LakeSPI assessment of the Parangarahu Lakes and Lake Pounui

with reference to management of ecological values

Prepared for Greater Wellington Regional Council

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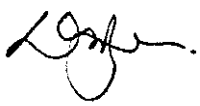

David Roper

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1. Executive summary

Greater Wellington Regional Council (GWRC) contracted NIWA to undertake an ecological assessment of Lakes Kohangatera, Kohangapiriri and Pounui, using LakeSPI (Submerged Plant Indicators). This report presents current LakeSPI scores for these three lakes - based on field assessments undertaken in March 2011 - and estimates scores from historical vegetation data. The diversity and depth extent of native vegetation (Native Condition) and the extent and impact of invasive weeds (Invasive Impact) were measured, and results integrated into an overall LakeSPI Index. Lake scores were expressed as a percentage of expected pristine state (pre-European). Lake ecological condition was compared within a national context, and botanical values identified. Current and potential threats to the ecological condition and botanical values were considered, and recommendations made on management actions.

The current LakeSPI score of 89% for Lake Kohangatera places it 10th best out of 206 assessed New Zealand lakes, and lake condition qualifies as 'Excellent'. Lake Kohangapiripiri scored 63% and Lake Pounui scored 56%, giving them a 'High' lake condition. Historical vegetation data suggests the submerged vegetation has been stable for up to 35 years in Lake Pounui, whilst similar vegetation was recorded from the Parangarahu Lakes in 2004.

A new record for the exotic weed *Elodea canadensis* (elodea) in Lake Kohangatera led to a subsequent weed delimitation survey by NIWA that showed it to be widespread at low abundance. Elodea was common, but not dominant, in Lake Pounui, but not recorded from Lake Kohangapiripiri.

The botanical values in Lake Kohangatera are considered nationally outstanding, with a high diversity and heterogeneity of native submerged vegetation that probably results from spatial gradients of fresh to brackish water in this water body. Elsewhere, intact examples of coastal lagoon vegetation have largely disappeared from New Zealand due to human impacts. Rare and/or endangered plant species were recorded at the Parangarahu Lakes, and Lake Pounui is the only known recent regional record for a native quillwort (*Isoetes kirkii*) that has a diminishing distribution in the North Island.

Biosecurity threats to the ecological condition of the lakes include possible expansion of elodea, and the presence of the exotic weed *Egeria densa* (egeria) in the upper catchment of Lake Kohangatera. The greatest impacts to all lakes would be expected if the exotic weed *Ceratophyllum demersum* (hornwort) were introduced. Human activity, via contaminated boats, nets, fish liberations and intentional plantings are the major pathways for these submerged weeds, which are not transported by biota. The intentional introduction of exotic fish would likewise impact on ecological values of the lakes.

These lakes are not at great risk of nutrient enrichment because of their status (e.g., regional park or QE2 Covenant), but there may be scope for riparian protection in the upper catchment of the Parangarahu Lakes, while fire and erosion remain another risk. The cause of algal blooms over the past two years at Lake Pounui may involve internal nutrient loading and should be investigated further.

As shallow (c.2 m) water bodies, the Parangarahu Lakes would be impacted by large, sustained changes in water level. Currently, the lakes drain rapidly after flooding, and risk of sustained breaching to the sea appears limited by stability of the gravel barrier and underlying bedrock. Saline intrusions are possible, which in coastal water bodies elsewhere have been associated with low lake levels. However, we consider botanical values would recover rapidly from temporary increases in salinity. We also note that Lake Kohangatera had plant records indicative of higher salinity levels in the past.

Based on findings and available information of the ecological values and condition of these lakes our recommendations for management, monitoring and research include:

- Seeking additional status for the Parangarahu Lakes (e.g., RAMSAR designation, Waters of National Importance), towards more appropriate recognition or protection of the outstanding ecological values.
- A delimitation survey for egeria in the upper catchment of Lake Kohangatera to inform management. Actions should also be taken (e.g., lake user awareness) towards the containment of elodea.
- Experimental determination of elodea and egeria growth performance under the salinity and sediment range typical of Lake Kohangatera would provide more guidance on their likely future impacts, and inform management options.
- Control, or preferably exclusion, of vehicular and/or boat access to the lakes, as the most effective proactive biosecurity action to remove the highest risk pathway for new invasive weeds or fish to enter the lakes. Access should be controlled, and discretionary, with all reasonable steps taken to remove weed threats (i.e., use of Check, Clean, Dry principles). Adjacent land owners should also be made aware of the risk that weed contaminated drainage clearing equipment poses in the upper catchment of lakes.
- LakeSPI monitoring and a re-assessment of weed extent and impacts should be repeated in Lake Kohangatera in two years time as part of a recommended reassessment of the impact of elodea and egeria. Lakes Pounui and Kohangapiripiri can be re-considered in five years time, unless the lakes show signs of change.
- Access and biosecurity issues should be discussed with the land owner at Lake Pounui, and if possible, responsibilities or best practices agreed over the use of the lake.
- Work with land owners of the upper Gollans Stream and Cameron Creek to retire and plant riparian edges along agricultural land, if this has not already been done.
- Any planned modifications to the Pounui stream outlet should be cognisant of retaining restrictions for exotic fish on access from downstream waterways.
- Locate/position tracks or other development where run-off will not channelize to the lakes. Consider contingencies for fire management (e.g., monitoring, fire breaks).

2. Introduction

Greater Wellington Regional Council (GWRC) are responsible for regulating the use of the Wellington Region's natural resources, and the council undertake monitoring as the basis of reporting on the state of the environment (SOE) every six years (Greater Wellington Regional Council 2005). Currently, water level and water quality monitoring are undertaken for several lakes in the region, but Greater Wellington also wanted to consider the feasibility of direct ecological assessment for selected lakes. Prioritised for special consideration were regional water bodies with likely high ecological value, the Parangarahu Lakes (Kohangatera and Kohangapiriri) and Lake Pounui.

One method to assess lake ecological condition is LakeSPI (Submerged Plant Indicators), which characterises lakes by the composition of native and invasive plants and the depth to which they grow. Three scores are generated, based on the development, quality and intactness of the native submerged vegetation (Native Condition Index), the level of impact by any weed species that may be present (Invasive Impact Index), while a LakeSPI Index combines elements of these into an overall score. LakeSPI was designed to:

- Monitor trends for a lake or selected group of lakes over time.
- Rank lakes in a region based on ecological condition, and thereby help to prioritise those most in need of protection, surveillance or management.
- Compare current lake condition with LakeSPI indices generated from historical vegetation records (where available).
- Assess and compare the ecological condition of different lakes within or between the regions.
- Help assess the effectiveness of catchment and lake management initiatives.
- Provide relevant information for regional and national reporting requirements, including operational monitoring and SOE reporting.

LakeSPI has been implemented by seven Regional Councils and by the Department of Conservation, and has been favourably reviewed (Hamill 2006).

This report presents the current LakeSPI status for Lakes Kohangatera, Kohangapiriri and Pounui, and describes the vegetation features that contribute to these scores. The report also briefly reviews historical information on lake vegetation, and interprets data from LakeSPI scores to provide longer-term trends in ecological condition.

The ecological values of the lakes and current and future possible threats to these values are considered and management issues identified. Finally this report presents recommendations for future management of the lakes (e.g., LakeSPI monitoring frequency).

3. Methods

The LakeSPI method (Clayton and Edwards 2006) was applied at five representative sites in each lake (Figure 1, Figure 2, Figure 3) over the 16th to 17th March 2011. Where possible, site selection aligned with previous vegetation survey sites according to Wells & Champion (2004) for Lakes Kohangatera and Kohangapiriri, and Persse (undated) and Jellyman (1990) for Lake Pounui. Site locations were recorded by GPS (Appendix 1) and mapped for future reference.

At each site scuba divers scored 11 metrics over a 2 m wide transect from shore to the deepest vegetation limit. Metrics included measures of diversity from the presence of key plant communities, the depth of vegetation growth, and the extent that invasive weeds are represented. A complete description of measured characters is given in the technical report at http://lakespi.niwa.co.nz/. An inventory of all plant species encountered was also made (Appendix 2-4) and voucher specimens were made.

Results were entered to NIWA's LakeSPI database for generation of three indices. The Native Condition Index measures the diversity and extent of native vegetation, the Invasive Impact Index measures invasive weed extent, and these are integrated within an overall LakeSPI Index. Indices are expressed as a percentage of expected pre-European (pristine) state. LakeSPI Index scores place lakes into one of five narrative classes of lake condition, either as Non-vegetated (0%), Poor (>0-20%), Moderate (>20- 50%), High (>50-75%) and Excellent (>75%).

Current and future possible threats to the ecological values of the lakes are considered. Lake management issues relevant to the development of specific lake management plans are identified as far as possible based on the experience and opinion of the surveying staff and available information.

Previous accounts of submerged vegetation of the lakes were examined (where available) to gauge if changes in vegetation character or ecological condition had occurred, and to estimate historical LakeSPI scores for comparison to current condition.

Figure 1: Location of 5 survey sites in Lake Pounui.

Figure 2: Location of 5 survey sites in Lake Kohangapiripiri.

Figure 3: Location of 5 survey sites in Lake Kohangatera.

4. Results

4.1 Lake Pounui

Lake condition:	High
Stability:	Stable
Lake depth:	9.8

Currently, a LakeSPI Index score of 56% (Table 1) places Lake Pounui in the 'High' category for ecological condition. This lake had relatively diverse native vegetation that extended to moderate depths of 4.5 to 4.9 m, resulting in a Native Condition Index of 65%, whilst the impact of two invasive weed species contributed to an Invasive Impact Index of 44%.

Table 1: LakeSPI results for Lake Pounui from a survey in 2011, and estimated values from a vegetation description made in 1976 (Persse undated, Jellyman 1990). ..

Date	LakeSPI Index	Native Condition Index	Invasive Impact Index
1976	52	64	52
2011	56	65	44

All six key native community types recognised by LakeSPI were represented within the lake (Appendix 2). Beds of emergents dominated by *Schoenoplectus tabernaemontanii* and *Typha orientalis*, were present along the sheltered (north and western) shorelines. At other more exposed shores these emergent beds were replaced by shallow turfs dominated by *Glossostigma cleistanthum*, *Lilaeopsis novae-zelandiae, Elatine gratioloides* and *Crassula sinclairii*. *Isoetes kirkii* contributed to this shallow community but did not form the high-cover swards seen in some North Island lakes such as Lake Taupo. The native pondweed, *Potamogeton ochreatus*, dominated the mid-depth zone (Figure 4) between 1 and 3.5 m depth. Native milfoil, *Myriophyllum triphyllum*, formed a narrow bed on the inshore margin of the pondweed bed, with scattered plants growing deeper. High cover (>75%) charophyte meadows of *Nitella* aff. sp. *cristata* occurred between 3 and 4.9 m depth. Isolated shoots of native pondweed were present to a maximum depth of 5.6 m.

Two invasive weeds were recorded but had a relatively limited impact on the composition and structure of the native vegetation. *Potamogeton crispus* occurred as scattered plants through the native pondweed beds, while elodea, *Elodea canadensis* (Figure 4), also formed as clumps or discontinuous beds.

Shallow depressions in the sediment beyond the main band of vegetation and rolls of dislodged vegetation in deeper water were suggestive of biotic disturbance by fish, while grazing of elodea shoot tips typical of swan grazing was also evident.

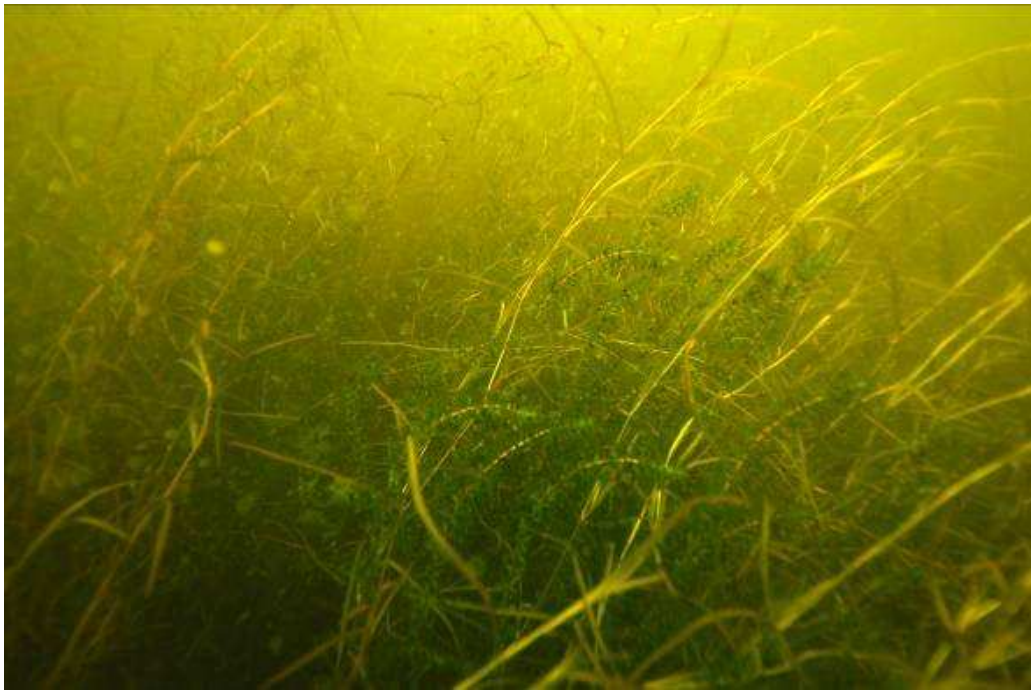

Figure 4: A mid-depth (c. 3 m) bed of taller native pondweed, with scattered shoots of dark green elodea shoots.

The description from 1976 (Persse undated, Jellyman 1990) closely resembled current vegetation composition (Appendix 2). However, it appeared elodea beds were previously more widespread, and an additional invasive species, *Ranunculus trichophyllus* (water buttercup) was recorded, contributing to a slightly higher Invasive Impact Index and lower LakeSPI Index estimated for 1976 (Table 1). Another apparent change is the switch in charophyte dominance, with *Chara australis* dominant in 1976, and the first record of *Potamogeton ochreatus* in 2011, when it was dominant. A macrophyte survey of three sites in 2007 used an underwater viewer and/or grab samples at 5 m intervals (Drake et. al. 2010), which recorded most of the common species found in 2011. However, their records for *Potamogeton cheesemanii*, *Chara fibrosa* and *Nitella hookerii* were not confirmed by the 2011 survey. Because of the methodology employed, we could not generate LakeSPI results from the data collected in 2007.

4.2 Lake Kohangapiripiri

Lake condition:	High
Stability:	Stable
Lake depth:	1.5

A LakeSPI Index of 63% places the lake in the ‘High’ category for ecological condition (Table 2). Diverse native vegetation extended across most of the lake bed and scored a Native

Condition Index of 73%. Only localized beds of a relatively benign invasive weed were encountered, resulting in an Invasive Impact Index of 38%.

Table 2: LakeSPI results for Lake Kohangapiripiri from surveys in 2004 (Wells and Champion 2004) and 2011.

Date	LakeSPI Index	Native Condition Index	Invasive Impact Index
2004	63	70	39
2011	63	73	38

All plant community types recognised by LakeSPI were present (Appendix 3). Beds of the emergent *Schoenopletus tabernaemontanii* were widespread around the lake, with turf species, mainly *Glossostigma cleistanthum*, *Lilaeopsis novae-zelandiae and Elatine gratioloides,* present at the open shorelines. Native milfoil (*Myriophyllum triphyllum*) and pondweed (*Potamogeton ochreatus*) dominated the vegetation across the lake bed, with smaller patches of the charophyte, *Chara australis*. Less commonly encountered were *Ruppia polycarpa* and *Zannichellia palustris*, which tend to indicate brackish water conditions. Areas of low vegetation cover were observed, where plants seemed to have been removed by swan grazing or possibly another disturbance (Figure 5) whilst other areas of similar depth supported high plant covers (Figure 6).

The only invasive species encountered was *Ranunculus trichophyllus*, which formed a narrow bed of high cover in 0.8 to 1.1 m depth of water adjacent to the edge of the emergents.

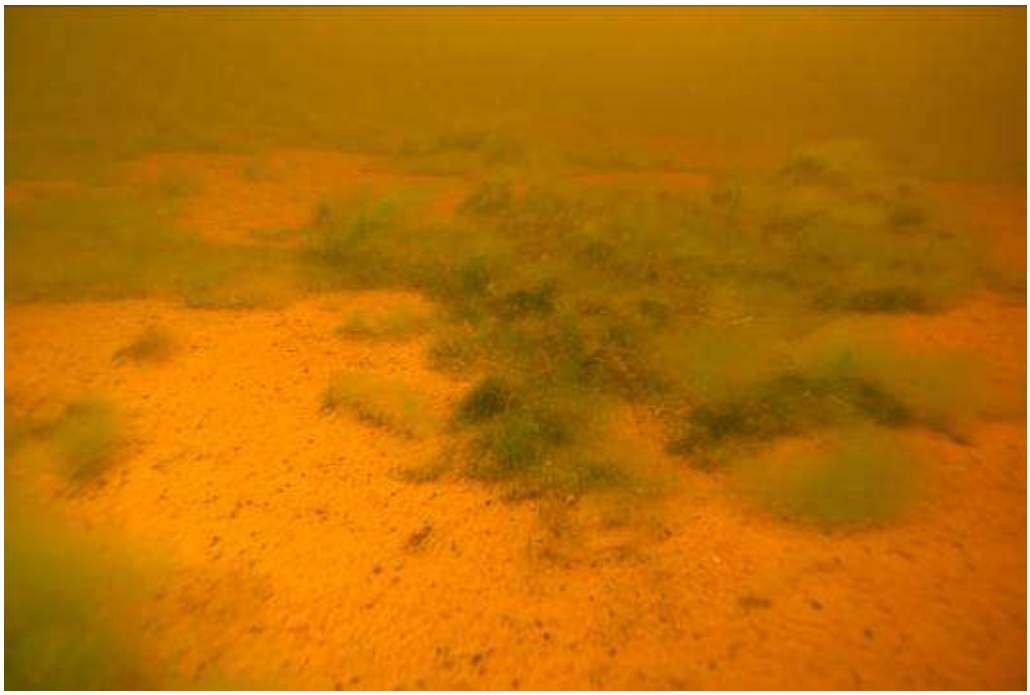

Figure 5: Area of low vegetation where plants seemed to have been disturbed and filamentous algal growths comprised the predominant cover.

Figure 6: High cover bed of mixed native pondweed and milfoil, with a central patch of filamentous alga.

A survey undertaken by NIWA in 2004 (Wells and Champion 2004) indicated a very similar vegetation composition (Appendix 3) and almost identical LakeSPI scores (Table 2). Earlier species records (Mason 1950) also showed a mixture of submerged plants typical of freshwater and brackish water conditions (Appendix 3), although the record for *Lamprothamnium macropogon* suggests conditions have been more saline in the past at least in some areas of the lake.

4.3 Lake Kohangatera

Lake condition:	Excellent
Stability:	Stable
Lake depth:	2.3

Currently the lake has an 'Excellent' ecological condition, with a LakeSPI index of 89% (Table 3). A Native Condition Index of 83% reflected the vegetation diversity at all sites, which extended across the entire lake bed. A low cover patch of the invasive weed *Elodea canadensis* at a survey site was responsible for the minimal invasive impact score of 5%.

Table 3: LakeSPI results for Lake Kohangatera from surveys in 2004 (Wells and Champion 2004) and 2011.

Date	LakeSPI Index	Native Condition Index	Invasive Impact Index
2004	72	70	23
2011	89	83	5

All major plant communities recognised by LakeSPI were present (Appendix 4). Emergent beds of *Schoenoplectus tabernaemontanii, Typha orientalis* and salt tolerant *Apodasmia similis* and *Juncus kraussii* were common around the lake, with turf species, *Glossostigma cleistanthum* and *Lilaeopsis novae-zelandiae* on open, exposed shorelines. Native milfoil, *Myriophyllum triphyllum* (Figure 7), and pondweed, *Potamogeton ochreatus* were widespread but more abundant at the northern survey sites. Four species of charophytes were recorded but did not form high cover meadows. A number of plant species indicative of brackish water, *Lepilaena bilocularis*, *Ruppia polycarpa*, *Zannichellia palustris* and *Stuckenia pectinata* (Figure 8) also contributed to a heterogeneous mosaic of diverse submerged vegetation. Interestingly, inviable seed of *Ruppia megacarpa* were observed entangled in the root systems of sampled plants, suggesting this brackish water species has been a component of the vegetation in the past.

The exotic weed elodea was recorded at one site only (Site B) forming low covers (≤5%) in water depths of 1.4 to 1.6 m depth at the north-west shoreline (Figure 3). A subsequent delimitation survey of the elodea (Wells et al. 2011) showed it was widely distributed along the northern and western shoreline as low cover patches typical of Site B.

The survey by NIWA in 2004 (Wells and Champion 2004) recorded most of the dominant species observed in 2011, although charophytes and elodea were not recorded (Appendix 4) and areas of the lake that were deeper than 2 m were devoid of vegetation. Also, two invasive weeds, *Ranunculus trichophyllus* and *Potamogeton crispus* were present at some sites but not seen in this lake in the current survey. These differences lead to a lower ecological condition being calculated for 2004 (Table 3).

In 1950 a number of the common plant species in NIWA's surveys were recorded by Moar (1950) for Lake Kohangatera and the Gollans Stream Wetland (Appendix 4). Present at this time was *Lamprothamnium macropogon*, a charophyte species that generally requires some degree of salinity.

Figure 7: A mixed vegetation of milfoil and *Ruppia polycarpa* at a depth of about 1.8 m.

Figure 8: *Stuckenia pectinata* and flowering *Ruppia polycarpa* at the southern end of the lake.

5. Discussion

5.1 LakeSPI comparison to lakes nationally

Lake Kohangatera falls within the 'Excellent' grouping for lake condition and is one of 32 lakes in this category at present, out of a total of 206 New Zealand lakes assessed (Figure 9), being ranked 10th best nationally. Lakes Kohangapiripiri and Pounui fall within the 'High' grouping (41 lakes nationally) for lake condition and lie at 47th and 66th national ranking respectively (Figure 9). No other LakeSPI results for Wellington lakes are available for a regional comparison.

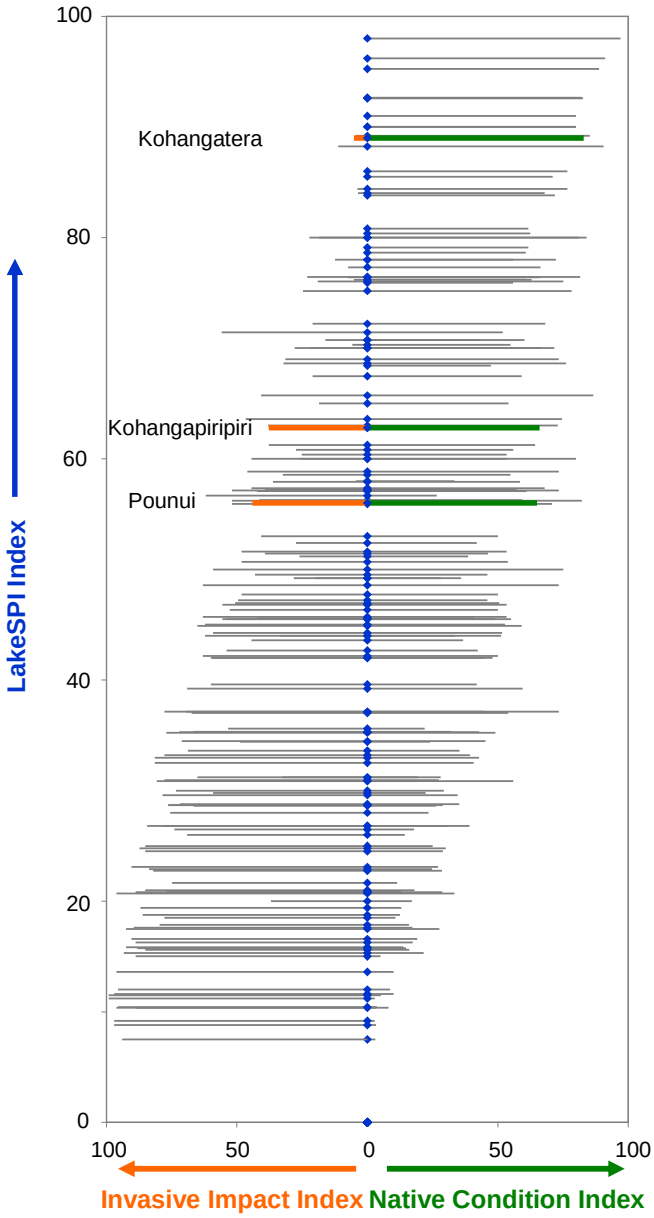

Figure 9: Current LakeSPI scores for 206 New Zealand lakes as LakeSPI index (blue dots) Native Condition Index (right hand bars), and Invasive Impact Index (left).

5.2 Botanical values

The Parangarahu Lakes recorded several plant species (Appendix 3 and 4) that are considered naturally uncommon or that have an endangered status (de Lange et al. 2009). *Ranunculus limosella* and the marginal turf plant *Eryngium vesiculosum* are considered as 'in decline', whilst the turf plants *Crassula kirkii* and *Centipeda aotearoana* and the submerged macrophytes *Lepilaena bilocularis* and *Stuckenia pectinata* are all recognised as naturally uncommon, the latter two species largely confined to brackish water bodies.

The particularly high diversity and heterogeneity of vegetation in Lake Kohangatera may relate to an apparent gradient from freshwater inflows at the northern end of the lake, to more saline conditions at the southern shore. For example, in summer 2006 salinity (measured as conductivity) steadily declined with distance north from 78.8 mS/m at the beach outlet, to 65.4 mS/m at 60 metres from the northern shore, and down to 36.8 mS/m at the shore (Nicholson 2008). The development of brackish water species in Lake Kohangatera was in keeping with a higher electrical conductivity (96 mS/m) than in Lake Kohangapiripiri (58 mS/m) on the day of survey (GWRC data). Components of the marginal vegetation of Lake Kohangatera were also typical of salt marsh including *Plagianthus divaricatus, Juncus kraussii, Selliera radicans* and *Samolus repens*.

Equivalent brackish water vegetation of coastal lagoons has become increasingly rare following widespread impacts on shallow lowland lakes from land use intensification. Examples of water bodies that have lost submerged vegetation that resembled the Parangarahu Lakes include Lakes Ellesmere and Forsyth (Canterbury), Wainono lagoon (Canterbury), and Lake Onoke (Wellington). Remaining lagoon vegetation examples include Waitahora Lagoon (Northland), Whakaki Lagoon (Gisborne), Coopers Lagoon (Canterbury), several Chatham Island lakes and Waituna Lagoon (Southland).

The current botanical features are in keeping with the high value ratings of previous assessments based on vegetation and other biotic character (Gibbs 2002). We conclude that the Parangarahu Lakes are nationally outstanding examples of lowland lagoon systems.

Whilst no rare and endangered species were sampled from Lake Pounui, *Isoetes kirkii* is currently unknown from other water bodies within the Wellington Region, although historical records exist from Lake Wairarapa. Elsewhere within the North Island the distribution and abundance of this native 'quillwort' is declining, with extant populations known from lakes of the Central Volcanic Plateau and Lake Waikaremoana.

5.3 Additional ecological values

All three lakes are recognised as having significant indigenous ecosystems in the proposed Regional Policy Statement' (GWRC PRPS May 2011), specifically the presence of threatened indigenous fish and diversity of migratory indigenous fish.

According to the Freshwater Environments of New Zealand (FENZ 2010) categories of 3594 lakes, all three lakes are 'warm, shallow, moderately sized' water bodies. FENZ takes into account the representativeness of freshwater systems and degree of human pressures to rank water bodies for conservation within biogeographic units (not equivalent to territorial units). The Parangarahu Lakes were ranked highly (in top 5) out of lakes and wetlands within their biogeographic unit. Lake Pounui ranked 167, with a ranking of 5 for the associated wetlands.

5.4 Threats

5.4.1 Current biosecurity issues

The observation of elodea represents the first record for Lake Kohangatera. A subsequent delimitation survey in April 2011 (Wells et al. 2011) has shown elodea to be distributed along the northern and western shorelines of the lake, which were not surveyed in 2004. Therefore we cannot rule out its presence earlier than 2004. Elodea was also present in the Gollans Stream and in all the open water areas of the Gollans Stream Wetland in April 2011 (Wells 2011), suggesting it has been present in the system for some time.

Elodea is a successful coloniser in disturbed environments and is capable of forming dense, monospecific beds in shallow water bodies. However, under some circumstances it co-exists with native vegetation by forming sparse or open-canopy beds. For example, in Lake Pounui elodea has not dominated the submerged vegetation despite its presence for over 35 years. Elsewhere, in North Island tidal rivers such as the Kaituna and Pongakawa systems, elodea does not extend far into saline-influenced waters. Elodea may not perform well under the moderately saline conditions in Lake Kohangatera, but this can only be established by longer term monitoring.

During the April 2011 delimitation survey, the weed *Egeria densa*, was found to be established in the uppermost of three open water ponds in the Gollans Stream Wetland, however it was not detected in the other ponds, nor in the lake (Wells 2011). It is not known if egeria is restricted within the emergent-fringed pool, or whether fragments have already entered the lake. Elsewhere in the Wellington Region, egeria is known mainly from the Kapiti Coast District, including Lake Waitawa, with records also from the South Wairarapa District, Hutt City and Wellington City.

Egeria proves most competitive in shallow nutrient enriched lakes with poor water clarity, where it is capable of forming 4 to 5 m tall and surface reaching weed beds. Like elodea, there are questions over its performance within a saline-influenced lake like Kohangatera.

More benign weeds *Potamogeton crispus* and *Ranunculus trichophyllus* have been recorded from the Parangarahu Lakes for over 10 years (Gibbs 2002) and Lake Pounui for over 35 years, without a substantial impact on vegetation composition. As their seed is spread by waterfowl, there is little scope for management of either of these species.

5.4.2 Future biosecurity threats

Sources of other highly invasive water weeds exist within the region (de Winton et al. 2009), with hornwort (*Ceratophyllum demersum*) presenting the greatest threat to the botanical values of the all three lakes. Hornwort is already widespread in the South Wairarapa District, including Lake Wairarapa complex, lagoons, streams and drains. It is also common in the Kapiti Coast District, such as at Lake Waitawa, with fewer records from Carterton District, Masterton District, and Porirua, Upper Hutt and Wellington Cities.

Not only is hornwort considered the most highly invasive submerged weed in the region, it is also the species most tolerant of salinity based on observations in tidal rivers. Therefore, if introduced to Lake Kohangatera, we would expect it to colonise more widely than elodea or egeria. If introduced to a lake such as Pounui, hornwort would be capable of replacing the

majority of the vegetation and, being a non-rooted plant, could also produce considerable amounts of nuisance drift on the shores.

Lagarosiphon major is well known from the Kapiti Coast District and South Wairarapa District, including the Lake Wairarapa complex. Lagarosiphon is also recorded from Carterton District, Masterton District and Hutt (e.g., Waiwhetu stream), Upper Hutt and Wellington Cities.

These highly invasive weeds, like elodea and egeria, require the transfer of small fragments, as little as a few cm in length and bearing a viable bud, in order to develop colonies in new water bodies. Elodea, egeria, hornwort and lagarosiphon do not produce seed, so their transfer between catchments is only mediated by human activities, via contaminated boats and equipment (e.g. fishing nets), intentional plantings, or release of fish (de Winton et al. 2009), with no evidence for transfers via biota (e.g., swans). Intentional, but misguided, plantings of weeds such as crack willow (*Salix fragilis*) and alligator weed (*Alternanthera philoxeroides*) have elsewhere been associated with attempts to enhance habitat for water fowl in the vicinity of shooting hides or mai-mai.

Another biosecurity risk to the lakes is exotic fish. All three lakes have native fish values (Gibbs 2002, McEwan 2010), which are important to preserve. Brown trout (*Salmo trutta*) and perch (*Perca fluviatilis*) have been present in Lake Pounui since at least 1977 (McEwan 2010), and are known to impact as predators of native fish species (Wilding and Rowe 2008). Brown trout have also been recorded from the catchment of Lake Kohangatera (Gibbs 2002, Nicholson 2008). Other exotic or 'coarse' fish species represent a substantial risk to vegetation values (Dugdale et al. 2006, de Winton et al. 2003) and water quality (Rowe 2007).

5.4.3 Water quality impacts

The status of the lakes, with the Parangarahu Lakes being within a Regional Park and Lake Pounui within a QEII National Trust covenanted area, removes much of the risk of increased nutrient loading from the catchment, although the possibility of bush fire and subsequent erosion remains. Intensification of agriculture on private land in the upstream catchment of the Parangarahu Lakes is possible, but there is substantial filtering capacity provided by the Gollans Stream and Cameron Creek wetlands that would provide some protection to the lakes.

We note that Lake Pounui has experienced prolonged algal blooms that suggest scope for internal nutrient generation, such as during periods of thermal stratification and de-oxygenation of bottom waters. Alternatively, trophic interactions by the perch populations in Lake Pounui could promote phytoplankton biomass, as has been suggested for the Lower Karori Reservoir (Smith and Lester 2007).

Freshwater mussels (*Echyridella menziesi*) were abundant in the Parangarahu lakes, and common in Lake Pounui. These filter feeders are capable of removing suspended material from the water column, and at high abundance (e.g., 6 m^{-2}) in shallow lakes (c. 2 m or less) are estimated as able to suppress phytoplankton abundance (James et al. 1998).

5.4.4 Water level impacts

The Parangarahu Lakes are shallow lakes (c. 2 m depth) and their ecology would be particularly impacted by extended periods of extreme high or low water level, although a degree of water level variability would contribute to vegetation diversity. GWRC water level data since August 2007 (http://www.gw.govt.nz/Pencarrow-lakes/) show Lake Kohangapiripiri had about a 1.5 m range, with 1.2 m for Lake Kohangatera. Transient high lake levels contributed much of the range observed, but past droughts have been known to expose areas of shallow lake bed in Lake Kohangapiripiri (Gibbs 2002).

Lake Kohangapiripiri appears to drain to the sea via seepage through the wide gravel barrier, with the outlet rarely opening to sea (Gibbs 2002). Prior to 2004, Lake Kohangatera drained in a similar way, but it was known to breach to the sea (Gibbs 2002) with a frequency of up to 10 years (Owen Spearpoint, GWRC, pers. comm., 2011). In 2004, however, a major flood damaged the road and scoured the barrier, with the lake now breaching regularly after heavy rain (Owen Spearpoint, GWRC, pers. comm., 2011). These differences account for the slow ramping down of high levels in Lake Kohangapiripiri, compared to more abrupt reductions in Lake Kohangatera (http://www.gw.govt.nz/Pencarrow-lakes/). Regular lake breaching to the sea were seen as necessary for the maintenance of a diverse native fish community in Lake Kohangatera (Nicholson 2008).

Scope for scour of outflow levels and risk of severe drainage of the lakes would depend on the stability of the gravel barrier and depth to bedrock in the vicinity of the outflows. The coastal road and associated culverts were developed in the 1960s (Gibbs 2002), and their influence on the opening regime of the lakes is unknown. Likewise, the impact of sand quarrying in eastern Fitzroy Bay on the gravel barriers and the opening regimes is not known.

5.4.5 Saline intrusions

Intermittent saline intrusions are a common feature of many coastal lakes and wetlands, including the Waipori/Waihola Lake complex, and Waituna Lagoon, and are often associated with breached coastal barriers. Other inputs of marine water to coastal lagoons can be via storm surge or tidal waves overtopping barriers. Rising sea levels may increase the frequency of these events.

Vegetation values in the Parangarahu Lakes would be capable of recovering from periods of higher salinity via seed banks and colonisation from the upper freshwater catchment. There is evidence that more saline vegetation existed in the past, as indicated by past records of a brackish water charophyte species and discovery of inviable seed of *Ruppia megacarpa* in Lake Kohangatera.

5.4.6 Biological disturbances

Black swan (*Cygnus atratus*) grazing is believed responsible for the areas of low plant cover observed in Lake Kohangapiripiri. Vegetation would be more susceptible to swan grazing at times of lower water levels, or on unconsolidated sediments that permits entire uprooting of plants. However, rapid vegetation recovery is likely as the shallow lagoon provides good

conditions for plant growth; therefore we do not see swan browsing as a significant threat to lake ecological values.

6. Recommendations

6.1 Ecological status

- The Parangarahu Lakes are nationally significant as examples of lowland lagoon systems that are remain in a high to excellent ecological condition, where other similar systems are mostly highly de-graded. The possibility of seeking additional status for the lakes, towards more appropriate recognition or protection of ecological values, could be explored (e.g., RAMSAR designation, Waters of National Importance).

6.2 Biosecurity

- As recommended by Wells et al. (2011), a delimitation survey for egeria should be conducted in the upper catchment of Lake Kohangatera, checking areas of available habitat upstream of the current infestation and including tributaries and any ponds within the adjacent flood zone. Identification of further management options is dependent on the current status of this weed.
- Wells et al. (2011) recognise the containment of elodea within Lake Kohangatera is important, so lake users and activities should aim not to disturb or spread the weed. A major consideration is preventing transport and introduction to Lake Kohangapiripiri.
- The extent and performance of elodea and egeria in Lake Kohangatera should be monitored after two years (Wells et al. 2011).
- Control, or preferably exclusion, of vehicular and/or boat access to the lakes is the most effective proactive biosecurity action, as this is the highest risk pathway for new invasive weeds or fish to enter the lakes. Locked gates or the requirement for landowner permission should be continued. Activities requiring entry to the lakes or the introduction of equipment should be discretionary, and require evidence that all reasonable steps have been taken to remove weed threats (i.e., use of Check, Clean, Dry principles). Adjacent land owners should also be made aware of the risk that weed contaminated drainage clearing equipment poses in the upper catchment of lakes.
- Signage that informs the general public of the status of the Parangarahu Lakes and the risks to their values, especially biosecurity threats, should be considered. However, we emphasise that signage alone does not prevent incursions, and should be undertaken with other initiatives to modify or remove high risk activities. User groups should be kept well informed of the risks by additional means (e.g., talks, flyers).
- Discuss access and biosecurity issues with the land owner at Lake Pounui, and if possible, agree on some responsibilities or best practice standards over use of the lake.
- Any planned modifications to the Pounui stream outlet should be cognisant of retaining restrictions for exotic fish on access from downstream waterways.

6.3 Water quality impacts

- Locate/position tracks or other development where run-off will not channelize to the lakes. Consider contingencies for fire management (e.g., fire breaks).

- Work with land owners of the upper Gollans Stream and Cameron Creek to retire and plant riparian edges along agricultural land, if this has not already been done.

6.4 Monitoring and research

- The frequency of LakeSPI monitoring for stable lakes is suggested at 5 years or more, with the interval decreased to 2-yearly if lakes show signs of change, such as new weed incursions or spread. We therefore recommend Lake Kohangatera is resurveyed in two years time to determine any changes in the impact of elodea, or possibly egeria. A repeat survey of submerged vegetation adjacent to emergent beds (as undertaken in Wells et al. 2011) is also recommended to determine any change in distribution of invasive weeds. Surveying of Lakes Pounui and Kohangapiripiri can be re-considered in five years time.
- Experimental determination of elodea and egeria growth performance under the salinity and sediment range typical of Lake Kohangatera would provide more guidance on their future impacts (Wells et al. 2011).
- Algal blooms at Lake Pounui are unexpected given the protected catchment, and the cause of these (e.g., internal nutrient generation) may need to be investigated further.

7. Acknowledgements

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Appendix 1. GPS positions (New Zealand Map Grid) for the survey sites in 2011.

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

Lake Kohangapiripiri	NZMG (Easting, Northing)
A	2665574 5981389
B	2665439 5981469
C	2665307 5981245
D	2665474 5981290
E	2665333 5980923

Lake Kohangatera	NZMG (Easting, Northing)
A	2666187 5980630
B	2666009 5980606
C	2666068 5980198
D	2666261 5980117
E	2666160 5980030

Appendix 2. Species list for Lake Pounui based on surveys in 1976 (Persse undated, Jellyman 1990), 2007 (Drake et al. 2010), and the current survey (synonyms in parenthesis).

LakeSPI plant community	Species	Taxonomic Authority	1976	2007	2011
Emergents	*Schoenoplectus tabernaemontani* (*S. validus*)	(Gmel.) Palla			✓
	Typha orientalis	C.B. Presl.	✓	✓	✓
Turf plants	*Crassula sinclairii*	(Hook. f.) A.P. Druce & D.R.			✓
	Glossostigma elatinoides	Benth.	✓		✓
	Glossostigma cleistanthum	W.R. Barker			✓
	Glossostigma submersum (*G. diandrum*)	Petrie	✓		
	Elatine gratioloides	Cunn.			✓
	Lilaeopsis novae-zelandiae	(Gand.) A.W. Hill	✓		✓
	Limosella lineata	R. Br.	✓		
Isoetes	*Isoetes kirkii*	A. Braun	✓	✓	✓
Milfoils	*Myriophyllum triphyllum* (*M. elatinoides*)	Orchard	✓	✓	✓
Pondweeds	*Potamogeton ochreatus*	Raoul			✓
	Potamageton cheesemanii			✓	
Charophytes	*Chara australis* (*C. corallina*)	Brown	✓		✓
	Chara fibrosa	Ag. ex Bruz., em. R.D.W.		✓	
	Nitella sp. aff. *cristata*				✓
	Nitella pseudoflabellata	A. Br.	✓		✓
	Nitella hookerii	A. Br.		✓	
	Nitella stuartii	A. Br.			✓
	Nitella hyalina	(DC.) Ag.			
Invasive species	*Elodea canadensis*	Michaux	✓	✓	✓
	Ranunculus trichophyllus	Chaix	✓		
	Potamogeton crispus	L.	✓		✓
Other species	*Lemna minor*	L.	✓		
	Azolla filiculoides (*A. rubra*)	Lam.	✓		

Appendix 3. Species list for Lake Kohangapiripiri based on surveys in 1950, 2004 (Wells and Champion 2004) and the current survey (synonyms in parenthesis).

LakeSPI plant community	Species	Taxonomic Authority	1950	2004	2011
Emergents	*Apodasmia similis* (*Leptocarpus similis*)	(Edgar) B.G. Briggs & L.A.S.			✓
	Schoenoplectus tabernaemontani (*S. validus, Scirpus lacustris*)	(Gmel.) Palla	✓	✓	✓
	Typha orientalis (*T. angustifolia*)	C.B. Presl.	✓		✓
	Eleocharis acuta	R. Br.			✓
Turf plants	*Crassula kirkii*†	(Allan) A.P. Druce et Given		✓	✓
	Elatine gratioloides	Cunn.		✓	✓
	Glossostigma cleistanthum	W.R. Barker			✓
	Glossostigma elatinoides	Benth.	✓	✓	✓
	Glossostigma submersum (*G. diandrum*)	Petrie			✓
	Lilaeopsis novae-zelandiae	(Gand.) A.W. Hill		✓	✓
	Limosella lineata	Gleuck	✓		✓
	Ranunculus limosella†	Kirk		✓	✓
Milfoils	*Myriophyllum triphyllum* (*M. elatinoides*)	Orchard		✓	✓
	Myriophyllum propinquum	A. Cunn.		✓	✓
Pondweeds	*Potamogeton ochreatus*	Raoul		✓	✓
	Potamogeton cheesemanii	A. Bennett	✓	✓	
Charophytes	*Chara australis* (*C. corallina*)	Brown	✓	✓	✓
	Lamprothamnium macropogon (*L. papulosum*)	(A. Braun) J.L. Ophel	✓		
	Nitella hyalina	(DC.) Ag.	✓		✓
	Nitella pseudoflabellata	A. Br.			✓
	Nitella stuartii	A. Br.			✓
Invasive species	*Ranunculus trichophyllus*	Chaix		✓	✓
Brackish water species	*Ruppia polycarpa* (*R. spiralis*)	R. Mason	✓		✓
	Zannichellia palustris	L.			✓
	Lepilaena bilocularis‡	Kirk	✓	✓	
Other species	*Azolla filiculoides* (*A. rubra*)	Lam.	✓		✓
	Centella uniflora	(Colenso) Nannf.		✓	
	Centipeda aotearoana‡	N.G. Walsh			✓
	Hydrocotyle novae-zeelandiae	Kirk		✓	✓
	Isolepis prolifer	(Rottb.) R.Br. (1810)			✓
	Lemna minor	L.	✓		✓
	Ludwigia palustris	(L.) Elliott		✓	✓
	Ranuculus macropus	Hook. f.	✓		

LakeSPI plant community	Species	Taxonomic Authority	1950	2004	2011
Other species (cont.)	*Ranunculus glabrifolius* (*R. rivularis*)	Hook.	✓		
	Riccia fluitans	L.			✓
	Triglochin striata	Ruiz Lopez et Pav.			✓

* Cited in Wood and Mason 1977.
† Declining.
‡ Naturally uncommon.

Appendix 4. Species list for Lake Kohangatera based on surveys in 1950 (Moar 1950), 2004 and the current survey (synonyms in parenthesis).

LakeSPI plant community	Species	Taxonomic Authority	1950	2004	2011
Emergents	*Apodasmia similis* (*Leptocarpus similis*)	(Edgar) B.G. Briggs & L.A.S.	✓		✓
	Eleocharis acuta	R. Br.	✓		
	Schoenoplectus tabernaemontani (*S. validus*, *Scirpus lacustris*)	(Gmel.) Palla	✓	✓	✓
	Typha orientalis	C.B. Presl.	✓	✓	✓
Turf plants	*Crassula kirkii*†	(Allan) A.P. Druce et Given		✓	
	Glossostigma cleistanthum	W.R. Barker		✓	✓
	Glossostigma elatinoides	Benth.	✓	✓	✓
	Lilaeopsis novae-zelandiae	(Gand.) A.W. Hill	✓	✓	✓
	Limosella lineata	Gleuck			✓
Milfoils	*Myriophyllum triphyllum* (*M. elatinoides*)	Orchard		✓	✓
	Myriophyllum propinquum	A. Cunn.	✓		
Pondweeds	*Potamogeton cheesemanii*	A. Bennett	✓	✓	
	Potamogeton ochreatus	Raoul	✓	✓	✓
	Stuckenia pectinata (*Potamogeton pectinatus*) ‡	(L.) Boerner)			✓
Charophytes	*Chara australis* (*C. corallina*)	Brown	✓*		✓
	Chara globularis	Thuill.			✓
	Lamprothamnium macropogon (*L. papulosum*)	(A.Braun) J.L. Ophel	✓*		
	Nitella hyalina	(DC.) Ag.			✓
	Nitella pseudoflabellata	A. Br.			✓
	Nitella stuartii	A. Br.			✓
Invasive species	*Elodea canadensis*	Michaux			✓
	Potamogeton crispus	L.		✓	
	Ranunculus trichophyllus	Chaix		✓	
Brackish water	*Lepilaena bilocularis*‡	Kirk			✓
	Zannichellia palustris	L.		✓	✓
	Ruppia polycarpa (*R. spiralis*)	R. Mason	✓	✓	✓
Other	*Azolla filiculoides* (*A. rubra*)	Lam.		✓	✓
	Callitriche petriei	R. Mason		✓	✓
	Isolepis prolifer	(Rottb.) R.Br. (1810)		✓	✓

LakeSPI plant community	Species	Taxonomic Authority	1950	2004	2011
Other (cont.)	*Lemna minor*	L.		✓	
	Ludwigia palustris	(L.) Elliott	✓		
	Riccia fluitans	L.			✓
	Triglochin striata	Ruiz Lopez et Pav.			✓

* Cited in Wood and Mason 1977.
† Declining.
‡ Naturally uncommon.