depth of 1.9 m (at time of recent survey).

Invasive species *Elodea canadensis* and pondweed *Potamogeton crispus* dominated the submerged vegetation in the lagoon. Both were surface reaching across the lagoon and formed high covers extending over the lagoon bottom at all four LakeSPI sites. An introduced water lily (*Nymphaea alba*) was also observed at the western end of the lagoon.

Native submerged plants included the native pondweeds *Stuckenia pectinata* and *Potamogeton ochreatus*. Two native free-floating species *Azolla rubra* and *Lemna disperma* were also present.

At the time of the survey the through-water visibility estimated by divers ranged from c. 1-2 m. A filamentous green alga (Figure 115) was recorded at all four baseline sites. No freshwater mussels were observed.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out by NIWA in March 2003 (Champion and Wells 2003) recorded both elodea and *Potamogeton crispus* but to a maximum depth of only 0.3 m. Free-floating species *Azolla rubra*, *Lemna disperma* and *Landoltia punctata* were also recorded. Note: an error in lake names cited in the 2003 report has resulted in the submerged plant observations for lakes Karere and Karere South (Voss Lagoon) being listed around the wrong way - but are corrected here.

### 3.42.2 Discussion

An earlier survey of the lake at one site in 2003 (Champion and Wells 2003) suggests that Voss Lagoon has changed very little since that time with no new invasive species recorded during the current survey.

While introduced species are not favourable in terms of overall lake condition, the presence of any submerged plants in a lake is preferable to none, in that they are able to help mitigate many of the symptoms of eutrophication (e.g., lock-up nutrients in the sediments, maintain water clarity, compete with phytoplankton). While threats from worse weed species (e.g., *Ceratophyllum demersum*, *Egeria densa*) appear minimal on account of restricted public access, it is advisable that the land owners be notified to exercise discretion in allowing access to the lake for users of equipment that may be contaminated with invasive species (e.g., boats used for duck shooting, eel fishing nets).

With an average maximum depth of only 1.6m calculated from the four baseline sites, care must also be taken when interpreting results for Voss Lagoon. The shallow nature of this waterbody makes it particularly vulnerable to change over a short time frame (e.g., seasonal storms, drought).

**Figure 115: Diver swimming across a profile in Voss Lagoon.** Note: filamentous green alga (bottom) and surface reaching plants (above).

## 3.43 Lake Waipakuranui

### 3.43.1 Results

| | |
|---|---|
| Lake condition: | Excellent |
| Lake ranking: | 7th |
| Lake maximum depth: | 6.4 m |
| Max depth of vegetation: | 4.2 m |

**Lake Waipakuranui Submerged Plant Indicators**

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2019 | Excellent | 83% | 65% | 0% |

**Figure 116: LakeSPI results for Lake Waipakuranui.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Waipakuranui is categorised as being in excellent condition with a LakeSPI Index of 83% (Figure 116).

A dense stand of emergent species (*Typha orientalis*) surrounded the lake growing down to c. 1 m in depth. Beyond this, two native charophytes (*Chara australis* and *Nitella* sp. aff. *cristata*) formed meadows (>75% cover) at all four LakeSPI sites (Figure 117). Charophytes were tall, in places up to 1.9 m in height, and extended down to a maximum depth of 3.4 m. A native pondweed, *Potamogeton ochreatus* (Figure 117Figure 116), was also present at all sites growing through the charophytes and extended down to a maximum depth of 4.2 m. *Potamogeton ochreatus* grew up to 3.8 m tall and was surface reaching in shallower areas around the lake.

Two free-floating native species, *Azolla rubra* and *Lemna disperma* were observed near the edges of emergent growth. No invasive species were recorded from within the lake.

At the time of the survey, an algae bloom was present on the lake and water clarity was poor. Through-water visibility estimated by divers was < 0.5 m. The water appeared to be tannin stained and very dark in colour. A Secchi disk measurement of 1.35 m was recorded from the lake centre. Plants appeared clean and were not covered in algae. No freshwater mussels were observed.

### 3.43.2 Discussion

Lake Waipakuranui is categorised as being in excellent condition, representative of those lakes in the Manawatū-Whanganui Region that maintain a well-developed native plant community in the absence of any invasive weed species (Table 3). This is reflected in a high LakeSPI Index of 83% and Native Condition Index of 65%.

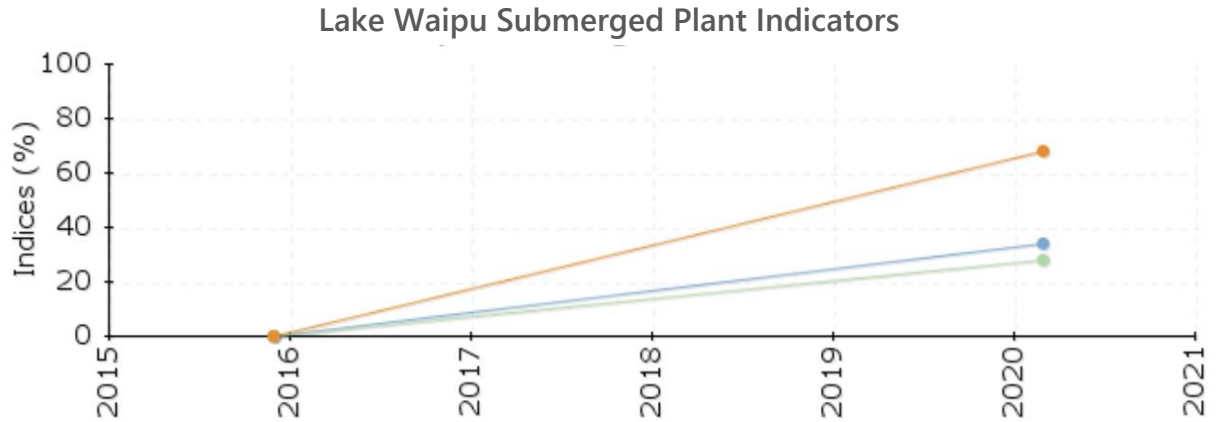
While threats from invasive weed species appear minimal on account of restricted public access into Lake Waipakuranui, it is advisable that the land owners be notified to exercise discretion in allowing access to the lake for users of equipment that may be contaminated with invasive species (e.g., boats used for duck shooting, eel fishing nets).

**Figure 117: Submerged plants in Waipakuranui.** Native charophyte *Chara australis* (top left); native Pondweed *Potamogeton ochreatus* (top right); and charophytes as seen underwater (bottom) .

## 3.44 Lake Waipu

### 3.44.1 Results

| | |
|---|---|
| Lake condition: | Non-vegetated |
| Lake ranking: | 25th |
| Lake maximum depth: | 4.7 m |
| Max depth of vegetation: | 3 m |




| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| February 2020 | Moderate | 34% | 28% | 68% |
| November 2015 | Non-vegetated | 0% | 0% | 0% |

*Note: 2015 survey based on only 3 sites on only the eastern side, and four sites in 2019.

**Figure 118: LakeSPI results for Lake Waipu.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Waipu is categorised as being in a moderate condition with a LakeSPI Index of 34% (Figure 118).

During the recent (2020) survey, the introduced pondweed *Potamogeton crispus,* dominated the submerged vegetation in Lake Waipu and was surface reaching over at least a third of the lake surface, at the northern end (Figure 119). At LakeSPI sites, *P. crispus* formed moderate to high covers from the shallows extending down to a maximum depth of c. 3 m.

Other plants recorded included native *Ruppia polycarpa*, pondweed *Potamogeton ochreatus*, milfoil *Myriophyllum triphyllum* (one plant) and two turf forming species *Glossostigma diandrum* and *Lilaeopsis novae-zealandiae*. All of these species grew in very shallow water, < 0.35 m.

At the time of this survey, water clarity was extremely low (Secchi disk reading of 0.51 m) with underwater visibility estimated by divers to be <0.2 m.

High densities of freshwater mussels (*Echyridella menziesii*) were recorded from within the lake. High numbers of waterfowl were also present.

*Historic vegetation notes:* A spot survey of submerged vegetation carried out in March 2003 (Champion and Wells 2003) recorded a similar species list to that found during the recent survey.

### 3.44.2 Discussion

Previously described in 2015 as sitting on the cusp between a vegetated and non-vegetated state, higher plant covers at LakeSPI sites in 2020 resulted in Lake Waipu moving from a default LakeSPI score of 0% (where most sites had plant covers that did not exceed 10%) to a moderate LakeSPI Index of 34% (Figure 118).

In 2015, the introduced pondweed *Potamogeton crispus* was recorded to a maximum depth of 0.8 m, while in 2020 it was present forming moderate to high covers to c. 3 m. At the northern end of the lake where lake depths were shallow (C. < 2.5 m), *P. crispus* was surface reaching (and flowering) over most of the lake surface in 2020 (Figure 119). Water levels were also c. 1 m lower during the February 2020 survey, with the maximum lake depth observed being 3.8 m, compared to 4.7 m recorded in November 2015.

The invasive free-floating filamentous green alga, water net (*Hydrodictyon reticulatum*) found in small amounts in 2015, was not observed in 2020.

While threats from additional weed species appear minimal on account of restricted public access into Lake Waipu, it is advisable that the land owners be notified to exercise discretion in allowing access to the lake for users of equipment that may be contaminated with invasive species (e.g., boats used for duck shooting, eel fishing nets).

**Note:** The 2020 LakeSPI survey was completed as part of a baseline survey looking at freshwater mussels in the lake (Fenwick and Burton, 2020).

**Figure 119: Surface reaching *Potamogeton crispus* in Lake Waipu.**

## 3.45 Lake Westmere

### 3.45.1 Results

| | |
|---|---|
| Lake condition: | Non-vegetated |
| Lake ranking: | 43rd equal |
| Lake maximum depth: | 5.9 m |
| Max depth of vegetation: | 1.5 |

Lake Westmere Submerged Plant Indicators

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2016 | Non-vegetated | 0% | 0% | 0% |

**Figure 120: LakeSPI results for Lake Westmere.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Westmere is categorised as being in a non-vegetated condition with a LakeSPI Index of 0% (Figure 120).

Sparse submerged plants (<10% cover) were recorded at all five baseline sites. The native pondweed (*Potamogeton ochreatus*) and a charophyte (*Chara australis*) were recorded from most sites to a maximum depth of 3.5 m. The native milfoil *Myriophyllum triphyllum*, was also observed at one site.

Occasional plants of the introduced pondweed (*Potamogeton crispus*) were recorded at three of the five baseline sites, and starwort (*Callitriche stagnalis*) was observed growing close to the lake margins.

Good water clarity was noted during the recent survey. No freshwater mussels were observed.

*Historic vegetation notes:* Kelly (1978) surveyed this lake in January 1978, at which time the lake water was described as being very turbid with a Secchi disc reading of around 0.8 m. By April of the same year this measurement had fallen to 0.2 m. Submerged plants were only observed in shallower areas, with the native pondweed *Potamogeton ochreatus*, recorded as the main species growing down to around 1.5 m. *Potamogeton crispus* and *Myriophyllum triphyllum* and four small fragments of charophytes (*Chara australis* and *Nitella* sp. aff. *cristata*) were also recorded in shallower water near the inlet and outlet.

A spot survey of submerged vegetation carried out by NIWA in March 2003 (Champion and Wells 2003) showed a similar species assemblage to that of the recent survey. In 2003, *Chara australis* was recorded to a depth of 3 m and the invasive weed species *Elodea canadensis* was recorded growing to a maximum depth of 2.1 m. Other species included *Myriophyllum triphyllum*, *Potamogeton ochreatus* and *Potamogeton crispus*.

### 3.45.2 Discussion

Submerged plants were present at all five baseline sites in Lake Westmere, but low plant covers (< 10%) at most sites meant that Lake Westmere received a default LakeSPI Index of 0% (Figure 120).

At the time of this recent survey, the water was very clear enabling the divers to view plants as deep as c. 2.5 m from the surface.

## 3.46 Lake William

### 3.46.1 Results

| | |
|---|---|
| Lake condition: | Poor |
| Lake ranking: | 40th equal |
| Lake maximum depth: | 9.5 m |
| Max depth of vegetation: | 6 m |

**Lake William Submerged Plant Indicators**

| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| November 2015 | Poor | 11% | 0% | 93% |

**Figure 121: LakeSPI results for Lake William.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake William is categorised as being in poor ecological condition with a LakeSPI Index of 11% (Figure 121).

*Egeria densa* dominated the submerged vegetation in Lake William forming a dense band of weed around the entire lake margin to a maximum depth of 6 m. A large number of swans were present on the lake and the canopy of the egeria beds had been cropped by grazing but still grew up to 5.2 m in height.

The only other species recorded from within the lake were occasional plants of the invasive weeds *Elodea canadensis* and *Potamogeton crispus*. No native submerged species were recorded from the lake.

Large numbers of freshwater mussels (*Echyridella menziesii*) were recorded from sediment beyond the egeria weed beds at c. 6 m depth. On closer investigation c. 90% of the mussels were dead or dying based on their soft and/or open shells (Figure 122).

At the time of this survey, water clarity was extremely low with underwater visibility estimated by divers to be <0.2 m.

*Historic vegetation notes:* When this lake was visited by NIWA in March 2003 (Champion and Wells 2003), egeria was already present and forming high covers. Other species recorded at this time included *Potamogeton crispus,* and native species *Potamogeton ochreatus, Glossostigma elatinoides* and *Lilaeopsis novae-zealandiae*.

### 3.46.2 Discussion

Lake William has one of the lowest LakeSPI Indices (11%) of any of the vegetated lakes in the Manawatū-Whanganui Region (Table 3).

Dense beds of egeria excluded nearly all other submerged vegetation from around the lake and no native submerged plants were observed. Egeria has been implicated in the loss of submerged vegetation of a number of New Zealand shallow lakes (Champion 2002) and has shown a significant possible association between shifting lake regimes between macrophyte dominated clear water states to de-vegetated turbid states (Schallenberg and Sorrell 2009).

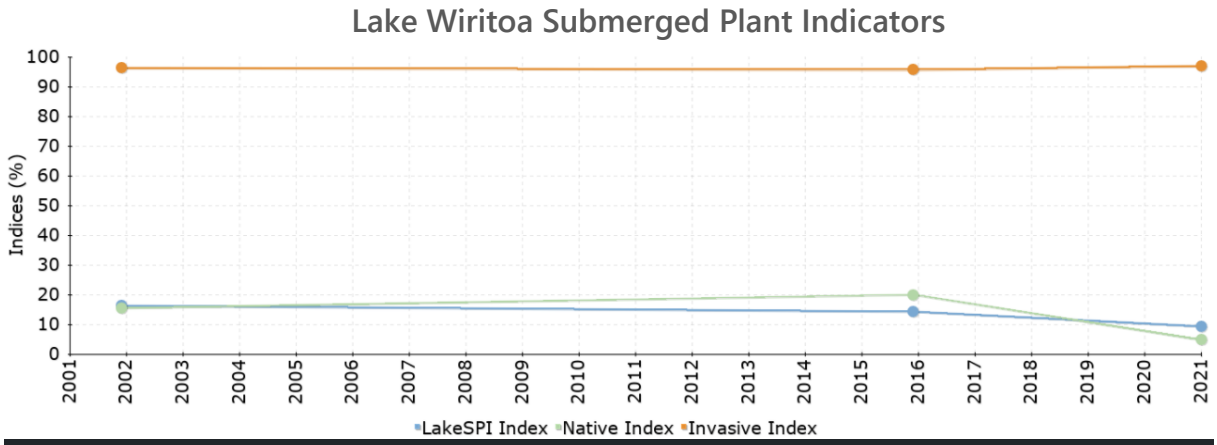
High numbers of mussels observed to be dead, or in the process of dying in the lake were a concern.

**Figure 122: Large numbers of freshwater mussels (either dead or dying) were found beyond egeria weed beds in Lake William.**

## 3.47 Lake Wiritoa

### 3.47.1 Results

| | |
|---|---|
| Lake condition: | Poor |
| Lake ranking: | 42nd |
| Lake maximum depth: | 19.5 m |
| Max depth of vegetation: | 6.8 m |




| Survey Date | Status | LakeSPI % | Native Condition % | Invasive Impact % |
|---|---|---|---|---|
| December 2020 | Poor | 9% | 5% | 97% |
| November 2015 | Poor | 14% | 20% | 96% |
| November 2001 | Poor | 16% | 16% | 96% |

*Note: 2001 survey based on only 2 sites.

**Figure 123: LakeSPI results for Lake Wiritoa.** LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Wiritoa is categorised as being in poor ecological condition with a LakeSPI Index of 9% (Figure 123).

Eel grass (*Vallisneria australis*) formed a dense surface-reaching fringe of weed around most of the lake margin (Figure 124) to a maximum depth of 3.6 m. Beyond this, hornwort (*Ceratophyllum demersum*) (Figure 125) formed a second band of weed into deeper water, growing up to 4.5 m tall and extending down to a maximum depth of 6.8 m. Other invasive species present included the introduced pondweed *Potamogeton crispus* and occasional plants of *Egeria densa*.

Native submerged plants were limited to two pondweeds *Potamogeton ochreatus* and *Potamogeton cheesemanii*.

Two free-floating fern species, *Azolla rubra* (native) and *Azolla pinnata* (invasive) also formed extensive covers in sheltered backwater areas of the lake.

At the time of this recent survey, a phytoplankton bloom was present and water clarity was extremely low. Through-water visibility was estimated by divers to be < 0.5 m. No freshwater mussels were observed.

*Historic notes:* Surveyed for the first time in 1977-1978 (Kelly 1978), pondweeds (*Potamogeton crispus, Potamogeton ochreatus* and *Potamogeton cheesemanii*) and *Myriophyllum triphyllum* were recorded as forming a "belt of rooted macrophytes around the entire lake" with a narrow band of charophytes (*Chara australis* and occasionally *Chara globularis*) growing beyond this. Kelly also noted two small patches of *Vallisneria australis* at this time and sparse populations of *Ranunculus trichophyllus* and *Ruppia megacarpa*. During a NIWA visit to the lake in 1994, elodea was recorded for the first time. Three years later egeria and hornwort were recorded by Ogle (1997). This was confirmed by a second NIWA visit in 1999 where hornwort, egeria and elodea were all found forming surface-reaching weed beds with *Potamogeton crispus* and *Vallisneria australis* noted as common around the lake margin. When the submerged vegetation was surveyed next in November 2001 (Edwards and Clayton 2002), the vegetation was noted as "entirely dominated by tall dense hornwort weed beds" with *Valllisneria australis* forming a dense narrow fringe around much of the lake margin. Occasional pondweeds (*Potamogeton crispus* and *Potamogeton ochreatus*) and charophytes (*Chara australis*, *Chara globularis* and *Nitella hyalina)* were noted in the shallows at this time.

### 3.47.2 Discussion

Lake Wiritoa has undergone extensive vegetation changes since first being surveyed by Kelly in 1978, with the invasive weed species hornwort and *Vallisneria australis* having now displaced practically all native vegetation. The negative impacts associated with these weeds are reflected in Lake Wiritoa having one of the highest Invasive Impact Indices (Figure 123) recorded for any of the 47 lakes of Manawatū-Whanganui Region. This has not changed since the earlier survey in 2001 when the full impact of hornwort had already occurred.

A decline in the LakeSPI and Native Condition Indices (Figure 123) during the recent 2020 survey reflects an absence of native vegetation from most sites. In particular, native charophytes (*Chara australis* and *Nitella sp. aff. cristata*) that were previously recorded forming meadows (>75% cover) at all five sites in 2015 were not observed in 2020. While unlikely, it is possible that the arduous conditions (zero visibility) encountered by divers meant some native plants may have been missed, particularly those growing in deeper water. However a grapnel (double sided rake) also failed to find any sign of charophytes from LakeSPI sites.

With a maximum depth of 19.5 m, Lake Wiritoa is the deepest of the Manawatū-Whanganui lakes surveyed.

**Figure 124: Invasive species *Vallisneria australis* (eel grass) formed a dense band around the lake margin of Lake Wiritoa.** Flower on right.

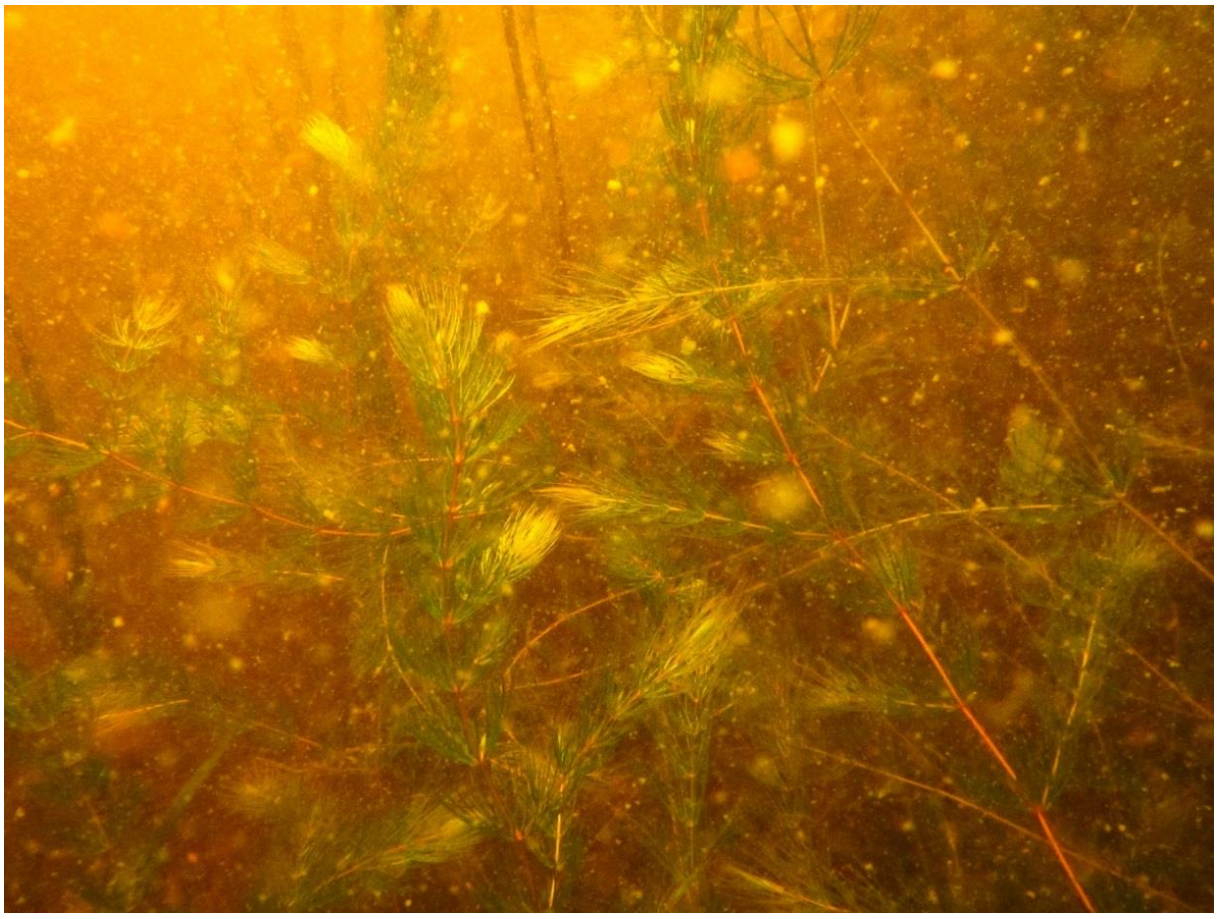


**Figure 125: Hornwort formed a tall weed bed in Lake Wiritoa up to 5.5 m high.**

# 4 Discussion

## 4.1 Current lake condition

Lakes in the Manawatū-Whanganui Region displayed a range of current LakeSPI scores from having no submerged vegetation (0%) to a maximum LakeSPI Index of 97% (Table 3).

For the purposes of ranking and discussing these results, Horizons lakes have been categorised into five lake condition categories (Excellent, High, Moderate, Poor, Non-vegetated) according to their current LakeSPI Index. Additionally, the lakes have been further grouped based on the apparent impacting factor influencing the score. Impacting factors include 'weed' invasion (Invasive Impact Index ≥ 60%), vegetation development limited by 'water quality' (WQ), and/or by 'water level' fluctuations.

**Table 3: Summary of current LakeSPI results for assessed lakes with overall condition category, an indication of main impact factor on scores, and invasive weed history.**

| Lake | LakeSPI Index (%) | Overall Condition | Impact factor | Worst weed present | First record of worst weed (new records <6 years old) |
|---|---|---|---|---|---|
| Hukanui Swamp | 97 | Excellent | Water level | None | - |
| Otamataraha | 94 | Excellent | Water level | None | - |
| Herbert | 94 | Excellent | Water level | None | - |
| Ohinetonga | 91 | Excellent | Water level | None | - |
| Twin Lakes | 90 | Excellent | Water level | None | - |
| Centennial Lagoon | 90 | Excellent | WQ | None | - |
| Waipakuranui | 83 | Excellent | WQ | None | - |
| Mahangaiti | 81 | Excellent | Water level | *P. crispus* | 2017 – first survey |
| Te Paata Wetland | 78 | Excellent | WQ | None | - |
| Green Pond Wetland | 78 | Excellent | Water level | *P. crispus* | 2018 – first survey |
| Meremere | 77 | Excellent | Water level | None | - |
| Karere Lagoon | 64 | High | Water level | *P. crispus* | 2003 – first survey |
| Rotorua | 56 | High | WQ/ Weed | Egeria | 2018 |
| Ram Hills Dam | 55 | High | WQ | *P. crispus* | 2018 – first survey |
| Pukepuke | 53 | High | Water level | Hornwort | 2015 – no record from 2002 |
| Omanuka | 52 | High | Water level | *P. crispus* | 2002 – first survey |
| Rotokauwau | 52 | High | Water level | Egeria | 2019 – no record from 2003 |
| Kaitoke | 46 | Moderate | WQ/ Weed | Elodea | 2017 – no record from 2003 |
| Rotoataha | 44 | Moderate | WQ | *P. crispus* | 2017 – first survey |
| Heaton | 43 | Moderate | WQ | *P. crispus* | 1978 – first survey |
| Huia Rd Dam | 42 | Moderate | WQ | *O. ovalifolia* | 2018 – first survey |
| Christies | 40 | Moderate | Weed | Egeria | 2017 – first survey |
| Otamangakau | 38 | Moderate | Weed | Lagarosiphon | 1982 – first survey |
| Virginia (Rotokawau) | 36 | Moderate | WQ/Weed | Egeria | 1997 |

| Lake | LakeSPI Index (%) | Overall Condition | Impact factor | Worst weed present | First record of worst weed (new records <6 years old) |
|---|---|---|---|---|---|
| Waipu | 34 | Moderate | WQ | *P. crispus* | 2003 – first survey |
| Saddle Rd Dam | 32 | Moderate | WQ | *P. crispus* | 2018 – first survey |
| Namunamu | 29 | Moderate | Weed | Hornwort | 2019 – only egeria in 2016 |
| Alice | 28 | Moderate | Weed | Egeria | 2015 – no record from 2003 |
| Voss | 28 | Moderate | Weed | Elodea | 2003 – first survey |
| Bernard | 27 | Moderate | WQ/ Weed | Hornwort | 2015 – no record from 2003 |
| Koputara | 25 | Moderate | Water level | Hornwort | 2003 |
| Maungarataiti | 22 | Moderate | WQ/ Weed | Egeria | 2003 – first survey |
| Maungaratanui | 22 | Moderate | WQ/ Weed | Egeria | 2003 – first survey |
| Koitiata | 19 | Poor | WQ/ Weed | Hornwort | 2015 – only Egeria in 2003 |
| Dudding | 18 | Poor | WQ/Weed | Egeria | 2015 – no record from 2003 |
| Omanu | 17 | Poor | Weed | Hornwort | 2003 – first survey |
| Pauri | 16 | Poor | WQ/ Weed | Hornwort | 2015 – only Egeria in 2003 |
| Kohata | 16 | Poor | Weed | Hornwort | 2015 – no record from 2003 |
| Ngaruru | 14 | Poor | Weed | Hornwort | 2016 – no record from 2003 |
| Kopureherehere | 11 | Poor | Weed | Hornwort | 1997 |
| William | 11 | Poor | WQ/Weed | Egeria | 2003 |
| Wiritoa | 9 | Poor | Weed | Hornwort | 1999 – Vallisneria in 1978 |
| Manawatu Gorge | 0 | Non-vegetated | WQ | - | No plants – first visit |
| Papaitonga | 0 | Non-vegetated | WQ | - | No plants – 2003 first survey |
| Poroa | 0 | Non-vegetated | WQ | - | No plants – 2016 first survey |
| Pounamu | 0 | Non-vegetated | WQ | - | No plants – 2003 first survey |
| Westmere | 0 | Non-vegetated | WQ? | *P. crispus* | 1978 |

### 4.1.1 Excellent condition lakes

Eleven lakes in the Manawatū-Whanganui region are currently categorised in excellent condition, remaining close to their maximum scoring potential or pristine state. Lakes in excellent condition reflect those that have substantial native vegetation (Native Condition Index >54%), with either no or very little impact from invasive weed species (Invasive Impact Index <16%). No invasive species were observed in the top seven lakes (Hukanui Swamp, Herbert, Otamataraha, Ohinetonga, Twin Lakes, Centennial, Waipakuranui) in this category. The invasive pondweed *Potamogeton crispus*, was recorded from lakes Mahangaiti and Green Pond Wetland but was having little to no impact on lake condition at the time of the surveys.

Because ten of the eleven lakes in this excellent category are shallow, with maximum depths ranging from 1 – 3.8 m, care is advised in interpreting LakeSPI results long term. Seemingly small impacts have the potential to cause big ecological changes in condition over short periods of time (e.g., vulnerability to drought). The exception in this group was Lake Waipakuranui with a maximum depth of 6.4 m.

### 4.1.2 High condition lakes

Six lakes are categorised in high condition representing those that generally have a well-developed diverse native plant community and/or limited impacts from invasive species. Like the lakes classified in excellent condition, the shallow nature of lakes Karere, Rotorua, Ram Hills Dam, Pukepuke Lagoon, Omanuka and Rotokauwau (≤3 m) make them particularly vulnerable to change. It is possible that small impacts could result in big ecological changes over a short period of time (e.g., seasonal storms, drought). While fragments of hornwort (*Ceratophyllum demersum*) were found in Pukepuke Lagoon, it was not having an impact on the submerged vegetation at the time of the recent survey(s).

### 4.1.3 Moderate condition lakes

Sixteen lakes with LakeSPI scores ranging from 22% - 46% were categorised in moderate condition (Table 3), reflecting differing degrees of impact from invasive weeds and/or restricted development of native plant communities. Lakes Kaitoke, Rotoataha and Heaton are at the top of this group. All have maintained a diverse submerged plant community with only limited impact from invasive species, in particular *Potamogeton crispus*. All other lakes in this group were being impacted on at varying degrees by invasive weeds but also retained elements of native vegetation. Huia Road Dam shows the only record of the invasive swamp lily *Ottelia ovalifolia* in a Horizon's lake.

### 4.1.4 Poor condition lakes

Nine lakes with LakeSPI scores between 9% and 19% were categorised as being in poor condition (Table 3), with all lakes being heavily impacted (Invasive Impact Index >80%) by hornwort or egeria. In the case of lakes Koitiata, Dudding, Pauri, Ngaruru, Kopureherehere, William and Wiritoa both poor water clarity and the presence of weed contributes to their poor condition. Prolonged effects of these impacts are likely to lead to further deterioration of submerged vegetation.

### 4.1.5 Non-vegetated lakes

Five lakes were categorised as being non-vegetated, as they either had no submerged vegetation, or recorded a <10% vegetation cover at most survey sites and therefore scored a default LakeSPI Index of 0% (Table 3). Absence of significant vegetation generally indicates a highly impacted lake condition (de Winton et al. 2012) where in most cases water quality issues have created unfavourable conditions for submerged plant growth. For lakes Manawatū Gorge Dam, Papaitonga, Poroa and Pounamu in this group, it is apparent that water quality is a major constraint for plant growth. This might also be the case for Lake Westmere although water clarity was good at the time of the most recent survey.

Although invasive species are not favourable in terms of overall lake condition, the presence of any submerged plants in a lake is preferable to none, in that they can help mitigate many of the symptoms of eutrophication (e.g., lock-up nutrients in sediment, maintain water clarity, compete with phytoplankton).

## 4.2 Invasive weed status

Currently, nine of the 47 lakes in the Manawatū-Whanganui Region surveyed since 2015 remain in a near pristine state, un-impacted by submerged weeds, and five lakes are categorised as being non-vegetated with no invasive species. The remaining 33 vegetated lakes are being impacted on by one or more introduced submerged weed species.

Kelly (1978) reported the presence of three invasive species: curled pondweed (*Potamogeton crispus*), water buttercup (*Ranunculus trichophyllus*) and eelgrass (*Vallisneria australis*) (in Lake Wiritoa only), in 12 lakes surveyed in the 1970's, but also noted the presence of some of New Zealand's worst submerged weed species: hornwort (*Ceratophyllum demersum*), egeria (*Egeria densa*), lagarosiphon (*Lagarosiphon major*) and elodea (*Elodea canadensis*), in the regions rivers and drains (Section 1.3). Submerged weeds in the region are ranked in the following order (worst first): Hornwort > Egeria > Lagarosiphon > Vallisneria > Elodea > Curled pondweed (*Potamogeton crispus*), based on potential impact factors ('weediness' – Champion and Clayton 2000), and are all capable of completely replacing native elements in the vegetation. Today, at least one of these worst submerged weed species are found in 32 of the lakes surveyed for this report and are actively spreading.

Hornwort and egeria are the regions worst submerged weed species and are currently in 43% of vegetated lakes. These weed species were recorded for the first time 22 years ago in Lake Wiritoa (Ogle 1997) and Kopureherehere (Champion and Wells 2003) in 1997. Since then they have continued to spread, causing havoc to other submerged vegetation and overall lake condition.

Hornwort was present in 11 of the 47 lakes surveyed for this report. Of concern were new records in seven of these lakes: Bernard, Kohata, Koitiata, Namunamu, Ngaruru, Pauri and Pukepuke, in the last seven years (since 2013). The most recent discovery of hornwort spreading to a new lake was in Lake Namunamu in 2019. The speed at which hornwort spread within neighbouring Lake Ngaruru; from isolated plants in 2016 to domination by dense hornwort weed beds by 2019, is a reminder of the devastating impact this weed can have on lake ecosystems, and likely in Lake Namunamu in coming years. While hornwort dominated the vegetation in lakes Bernard, Kohata, Koitiata, Ngaruru, Pauri and Wiritoa; only occasional plants continue to be found in Pukepuke Lagoon. It is possible that changes in water level may be inhibiting the establishment of hornwort in Pukepuke Lagoon.

Egeria was present in 13 (28%) of the regions lakes, and was the worst recorded weed species in eight of the lakes: Alice, Christies, Dudding, Maungarataiti, Maungaratanui, Rotokauwau, Rotorua and William (Table 3). In total egeria was recorded for the first time in five new lakes: Alice, Christies, Dudding, Ngaruru, Rotokauwau and Rotorua since 2003. The new records of egeria in lakes Rotokauwau and Rotorua likely reflect a very early stage of invasion. It is likely that we will see a reduction in lake condition as these egeria continues to spread and impact on submerged vegetation in these lakes in the future. While egeria was widespread in Christies lake, it is possible that this lake has not yet experienced the full impacts of egeria and if it continues to impact further on the vegetation, we could see lake condition values for this lake decrease.

Egeria has been implicated in the loss of submerged vegetation in a number of New Zealand shallow lakes (Champion 2002) and has shown a significant possible association between shifting lake regimes between macrophyte dominated clear water states to de-vegetated turbid states (Schallenberg and Sorrell 2009).

Lagarosiphon was recorded from two lakes. In Lake Otamangakau lagarosiphon formed extensive surface reaching weed beds but a shallower depth range (< 5 m) in this lake meant that some native vegetation was also present. Lagarosiphon was first recorded in a survey of Lake Otamangakau in 1982 (NIWA historic record). Fragments of lagarosiphon were also recorded from Lake Omanu, a lake dominated by hornwort.

Elodea was recorded in 14 (30%) lakes but was only recorded as the worst weed present in Lake Kaitoke. Generally, elodea is known to cause minimal problems in most lakes. In Kaitoke, elodea was present at only low covers and was having little to no impact on lake condition.

The introduced pondweed *Potamogeton crispus*, was recorded from 26 (55%) of the region's lakes, which included most of the coastal dune lakes surveyed for this report. *Potamogeton crispus* is a seed producing species and is spread by waterfowl. It seldom causes major problems in lakes and has been well established in the region's dune lakes for at least the last 40 years (Kelly 1978). *Potamogeton crispus* was the worst invasive weed species recorded for 10 of the lakes surveyed for this report (Table 3).

Of interest was the presence of an invasive filamentous green algae water net (*Hydrodictyon reticulatum*) in two lakes: Pauri and Waipu during the 2015 survey, although not observed in Pauri in 2020. These 2015 records represent the first of this algae in the Manawatū-Whanganui Region although it has been found previously in other regions (Bay of Plenty, Hawkes Bay, Waikato and Wellington). It was observed forming only a minimal nuisance on these lakes but has the potential to form large floating surface growths, often associated with tall invasive weed beds.

Poor water clarity and prevalence of planktonic and epiphytic algal blooms were also noted from most lakes, indicating eutrophication. Prolonged effects of these impacts are likely to lead to further deterioration of submerged vegetation.

## 4.3 National comparisons

Comparing the categories of lake ecological condition identified for the Manawatū-Whanganui Region to current LakeSPI Indices for 310 lakes nationally (Figure 126, Figure 127) shows:

- A slightly higher proportion of Manawatū-Whanganui now fall into the excellent category compared to lakes nationally. While 10 of the 11 lakes in this group were very shallow, they all remained close to their maximum ecological condition.
- Only six lakes in Manawatū-Whanganui were categorised in high condition, reflecting a much lower proportion of lakes nationally in this high category.
- There are a much higher proportion of lakes that fall in the moderate category in the region, which reflects the number of lakes that are impacted in varying degrees by invasive weeds but still retain some native vegetation character.
- There is a slightly higher proportion of lakes in the poor category, reflecting the number of lakes that are extensively invaded by the worst ranked invasive submerged weeds, egeria (*Egeria densa*) or hornwort (*Ceratophyllum demersum*).
- The Manawatū-Whanganui Region has a much lower proportion of lakes which do not possess significant submerged vegetation and are categorised as non-vegetated as is the case nationally.

This comparison is a simplified overview of current LakeSPI Indices for lakes nationally and does not consider different lake types.

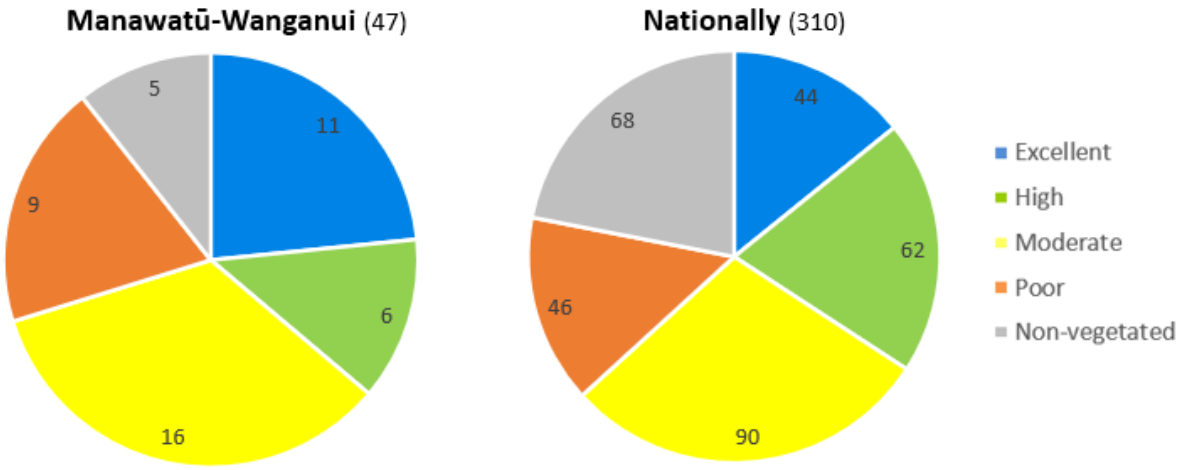



**Figure 126: Proportion of lakes that fall into each of five categories of LakeSPI Index for the region (47) and nationally (310)** with the number of lakes assessed shown in parentheses.

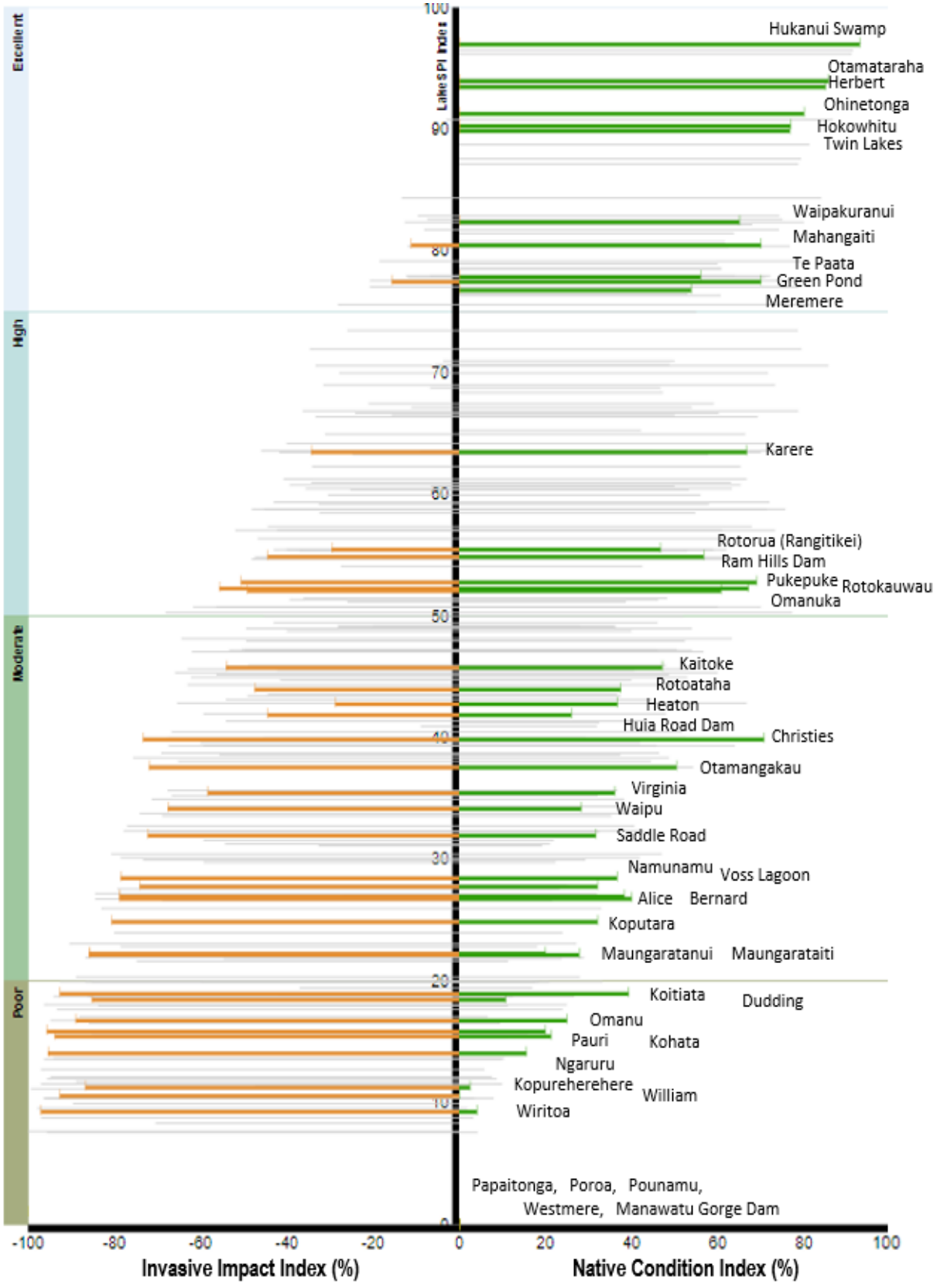



**Figure 127: LakeSPI Indices based on the latest results of 310 lakes in grey, showing the scores for the lakes of the Manawatū-Whanganui Region as an orange/green line.** LakeSPI scores are plotted on the vertical axis, with the Native Condition Index plotted on the right-hand horizontal axis, and the Invasive Impact Index on the left hand to show the negative influence on the LakeSPI score.

# 5 Recommendations

1. It is recommended that a schedule for LakeSPI surveys of lakes in the wider Manawatū-Whanganui Region be developed in association with Horizons Regional Council staff, with priorities and timing of re-survey based on perceived lake value, stability and known threats to the lakes. We would suggest that this schedule address:

   - High value lakes including the Hukanui Swamp, Otamataraha and Herbert. Resurvey on a regular basis (every 2-3 years) to identify any changes in ecological condition.
   - Ohinetonga Lagoon. Resurvey (every three years) to identify any changes. Surveillance is a priority for this lake as it has public access.
   - Lake Namunamu. Resurvey following discovery of hornwort at LakeSPI sites in 2020 to establish rates of spread and impact within the lake.
   - Lake Otamangakau. Resurvey on a regular basis (every three years) to identify any changes. Highest priority should remain in the prevention and surveillance for hornwort incursion into this lake.
   - New lakes. Lakes that have not yet been investigated should be assessed and prioritised based on those most likely to support submerged vegetation.

   On average LakeSPI surveys are recommended to be undertaken every 5 years but if changes are noticed in the lakes condition, or the lake is under high pressure from land-use intensification or from a new invasive species, then surveys should be undertaken on a more frequent basis.

2. Landowner awareness. Landowners should be made aware of the status of any lakes on their land and be made aware of weed transfer methods (eel fishing, boating activities) to help prevent further spread of invasive weed species.

# 6 Acknowledgements

We would like to thank Horizons staff members (Figure 128) Elizabeth Daly, Logan Brown, Mark Mitchell, Michael Gemmell, Erin Bocker and Sara Williams for arranging access to the various properties and for their good company and useful comments during the survey work, in 2020 and previous years. A special thanks also to Mary and David Duncan, Charlie Mc Nabb, Max Voss, David Lilburn, Jeanie Fowler, David Michael, Mr Bolton and others who accompanied us to their lakes and for sharing your knowledge of the lakes with us for this project. It was much appreciated. Aleki Taumoepeau and Susie Elcock (NIWA) provided assistance with the diving and underwater assessment of these lakes.

**Figure 128: Thank you to all those that assisted with the LakeSPI fieldwork.** Including, from left: Logan Brown, Elizabeth Daly, Erin Bocker (Horizons Regional Council); Aleki Taumoepeau and Susie Elcock (NIWA divers).

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# Appendix A Species list based on LakeSPI surveys of 47 Manawatū-Whanganui Region lakes.

**Table 4: Submerged aquatic plant species recorded for 47 lakes in the Manawatū-Whanganui Region;** based on LakeSPI surveys since 2015.

| | Alice | Bernard | Christies | Dudding | Green Pond | Heaton | Herbert | Centennial | Huia Road Dam | Hukanui Swamp | Kaitoke | Karere Lagoon | Kohata | Koitiata | Kopurehere | Koputara | Mahangaiti |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Invasive species** | | | | | | | | | | | | | | | | | |
| *Elodea canadensis* | ✓ | | | ✓ | | | | | | | ✓ | | | ✓ | | ✓ | |
| *Egeria densa* | ✓ | | ✓ | ✓ | | | | | | | | | | ✓ | | | |
| *Ceratophyllum demersum* | | ✓ | | | | | | | | | | | ✓ | ✓ | ✓ | ✓ | |
| *Lagarosiphon major* | | | | | | | | | | | | | | | | | |
| *Otellia ovalifolia* | | | | | | | | | | | | | | | | | |
| *Potamogeton crispus* | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| *Ranunculus trichophyllus* | | | | ✓ | ✓ | | | | | | | | ✓ | | | | |
| *Vallisneria australis* | | | | | | | | | | | | | | | | | |
| **Tall native vascular plants** | | | | | | | | | | | | | | | | | |
| *Myriophyllum propinquum* | | | | | ✓ | | ✓ | | | ✓ | | ✓ | ✓ | | | | |
| *Myriophyllum triphyllum* | ✓ | | ✓ | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ |
| *Potamogeton cheesemanii* | | | | | ✓ | ✓ | | | | | | | ✓ | | | | |
| *Potamogeton ochreatus* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | | | | ✓ |
| *Ruppia polycarpa* | | | | | | | | | | | | | | | | ✓ | |
| *Stuckenia pectinata** | | | | | | | | | | | ✓ | | | | | ✓ | ✓ |
| **Charophytes** | | | | | | | | | | | | | | | | | |
| *Chara australis* | ✓ | ✓ | ✓ | ✓ | | | | ✓ | | | | | | | | | |
| *Chara* sp. aff. *muelleri* | | | | | | | | | | | | | | | | | |
| *Chara globularis* | | | | | | | ✓ | | | | | | | ✓ | | ✓ | |
| *Nitella* sp. aff. *cristata* | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | | ✓ | | |
| *Nitella hyalina* | | | | | | | | | | | | | | | | | |
| *Nitella masonae* | | | | ✓ | | | | | | | | | | | | | |
| *Nitella pseudoflabellata* | | | ✓ | | | | | | | | | | | | | | |

| | Alice | Bernard | Christies | Dudding | Green Pond | Heaton | Herbert | Centennial | Huia Road Dam | Hukanui Swamp | Kaitoke | Karere Lagoon | Kohata | Koitiata | Kopureherehere | Koputara | Mahangaiti |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Turf plants** | | | | | | | | | | | | | | | | | |
| *Bryophyte* spp. | | ✓ | | | | | | | | | | | | | | | |
| *Callitriche petriei* | | | | | | ✓ | | | | | | | | | | | |
| *Glossostigma elatinoides* | | ✓ | | ✓ | | | | | ✓ | | | | ✓ | | | | |
| *Glossostigma diandrum* | | | | | | | | | | | | | | | | | |
| *Lilaeopsis novae-zelandiae* | | | | | | | | | | | | | | | | | |
| *Lilaeopsis ruthiana* | | | | | | | | | | | | | | | | | |
| *Ranunculus amphitrichus* | | ✓ | | | | | | | | | | | | | | | |
| *Ranunculus limosella* | | | | | | | | | | | | | | | | | |
| **Floating plants** | | | | | | | | | | | | | | | | | |
| *Azolla pinnata* | | | ✓ | | | | ✓ | | | | | | | | | ✓ | |
| *Azolla rubra* | ✓ | ✓ | | | | | | | | | | ✓ | | | | | ✓ |
| *Lemna disperma (minor)* | | | ✓ | | ✓ | | ✓ | | | | | ✓ | | | ✓ | ✓ | ✓ |
| *Nymphaea* sp. | | | | | | ✓ | | | | | | | | | | | |
| *Riccia fluitans* | | | | | | | | | | | | ✓ | | | | | |
| *Ricciocarpos natans*** | | | | | | | ✓ | | | | | | | | | | |
| **Submerged marginals** | | | | | | | | | | | | | | | | | |
| *Callitriche stagnalis* | | | | | | | | | | | | | | | | ✓ | |
| *Ludwigia palustris* | | | ✓ | | ✓ | | ✓ | | | | | | | | | | |
| *Nasturtium* sp. | | | | | | | | | | | | | | | ✓ | | |
| *Ranunculus flammula* | | | | | | | | | | ✓ | | | | | | | |
| *Veronica anagallis-aquatica* | | | | | | | | | | | | | | | | | |

* At-Risk, naturally uncommon (de Lange et al. 2018)

** At-Risk, declining (de Lange et al. 2020)

| | Manawatū Gorge | Maungarataiti | Maungaratanui | Meremere | Namunamu | Ngaruru | Ohinetonga Lagoon | Omanu | Omanuka Lagoon | Otamangakau | Otamataraha | Papaitonga | Pauri | Poroa | Pounamu | Pukepuke Lagoon | Ram Hills Dam |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Invasive species** | | | | | | | | | | | | | | | | | |
| *Elodea canadensis* | | | | | ✓ | ✓ | | ✓ | | ✓ | | | ✓ | | | | |
| *Egeria densa* | | ✓ | ✓ | | | ✓ | | | | | | | ✓ | | | | |
| *Ceratophyllum demersum* | | | | | ✓ | ✓ | | ✓ | | | | | ✓ | | | ✓ | ✓ |
| *Lagarosiphon major* | | | | | | | | | | ✓ | | | | | | | |
| *Otellia ovalifolia* | | | | | | | | | | | | | | | | | |
| *Potamogeton crispus* | | | | | | ✓ | | ✓ | ✓ | | | | ✓ | | | ✓ | |
| *Ranunculus trichophyllus* | | | | | | | | | ✓ | ✓ | | | ✓ | | | ✓ | |
| *Vallisneria australis* | | | | | | | | | | | | | | | | | |
| **Tall native vascular plants** | | | | | | | | | | | | | | | | | |
| *Myriophyllum propinquum* | | | | | | | | | ✓ | ✓ | | | | | | | |
| *Myriophyllum triphyllum* | | | | | ✓ | | | | ✓ | | | | ✓ | | | ✓ | |
| *Potamogeton cheesemanii* | | | | | | ✓ | | | | | | | | | | | ✓ |
| *Potamogeton ochreatus* | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | | | | ✓ |
| *Ruppia polycarpa* | | | | | | | | | ✓ | | | | ✓ | | | ✓ | ✓ |
| *Stuckenia pectinata** | | | | | | | | ✓ | ✓ | | | | ✓ | | | ✓ | |
| **Charophytes** | | | | | | | | | | | | | | | | | |
| *Chara australis* | | ✓ | ✓ | | ✓ | ✓ | | | | | | | ✓ | | | | ✓ |
| *Chara* sp. aff. *muelleri* | | | | | | | | | ✓ | | | | | | | | |
| *Chara globularis* | | | | | | | | | | | | | ✓ | | | ✓ | |
| *Nitella* sp. aff. *cristata* | | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ | | ✓ | | | | |
| *Nitella hyalina* | | | | | | | | | | ✓ | | | | | | | ✓ |
| *Nitella masonae* | | | | | | | | | | | | | | | | | |
| *Nitella pseudoflabellata* | | | | | | | | | | ✓ | | | | | | | ✓ |
| *Nitella stuartii* | | | | | | | | | | | | | | | | | |

| | Manawatū Gorge | Maungaratiti | Maungaratanui | Meremere | Namunamu | Ngaruru | Ohinetonga Lagoon | Omanu | Omanuka Lagoon | Otamangakau | Otamataraha | Papaitonga | Pauri | Poroa | Pounamu | Pukepuke Lagoon | Ram Hills Dam |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Turf plants** | | | | | | | | | | | | | | | | | |
| *Bryophyte* spp. | | | | | | | | | | | | | | | | | |
| *Callitriche petriei* | | | | | | | | | | | | | | | | ✓ | |
| *Glossostigma elatinoides* | | | | | | | | | | ✓ | | | | | | | |
| *Glossostigma diandrum* | | | | | | | | | | ✓ | | | | | | | ✓ |
| *Lilaeopsis novae-zelandiae* | | | | | | | | | | | | | | | | | |
| *Lilaeopsis ruthiana* | | | | | | | | | | ✓ | | | ✓ | | | | |
| *Ranunculus amphitrichus* | | | | | | | | | | | | | | | | | |
| *Ranunculus limosella* | | | | | | | | | | ✓ | | | | | | | |
| **Floating plants** | | | | | | | | | | | | | | | | | |
| *Azolla pinnata* | | | | | ✓ | | | | | | | | | | | | |
| *Azolla rubra* | | | | ✓ | ✓ | ✓ | | | | | | | ✓ | | | ✓ | |
| *Lemna disperma* | | ✓ | | ✓ | | ✓ | | | ✓ | | | | ✓ | ✓ | | | |
| *Nymphaea* sp. | | | | | | | | | | | | | ✓ | | | | |
| *Riccia fluitans* | | | | | | | | | | | | | | | | | |
| *Ricciocarpos natans*** | | | | | | | | | ✓ | | | | ✓ | | | | |
| **Submerged marginals** | | | | | | | | | | | | | | | | | |
| *Callitriche stagnalis* | | ✓ | ✓ | | | | | ✓ | ✓ | ✓ | ✓ | | | | | | |
| *Ludwigia palustris* | | ✓ | ✓ | | | ✓ | | | | | | | | | | | |
| *Nasturtium* sp. | | | | | | | | | | | | | | | | | |
| *Ranunculus flammula* | | | | | | | | | | ✓ | | | | | | | |
| *Veronica anagallis-aquatica* | | | | | | | | | ✓ | | | | | | | | |

* At-Risk, naturally uncommon (de Lange et al. 2018)

** At-Risk, declining (de Lange et al. 2020)

| | Rotoataha | Rotokauwau | Rotorua | Saddle Road | Te Paata | Twin Lakes | Virginia | Voss Lagoon | Waipakuranui | Waipu | Westmere | William | Wiritoa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Invasive species** | | | | | | | | | | | | | |
| *Elodea canadensis* | | | ✓ | ✓ | | | | ✓ | | | | ✓ | |
| *Egeria densa* | | ✓ | ✓ | | | | ✓ | | | | | ✓ | ✓ |
| *Ceratophyllum demersum* | | | | | | | | | | | | | ✓ |
| *Lagarosiphon major* | | | | | | | | | | | | | |
| *Otellia ovalifolia* | | | | | | | | | | | | | |
| *Potamogeton crispus* | ✓ | ✓ | ✓ | ✓ | | | | ✓ | | ✓ | ✓ | ✓ | ✓ |
| *Ranunculus trichophyllus* | | | | | | | | | | | | | |
| *Vallisneria australis* | | | | | | | | | | | | | ✓ |
| **Tall native vascular plants** | | | | | | | | | | | | | |
| *Myriophyllum propinquum* | | | | ✓ | | | | | | | | | |
| *Myriophyllum triphyllum* | | ✓ | | | | | ✓ | | | ✓ | ✓ | | ✓ |
| *Potamogeton cheesemanii* | ✓ | | | ✓ | | | | | | | | | ✓ |
| *Potamogeton ochreatus* | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| *Ruppia polycarpa* | | | | | | | | | | | | | |
| *Stuckenia pectinata** | | ✓ | | | | | | ✓ | | | | | |
| **Charophytes** | | | | | | | | | | | | | |
| *Chara australis* | | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | | ✓ | | ✓ |
| *Chara* sp. aff. *muelleri* | | | | | | | | | | | | | |
| *Chara globularis* | ✓ | ✓ | | | | | | | | | | | |
| *Nitella* sp. aff. *cristata* | | ✓ | | | ✓ | ✓ | ✓ | | ✓ | | | | ✓ |
| *Nitella hyalina* | | | | | | | | | | | | | |
| *Nitella masonae* | | | | | | | | | | | | | |
| *Nitella pseudoflabellata* | | | | | | | | | | | | | |
| *Nitella stuartii* | | ✓ | | | | | | | | | | | |

| | Rotoataha | Rotokauwau | Rotorua | Saddle Road | Te Paata | Twin Lakes | Virginia | Voss Lagoon | Waipakuranui | Waipu | Westmere | William | Wiritoa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Turf plants** | | | | | | | | | | | | | |
| *Bryophyte* spp. | | | | | | | | | | | | | |
| *Callitriche petriei* | | | | | | | | | | | | | |
| *Glossostigma elatinoides* | | ✓ | | | | | | | | | | | |
| *Glossostigma diandrum* | | ✓ | | | | | | | | ✓ | | | |
| *Lilaeopsis novae-zelandiae* | | | | | | | | | | ✓ | | | |
| *Lilaeopsis ruthiana* | | | | | | | | | | | | | |
| *Ranunculus amphitrichus* | | | | | | | | | | | | | |
| *Ranunculus limosella* | | | | | | | | | | | | | |
| **Floating plants** | | | | | | | | | | | | | |
| *Azolla pinnata* | | | | | | | | | | | | | ✓ |
| *Azolla rubra* | | ✓ | ✓ | | | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ |
| *Lemna disperma* | | ✓ | ✓ | | | | | ✓ | ✓ | | | | |
| *Nymphaea* sp. | | | | | | ✓ | ✓ | ✓ | | | | | |
| *Riccia fluitans* | | | | | | | | | | | | | |
| *Ricciocarpos natans*** | | | | | | | | | | | | | |
| **Submerged marginals** | | | | | | | | | | | | | |
| *Callitriche stagnalis* | | | | | | | | | | | | | |
| *Ludwigia palustris* | | ✓ | ✓ | | | | | | | | | | |
| *Nasturtium* sp. | ✓ | | | | | | | | | | | | |
| *Ranunculus flammula* | | | | | ✓ | | | | | | | | |
| *Veronica anagallis-aquatica* | | | | | | | | | | | | | |

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** At-Risk, declining (de Lange et al. 2020)


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