NIWA
Taihoro Nukurangi

LakeSPI surveys of waterbodies in Wellington Region: 2021/22

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Executive summary

Greater Wellington Regional Council contracted NIWA to survey 13 waterbodies in the Wellington Region during March 2022 using the LakeSPI (Submerged Plant Indicators) survey method. LakeSPI was developed to assess the ecological condition of lakes and two LakeSPI indices have been adopted as ecosystem health attributes under the National Policy Statement for Freshwater Management (NPS–FM). These attributes assign lakes to bands A-D and set a national bottom line as a minimum acceptable condition, with D band lakes falling below this bottom line. The NPS-FM directs that reassessments of these attributes are made every three years.

Four of the 13 selected waterbodies were unsuitable for LakeSPI assessment, due to past or present high salinity levels or wetland rather than lake character. In the remaining nine waterbodies, features of aquatic vegetation structure and composition were used to calculate three LakeSPI indices that are expressed as percentages of a lakes highest potential condition. Key assumptions are that native plant species, high plant diversity and deeper vegetation extent represent healthier lakes or better lake condition, while invasive plants are ranked for undesirability based on their displacement potential and degree of ecological impact. A higher LakeSPI and Native Condition Index denotes better lake ecological condition and higher Invasive Impact Index denotes poorer lake condition. Lakes that do not have submerged vegetation (<10% plant cover) are termed 'non-vegetated' and receive a default Indices values of 0%.

Together with three waterbodies that were previously surveyed, Wellington Region currently has LakeSPI results for 12 waterbodies. These results spanned from a LakeSPI Index of 83% (Lake Kohangatera) down to the default score of 0% (Lake Waiorongomai).

Only Lake Kohangatera had an 'excellent' ecological condition based on a high Native Condition Index (>70%) and a low Invasive Impact Index (<10%). Six waterbodies had 'high' ecological condition due either to a good representation of native plants (Native condition Index >60%) and moderate impacts by invasive weeds (Invasive Impact Index 20-50%), or a lower Native Condition Index (c. 50%) and very low impact from weeds (Invasive Impact Index <10%). Three waterbodies had a 'moderate' ecological condition due to a good representation of native plants (Native Condition Index >60%) but higher impacts from invasive weeds (Invasive Impact Index 50-75%). Lake Waitawa was the only Wellington waterbody within the LakeSPI category of 'poor' ecological condition due to an almost complete domination of the lake by two New Zealand's worst aquatic weeds, *Ceratophyllum demersum* and *Egeria densa*. Lake Waiorongomai was the only 'non-vegetated' lake, however, past development of *Ceratophyllum demersum* suggests this waterbody may at times enter the 'poor' category for LakeSPI. Wellington Region had a higher proportion of lakes in the 'high' category than is the case nationally, and a lower proportion in the 'poor' and 'non-vegetated' categories; although the waterbodies sampled here are not necessarily representative of all lakes in the Wellington Region.

Under the NPS-FM attribute entitled "Submerged plants - natives" (Native Condition Index), Boggy Pond was assigned to the A band; eight waterbodies were assigned to the B band; Upper Karori Reservoir was assigned to the C band; while Lakes Waitawa and Waiorongomai fall below the national bottom line into the D band.

Under the attribute "Submerged plants - invasive species" (Invasive Condition Index) the Upper Karori Reservoir is placed into the A band; Lakes Kohangatera, Pounui and Barton's Lagoon in the B band; six of the remaining waterbodies into the C band; while Lake Waitawa falls below the national

bottom line into the D band. No band was assigned for Lake Waiorongomai because non-vegetated lakes by definition cannot be invaded by weeds.

1 Introduction

Greater Wellington Regional Council (GWRC) undertakes statutory environmental monitoring, including meeting requirements under the National Policy Statement for Freshwater Management (NPS–FM). The LakeSPI (Submerged Plant Indicators) survey method was developed by NIWA to assess the ecological condition of lakes (Clayton and Edwards 2006, de Winton et al. 2012). More recently, two indices derived from LakeSPI have been incorporated as new ecosystem health attributes under the NPS–FM[1] that have bands and national bottom lines.

GWRC contracted NIWA to survey 13 waterbodies in the Wellington Region in March 2022 using LakeSPI. The LakeSPI method has now been applied to a large number of New Zealand lakes (>300), with a proportion surveyed on more than one occasion. This method measures the diversity and extent of native submerged vegetation and the degree to which invasive introduced weeds have altered the vegetated littoral zone. LakeSPI complements traditional water quality monitoring, such as the Trophic Level Index method (Burns and Bryers, 2000), by providing additional ecological information. For example, LakeSPI focuses on the littoral edges of lakes where human interaction is the greatest and where impacts from water quality resulting from catchment activities is often most apparent (Clayton and Edwards 2006).

In this report, we present the LakeSPI results for suitable waterbodies in Wellington Region to describe their current ecological condition. Results are given for the recently surveyed (2022) waterbodies, but Lake Kohangatera and Kohangapiripiri (surveyed 2019) and the Upper Karori Reservoir (surveyed 2013) are also included in the overall reporting. Three scores are generated from LakeSPI; a measure of native vegetation presence, extent and diversity (Native Condition Index), the level of impact by any weed species that may be present (Invasive Impact Index), and an overall score (LakeSPI Index) that combines these values and impacts. LakeSPI scores are reported, accompanied by a brief description of the vegetation character driving the scoring, while for those waterbodies that have been assessed previously (Lakes Waitawa and Pounui), changes since 2016 are briefly described. Current (2022) LakeSPI scores are collated and ranked in order with the other Wellington Region waterbodies and compared to LakeSPI results for lakes nationally. Finally, lakes are assigned to attribute bands (A-D) according to the NPS–FM.

[1] exposure-draft-changes-to-npsfm-2020.pdf (environment.govt.nz), (https://consult.environment.govt.nz/freshwater/npsfm-and-nesf-exposure-draft/)

2 Methods

2.1 Waterbody surveys

Thirteen waterbodies (Table 1) were surveyed between 21 - 25 March 2022. The results for lakes are presented in order of geographic location given in Table 1.

For Lakes Waitawa and Pounui, which had been surveyed previously (de Winton 2016), five baseline sites were relocated from GIS and maps documenting the previous surveys. For the other waterbodies, sites were selected depending on waterbody size and vegetation complexity, situated away from strong local influences that may alter the vegetation (e.g., inflows). Appendix A shows the location of survey sites.

The LakeSPI assessment method is not appropriate for waterbodies with wetland rather than lake character (e.g., limited open water, <0.5 m depth, free-floating plants dominant, encroaching emergents) or strongly saline-influenced coastal lagoons, therefore waterbodies were assessed for their suitability. A vegetation description is provided for unsuitable waterbodies, but LakeSPI metrics and indices were not calculated.

Table 1: The area, waterbody name, location, and date of survey for the 2022 LakeSPI surveys in Wellington Region.

Area	Waterbody	Location	Survey date
Ōtaki	Lake Waiorongomai	40°42'42.77"S 175° 8'34.57"E	22/03/2022
	Lake Waitawa	40°43'28.25"S 175°10'21.51"E	22/03/2022
Waikanae	Waimeha Lagoon	40°52'1.98"S 175° 1'8.52"E	21/03/2022
	Waimanu Lagoons	40°52'17.37"S 175° 0'40.47"E	21/03/2022
	Lake Ngarara	40°52'38.63"S 175° 0'18.33"E	21/03/2022
	Manly Street Lagoon	40°52'47.81"S 175° 0'2.63"E	21/03/2022
Wairarapa	Turner's Lagoon	41° 9'2.36"S 175°17'14.57"E	24/03/2022
	Barton's Lagoon	41°10'5.20"S 175°18'50.30"E	25/03/2022
	Boggy Pond	41°15'2.57"S 175°15'59.41"E	24/03/2022
	Matthew's Lagoon	41°15'35.78"S 175°16'8.94"E	24/03/2022
	Lake Nganoke	41°21'21.70"S 175°11'9.75"E	24/03/2022
	Lake Pounui	41°20'39.76"S 175° 6'51.06"E	23/03/2023
	Pounui Lagoon	41°21'43.16"S 175° 7'42.79"E	23/03/2023

For LakeSPI, scuba/snorkel divers scored 11 vegetation metrics (Figure 1) over a 2 m wide transect from shore to the deepest vegetation limit at each site.

Recorded metrics for native vegetation assessment included:

- Native maximum depth – The maximum depth of native plants at >10% cover within any $2m^2$ surveyed area.
- Native ratio – the proportion of the vegetated transect occupied by native plants.

- Charophyte meadows – the maximum depth of the deepest-growing charophyte meadow that exceeds 75% cover within any $2m^2$ surveyed area.
- Native diversity – measures of diversity from the presence of representative species for key native plant community types.
- Native distribution – scored where any of three key native plant communities are found deeper than 5 m depth.

Metrics for invasive impact based on 10 invasive weed species included:

- Invasive ratio – the proportion of the vegetated transect occupied by invasive weeds.
- Invasive species impact – a score between 1 and 7 for the top ranked (most invasive) weed present.
- Invasive depth impact – measured from the maximum depth of invasive weeds at >10% cover within any $2m^2$ area.
- Nature of invasive cover – scores 5 categories of weed bed development.
- Invasive maximum height – records the maximum weed height.

An additional LakeSPI metric comprised:

- Vegetation maximum depth – the deeper of measures for either the 'native maximum depth' or 'invasive depth impact'.

A complete description of measured characteristics is given in the user manual [2]. An inventory of all plant species encountered was also made (Appendix B).

[2] http://lakespi.niwa.co.nz/.

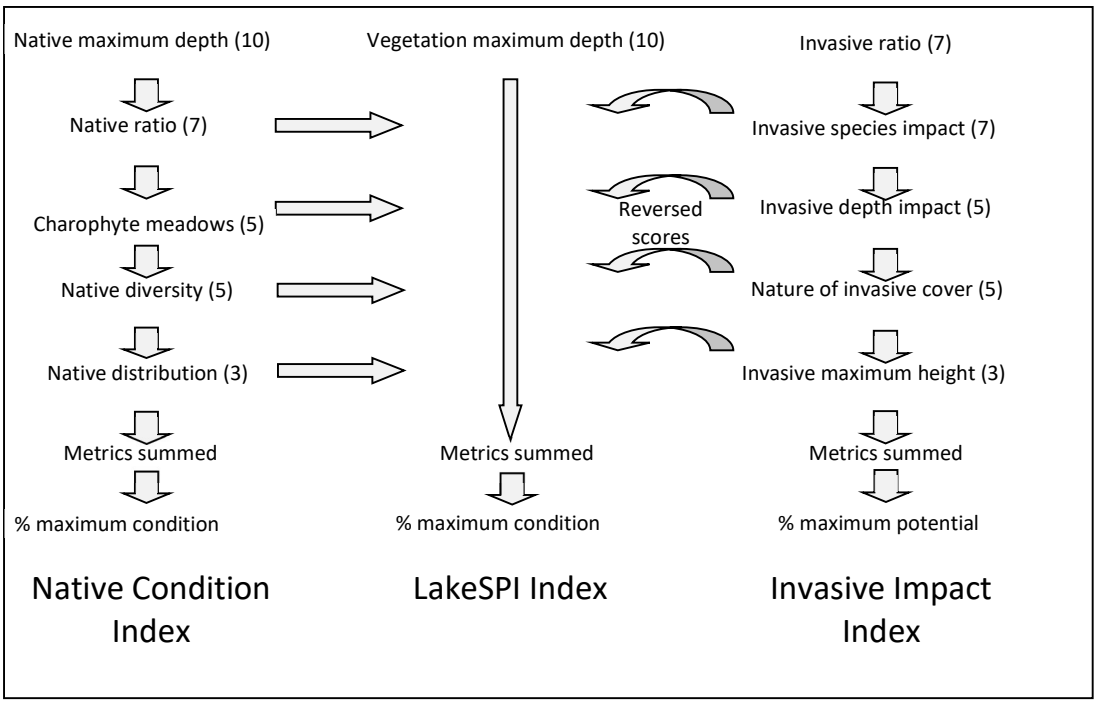


Figure 1: Contribution of the eleven LakeSPI metrics to the three LakeSPI indices, with maximum metric score in parenthesis.

2.2 Data analysis

These key features of aquatic plant structure and composition are used to generate three LakeSPI indices (Figure 1):

- 'Native Condition Index' – This captures the native character of vegetation in a lake based on diversity and quality 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 Index and Invasive Impact Index (reversed) 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, high plant diversity and deeper vegetation extent are taken to represent 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%. Lakes that do not have expected submerged vegetation development (>10% plant cover at the majority of surveyed sites) are termed 'non-vegetated' lakes and receive default Indices values of 0%.

The value of the LakeSPI Index places waterbodies into one of five narrative classes of lake ecological condition, either as non-vegetated (0%), poor (>0-20%), moderate (>20- 50%), high (>50-75%) or excellent (>75%).

The LakeSPI method is supported by a web-reporting service found at Lakespi (niwa.co.nz)[3], where scores for lakes surveyed 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.

For Lake Waitawa and Lake Pounui that have been assessed using LakeSPI previously, the likelihood of a significant change in lake status was based on agreement in the direction and magnitude of change in LakeSPI Indices across all five sites. A paired t-test[4] compared site results from each survey to the same sites at the previous survey to identify change at a significance level of $p < 0.05$.

In addition to statistical significance, the ecological significance of change was assessed using the guidelines below (Figure 2) which give a scale of probabilities for ecologically significant change in lake condition based on change in averaged LakeSPI indices (LakeSPI units as %) over repeated surveys. These guidelines, based on expert judgment, have considered observer-based variation and the response of LakeSPI scores to major ecological events in lakes (NIWA unpublished data).

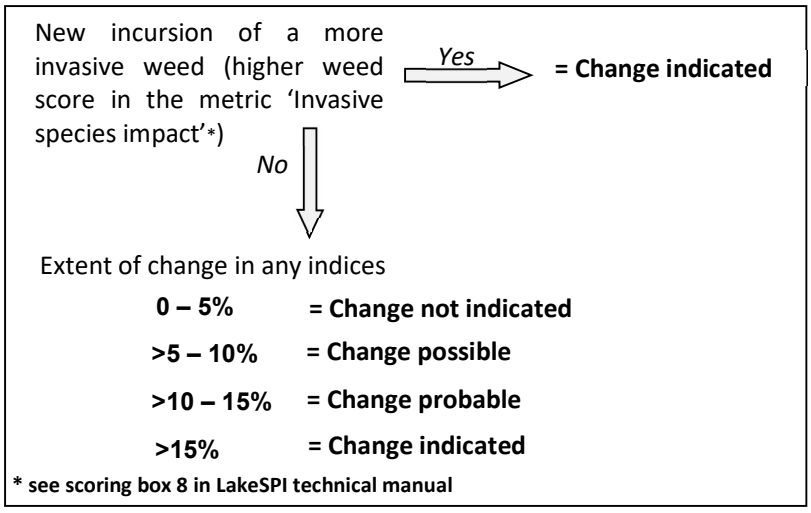


Figure 2: Guidelines for assessing the significance of change in LakeSPI Indices over multiple surveys of a lake.

[3] https://lakespi-uat.niwa.co.nz/
[4] Paired t test calculator - dependent t-test (statskingdom.com)

2.3 National Policy Statement for Freshwater Management

The NPS-FM has included two LakeSPI indices as attributes in its National Objectives Framework that require action plans (NPS-FM 2022[5], Appendix 2B, Tables 11 and 12). Attribute bands are related to Native Condition Index and Invasive Impact Index values as shown in Table 2. Any lake that falls below the national bottom line is considered degraded and may require councils to prepare a time-based action plan to achieve a target status. If the current state is below the national bottom line due to natural processes (e.g., naturally non-vegetated geothermal or peat lakes), a target attribute state below the national bottom line may be set. Currently, the Ministry for the Environment state that the Native Condition Index and Invasive Impact Index should be assessed every three years[5]. Invasive Impact Index for non-vegetated lakes is not included in the A band (Table 2), because lakes without submerged vegetation cannot be considered invaded or uninvaded.

Table 2: National Objectives Framework attribute table for LakeSPI indices. Native Condition Index and Invasive Impact Index attribute bands from the NPS-FM (2020, Appendix 2B, Tables 11 and 12).

Attribute band	Native Condition Index	Invasive Impact Index
A	>75%	0*
B	>50 and ≤75%	>1 and ≤25%
C	≥20 and ≤50%	>25 and ≤90%
National bottom line	20%	90%
D	<20%	>90%

*Note Invasive Impact Index for non-vegetated lakes is not included in the A band.

[5] exposure-draft-changes-to-npsfm-2020.pdf (environment.govt.nz), (https://consult.environment.govt.nz/freshwater/npsfm-and-nesf-exposure-draft/)

3 LakeSPI Results

3.1 Ōtaki

3.1.1 Lake Waiorongomai

Lake condition:	Non-vegetated
Stability:	-
Lake depth:	1.5

Results

In 2022, Lake Waiorongomai had very low covers of submerged plants and did not exceed the 10% cover threshold at the majority of surveyed sites for generation of LakeSPI scores. Therefore, the default LakeSPI Indices values were 0% (Figure 3) and the lake was designated as a non-vegetated.

At this time, native *Ruppia polycarpa* was the most common submerged plant, together with native pondweeds *Potamogeton ochreatus* and *Stuckenia pectinata*. Invasive exotic weeds included hornwort (*Ceratophyllum demersum*, Figure 4) and curled pondweed (*Potamogeton crispus*). The floating plant *Lemna disperma* was recorded at the lake margins and a waterlily (*Nymphaea* hardy cultivar) was observed in the vicinity of the lake outlet (Figure 4).

Scattered submerged plants at average individual covers of ≤5% were mostly restricted to hard sandy substrates on the eastern third of the lake. Plants were mostly recorded to a depth of 0.6 m, apart from *Stuckenia pectinata* which was recorded to a maximum depth of 1.3 m.

Figure 3: LakeSPI results for Lake Waiorongomai from 2022.

Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2022	Non-vegetated	0.0%	0.0%	0.0%

Discussion

At the time of NIWA's 2022 survey, submerged plants did not exceed 10% cover and the lake was categorised as non-vegetated. Hornwort has been present at Lake Waiorongomai since at least February 2013 and has previously formed a complete cover, with surface reaching bands along parts of the lake margin and amongst emergent plants (Spinks 2018). However, large die-backs of hornwort have been observed at the lake in late summer (Spinks 2018) and it may be that our survey coincided with such an event. Alternatively, our survey may reflect a major vegetation decline indicating the that the state of the lake has deteriorated further, and it can no longer support extensive growths of hornwort

All of the plant species (Appendix B) noted in our survey were previously documented during ecological baseline monitoring and other investigations described by Spinks (2018). The native water

fern *Azolla rubra* and the *Chara* and *Nitella* species listed in 2014 (Spinks 2018) were not relocated by NIWA in 2022.

Amongst the ecological issues identified for Lake Waiorongomai is the reduction in water level and lake size due to drainage in the catchment, and reduced flows to the sea (Hapai Whenua Consultants 2006). For instance, a c. 0.5 m reduction in lake level occurred during the 1970s (Spinks 2018). Descriptions of silt entering the lake and accumulating on the deeper western side as a result of these modifications (Spinks 2018) were reinforced by NIWA's snorkel survey, where a diver could insert their arm almost up to the shoulder in the very soft muds on the western side. This soft, easily disturbed substrate would provide a poor rooting environment for submerged plants. By contrast, substrates along the eastern lake side were firm and sandy, and most submerged plant species were limited to this area.

The status of Lake Waiorongomai as supertrophic to hypertrophic (Perrie and Royal 2022) also suggests water quality issues for submerged plants, particularly limited light availability for plant growth from the poor water clarity, as observed during the 2022 survey. Recorded salinities of 0.2-0.3 PSU (Spinks 2018) are reflected in the plant composition, with *Ruppia polycarpa* and *Stuckenia pectinata* being common in slightly saline coastal waterbodies.

Figure 4: Aquatic vegetation at Lake Waiorongomai. A) hornwort (*Ceratophyllum demersum*) occurred as scattered plants or floating fragments (ringed), B) raupō (*Typha orientalis*) and *Nymphaea* hardy cultivar near the lake outlet.

In 2009, mapping of remaining native plants, the eastern shoreline had offshore beds of reeds or rushes present (Spinks 2018). These beds are visible in Google Earth images up until May 2018 but were not evident during NIWA's 2022 survey. This loss is at odds with the recent riparian

regeneration seen around the lake as a result of fencing-off of the lake margins from 2014 (Spinks 2018). Offshore reeds and rushes might provide beneficial sheltered habitat for submerged plants.

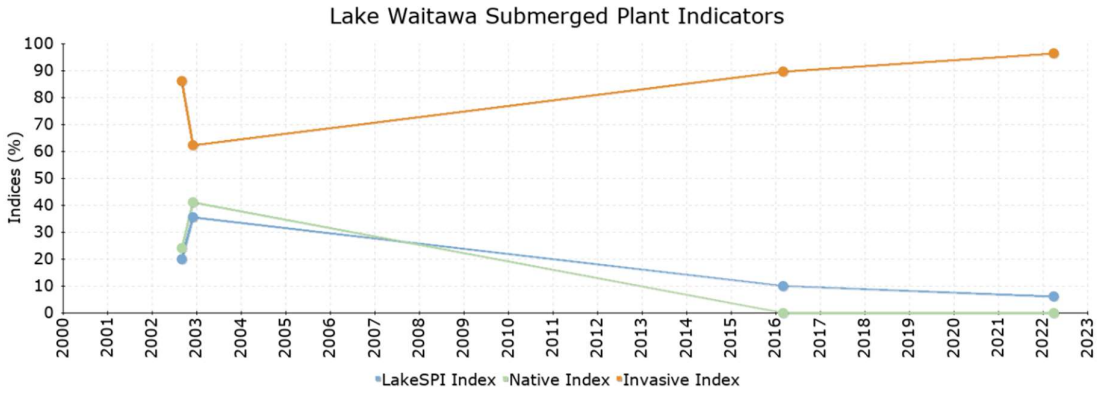
3.1.2 Lake Waitawa

Lake condition:	Poor
Stability:	Declining
Lake depth:	6.9

Results

In 2022, Lake Waitawa had a LakeSPI Index of 6%, indicating a poor lake ecological condition (Figure 5). The lake had a high Invasive Impact Index of 96% and a Native Condition Index of 0% (Figure 5).

Figure 5: LakeSPI results for Lake Waitawa from the 2022 and earlier surveys.



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2022	Poor	6.0%	0.0%	96.3%
February 2016	Poor	10.0%	0.0%	89.6%
November 2002	Moderate	35.5%	41.0%	62.2%
August 2002	Poor	20.0%	24.0%	85.9%

In the 2022 survey, no native submerged plants were recorded in Lake Waitawa. Hornwort (*Ceratophyllum demersum*) formed a dense, surface-reaching band weed around the margin of the lake (Figure 6A and B) to an average of 2.7 m depth. Hornwort fragment fall-out was present down to 4 m depth but was probably not viable long-term (Figure 6C). Egeria (*Egeria densa*) was the only other submerged plant present (Figure 6A), where it mainly contributed to the weed bed in shallow water to 1.5 m depth.

Emergent bands of raupō (*Typha orientalis*) fringed the lake margin and waterlilies (*Nymphaea* hardy cultivar) occurred in shoreline patches. The floating plants, native *Azolla rubra* and non-native *Landoltia punctata*, were associated with the marginal lake vegetation.

Figure 6: Lake Waitawa vegetation. A) a surface reaching band of hornwort (*Ceratophyllum demersum*) and white flowering egeria (*Egeria densa*), B) hornwort near the surface and C) fragments at c. 4 m depth.

Discussion

LakeSPI results from 2022 indicated a statistically significant ($p>0.01$) increase in Invaded Impact Index and reduction in LakeSPI Index since 2016. While hornwort also dominated the vegetation at the time of the 2016 survey, the weed beds were not as tall or dense as those recorded in 2022.

Two earlier LakeSPI results were derived from submerged vegetation surveys that monitored the outcome of herbicide application to control large weed beds of hornwort (Dugdale and Champion 2002). This herbicide treatment decreased the Invasive Impact Index by 24%, increased the Native Condition Index by 17% and increased the LakeSPI Index by 16% (Figure 5). At this time (2002), native pondweeds and charophytes were commonly recorded, and the average depth extent of plants was 5.16 m. Much earlier in 1949 (Cunningham et al. 1953), Lake Waitawa was described as having a sparse submerged vegetation comprised of charophytes, with a fringing band of raupō (*Typha orientalis*).

Lake Waitawa was assessed as supertrophic in 2007 and over 2019 to 2010 (Perrie and Milne 2012), with more recent water quality sampling suggesting a status of eutrophic to supertrophic (Perrie and Royal 2022). Hornwort can dominate and persist in sheltered, shallow lakes with poor water quality and clarity due to the plants ability to form tall weed beds with a photosynthetic canopy close to the water surface typified by the beds documented in Lake Waitawa in 2022. However, the earlier LakeSPI assessment for Lake Waitawa in 2016 showed reduced hornwort beds that might suggest vulnerability to vegetation decline and a risk of a future 'non-vegetated' status.

Issues at the lake identified by the community (Hapai Whenua Consultants 2006) have included 'noxious' weed and exotic fish. Exotic fish recorded from the lake (New Zealand Freshwater Fish database) include rudd (*Scardinius erythrophthalmus*), tench (*Tinca tinca*), perch (*Perca fluviatilis*) and goldfish (*Carassius auratus*). Exotic fish introductions have been associated with a decline in water clarity, with presence of multiple feeding guilds (i.e., planktivorous, benthivorous and herbivorous) implicated in particular (Rowe 2007). Benthivorous and herbivorous exotic fish also represent a direct disturbance pressure on the submerged vegetation (de Winton et al. 2002, Dugdale et al. 2006). However, hornwort is thought to be less susceptible to exotic fish disturbance due to this free-floating plant being un-reliant on root formation, having a strong regeneration via fragmentation, and also its low palatability to herbivorous rudd (Lake et al. 2002).

The earlier (2002) herbicide treatments with diquat temporarily reduced the abundance of hornwort and saw a partial recovery by native plants, which are far less susceptible to this herbicide. However, diquat is not an eradication tool for hornwort and other management tools (i.e., grass carp, endothall herbicide) would need to be carefully considered if eradication was sought.

3.2 Waikanae

3.2.1 Waimeha Lagoon

Results

This lagoon was not considered suitable for a LakeSPI assessment on the basis of shallow depth and dominance of floating plants rather than submerged vegetation.

Waimeha Lagoon was very shallow (0.4 m) with deep soft mud. At the time of NIWA's survey in March 2022, an estimated one-third of the water surface was covered by the native water fern *Azolla rubra* and non-native duck weed *Landoltia punctata.* Low covers of submerged plants (<10%) comprised native pondweeds (*Potamogeton ochreatus* and *Stuckenia pectinata*) and *Ruppia polycarpa* and the invasive weed elodea (*Elodea canadensis*). These were distributed as scattered plants to the maximum lake depth. Emergent beds of raupō (*Typha orientalis*) and *Schoenoplectus tabernaemontani* commonly fringed the lagoon margin.

Discussion

Based on historic aerial photos of Waimeha Lagoon from the 1940s (Kapiti Coast District Council[6]) this natural, shallow waterbody has substantially decreased in area of open water (Figure 7). The wetland pond-like character, including dominance of floating plants, mean it is not suitable to assess using LakeSPI.

Figure 7: Waimeha Lagoon aerial photographs. A) the 1940's, B) 2020.

[6] Aerial Photos (Historic) (kapiticoast.govt.nz), https://maps.kapiticoast.govt.nz/LocalMaps/Viewer/

3.2.2 Waimanu Lagoons

Results

Waimanu Lagoons were not considered suitable for assessment using LakeSPI on account of an apparent saline influence that strongly structured the submerged vegetation.

Ruppia polycarpa and *R. megacarpa* were recorded in the southern lagoon (south of Barrett Drive) (Figure 8A and B) to c. 1.4 m depth. Both species formed local average covers of up to 50%. Plants in the shallows appeared to have been heavily grazed by waterfowl. The northern lagoon had noticeably lower plant covers of *R. polycarpa* at ≤5% cover to 0.5 m depth, poorer water clarity, sediment algal covers, blackened sediments, and seemed to have an inverted thermocline with warmer temperature deeper.

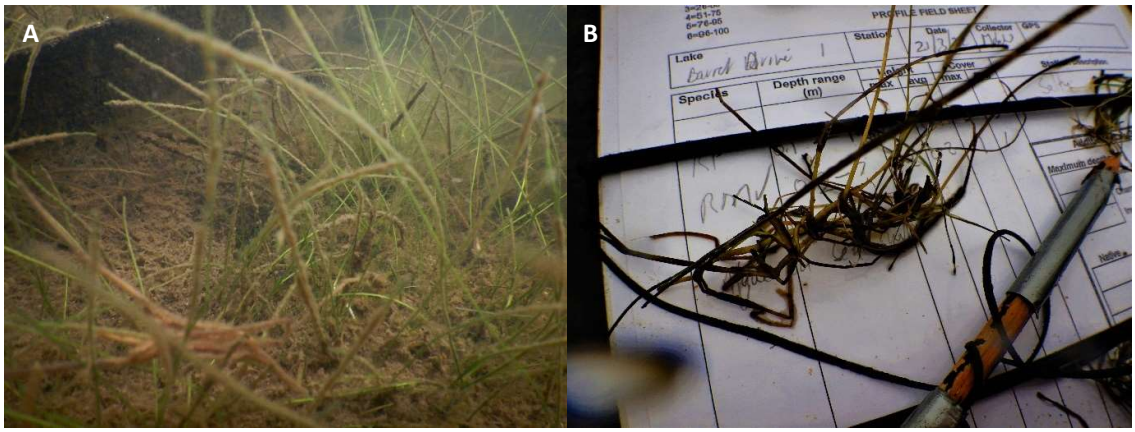


Figure 8: Submerged vegetation at southern Waimanu Lagoon. A) *Ruppia polycarpa*, B) *Ruppia megacarpa* sample.

Discussion

Based on historic aerial photos (Kapiti Coast District Council), Waimanu Lagoons are not natural waterbodies but represent excavated basins. The lagoons are reported to have been shaped into their current form in the 1970's (Boffa Miskell Limited 2000). The south lagoon has a controlled opening to the Waikanae River estuary, located c. 1.5 km from the sea along the river path and they also receive stormwater flows (Boffa Miskell Limited 2000).

In 1999, tidal exchange was restricted under lagoon management at the time and freshwater plant species were recorded, including pondweed (*Potamogeton ochreatus*), nitella (identified as '*Nitella hookeri*' but unlikely to be that species) and 'duckweed' (species unknown). 'Tidal flushing' was

reintroduced over 1999/2000 following management recommendations for up to four exchanges for 48 hours per annum, in part to limit nuisance vegetation development (Boffa Miskell Limited 2000). It appears this opening regime has been continued[7]. It was also noted that the migrating river mouth would influence levels of salinity in the lagoons when opened.

The level of salinity over the longer term was recognised as likely to affect the type of aquatic plants in the lagoons (Boffa Miskell Limited 2000). We conclude that a regularly open lagoon is likely responsible for the dominance of *Ruppia* species here. According to the Australasian Virtual Herbarium, the record for *R. megacarpa* is the first from Waikanae and second for Kāpiti outside of Kāpiti Island. This species is rare, ranked as being at-risk: naturally uncommon (de Lange et al. 2018).

These lagoons are not considered suitable for LakeSPI due to the saline influences constraining the submerged vegetation composition.

[7] Resident wants Waimanu Lagoons flushing delay to protect fledglings - NZ Herald (https://www.nzherald.co.nz/kapiti-news/news/resident-wants-waimanu-lagoons-flushing-delay-to-protect-fledglings/RJGLA7EBSVXIOJNWFQ7CIMJJGY/)

3.2.3 Lake Ngarara

Lake condition:	Moderate
Stability:	-
Lake depth:	2.5

Results

Lake Ngarara was assessed in a moderate condition according to a LakeSPI Index of 46% (Figure 9). A high Native Condition Index of 64% and Invasive Impact Index of 58% were recorded (Figure 9).

Figure 9: LakeSPI results for Lake Ngarara from 2022.

Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2022	Moderate	45.6%	64.3%	58.3%

The most common native submerged plants were pondweeds *Potamogeton ochreatus* and *P. cheesemanii* (Figure 10A and B). Also common were sago pondweed (*Stuckenia pectinata*), *Ruppia polycarpa* and charophytes (*Chara globularis*, *Nitella hyalina,* Figure 10C). Much of the native plant diversity was associated with a shallow hummock of sandy substrate in one basin.

The invasive weed elodea (*Elodea canadensis*) formed patches of high cover (Figure 10D) but was sub-dominant to native pondweed, and invasive curled pondweed (*Potamogeton crispus*) was also common.

Two non-native floating plants, *Landoltia punctata* and *Azolla pinnata*, and the native liverwort *Riccia fluitans* were encountered at the lake margins, amongst the emergent plants that included raupō (*Typha orientalis*) and *Eleocharis acuta*. Water lily (*Nymphaea* hardy cultivar) also occurred in patches and the native milfoil *Myriophyllum propinquum* occurred in emergent form amongst marginal turfs.

Discussion

Historical photographs (Kapiti Coast District Council) show that an open water system existed in the location of Lake Ngarara in the 1940's, and but is likely to have been modified for stormwater conveyance and this waterbody existed close to the current configuration from at least 2005 onwards. Stormwater structures (e.g., under-road concrete culverts) were observed in association with the lake in 2022.

Although this appears to be a modified waterbody, Lake Ngarara had an unusually high diversity of native vegetation in 2022 that was associated with apparently good water clarity and a diversity of substrate, with areas of sand amongst the predominant silty substrate. Prevention of excessive siltation and turbid water events from the modified urban catchment will be important to preserve this vegetation diversity.

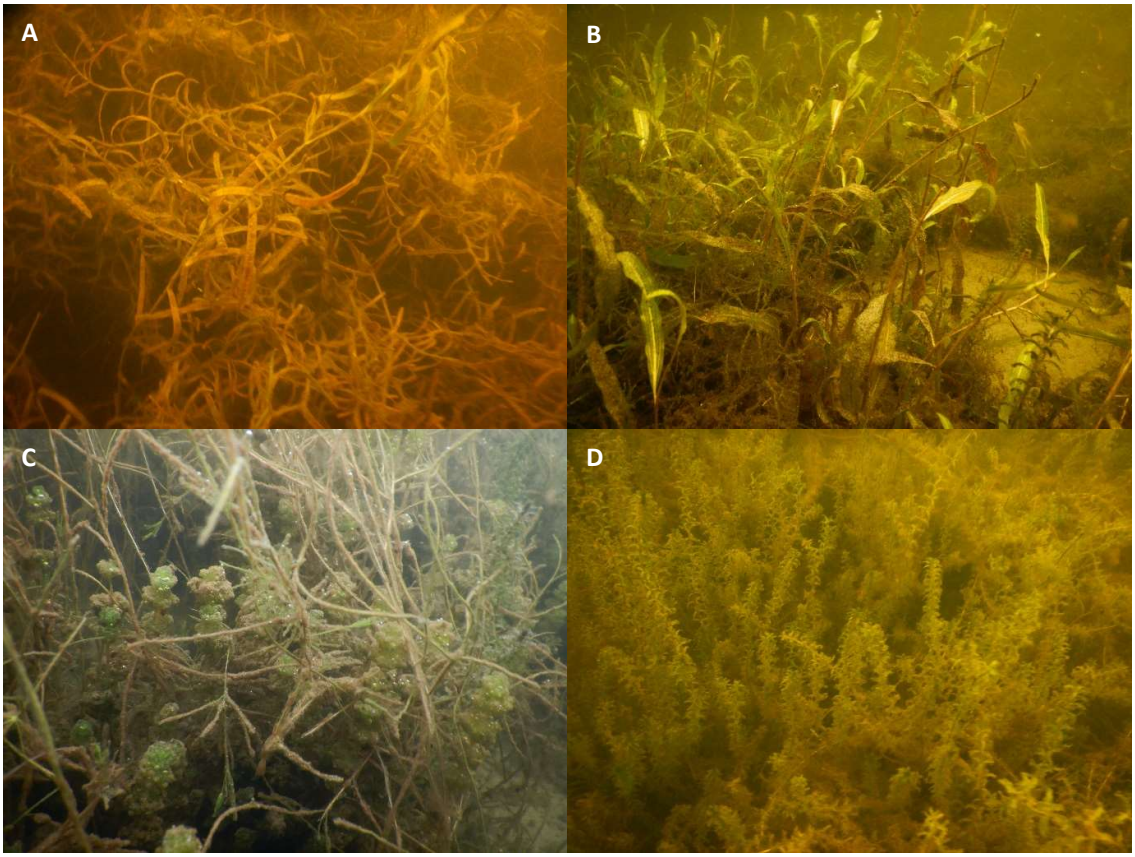


Figure 10: Submerged vegetation at Lake Ngarara. A) native pondweed (*Potamogeton ochreatus*) in deeper water, B) *Potamogeton cheesemanii* (large leaf) and mixed species, C) charophytes and *Ruppia polycarpa*, D) a patch of *Elodea canadensis*.

3.2.4 Manly Street Lagoon

Results

Manly Street Lagoon was not suitable for assessment by LakeSPI on account of its shallow nature, and encroachment by emergent and floating vegetation types.

The lagoon was shallow at 0.4 m depth with soft, easily re-suspended sediment and low water clarity (c. 0.3 m visibility). The only submerged plant present was the native charophyte *Chara australis* (Figure 11) which covered the bed of the open water area at between >5-25% cover. This charophyte was heavily fouled by sediment and algae (Figure 11).

The waterbody was fringed by dense beds of raupō (*Typha orientalis*) that extended into the open water area at lower covers. Abundant floating plants of native duckweed (*Lemna disperma*) had accumulated within the open margins of emergent beds.

Figure 11: Submerged vegetation at Manly Street Lagoon comprised *Chara australis*, with plants encrusted with sediment.

Discussion

This lagoon appears in 1940s aerial photographs (Kapiti Coast District Council) that seem to show a natural waterbody with sandy margins (Figure 12). The waterbody in Google Earth (Figure 12) shows a smaller area of open water and various levels of encroachment by emergent and floating aquatic plants. The shallow nature of this waterbody and other wetland characteristics mean it is not considered suitable for a LakeSPI assessment.

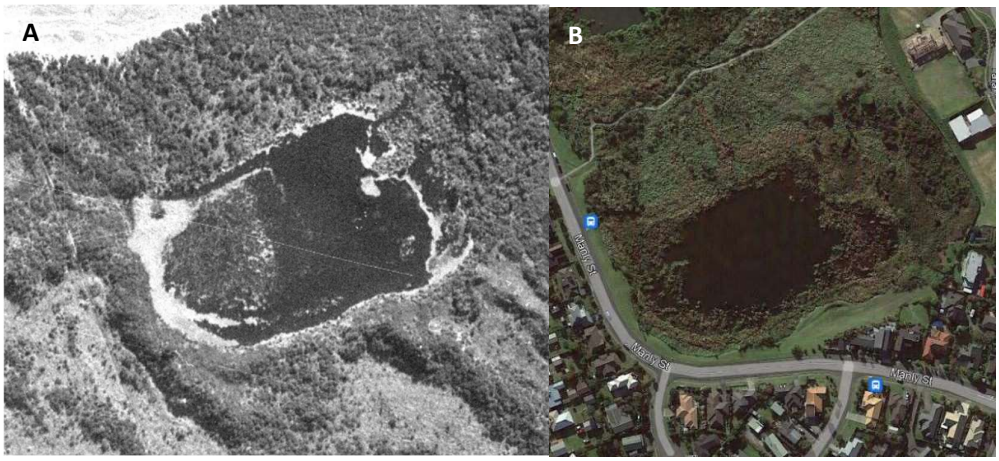


Figure 12: Manly Street Lagoon in aerial photographs. A) Lagoon in 1940's, B) Lagoon in March 2022.

3.3 Wairarapa

3.3.1 Turner's Lagoon

Lake condition:	High
Stability:	-
Lake depth:	0.4 m

Results

Turner's Lagoon was in a high ecological condition according to a LakeSPI Index of 68%, a Native Condition Index of 74% and a low Invasive Impact Index of 31% (Figure 13).

Figure 13: LakeSPI results for Turner's Lagoon from the 2022 survey.

Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2022	High	67.6%	73.8%	30.9%

This shallow (0.4 m) waterbody was widely vegetated by a diverse mosaic of native submerged plant species. Most surveyed areas were dominated by native milfoil (*Myriophyllum triphyllum*) and pondweed (*Potamogeton ochreatus*), especially in deeper areas with soft substrates (Figure 14A). Additional native plants recorded in more limited areas of harder substrates included swards of *Althenia bilocularis* (Figure 14B) and turf plants *Glossostigma elatinoides* and *Ranunculus limosella* (Figure 14C). Also common were small clumps of native charophytes *Chara australis* (Figure 14D) and *Nitella* sp. aff *cristata*, and *Ruppia polycarpa*. Uncommonly encountered native plants were *Potamogeton cheesemanii* and *Zannichellia palustris*.

Invasive weed species *Potamogeton crispus* and *Elodea canadensis* were common, usually at covers of <10%. Interestingly, the invasive algae water net (*Hydrodictyon reticulatum*) was also present in small quantities.

Discussion

The diversity and composition of vegetation in Turner's Lagoon is surprising given the predominant dairy farming land use in the immediate catchment. However, reported spring inflows may explain the better than expected water quality and observed plant health. Recent water quality sampling suggested a eutrophic status (Perrie and Royal 2022).

The mosaic vegetation pattern and species diversity may also be promoted by the different sediment types and also by grazing of the large black swan population observed at the lake. Disturbed plants and cleared patches were associated with swan presence in some areas of Turners Lagoon and may have contributed to the submerged plant diversity in this very shallow waterbody. In addition, several of the native species contributing to the vegetation diversity, *Ruppia*, *Zannichellia* and *Althenia,* are usually associated with higher conductivity conditions or saline influences. *Althenia bilocularis* is designated Nationally Vulnerable and *Zannichellia palustris* At-risk Naturally Uncommon

(de Lange et al. 2018). *Althenia* appears to have some characteristics of an annual (easily regenerated from seed) and may be more widespread than its threat status suggests.

Hydrodictyon reticulatum has been known from the Wairarapa Moana Wetlands for several decades but does not appear to form the extreme nuisance growths seen previously in waterbodies of other regions (Hall and Cox 1995).

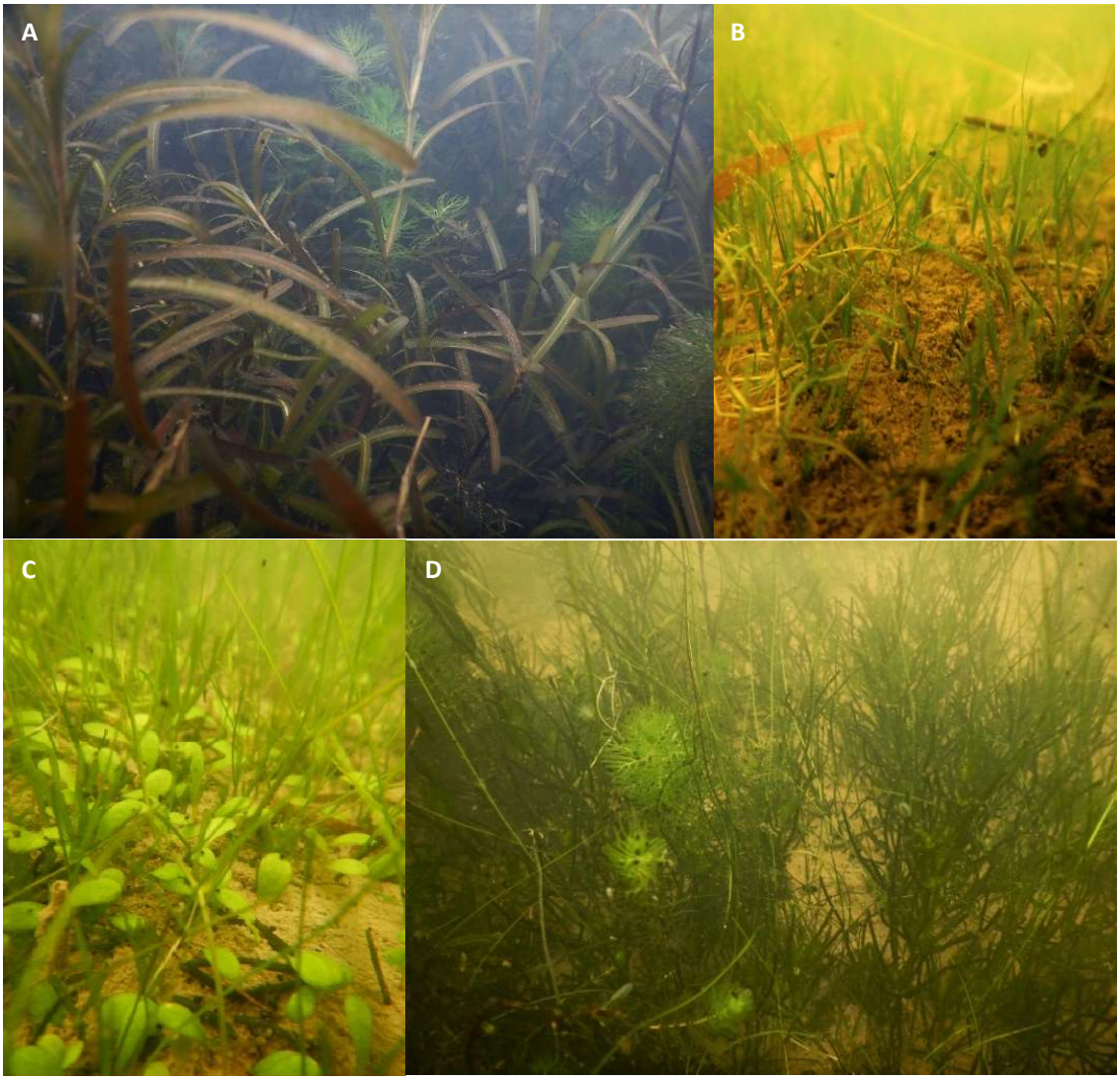


Figure 14: Vegetation in Turners Lagoon. A) dominant native pondweed and milfoil, B) *Althenia bilocularis*, C) spoon-shaped leaves of *Glossostigma elatinoides* and narrow stems of *Ruppia polycarpa*, D) clumping growths of *Chara australis*, with a few shoots of milfoil (lighter green).

3.3.2 Barton's Lagoon

Lake condition:	High
Stability:	-
Lake depth:	1 m

Results

In 2022, Barton's Lagoon had a high ecological condition according to LakeSPI, with a LakeSPI Index of 73%, a Native Condition Index of 71% and a low Invasive Impact Index of 22% (Figure 15).

Figure 15: LakeSPI results for Barton's Lagoon from the 2022 survey.

Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2022	High	73.5%	71.4%	22.2%

The submerged vegetation in the deeper parts of the lagoon was dominated by native pondweed (*Potamogeton ochreatus*) with native milfoils (*Myriophyllum triphyllum* and *M. propinquum*) and *Ruppia polycarpa* was also abundant (Figure 16A and B). *Zannichellia palustris* was also detected as drift fragments and liverwort 'balls' of *Riccia fluitans* were present.

The only exotic weed encountered within the lagoon was curled pondweed, *Potamogeton crispus* (Figure 16C). However, hornwort (*Ceratophyllum demersum*) formed large beds within the outlet stream (Figure 16D and E).

Shallower areas of the lagoon were observed to have a complete cover of filamentous algae over mostly bare sediment. Large emergent beds of raupō (*Typha orientalis*) fringed most of the lagoon.

Discussion

Barton's Lagoon is described as lacustrine wetland and palustrine swamp (Reeves et al. 2013). Recent water quality monitoring suggests a mesotrophic to eutrophic status (Perrie and Royal 2022).

Despite the abundance of hornwort in the outlet in 2022, we did not find this weed within the main body of Barton's Lagoon. Hornwort has been recorded on the outlet of Barton's Lagoon since 1996 and in the lagoon since 1999 (NIWA FW pest plant records). In 2007, submerged plants in the downstream drains of Barton's Lagoon included dominant hornwort, and also *Potamogeton crispus*, *Lagarosiphon major*, *Elodea canadensis* and *Nitella* sp. aff. *cristata* (Champion and Taumoepeau 2007). Hornwort was also noted as dominant in large drainage channels on the lagoon margins in 2011 (Reeves et al. 2013). Hornwort beds dense enough to prevent outboard use in the lagoon were described in January 2021[8], however this may have been in reference to other aquatic plants.

[8] *https://lakes380.com/blog/tuhono-ki-wairarapa-moana/*

Figure 16: Submerged vegetation in Barton's Lagoon. A) dominant native pondweed with B) *Ruppia polycarpa*, C) occasional invasive *Potamogeton crispus*, D) hornwort (*Ceratophyllum demersum*) beds in E) the outlet stream.

3.3.3 Boggy Pond

Lake condition:	Moderate
Stability:	-
Lake depth:	1.1 m

Results

In 2022, Boggy Pond was assessed as having a moderate ecological condition according to a LakeSPI Index of 44% (Figure 17). A high Native Condition Index of 79% reflected native plant dominance and high diversity, with an Invasive Impact Index of 67% reflecting widespread presence of less abundant weeds (Figure 17).

Figure 17: LakeSPI results for Boggy Pond from the 2022 survey.

Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2022	Moderate	44.1%	78.6%	66.7%

High cover (>75%) charophyte meadows, dominated by *Chara australis* (Figure 18A), were present immediately out from the fringing emergents, but the central lagoon bed (Figure 18B, C and D) was occupied mainly by native milfoil (*Myriophyllum triphyllum*) and pondweed (*Potamogeton ochreatus*), with patches of charophytes (*C. australis* and *Nitella* sp. aff. *cristata*).

Invasive weeds generally contributed low covers (≤25%) across the lagoon and comprised hornwort (*Ceratophyllum demersum*), curled pondweed (*Potamogeton crispus*) and elodea (*Elodea canadensis*).

Fringing raupō (*Typha orientalis*) beds typically extended to 0.9 m depth at the lake margins, accompanied by floating plants *Azolla rubra*, *Landoltia punctata* and the liverwort *Ricciocarpos natans*.

Discussion

Boggy Pond has been described as a palustrine wetland, comprising swamp and shallow water, and is rainwater fed rather than groundwater as the water level is above the local water table (Shi 2014). Boggy Pond had similar submerged vegetation species records to adjacent Matthew's Lagoon but is assessed in a better ecological condition according to LakeSPI due to lower dominance by invasive weeds and the presence of extensive charophyte meadows.

Differences in ecological condition of the two adjacent lagoons may reflect a better water quality at Boggy Pond, with lower nutrient levels than adjacent Matthew's Lagoon. An oligotrophic to mesotrophic status was assessed in 2013 (Shi 2014), but recent water quality sampling suggested a eutrophic to supertrophic status (Perrie and Royal 2022). Boggy Pond also has less water level fluctuation than Matthew's Lagoon with a range of c. 0.7 m (Shi 2014).

Hornwort did not dominate in Boggy Pond in 2022 despite being present for over 20 years. Hornwort was first recorded in drains entering Boggy Pond in 1999 and was present in the lagoon in 2000 (NIWA freshwater pest plant records). The low cover and 'spindly' appearance of hornwort (Figure 18C) suggests its growth is limited by conditions in Boggy Pond.

The liverwort *Ricciocarpos natans* recorded at Boggy Pond and Matthew's Lagoon has the conservation status of at-risk; declining (de Lange et al. 2020).

Swan grazing was likely given the bird numbers seen on the lagoon. We note that exotic rudd (*Scardinius erythrophthalmus*) and goldfish (*Carassius auratus*) are recorded in Boggy Pond (New Zealand Freshwater Fish Database), but while these fish are known to browse on submerged vegetation there was no obvious impact on the submerged vegetation.

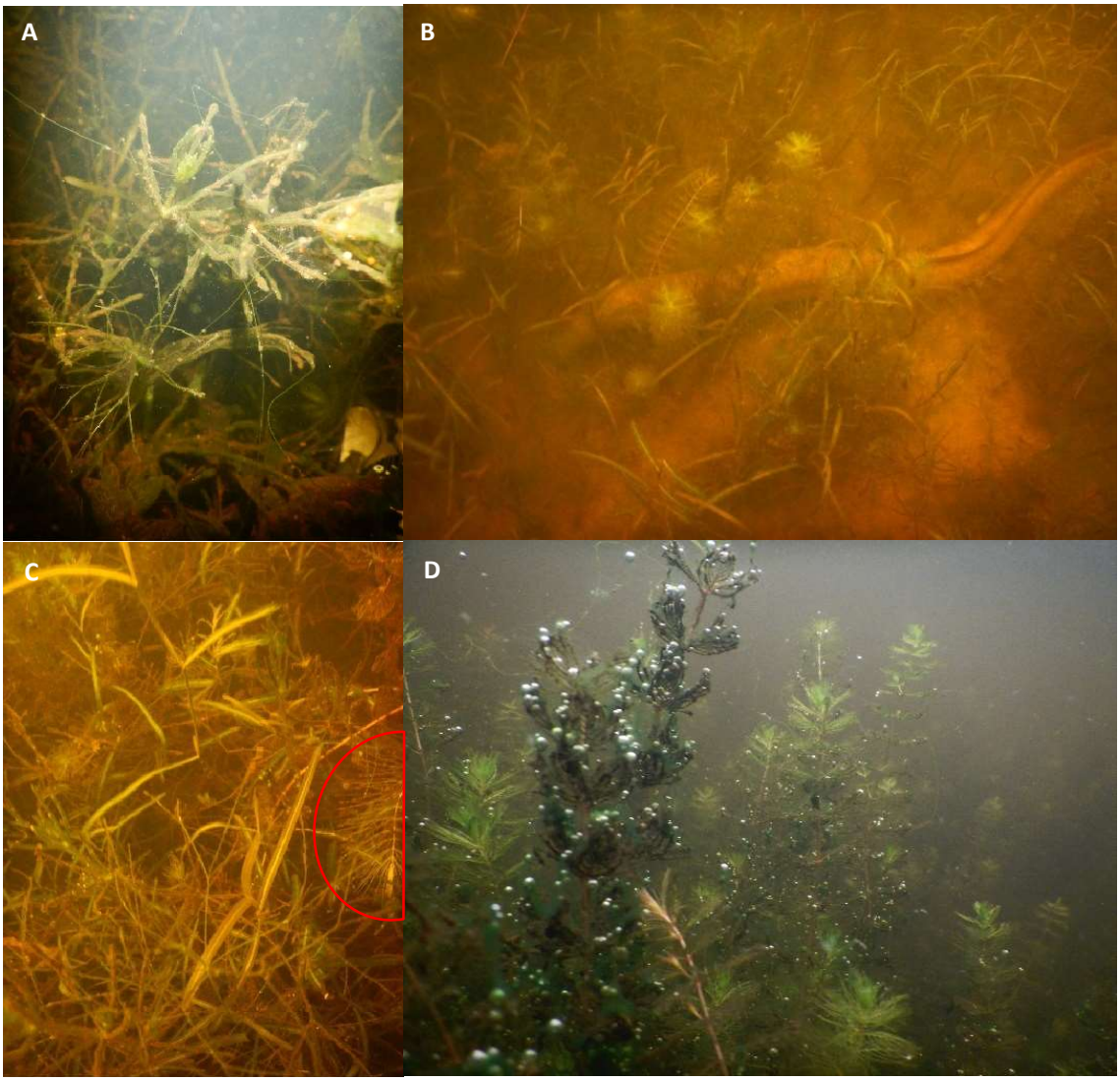


Figure 18: Vegetation in Boggy Pond. A) Charophyte meadows of *Chara australis* and *Nitella* sp. aff. *cristata* were present at the lagoon margins, B) open vegetation and tuna, C) typical mixed vegetation of native pondweed, charophytes and a hornwort (*Ceratophyllum demersum*) plant (ringed right), D) a stand of native milfoil.

3.3.4 Matthew's Lagoon

Lake condition:	Moderate
Stability:	-
Lake depth:	1.3 m

Results

Matthew's Lagoon had a moderate ecological condition according to the 2022 survey with a LakeSPI Index of 34% (Figure 19). Although the Native Condition Index was relatively high at 62%, the lagoon had areas dominated by invasive weeds and recorded an Invasive Impact Index of 73% (Figure 19).

Figure 19: LakeSPI results for Matthew's Lagoon from the 2022 survey.

Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2022	Moderate	34.3%	61.9%	72.8%

Invasive weeds included high cover (>75%) patches of hornwort (*Ceratophyllum demersum*) and scattered plants of elodea (*Elodea canadensis*), but these did not form continuous weed beds (Figure 20A and B).

Native pondweed (*Potamogeton ochreatus*) was the most abundant submerged plant at all surveyed sites. Another common native submerged plant was the milfoil *Myriophyllum triphyllum* and occasionally, the charophyte *Chara australis* (Figure 20C) and an unidentified bryophyte.

All surveyed shorelines were fringed by dense beds of raupō (*Typha orientalis*). Complete surface covers of floating plants had rafted against the shoreline (Figure 20D) that included the native fern *Azolla rubra*, duckweeds *Landoltia punctata* and *Lemna disperma*, watermeal *Wolffia australiana*, and the liverwort *Ricciocarpos natans*.

Discussion

Matthew's Lagoon has been identified as a palustrine wetland with some riverine areas and categorised as marsh and shallow water (Shi 2014). The lagoon receives nutrient rich agricultural runoff via the Te Hopai drainage system, although some lagoon bypass of this water was suspected (Shi 2014). The lagoon was variously categorised as mesotrophic to hypertrophic in 2013 (Shi 2014) and more recently as supertrophic to hypertrophic (Perrie and Royal 2022). Matthew's Lagoon has a relatively variable water level with a 1 m range (Shi 2014).

Hornwort was first recorded in drains entering the lagoon in 1998 and confirmed in the lagoon in 1999 (NIWA freshwater pest plant records). Although hornwort has been present for over 20 years it did not dominate the lagoon but did form patches of high cover. Exotic rudd (*Scardinius erythrophthalmus*) and goldfish (*Carassius auratus*) are reported for the Boggy Pond/Matthew's Lagoon complex (Reeves et al. 2013), but no obvious fish disturbance damage for plants was observed.

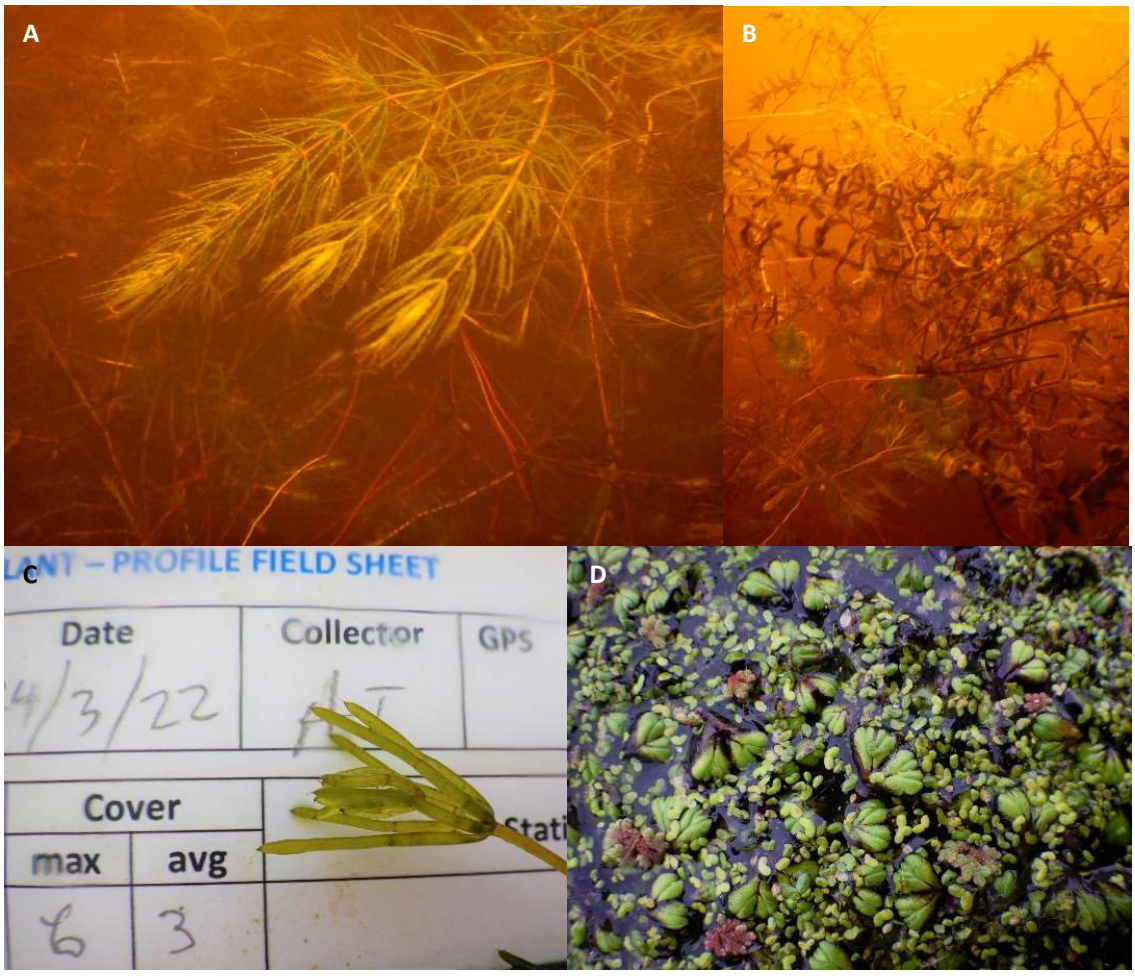


Figure 20: Matthew's lagoon vegetation. A) hornwort (*Ceratophyllum demersum*) and B) elodea (*Elodea canadensis*) plants occurred in patches, C) *Chara australis*, D) mixed assemblage of floating plants at the lagoon margin.

3.3.5 Lake Nganoke

Lake condition:	High
Stability:	-
Lake depth:	1.6

Results

In 2022, Lake Nganoke had a high ecological condition according to a LakeSPI Index of 68% (Figure 21). This status was driven by a relatively high Native Condition Index of 69% and a moderate Invasive Impact Index of 30% (Figure 21).

Figure 21: LakeSPI results for Lake Nganoke from the 2022 survey.

Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2022	High	67.6%	69.0%	29.6%

The shallow lake had dense (>75% cover) charophyte meadows across much of the lake bed, comprising mainly of 0.5 m tall *Nitella* sp. aff. *cristata* (Figure 22A), but with *Chara australis* present at the un-surveyed shallow eastern end (A. Perrie, GWRC, pers. comm. 24/3/2022). Native pondweed (*Potamogeton ochreatus*) extended as an open canopy above the meadows at average covers of 6-25% and up to 1.2 m in height.

The only invasive weed seen was curled pondweed (*Potamogeton crispus*) which formed an average cover ≤5%.

A large proportion (c. two-thirds) of the water surface of Lake Nganoke was covered with floating plants including *Azolla rubra*, *Landoltia punctata*, *Lemna disperma* and watermeal *Wolffia australiana* (Figure 22B).

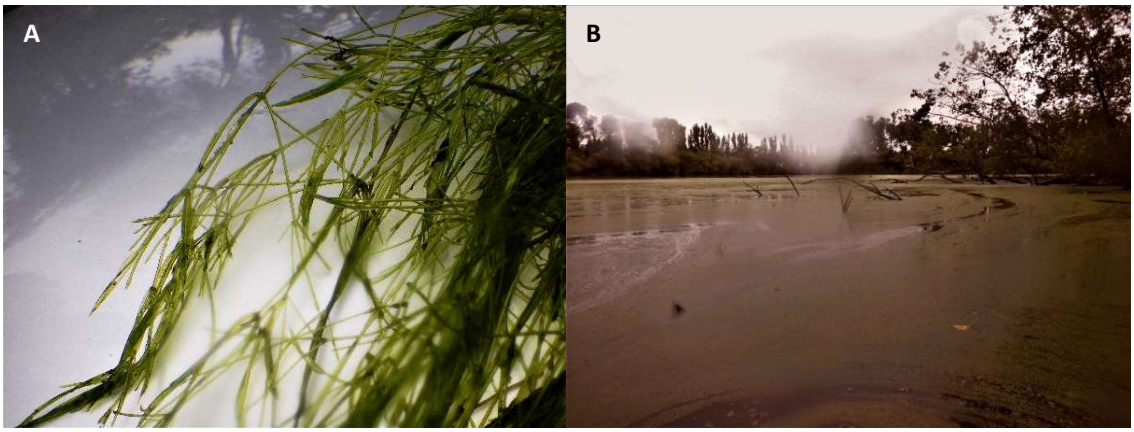


Figure 22: Lake Nganoke vegetation. A) *Nitella* sp. aff. *cristata* dominated charophyte meadows, B) floating plants extended across much of the water surface.

Discussion

Lake Nganoke had a submerged vegetation composition dominated by relatively few native species, but also limited exotic weed development. This waterbody had a hypertrophic status based on recent water quality sampling (Perrie and Royal 2022).

The lake is known to occasionally dry and expose marginal lake substrates[9] and the extent of drying can be seen on the Google Earth image for April 2016. The plants that dominate this lake are capable of periodically regenerating from seed and propagule banks laid down in the substrate, but the absence of marginal turf plants (e.g., *Glossostigma*) suggests that there are no regular drying and wetting cycles for the lake.

Seasonal development of the floating plants at Lake Nganoke is in keeping with nutrient enrichment but also likely reflects the shelter provided by tall riparian trees, where wind-wave action would otherwise displace these small plants to the water body margins.

[9] Lake Nganoke — LAKE STORIES AOTEAROA NEW ZEALAND (lakestoriesnz.org)

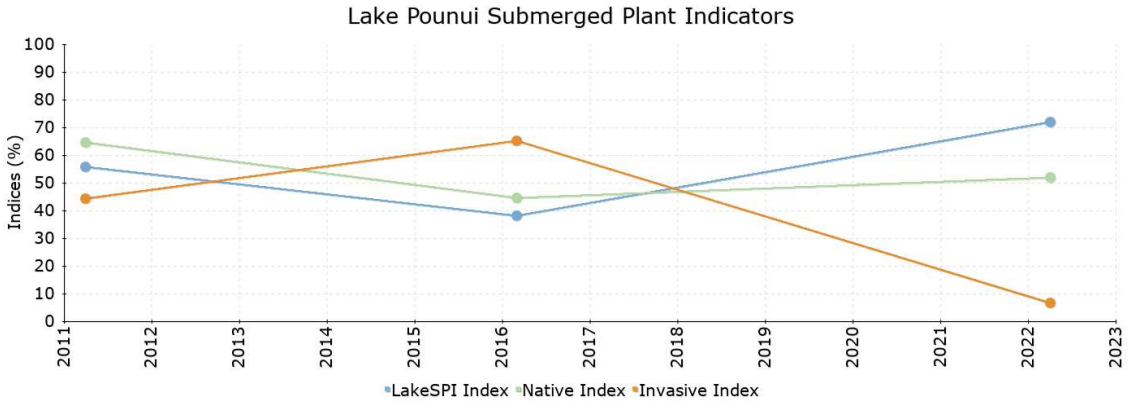
3.3.6 Lake Pounui

Lake condition:	High
Stability:	Declining
Lake depth:	9.8

Results

In 2022, a LakeSPI Index of 71% places Lake Pounui into the high category of lake ecological condition (Figure 23). This result was driven by a low Invasive Impact Index of 7% and a Native Condition Index of 52% (Figure 23). However, a closer examination of results suggests that a widescale vegetation decline has occurred in the lake and the current lake condition may be unstable.

Figure 23: LakeSPI results for Lake Pounui from the 2022 and earlier surveys.



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2022	High	71.9%	51.8%	6.7%
February 2016	Moderate	38.1%	44.5%	65.2%
March 2011	High	55.7%	64.5%	44.4%

Native pondweed (*Potamogeton ochreatus*) was the most widespread and deepest growing submerged plant, but it only formed covers of ≤25%, to the average maximum depth of 2 m at >10% cover. Scattered pondweed plants at lower cover were recorded to a maximum depth of 3.3 m. These plants appeared to be in poor health, black and stalky, with little fresh green growth.

Charophytes *Nitella* sp. aff. *cristata* and *Chara australis* (Figure 24A) formed high cover (>75%), but shallow meadows to an average depth of 1.4 m at several sites. Native milfoil was also encountered at covers of ≤25% to 1.3 m depth. Emergent plants *Schoenoplectus tabernaemontani* and *Typha orientalis* were common at the margins.

The only invasive weed species detected comprised scattered plants of elodea (*Elodea canadensis*) to 2 m depth at one of the five surveyed sites. An algal bloom reduced the water clarity and had formed scums along the margin in downwind areas (Figure 24B).

Figure 24: Lake Pounui in 2022. A) the charophyte *Chara australis* and B) algal bloom conditions at the lake.

Discussion

There was a statistically significant increase ($p<0.01$) in LakeSPI Index by 2022 compared with 2016 that was driven by a decrease in the Invasive Impact Index ($p<0.001$). However, Native Condition Index did not differ significantly between surveys (Figure 23). It appears there has been a major reduction in submerged vegetation abundance and depth extent evident by 2022, including a reduction in previously dominant invasive weed elodea, but native plants have not expanded in response.

High cover elodea weed beds that were recorded at all sites in 2016 were not present in 2022. Other differences included halving in the depth extent for significant (>10%) vegetation cover, from an average of 4 m depth in 2016 to 2 m in 2022.

A greater vegetation diversity was also recorded in 2016. In addition to the four native plant species recorded in 2022, two species of turf plant and *Isoetes kirkii* were recorded at some survey sites in 2016, and two other invasive weeds were also present. For these reasons, the increased LakeSPI Index in 2022 may not indicate improved lake ecological condition but instead points to an unstable lake vegetation that may be at risk of further decline.

The suspected instability of vegetation in 2022 follows earlier retractions in the (deeper) native vegetation depth limits between 2011 and 2016, and loss of deep charophyte meadows that were previously found to depths of between 3 and 4.9 m (de Winton et al. 2011). These changes led to statistically significant reductions in the LakeSPI and Native Condition Indices between 2011 and 2016, and a proportional increase in the Invasive Impact Index (Figure 23) because elodea weed beds remained that primarily occupied shallow lake habitat.

A historical lake vegetation description from 1976 (Persse undated, Jellyman 1990) gave indicative LakeSPI results similar to 2011, with a LakeSPI Index of 52%, Native Condition Index of 64% and an

Invasive Impact Index of 52%. This suggests that the lake vegetation was largely stable between the late 1970's and 2011.

A review of previous water quality monitoring at Lake Pounui suggested the lake status in the 1970's to 1980's was mesotrophic to oligotrophic, in 2007 was mesotrophic and in 2011 to be eutrophic (Perrie and Milne 2012). Recent water quality sampling suggested a hypertrophic status (Perrie and Royal 2022).

Changes in LakeSPI status previously raised questions about the drivers for apparent increasing nutrient status in Lake Pounui, which has a predominantly forested catchments and extensive receiving wetlands. The tendency for lakes with exotic fish (especially perch) to exhibit poorer water quality has been noted (see de Winton 2016) and subsequently the Lakes380 project has also linked the introduction of these exotic fish with rising levels of bloom-forming cyanobacteria and bacteria associated with degraded water[10].

The native quillwort *Isoetes kirkii* has the conservation status of At Risk – Declining (de Lange et al. 2018). Lake Pounui is the only remaining record for the species in the lower North Island (de Winton et al. 2011). However, LakeSPI surveys have documented ongoing reduction in abundance and distribution of this species at this lake. In 2011, quillwort was recorded at three survey sites, but it was present at one site 2016 and was not detected at the surveyed sites in 2022. A specific search for quillwort in 2022 at an area where it was previously common (41°20'45.41"S, 175° 6'40.25"E) resulted in just two plants found during 15 minutes of searching by a snorkel diver. The consequences for quillwort persistence of a shift to higher productivity waters was raised (de Winton 2016) and appears to have resulted in a further reduction of this plant species in the region.

Quillwort plants from Lake Pounui were earlier collected and cultured and were used in a genetics study undertaken by NIWA for Department of Conservation (Hofstra and de Winton 2013). Lake Pounui quillwort were genetically similar to plants found in Lake Waikaremoana and Lake Taupo (Hofstra and de Winton 2016) but they displayed a relatively high level of genetic variation in comparison with the other populations (Hofstra and de Winton 2013). These plants are still maintained within NIWA's macrophyte culture facility in Hamilton (Figure 25).

Figure 25: ***Isoetes kirkii*** **plants collected from Lake Pounui, grown in culture for over a decade.**

[10] Lake Pounui – Lakes 380

3.3.7 Pounui Lagoon

Lake condition:	-
Stability:	-
Lake depth:	m

Results

The original state of Pounui Lagoon would once have been a strongly saline influenced system, and salinity is still likely to structure the submerged vegetation at times. Therefore, LakeSPI is not considered a suitable assessment method for this waterbody.

In 2022, the most abundant submerged plant was native milfoil (*Myriophyllum triphyllum*), which formed average covers of 50% to the maximum surveyed depth of 0.5 m (Figure 26). Also common was *Ruppia polycarpa* and *Zannichellia palustris*, which appeared to have colonised disturbed patches where milfoil had been grazed by waterfowl. The native turf *Lilaeopsis novae-zelandiae* and charophyte *Nitella hyalina* were recorded at the site in the south of the lagoon. Beds of raupō were common at the lagoon margin. High covers of filamentous green algae were recorded at sites in the northern half of the lagoon that appeared to have prevented development of the shorter-growing plants. The only invasive weed was curled pondweed (*Potamogeton crispus*), which was uncommon.

Figure 26: Native milfoil dominated Pounui Lagoon.

Discussion

Water level at Pounui Lagoon is influenced by adjacent Lake Ōnoke and whether or not that waterbody is open to the sea. However, Pounui Lagoon has been separated from Lake Ōnoke by a stop bank since the mid 1960's, with two culverts connecting the two waterbodies (Airey et al. 2000). Flapgates installed to stop tidal flows have reduced saline inflows into the lagoon (Airey et al. 2000). With the reduction in tidal flush the wetland is reported to be gradually changing from an estuarine system to a freshwater system and silt deposition is occurring in the lagoon as the inflows from Pounui Stream are no longer being flushed out by the tide (Reeves et al. 2013). Recent water quality sampling suggested a status of eutrophic to supertrophic (Perrie and Royal 2022).

The 2022 vegetation survey did not detect *Stuckenia pectinata* or *Althenia* (*Lepilaena*) *bilocularis* which were previously known from Pounui Lagoon (Reeves et al. 2013). These species, together with the recorded *Ruppia* polycarpa and *Zannichellia palustris*, are particularly associated with saline influenced waterbodies. *Zannichellia palustris* is designated At-risk Naturally Uncommon (de Lange et al. 2018). The reduction in occurrence of these typically brackish plants may reflect decreasing salinity from the more limited tidal exchange recently, with similar shifts noted for wetland composition at Pounui Lagoon (Reeves et al. 2013). The 2022 survey results with dominance by the freshwater milfoil supports the suggestion that Pounui Lagoon is becoming more freshwater in character.

4 Discussion

4.1 Current lake state

In this section, together with the 2022 survey findings, we include other results for assessed waterbodies in Wellington Region. This includes assessment of the two Parangarahu Lakes (Lakes Kohangatera and Kohangapiripiri) in 2020 (de Winton 2020) and the Upper Karori Reservoir in 2013 (de Winton 2013).

The 16 waterbodies assessed in the Wellington Region included four lagoons in 2022 that were not considered suitable for LakeSPI survey due to strong saline influence or for waterbodies with wetland rather than lake character (Table 3).

For the purposes of ranking and discussing results, the remaining 12 waterbodies have been categorised into lake condition categories according to their current LakeSPI Index, as excellent, high, moderate, poor and non-vegetated (Table 3, Figure 27). These waterbodies span a LakeSPI Index from 83% down to the default score of 0% (Table 3). The status and ranking of the 12 waterbodies are shown relative to the most recent results for all 331 lakes that have been surveyed using LakeSPI to date (Figure 27).

Table 3: Summary of current LakeSPI results for assessed lakes with overall condition category. - = not suitable for LakeSPI assessment.

Waterbody	LakeSPI Index (%	Native Condition Index (%)	Invasive Impact Index (%)	Overall Condition
Lake Kohangatera	83	74	10	Excellent
Barton's Lagoon	74	71	22	High
Lake Pounui	72	52	6.7	High
Upper Karori Reservoir	73	49	0	High
Turner's Lagoon	68	74	31	High
Lake Nganoke	68	69	30	High
Lake Kohangapiripiri	55	64	48	High
Lake Ngarara	45	64	58	Moderate
Boggy Pond	44	79	67	Moderate
Matthew's Lagoon	34	62	73	Moderate
Lakes Waitawa	6	0	96	Poor
Lake Waiorongomai	0	0	0	Non-vegetated
Waimeha Lagoon	-	-	-	-
Waimanu Lagoons	-	-	-	-
Manly Street Lagoon	-	-	-	-
Pounui Lagoon	-	-	-	-

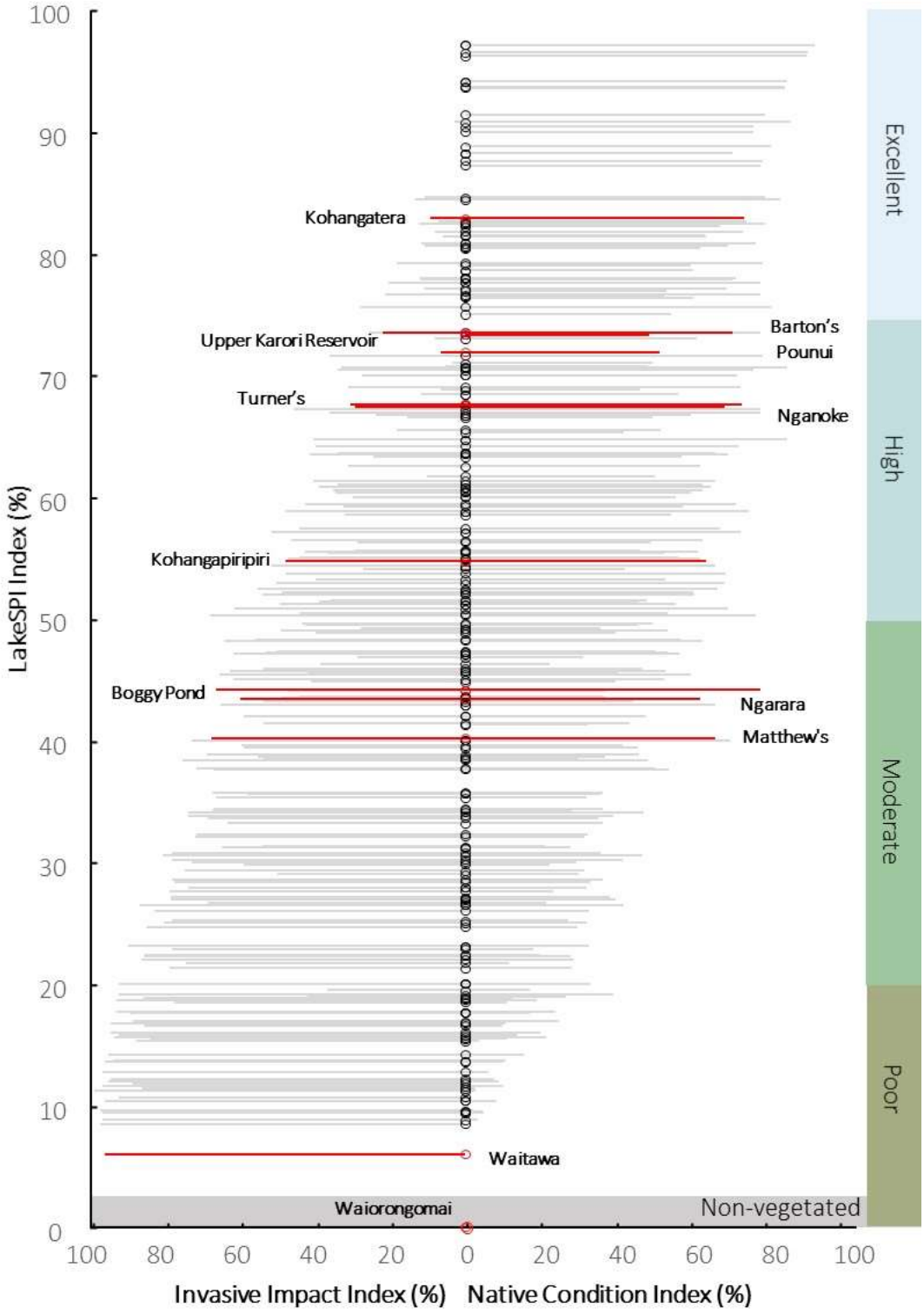


Figure 27: The most recent LakeSPI scores for lakes of the Wellington Region (red lines) are plotted with scores for a total of 331 New Zealand lakes. LakeSPI Index is plotted on the y-axis (points), Native Condition Index as lines to the right and Invasive Impact Index lines to the left. Five categories of LakeSPI condition are indicated on the right.

Excellent condition lakes

Lake Kohangatera, surveyed in 2019, had an excellent ecological condition (Table 3) due to the combination of a high Native Condition Index (>70%) and a low Invasive Impact Index (<10%). Lake Kohangatera remains one of the few national examples of a little impacted lowland lake (Figure 27), but that status may be under threat from a recent incursion by the weed *Egeria densa*.

High condition lakes

Six of the region's lakes were in a high ecological condition according to LakeSPI (Table 3). These either had a good representation of native plants (Native condition Index >60%) and moderate impacts by invasive weeds (Invasive Impact Index 20-50%), or a lower Native Condition Index (c. 50%) and very low impact from weeds (Invasive Impact Index <10%). Examples of higher native diversity but moderate impacts by invasive weeds include Turner's Lagoon and Lake Kohangapiripiri. Lakes Pounui and the Upper Karori Reservoir were included in this group due to a very low invasive weed presence, although native vegetation was of lower diversity or of restricted extent. Care must be taken in interpreting the high condition LakeSPI results for Lake Pounui as it may be transitioning to a poorer ecological condition with potential for submerged vegetation loss (below the 10% cover threshold for LakeSPI).

Moderate condition lakes

Three Wellington waterbodies had a moderate ecological condition (Table 3) due to good representation of native plants (Native Condition Index >60%), but also a relatively high Invasive Impact Index (50-75%). Aquatic weeds hornwort (*Ceratophyllum demersum*) and/or elodea (*Elodea canadensis*), although widespread, did not dominate in these waterbodies. These are comprised of the Wairarapa Moana lagoons Boggy Pond and Matthew's Lagoon and a waterbody in Waikanae (Lake Ngarara).

Poor condition lakes

Lake Waitawa was the only Wellington waterbody within the LakeSPI category of poor ecological condition (Table 3). This assessment resulted from an almost complete invasion of the lake by two New Zealand's worst aquatic weeds, hornwort (*Ceratophyllum demersum*) and egeria (*Egeria densa*), leaving no native submerged vegetation values.

Non-vegetated lakes

Lake Waiorongomai was the only non-vegetated lake amongst surveyed waterbodies of the Wellington Region (Table 3). This result indicates an extremely degraded lake ecological condition that can no longer support significant submerged plant growth. However, past development of hornwort suggests this waterbody may at times enter the poor category for LakeSPI.

4.2 National comparison

It is acknowledged that the 12 waterbodies with LakeSPI results may not be representative of the Wellington Region as a whole. However, comparing the categories of lake ecological condition for these waterbodies to current LakeSPI Indices for 331 lakes nationally (Figure 28) shows that:

- A slightly lower proportion of Wellington waterbodies fell into the 'excellent' category according to LakeSPI compared to nationally.
- There was a much higher proportion of the 12 lakes in the 'high' category than is the case nationally.

- A similar proportion of lakes were recorded in the 'moderate' category for Wellington Region and nationally.
- A lower proportion of Wellington waterbodies were recorded in the 'poor' and 'non-vegetated' categories.

Figure 28: Proportion of lakes that fall into each of five categories of LakeSPI Index. A) Wellington Region (12 surveyed lakes) and nationally (331 lakes), with number of lakes assessed shown for each category.

LakeSPI Index rankings for Wellington Region waterbodies (Figure 27) included Lake Kohangatera within the top 20 ranked lakes out of 262 ranks for 331 lakes. Five additional Wellington waterbodies were ranked within the top 50-100 rankings, four additional lakes within the 100 to 200 rankings and two of the region's lakes were in the bottom two ranks nationally (including all non-vegetated lakes).

4.3 NPS-FM scoring

The attribute bands for 12 Wellington waterbodies are provided in Table 4. According to the attribute entitled 'Submerged plants – natives' (Native Condition Index): Boggy Pond was assigned to the A band, due to the representation of different native vegetation types; eight waterbodies were assigned to the B band; Upper Karori Reservoir was assigned to the C band and Lakes Waitawa and Waiorongomai fall below the national bottom line into the D band.

The attribute Submerged plants - invasive species (Invasive Condition Index) is not assigned for non-vegetated lakes, as these by definition cannot be invaded by weeds. Therefore, no band was assigned for Lake Waiorongomai in Table 4. This attribute placed: Upper Karori Reservoir into Band A; Lakes Kohangatera, Pounui and Barton's Lagoon in band B; six of the remaining waterbodies into band C; while Lake Waitawa fell below the national bottom line into band D (Table 4).

The proportion of lakes within attribute bands under the NPS-FM (2022) is shown for lakes nationally together with the proportion for waterbodies in the Wellington Region (Figure 29). Compared with lakes nationally, Wellington Region has noticeably more waterbodies within the B band for Native Condition Index and fewer in the C and D band. Also, there are more waterbodies in the B band and fewer in the C band for Invasive Impact Index (Figure 29).

Table 4: Attribute bands for the Native condition Index and Invasive Impact Index of 13 Wellington waterbodies. - = waterbodies not assigned to bands.

Waterbody	Native Condition Index (%)	Invasive Impact Index (%)
Lake Kohangatera	B	B
Upper Karori Reservoir	C	A
Barton's Lagoon	B	B
Lake Pounui	B	B
Turner's Lagoon	B	C
Lake Kohangapiripiri	B	C
Lake Nganoke	B	C
Lake Ngarara	B	C
Boggy Pond	A	C
Matthew's Lagoon	B	C
Lakes Waitawa	D	D
Lake Waiorongomai	D	-*
Waimeha Lagoon	-	-
Waimanu Lagoons	-	-
Manly Street Lagoon	-	-
Pounui Lagoon	-	-

*Non-vegetated lakes are not scored for Invasive Impact Index under the NPS-FM.

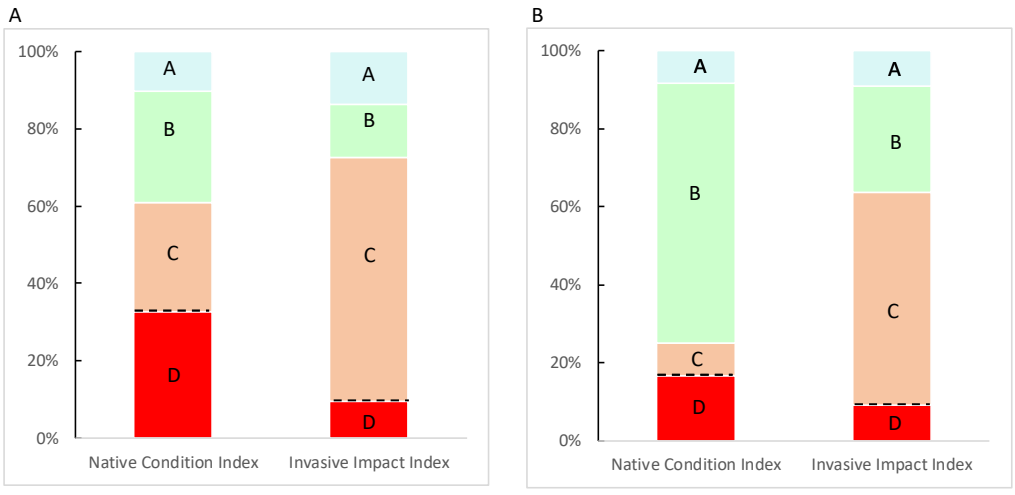


Figure 29: Proportion of lakes in each attribute band for Native Condition Index and Invasive Impact Index, A) nationally and B) for Wellington Region. The black dotted line indicates the national bottom line. Number of assessed lakes for Native Condition Index is 331 nationally and 12 for Wellington Region. Number of assessed lakes for Invasive Impact Index is 263 nationally and 11 for Wellington Region (non-vegetated lakes excluded).

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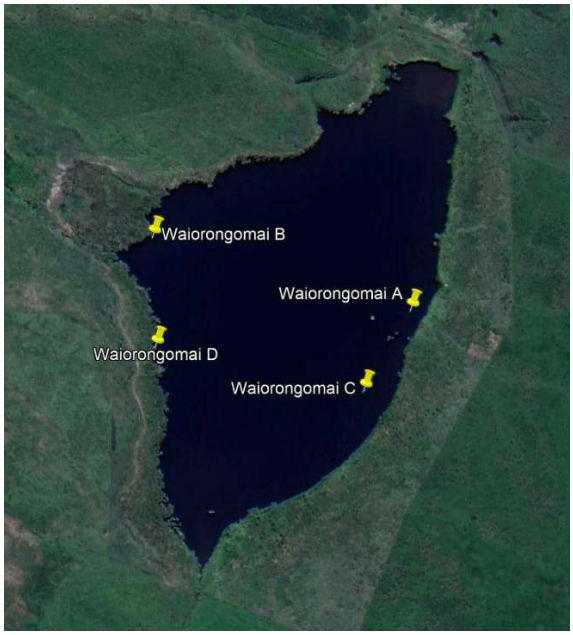
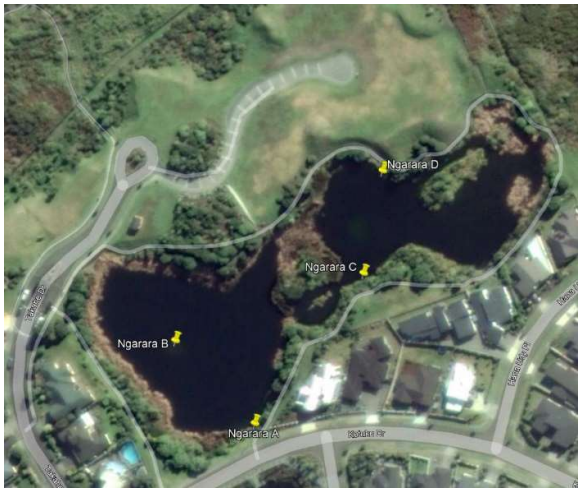
Appendix A Location of LakeSPI sites

Maps and tables show the location of survey sites selected for each waterbody, or approximate reconnoitre tracks for those waterbodies that were not assessed using LakeSPI.

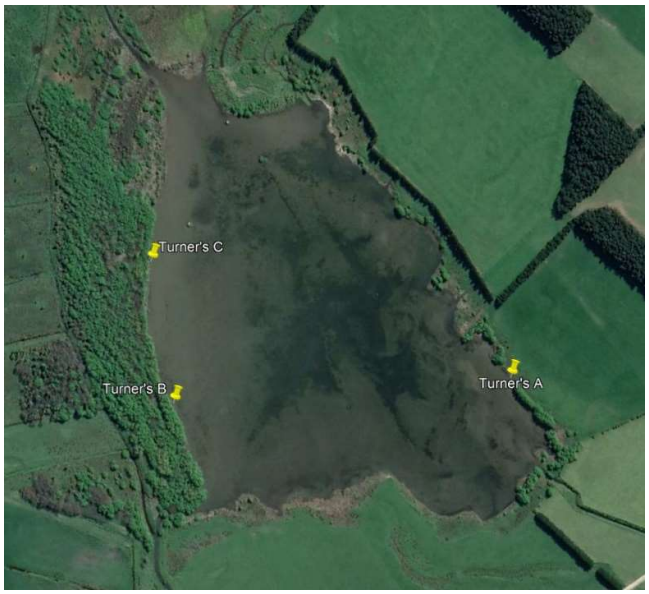
Lake Waiorongomai map	Sites	NZMG (Easting, Northing)
	A	2691127 6052709
	B	2690917 6052774
	C	2691087 6052644
	D	2690917 6052684

Lake Waitawa map	Sites	NZMG (Easting, Northing)
	A	2693509 6051314
	B	2693583 6051236
	C	2693535 6051066
	D	2693388 6051036
	E	2693300 6051150

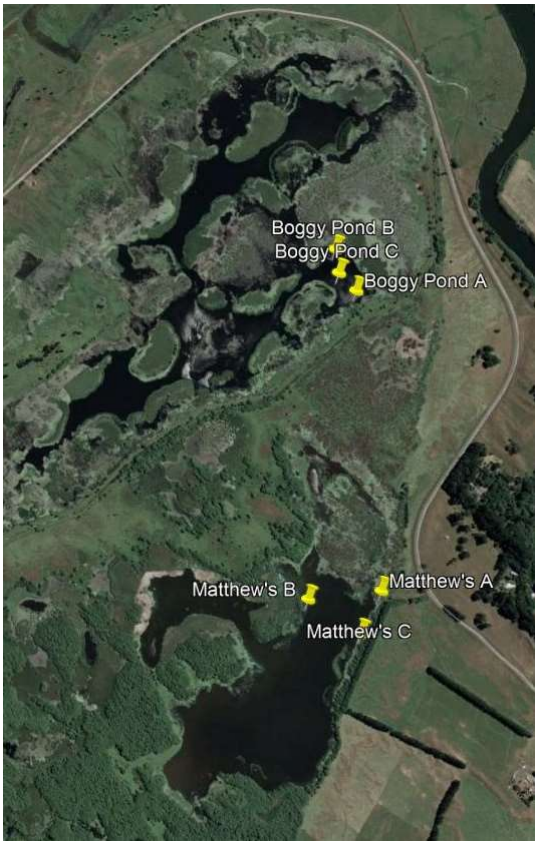
Waimeha and Waimanu Lagoons map (reconnoitre tracks in red)

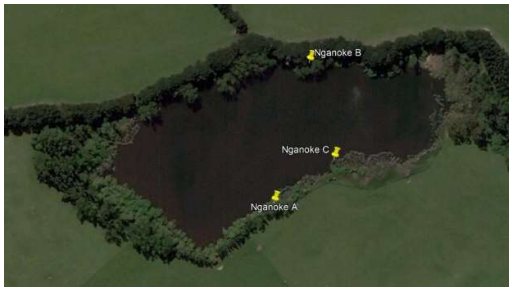

Lake Ngarara map	Sites	NZMG (Easting, Northing)
	A	2678958 6034562
	B	2678922 6034601
	C	2679010 6034630
	D	2679020 6034677

Manly Street Lagoon map (reconnoitre tracks in red)


Turner's Lagoon map	Sites	NZMG (Easting, Northing)
	A	2702160 6003665
	B	2701817 6003648
	C	2701798 6003792

Barton's Lagoon map	Sites	NZMG (Easting, Northing)
	A	2703991 6001788
	B	2704151 6001650

Matthew's Lagoon and Boggy Pond map	Sites	NZMG (Easting, Northing)
	Matthew's	
	A	2700366 5991860
	B	2700149 5991841
	C	2700303 5991737
	Boggy Pond	
	A	2700315 5992748
	B	2700256 5992872
	C	2700265 5992802

Lake Nganoke Map	Sites	NZMG (Easting, Northing)
	A	2692894 5981078
	B	2692935 5981227
	C	2692959 5981123

Lake Pounui Map	Sites	NZMG (Easting, Northing)
	A	2687179 5982378
	B	2686897 5982278
	C	2686380 5982544
	D	2686532 5982753
	E	2686781 5982828

Pounui Lagoon map (reconnoitre tracks in red)


Appendix B Plant species lists

Table 1: Species list for Lake Waiorongomai. Records based on records over 2014-15 (Spinks 2018) and the current survey (synonyms in parenthesis).

Plant community	Species	2014-15	2022
Emergents	*Typha orientalis*	✓	✓
	Schoenoplectus tabernaemontani	✓	
	Isolepis prolifera	✓	✓
Pondweeds	*Potamogeton ochreatus*	✓	✓
	*Stuckenia pectinata**	✓	✓
Charophytes	*Chara* species	✓	
	Nitella species	✓	
Invasive species	*Ceratophyllum demersum*	✓	✓
	Potamogeton crispus	✓	✓
Floating species	*Lemna disperma* (*L. minor*)	✓	✓
	Azolla rubra (*A. filiculoides*)	✓	
Other	*Ruppia polycarpa*	✓	✓
	Nymphaea hardy cultivar	✓	✓

*At Risk – Naturally Uncommon under the New Zealand Threat Classification System (de Lange et al. 2018).

Table 2: Species list for Lake Waitawa. Records based on surveys in 2002 (Dugdale and Champion 2002), 2016 (de Winton et al. 2016) and the current survey (synonyms in parenthesis).

Plant community	Species	2002	2016	2022
Emergents	*Eleocharis sphacelata*	✓		✓
	Typha orientalis	✓	✓	✓
Pondweeds	*Potamogeton ochreatus*	✓		
Charophytes	*Nitella* sp. aff. *cristata*	✓		
Invasive species	*Elodea canadensis*		✓	
	Egeria densa		✓	✓
	Ceratophyllum demersum	✓	✓	✓
	Potamogeton crispus	✓	✓	
Floating species	*Landoltia punctata*			✓
	Azolla rubra (*A. filiculoides*)			✓
Other	*Nymphaea* hardy cultivar			✓

Table 3: Species list for Waimeha Lagoon. Records based on records from the current survey (synonyms in parenthesis).

Plant community	Species	2022
Emergents	*Schoenoplectus tabernaemontani*	✓
	Typha orientalis	✓
Pondweeds	*Potamogeton ochreatus*	✓
	*Stuckenia pectinata**	✓
Invasive species	*Elodea canadensis*	✓
Floating species	*Lemna disperma*	✓
	Landoltia punctata	✓
	Azolla rubra (*A. filiculoides*)	✓
Other	*Ruppia polycarpa*	✓

*At Risk – Naturally Uncommon under the New Zealand Threat Classification System (de Lange et al. 2018).

Table 4: Species list for Waimanu Lagoon. Records based on records from the current survey.

Plant community	Species	2022
Other	*Ruppia polycarpa*	✓
	*Ruppia megacarpa**	✓

*At Risk – Naturally Uncommon under the New Zealand Threat Classification System (de Lange et al. 2018).

Table 5: Species list for Lake Ngarara. Records based on records from the current survey.

Plant community	Species	2022
Emergents	*Typha orientalis*	✓
	Eleocharis acuta	✓
Milfoils	*Myriophyllum propinquum*	✓
Pondweeds	*Potamogeton ochreatus*	✓
	Potamogeton cheesemanii	✓
	*Stuckenia pectinata**	✓
Charophytes	*Chara globularis*	✓
	Nitella hyalina	✓
Invasive species	*Elodea canadensis*	✓
	Potamogeton crispus	✓
Floating species	*Lemna disperma*	✓
	Landoltia punctata	✓
	Azolla pinnata	✓
	Riccia fluitans	✓
Other	*Ruppia polycarpa*	✓
	Persicaria decipiens	✓
	Ludwigia palustris	✓
	Nymphaea cultivar	✓

*At Risk – Naturally Uncommon under the New Zealand Threat Classification System (de Lange et al. 2018).

Table 6: Species list for Manly Street Lagoon. Records based on records from the current survey synonyms in parenthesis).

Plant community	Species	2022
Emergents	*Typha orientalis*	✓
Charophytes	*Chara australis*	✓
Floating species	*Lemna disperma*	✓
	Azolla rubra (*A. filiculoides*)	✓

Table 7: Species list for Turner's Lagoon. Records based on records from the current survey.

Plant community	Species	2022
Turf plants	*Glossostigma elatinoides*	✓
	Ranunculus limosella	✓
Milfoils	*Myriophyllum triphyllum*	✓
Pondweeds	*Potamogeton ochreatus*	✓
	Potamogeton cheesemanii	✓
Charophytes	*Chara australis*	✓
	Nitella sp. aff. *cristata*	✓
Invasive species	*Elodea canadensis*	✓
	Potamogeton crispus	✓
Floating species	*Lemna disperma*	✓
Other	*Ruppia polycarpa*	✓
	*Zannichellia palustris**	✓
	Althenia bilocularis†	✓
Algae	*Hydrodictyon reticulatum*	✓

*At Risk – Naturally Uncommon under the New Zealand Threat Classification System (de Lange et al. 2018).
†Threatened - Nationally Vulnerable under the New Zealand Threat Classification System (de Lange et al. 2018).

Table 8: Species list for Barton's Lagoon. Records based on records from the current survey.

Plant community	Species	2022
Emergents	*Typha orientalis*	✓
Milfoils	*Myriophyllum triphyllum*	✓
	Myriophyllum propinquum	✓
Pondweeds	*Potamogeton ochreatus*	✓
Invasive species	*Ceratophyllum demersum**	✓
	Potamogeton crispus	✓
Floating species	*Riccia fluitans*	✓
Other	*Ruppia polycarpa*	✓
	Zannichellia palustris†	✓
	Persicaria decipiens	✓

* Only seen in lagoon outlet.
†At Risk – Naturally Uncommon under the New Zealand Threat Classification System (de Lange et al. 2018).

Table 9: Species list for Matthew's Lagoon. Records based on records from the current survey (synonyms in parenthesis).

Plant community	Species	2022
Emergents	*Typha orientalis*	✓
Milfoils	*Myriophyllum triphyllum*	✓
Pondweeds	*Potamogeton ochreatus*	✓
Charophytes	*Chara australis*	✓
Invasive species	*Elodea canadensis*	✓
	Ceratophyllum demersum	✓
Floating species	*Lemna disperma*	✓
	Landoltia punctata	✓
	Azolla rubra (*A. filiculoides*)	✓
	*Ricciocarpos natans**	✓
	Wolffia australiana	✓
	Riccia fluitans	✓
Other	*Unidentified bryophytes*	✓

∗ Classified as At Risk, Declining according to the New Zealand Threat Classification (de Lange et al. 2020).

Table 10: Species list for Boggy Pond. Records based on records from the current survey (synonyms in parenthesis).

Plant community	Species	2022
Emergents	*Typha orientalis*	✓
	Bolboschoenus fluviatilis	✓
Milfoils	*Myriophyllum triphyllum*	✓
Pondweeds	*Potamogeton ochreatus*	✓
Charophytes	*Chara australis*	✓
	Nitella sp. aff. *cristata*	✓
Invasive species	*Elodea canadensis*	✓
	Ceratophyllum demersum	✓
	Potamogeton crispus	✓
Floating species	*Landoltia punctata*	✓
	Azolla rubra (*A. filiculoides*)	✓
	*Ricciocarpos natans**	✓

* Classified as At Risk, Declining according to the New Zealand Threat Classification (de Lange et al. 2020).

Table 11: Species list for Lake Nganoke. Records based on records from the current survey (synonyms in parenthesis).

Plant community	Species	2022
Emergents	*Typha orientalis*	✓
Pondweeds	*Potamogeton ochreatus*	✓
Charophytes	*Chara australis*	✓
	Nitella sp. aff. *cristata*	✓
Invasive species	*Potamogeton crispus*	✓
Floating species	*Lemna disperma*	✓
	Azolla rubra (*A. filiculoides*)	✓
	Wolffia australiana	✓
	Persicaria decipiens	✓
	Ludwigia palustris	✓

Table 12: Species list for Lake Pounui. Records based on surveys in 1976 (Persse undated, Jellyman 1990), 2007 (Drake et al. 2010), 2011 (de Winton et al. 2011), 2016 (de Winton et al. 2016), and the current survey (synonyms in parenthesis).

Plant community	Species	1976	2007	2011	2016	2022
Emergents	*Schoenoplectus tabernaemontani* (*S. validus*)			✓	✓	✓
	Typha orientalis	✓	✓	✓	✓	✓
Turf plants	*Crassula sinclairii*			✓		
	Glossostigma elatinoides	✓		✓		
	Glossostigma cleistanthum			✓	✓	
	Glossostigma diandrum (*G. submersum*)	✓				
	Elatine gratioloides			✓		
	Lilaeopsis novae-zelandiae	✓		✓	✓	
	Limosella lineata	✓				
Isoetes	*Isoetes kirkii* ∗	✓	✓	✓	✓	
Milfoils	*Myriophyllum triphyllum* (*M. elatinoides*)	✓	✓	✓	✓	✓
Pondweeds	*Potamogeton ochreatus*			✓	✓	✓
	Potamageton cheesemanii		✓			
Charophytes	*Chara australis* (*C. corallina*)	✓		✓	✓	✓
	Chara fibrosa		✓			
	Nitella sp. aff. *cristata*			✓	✓	✓
	Nitella pseudoflabellata	✓		✓		
	Nitella hookerii (likely *Nitella* sp. aff. *cristata*)		✓			
	Nitella stuartii			✓		
Invasive species	*Elodea canadensis*	✓	✓	✓	✓	✓
	Ranunculus trichophyllus	✓			✓	
	Potamogeton crispus	✓		✓	✓	
Floating species	*Lemna disperma (L. minor)*	✓				
	Azolla rubra (*A. filiculoides*)	✓				

∗ Classified as At Risk, Declining according to the New Zealand Threat Classification (de Lange et al. 2018).

Table 13: Species list for Pounui Lagoon. Records based on records from the current survey.

Plant community	Species	2022
Emergents	*Typha orientalis*	✓
	Isolepis prolifera	✓
Turf plants	*Lilaeopsis novae-zelandiae*	✓
Milfoils	*Myriophyllum triphyllum*	✓
Charophytes	*Nitella hyalina*	✓
Invasive species	*Potamogeton crispus*	✓
Other	*Ruppia polycarpa*	✓
	*Zannichellia palustris**	✓
	Callitriche sp.	

*At Risk – Naturally Uncommon under the New Zealand Threat Classification System (de Lange et al. 2018).