NIWA
Taihoro Nukurangi

Assessment of 18 Canterbury lakes using LakeSPI

and weed surveillance in 22 waterbodies

Prepared for Environment Canterbury and Department of Conservation

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Prepared by:
Mary de Winton
Tracey Burton

For any information regarding this report please contact:

Mary de Winton
Group Manager
Aquatic Plants Group
+64-7-856 1797
mary.dewinton@niwa.co.nz

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

Phone +64 7 856 7026

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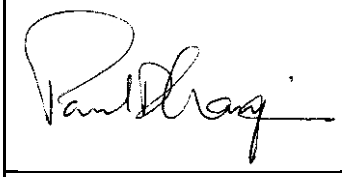	Reviewed by:	Paul Champion
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Executive summary

In 2017 NIWA surveyed 18 lakes that were due for reassessment using LakeSPI in order to update their current condition, to compare LakeSPI results to previous assessments and to identify change in lake condition. Surveys for the Ō Tū Wharekai lakes were commissioned by Department of Conservation to identify any impacts from changing land use pressures and to assess actions to protect ecological integrity in this Arawai Kākāriki wetland. Surveys for the Waitaki Lakes were commissioned by Environment Canterbury to contribute to reporting on the state of the freshwater environment. Concurrently, NIWA was also commissioned by Environment Canterbury (with additional funding from Meridian Energy Ltd) to carry out weed surveillance in 22 waterbodies, including all the surveyed lakes. Regular surveillance at high risk entry points enables early detection of new weed incursions and provides the best chance of containment/eradication.

LakeSPI (Submerged Plant Indicators) is a bioassessment method that uses the degree of development by native submerged plants, and level of impact by non-native, invasive weeds to indicate an ecological condition. A LakeSPI Index ranges from 0% (heavily impacted lakes) to 100% (pristine, unimpacted lakes) and provides 5 categories of condition.

The LakeSPI index for the Canterbury lakes surveyed in 2017 ranged from 13% to 94%. Lake Donne (Ō Tū Wharekai tarn) had a LakeSPI Index of 94%, with Lakes Tekapo and Ohau scoring over 80%. These lakes had no or negligible impact by invasive weeds and had a deep and/or highly diverse native vegetation. A further 6 lakes had a LakeSPI Index >50 to 75%, reflecting moderate impacts by invasive weeds with some constraints to the depth of vegetation extent or native plant depth or development. Nine lakes scored >20 to 50%, generally due to a major impact by invasive weed, but Lake Denny had poor water quality at the time of the survey and scored the lowest LakeSPI Index of 13%.

Incorporating the latest LakeSPI results for lakes surveyed in 2017 into results totalling thirty-eight lakes of the Canterbury Region showed that 7 lakes were assessed in the excellent category of lake ecological condition, 14 lakes were in the high category, 16 lakes fell into the moderate category and a single lake fell into the poor category. The Canterbury Region has a higher proportion of lakes in the excellent, high and moderate LakeSPI category than is the case nationally, but representation of Canterbury lakes is limited to high country waterbodies. Just over half of the lakes currently have a LakeSPI status meeting the desired fresh water outcomes identified under the operational Canterbury Land and Water Regional Plan.

NIWA holds data for all the previous LakeSPI surveys of these waterbodies, including data from 2007 and 2012 for the Ō Tū Wharekai lakes and data for the Waitaki lakes from 2009 or 2012, and frequently for 2015 also. Analysis of changes over time show that most of the Ō Tū Wharekai and Waitaki lakes have remained stable. However, significant improvement was detected for Lakes Tekapo, Ohau, Kellands Pond and Maori East Lake and a significant deterioration detected for Lake Denny. Improvements in Lake Tekapo and Ohau appear to relate to increased water clarity, possibly as an outcome from climate change and glacier retreat. Maori East Lake currently appears to be a better, less disturbed system for plant growth. The deterioration in Lake Denny appeared linked to poorer water quality due likely to land use changes.

To continue the recommended schedule for LakeSPI, so as to maintain a current overview of lake condition in the region, we recommend LakeSPI surveys are carried out in 2018 for Lake Benmore and the small lakes of the Coleridge/Craigieburn area.

No new (previously unknown) incursions of weeds were detected by NIWA's surveillance checks. We recommend that the strategy identified in the Waitaki Weed Surveillance Plan is again implemented in 2018. Consideration should be given to modifying the surveillance approach in Lake Aviemore and Lake Waitaki (i.e., check additional sites) on account of the confirmed presence of *Lagarosiphon major* in the upper riverine section of Lake Aviemore in 2017. Surveillance should also be undertaken at lakes that are to be surveyed using LakeSPI in 2018.

1 Introduction

Environment Canterbury (ECan) is responsible for managing Canterbury's water resources, including more than 4,700 lakes in the region. ECan have a duty to monitor, report and make information available about the state of the freshwater environment and must also plan and regulate to protect water resources with minimised or mitigated impacts to the natural environment.

Ō Tū Wharekai is an inter-montane wetland within Canterbury Region that incorporates a number of lake systems, and is one of the sites making up the national Arawai Kākāriki wetland restoration programme managed by Department of Conservation (DOC). DOC monitors natural systems in the area to identify any impacts from changing land use pressures and to assess actions to protect ecological integrity.

Amongst the threats to lakes are land use changes and agricultural intensification leading to a potential increase in the nutrient status of waterbodies. The introduction of aquatic weeds represents further pressure on vulnerable native ecosystems. NIWA have carried out aquatic plant inventory and weed surveillance surveys in the lakes for ECan since 2005, and more recently have included LakeSPI monitoring and assessments to enable a comparison of current and historic ecological condition. NIWA was also commissioned to undertake LakeSPI surveys in the Ō Tū Wharekai by DOC in 2007 and 2012.

In 2017, ECan and DOC together commissioned NIWA to carry out LakeSPI surveys of 18 Canterbury lakes (Lake Waitaki was unable to be completed due to bad weather) and to compare current ecological condition with that calculated from previous surveys or historical lake vegetation records (where available). ECan (with funding from Meridian Energy Ltd) also commissioned NIWA to undertake weed surveillance in 22 Canterbury waterbodies, including all surveyed lakes.

Weed surveillance in sixteen waterbodies in the Upper Waitaki catchment follows the Waitaki Weed Surveillance Plan (Sutherland and Clayton 2014). Similar surveillance approaches were used at main access points for all the Ō Tū Wharekai, including Lakes Camp and Clearwater.

This report details the results of the LakeSPI surveys and weed surveillance undertaken in 2017.

2 Methods

2.1 LakeSPI

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

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

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

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

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

2.1.1 Field surveys

The LakeSPI method was reapplied at established baseline sites within each of the lakes re-assessed in 2017. These included eleven Ō Tū Wharekai lakes of the Ashburton Basin (Table 1) and seven lakes in the Waitaki catchment (Table 2).

Table 1: Ō Tū Wharekai lakes surveyed in 2017 showing maximum lake depth and date of survey.

Lake	Depth (m)	Survey date
Camp	18.9	21/02/2017
Clearwater	19	22/02/2017
Denny	*1.5-2.1	23/02/2017
Donne	*1.1-2	24/02/2017
Emily	*2.3	24/02/2017
Emma	*2.7	23/02/2017
Heron	36.2	22/02/2017
Maori East	*1.3-1.2	24/02/2017
Maori West	*2.2-2.6	23/02/2017
Roundabout	*1.7-1.8	21/02/2017
Spider	*0.8-1.5	24/02/2017

**Range of previous reported maximum depth in shallow waterbodies.*

Table 2: Waitaki lakes surveyed in 2017 showing maximum depth and date of survey.

Lake	Depth (m)	Survey date
Alexandrina	30	1/05/2017
Aviemore	222	27/04/2017 & 12/06/2017
Kellands	5.4	27/04/2017
McGregor	12	27/04/2017 & 1/5/2017
Middleton	4.9	29/04/2017
Ohau	129	2/05/2017 & 13/06/2017
Tekapo	120	27/04/2017

Baseline sites were re-located with reference to site maps, GPS references and shoreline photos. At each site, divers recorded relevant vegetation characteristics on data sheets. A full description of the vegetation features that are assessed for the LakeSPI method can be found in the technical report and user manual on the web-reporting pages (www.lakespi.niwa.co.nz), but includes measures of diversity from the presence of key plant communities, the depth extent of vegetation and the extent that invasive weeds are represented. Observations were then entered into the NIWA LakeSPI database and used to calculate LakeSPI indices for each lake.

Boating and diving gear was examined and decontaminated between lakes according to current Check, Clean, Dry protocols (Figure 1) to ensure no transfer of freshwater pests (MPI 2017).

Figure 1: All equipment and diving suits were checked and decontaminated between water bodies.

2.1.2 LakeSPI stability

For lakes that had been assessed more than once using LakeSPI, the likelihood of an ecologically significant change in lake status over time was based on analysis of the direction and magnitude of change in LakeSPI Indices across sites.

Guidelines (Figure 2-1) based on expert judgement suggest a scale of probabilities for ecologically significant change in lake condition over longer periods and multiple surveys, using averaged LakeSPI indices over repeated surveys. These guidelines have considered variation by different observers and the response of LakeSPI scores to major ecological events in lakes.

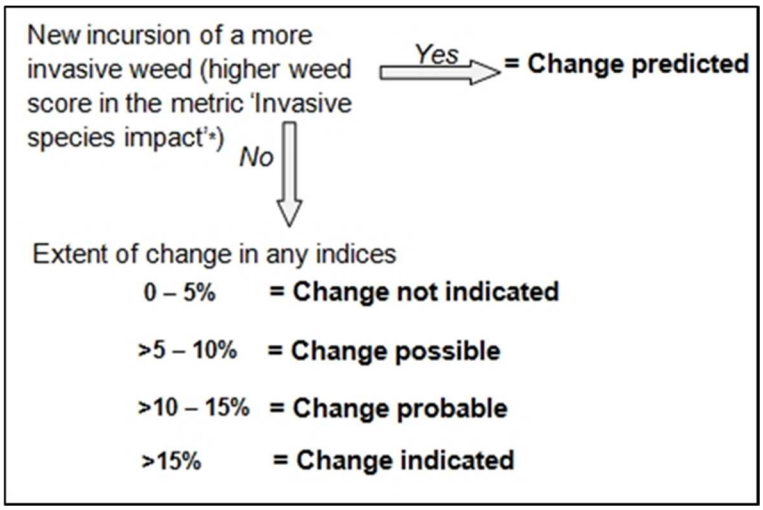


Figure 2: Guidelines for assessing the ecological significance of change in LakeSPI Indices over multiple surveys of a given lake.

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

2.1.3 LakeSPI status

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

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

2.2 Weed surveillance

Weed surveillance surveys were conducted in 22 Canterbury waterbodies during 2017 (Table 3). For waterbodies in the Upper Waitaki catchment, survey locations and survey methodology was undertaken in accordance with the Waitaki Weed Surveillance Plan (Sutherland and Clayton 2014, and updated 2015 spreadsheet). For the remaining waterbodies, weed surveillance was undertaken at known access points (both formed boat ramps and roadside launch sites) as well as high-risk sites (such as known popular fishing spots and anchor spots). At each lake, divers on snorkel and/or SCUBA conducted underwater surveys over a distance of between 50 and 200 m (depending on the suitable habitat present at each site) either side of the access point and down to a maximum water depth of 6 m (or local depth limit). Target weed species were those not known to be currently in the lakes, or under containment management, and included lagarosiphon (*Lagarosiphon major*), egeria (*Egeria densa*) and hornwort *Ceratophyllum demersum*). Shoreline searches were also conducted on foot to inspect all washed up plant fragments for the presence of target weeds.

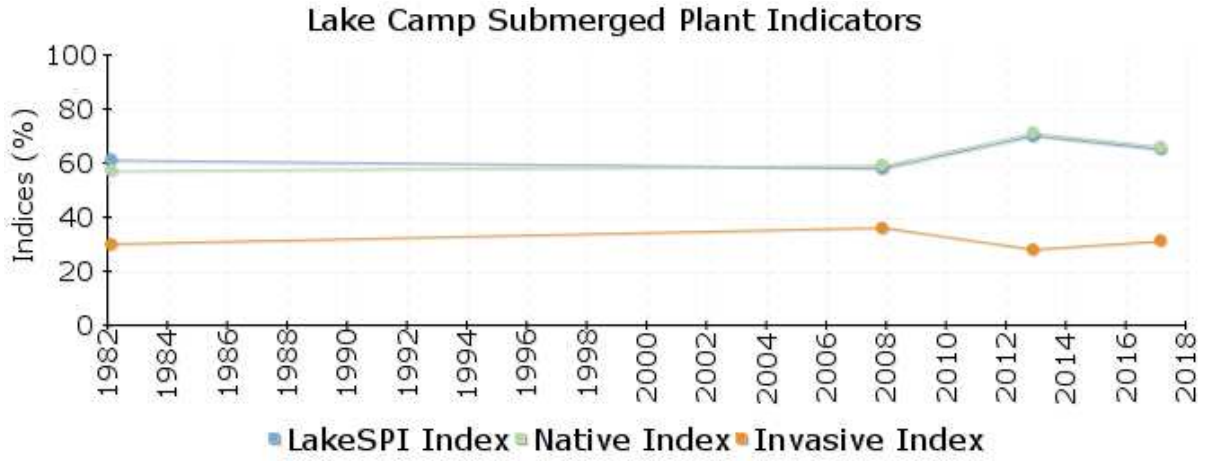
Table 3: Table of surveillance lakes, dates and sites, with surveillance for the Waitaki lakes following Sutherland and Clayton 2014.

Lake	Date	Sites
Alexandrina	April/May 2017	1 (outflow to McGregor)
Aviemore	April, June and August 2017	1 (Loch Laird), 2, 3, 4, 5, 6
Camp	February 2017	1 (boat ramp)
Benmore	June 2017	Upper 1, 2, 3, 4, Mid 1, 2, 3, 4
Clearwater	February 2017	1 (boat ramp)
Denny	February 2017	Access point
Donne	February 2017	Access point
Emily	February 2017	Access point
Emma	February 2017	2 launch sites
Heron	February 2017	1 launch site
Kellands	April 2017	1 (both sides of connection to Wairepo),
Maori west	February 2017	Access point
Maori East	February 2017	Access point
McGregor	May 2017	1 (inflow from Alexandrina)2 (outflow)
Middleton	April 2017	1, (north), 2 (south)
Ohau	April, May and June 2017	1, 2, 3, 4
Roundabout	February 2017	Access point
Ruataniwha	April 2017	1, 2, 3, 4
Spider	February 2017	Access point
Tekapo	April 2017	1 (township), 2 (bay by McGregor)
Wairepo Arm	May 2017	2 snorkel tow in Wairepo
Waitaki	June 2017	1, 2, 3

3 Ō Tū Wharekai LakeSPI Results

3.1 Lake Camp

Lake condition:	High
Lake ranking	10
Stability	Stable



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
February 2017	High	65%	66%	31%
November 2012	High	70%	71%	28%
November 2007	High	58%	59%	36%
* February 1982	High	61%	57%	30%

**NB based on two sites only*

Figure 3: LakeSPI results for Lake Camp. LakeSPI indices expressed as a percentage of lake maximum potential.

In 2017, Lake Camp was categorised as being in high ecological condition with a LakeSPI Index of 65% (Figure 3). A trend of improvement suggested by the LakeSPI Index in 2012 has not been sustained and the current LakeSPI Index has not changed significantly since the 2012 or 2007 results. Most of the change at that time was driven by an initial increase in the Native Condition Index between 2007 and 2012, followed by a small decline between 2012 and 2017.

The high LakeSPI score in 2017 is driven by vegetation depth extent to an average of 11.5 m, charophyte meadows to an average of 11 m depth, the limited impact of exotic weeds (occasional to open canopy only) and a diverse native vegetation commonly comprising four community types. Interestingly, native quillwort (*Isoetes alpina),* another native community recognised by LakeSPI*,* was not recorded during any LakeSPI surveys of Lake Camp or historically (1982) despite being present in many other Ō Tū Wharekai lakes.

Submerged vegetation (Figure 4) has always covered most of the bed of Lake Camp (maximum lake depth 18.9 m). Turf plants dominated by *Lilaeopsis ruthiana* contributed to vegetation diversity in the shallow zone (≤3 m depth). Native pondweeds and milfoils were common to ≤5 m depth. Introduced weeds, mostly elodea (*Elodea canadensis*) and occasionally water buttercup (*Ranunculus trichophyllus*) have been minor components of the vegetation (≤25% area). Three native charophytes species commonly contributed to a zonation pattern of *Chara fibrosa*, *C. globularis* and *C. australis* with increasing depth.

Most of the changes in the LakeSPI Index in 2012 related to an increased depth extent for vegetation at this time (an average of 14.2 m), and charophyte meadow (>75% cover) extent (an average of 13.9 m). A temporarily high water level was noted at the time of the 2012 survey, and vegetation depth records were adjusted by -1 m based on the degree of inundation of terrestrial plants. Prior to this, the average depth extent of vegetation was similar to 2017 at an average of 10 m in 2007 and 9.8 m in 1982.

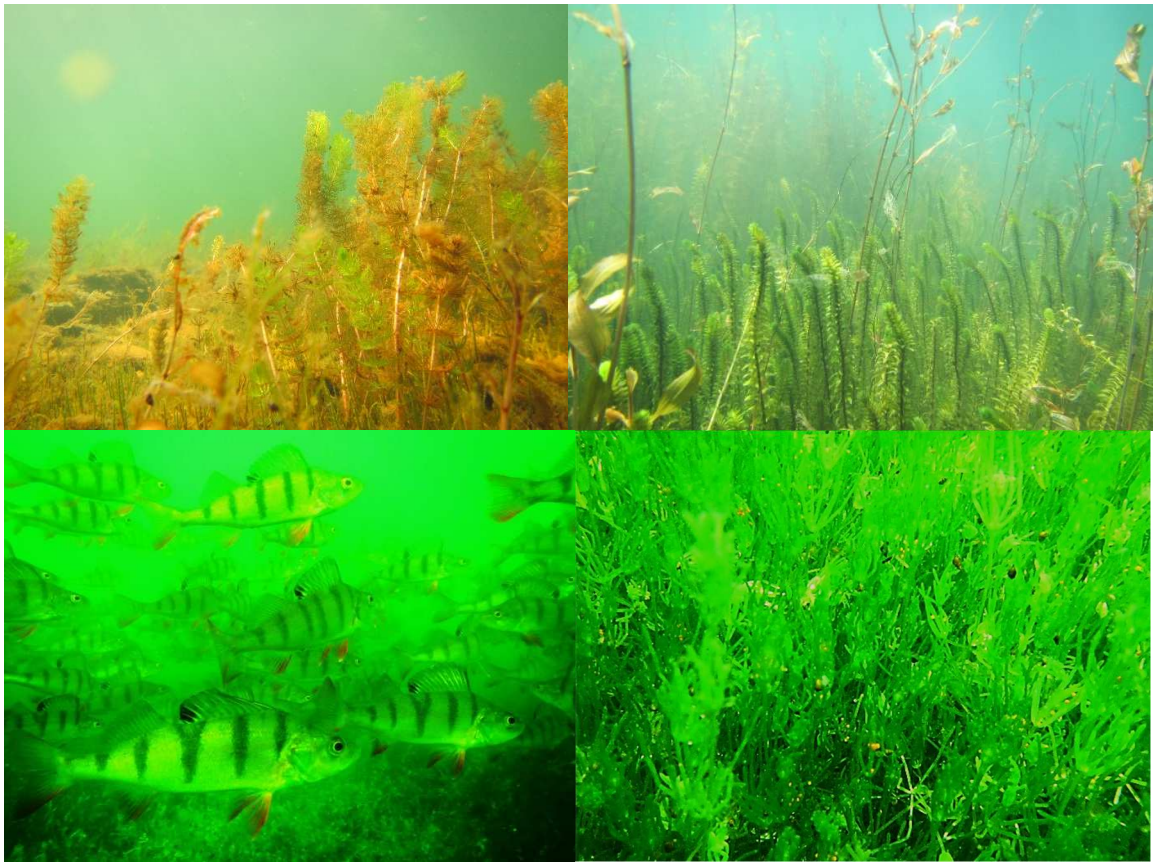


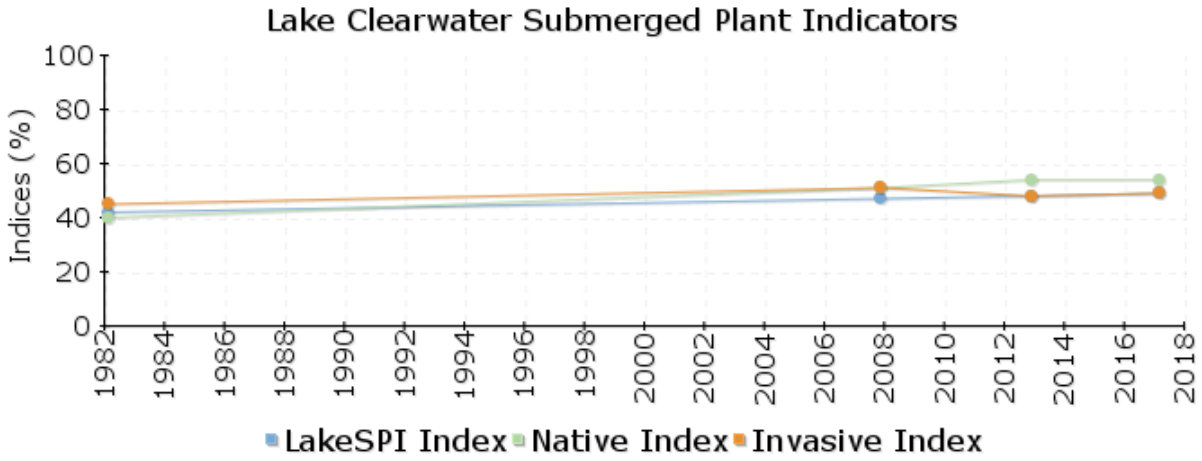
Figure 4: Submerged vegetation from Lake Camp. Clockwise from top left showing: shallow turf community grading into milfoil and pondweed; mid-depth elodea and pondweed, deeper water charophyte meadows of *Chara australis* and; large schools of juvenile perch seen at c. 10 m depth.

3.2 Lake Clearwater

Lake condition: Moderate

Lake ranking 22

Stability Stable



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
February 2017	Moderate	49%	54%	49%
November 2012	Moderate	48%	54%	48%
November 2007	Moderate	47%	51%	51%
* February 1982	Moderate	42%	40%	45%

**NB Plant depth limit not established*

Figure 5: LakeSPI results for Lake Clearwater. LakeSPI indices expressed as a percentage of lake maximum potential.

In 2017, a LakeSPI Index of 49% indicated a moderate condition for Lake Clearwater, with no changes detected from the earlier surveys in 2007 and 2012 (Figure 5). An earlier survey of vegetation in 1982 did not establish the plant depth limit therefore the Native Condition Index and LakeSPI Index from that time are underestimated.

Most recently (2017) submerged vegetation extended to an average of 7.7 m depth. Vegetation depths were slightly greater than those recorded in 2012 (5.8 m) and 2007 (6.5 m). In 2017 high cover 'meadows' of *Chara australis* grew to an average depth of 7.5 m leaving a relatively small area in the single deep (19 m) basin of the lake un-vegetated. Other charophyte species (Table A-1) contributed to a diverse vegetation on mid-depth slopes.

Native pondweeds (*Potamogeton ochreatus*, *P. cheesemanii*) and milfoils (*Myriophyllum triphyllum*) formed an open canopy above the charophyte meadows in mid-depths to 3.5 m depth (Figure 6). In the shallow zone (<2 m depth) quillwort (*Isoetes alpina*) formed swards slightly deeper than shallower turf plants. Native vegetation composition was similar for all surveys.

Elodea canadensis was the only invasive weed recorded from Lake Clearwater. In 2017, elodea was found < 5 m depth, commonly forming bands of partially- or fully-closed canopy, but did not exceed 25% of the vegetated area.

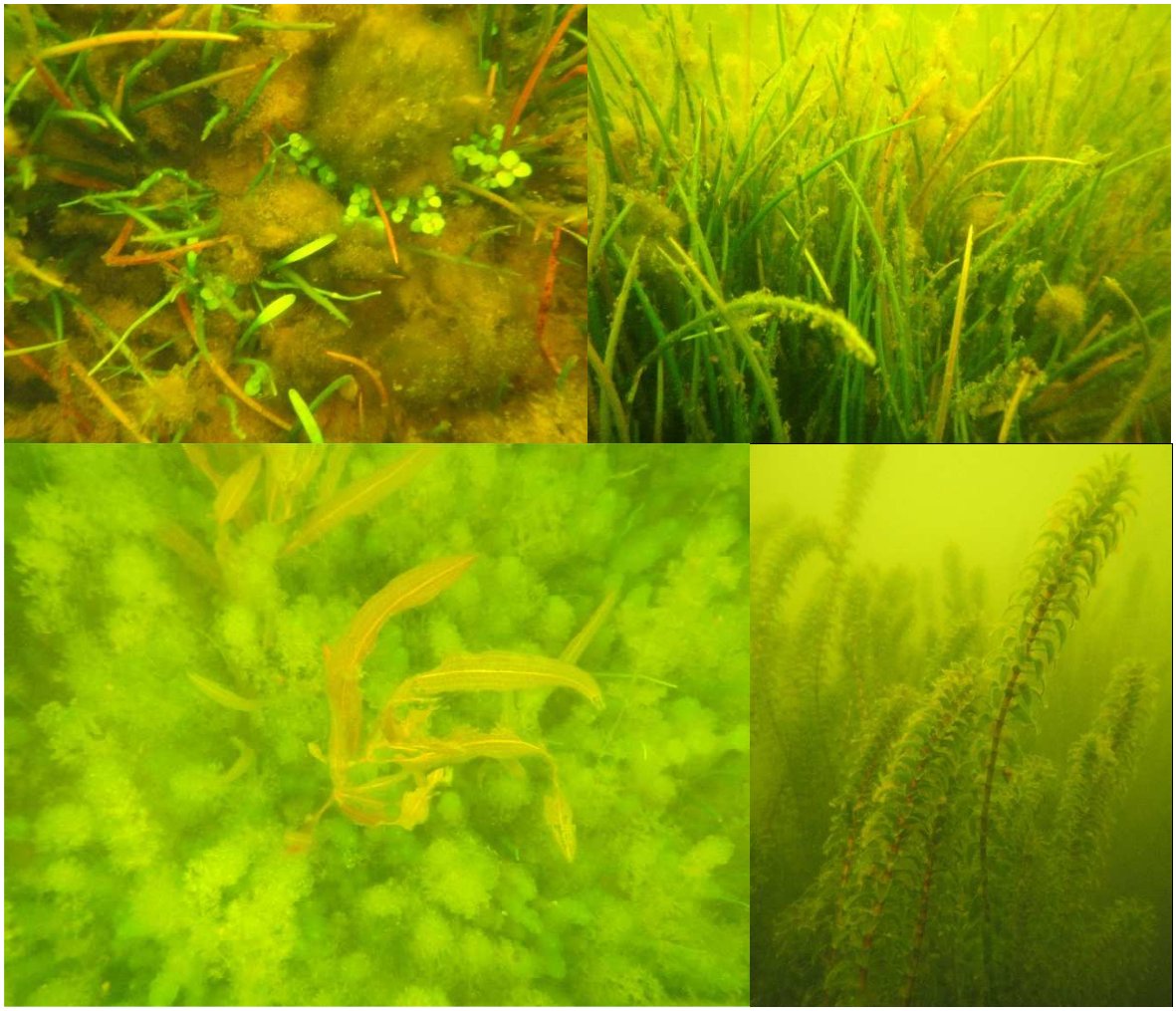
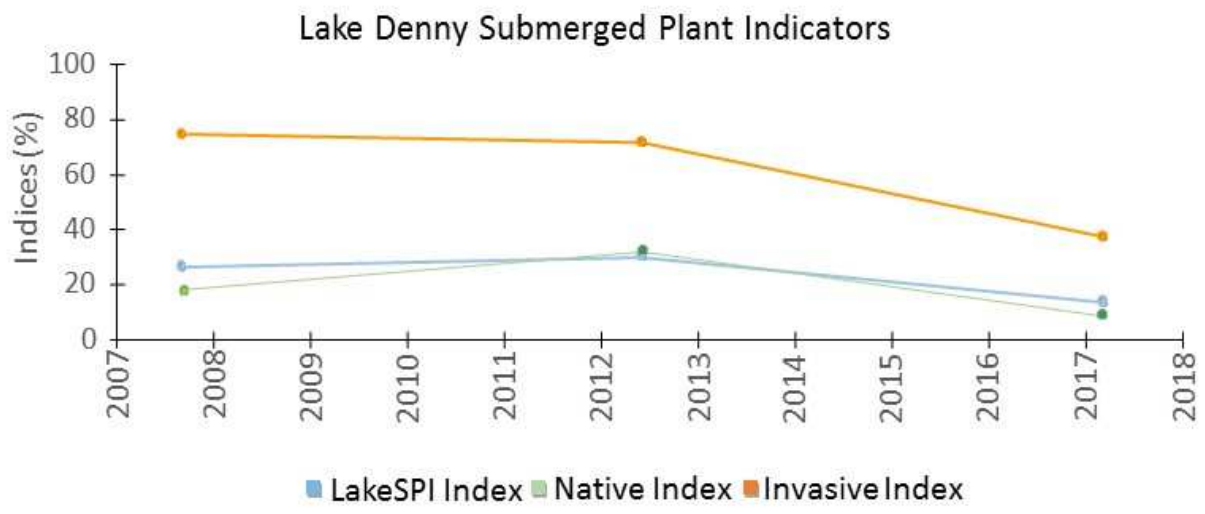


Figure 6: Submerged vegetation types recorded in Lake Clearwater. Clockwise from top left: three turf species in rocky shallows; quillwort beds; elodea bed; native pondweed and *Nitella pseudoflabellata* bed.

3.3 Lake Denny

Lake condition:	Poor
Lake ranking	39
Stability	Deteriorating



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
February 2017	Poor	13%	9%	37%
November 2012	Moderate	30%	32%	71%
November 2007	Moderate	26%	18%	74%

Figure 7: LakeSPI results for Lake Denny. LakeSPI indices expressed as a percentage of lake maximum potential.

In 2017, Lake Denny was categorised in poor ecological condition with a LakeSPI Index of 13% (Figure 7), reflecting a significant decrease since 2012 when the lake was categorised in moderate condition. This reduction was due to an apparent loss of vegetation at sites on the south-eastern side of the lake as well as a significantly lower Native Condition Index at the remaining north-western sites.

In 2017, water clarity was poor (Figure 8) and vegetation was restricted to the lake edges to a maximum of c. 1 m depth in this 2-m deep lake. Previously, in 2012 and 2007, the entire lake bed was covered by vegetation to 2.5 or 2.1 m depth. Only two submerged species, representing two plant community types, were recorded in 2017. The turf plant *Ranunculus limosella* was present at the

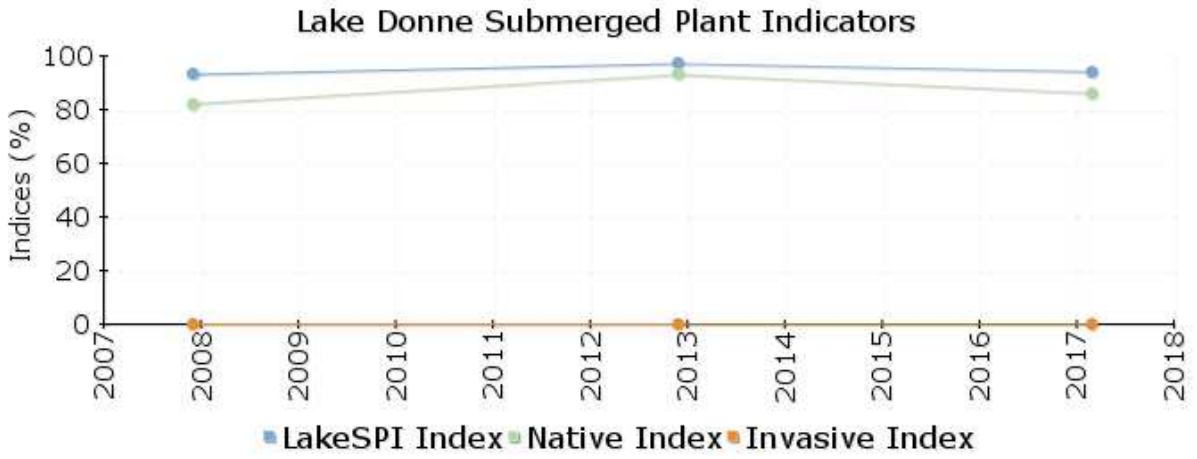
margins of the north-western shore, whilst the invasive weed *Elodea canadensis* dominated the vegetation.

Previously in 2012 and 2007, native milfoil (*Myriophyllum triphyllum*), and occasionally charophytes, contributed to the vegetation diversity. Elodea was the dominant plant, and the invasive water buttercup *Ranunculus trichophyllus* was widespread at low covers.

Figure 8: Lake Denny showing low water clarity at the margin, 2017.

3.4 Lake Donne

Lake condition:	Excellent
Lake ranking	1
Stability	Stable



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
February 2017	Excellent	94%	86%	0%
November 2012	Excellent	97%	93%	0%
November 2007	Excellent	93%	82%	0%

Figure 9: LakeSPI results for Lake Donne. LakeSPI indices expressed as a percentage of lake maximum potential.

In 2017, Lake Donne was categorised in excellent ecological condition with a LakeSPI Index of 94% (Figure 9), which was not significantly different from the 2012 or 2007 surveys.

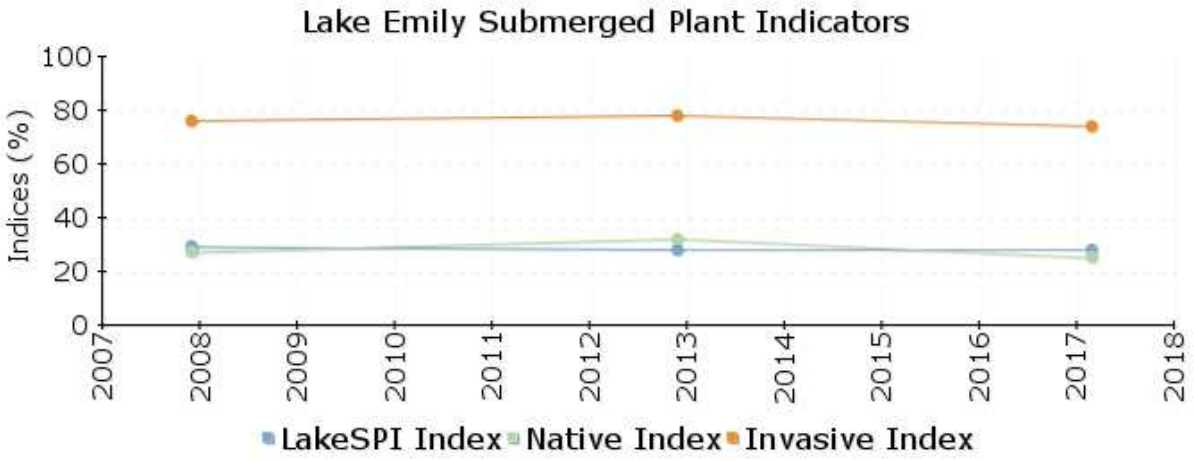
The high LakeSPI Index and Native Condition Index reflect a diverse native vegetation with no invasive species present. A diverse plant mosaic extended over the entire lake bed comprised of two milfoils, two pondweeds, *Ruppia polycarpa* and low cover charophytes and turf plants (Table A-1). The only noticeable difference to surveys in 2007 and 2012 is that high cover (≥75% cover)

charophyte meadows recorded previously were not recorded in 2017. Also in 2017, the lake was 0.9 m depth, slightly shallower than the 1.1 to 2 m recorded earlier.

Figure 10: Submerged vegetation in Lake Donne. Clockwise from top left: the turf plant *Lilaeopsis ruthiana* amongst boulders at the lake margin; charophytes and short plants of milfoil (*Myriophyllum triphyllum)*; *Ruppia polycarpa* (foreground), the pondweed *Potamogeton cheesemanii* (mid-ground) and taller milfoil (background); tall and flowering pondweed (*P. ochreatus)*.

3.5 Lake Emily

Lake condition:	Moderate
Lake ranking	38
Stability	Stable



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
February 2017	Moderate	28%	25%	74%
November 2012	Moderate	28%	32%	78%
November 2007	Moderate	29%	27%	76%

Figure 11: LakeSPI results for Lake Emily. LakeSPI indices expressed as a percentage of lake maximum potential.

Lake Emily remained categorised in moderate ecological condition in 2017 according to a LakeSPI Index of 28% (Figure 11). No significant changes in indices were detected from the surveys undertaken in 2007 and 2012.

The invasive weed *Elodea canadensis* occupied most of the lake basin to the maximum depth of 2 m (Figure 12). In places, native pondweed contributed cover at the edge of the main elodea bed. Turf plants comprised five species and included the aquatic fern *Pilularia novae-hollandiae* that was commonly found at the lake margin (≤1.0 m). Quillwort (*Isoetes alpina*) also contributed to the turf

locally. The only major change in vegetation composition in 2017 was the absence of charophytes, which had been recorded in the shallows at low covers previously.

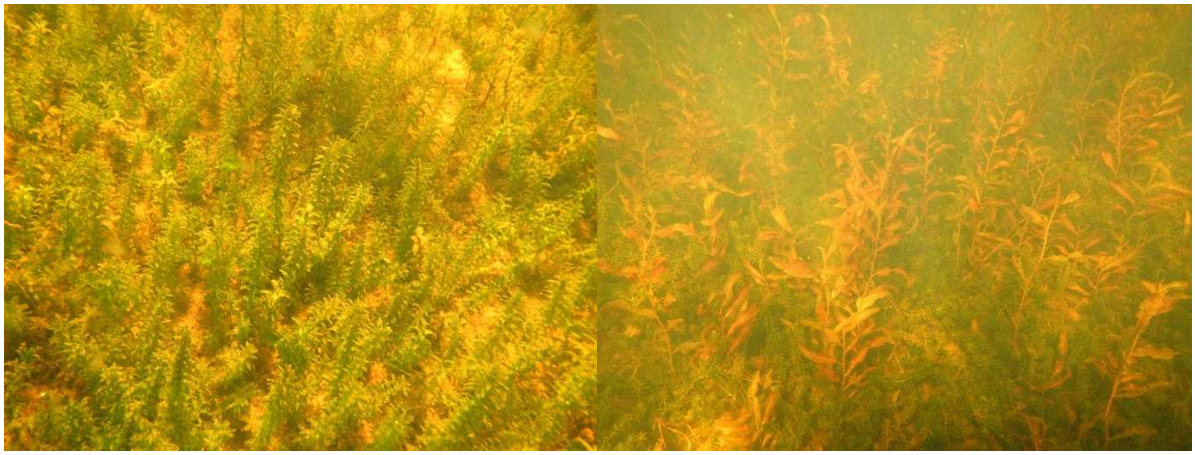
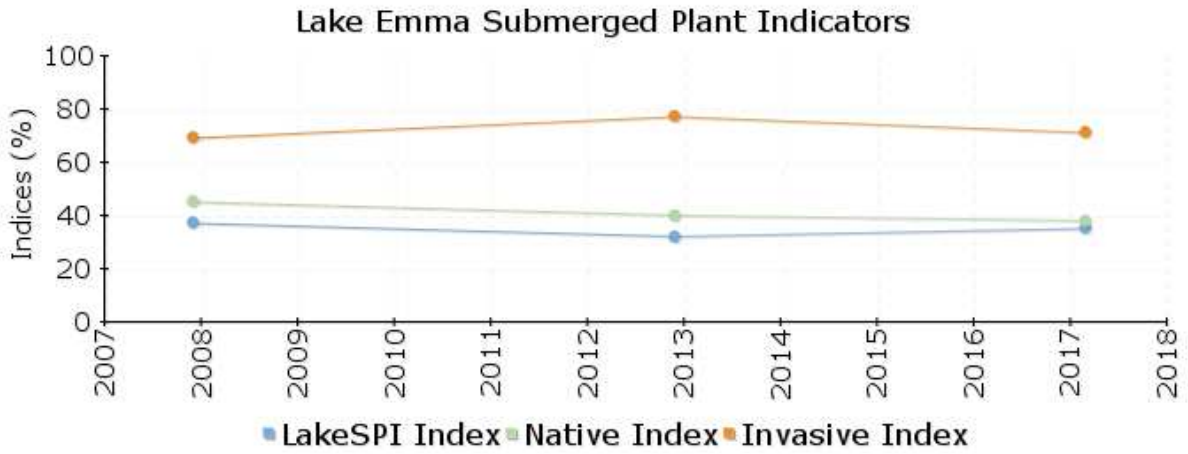


Figure 12: Submerged vegetation in Lake Emily. Most of the lake was covered by elodea (left), with native pondweed *Potamogeton cheesemanii* growing at the edges of the elodea bed (right).

3.6 Lake Emma

Lake condition:	Moderate
Lake ranking	34
Stability	Stable



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
February 2017	Moderate	35%	38%	71%
November 2012	Moderate	32%	40%	77%
November 2007	Moderate	37%	45%	69%

Figure 13: LakeSPI results for Lake Emma. LakeSPI indices expressed as a percentage of lake maximum potential.

In 2017, Lake Emma remained categorised in a moderate ecological condition with a LakeSPI Index of 35% (Figure 13), which was not significantly different to results from 2007 and 2012.

Submerged vegetation (Figure 14) extended across most of the lake bed to a maximum depth of 2.1 m in 2017. The moderate status reflects continuing dominance by *Elodea canadensis*, which generally formed a closed canopy but was not tall growing (<1.5 m in height). The invasive water buttercup *Ranunculus trichophyllus* was also common but restricted to shallow margins.

Up to five native plant community groups were still present (Table A-1). Milfoil (*Myriophyllum triphyllum*) was locally abundant and surface-reaching in patches across the lake. In contrast, pondweed (*Potamogeton ochreatus*) and charophytes (three species) were observed at low covers only. Turf plants *Lilaeopsis ruthiana* and *Ranunculus limosella* were common at low covers at the lake margins (<1.5 m). Quillwort (*Isoetes alpina*) also formed swards limited to the same shallow margins. Another native pondweed *Stuckenia pectinata* was only seen at one of the lake launch sites (not a LakeSPI site).

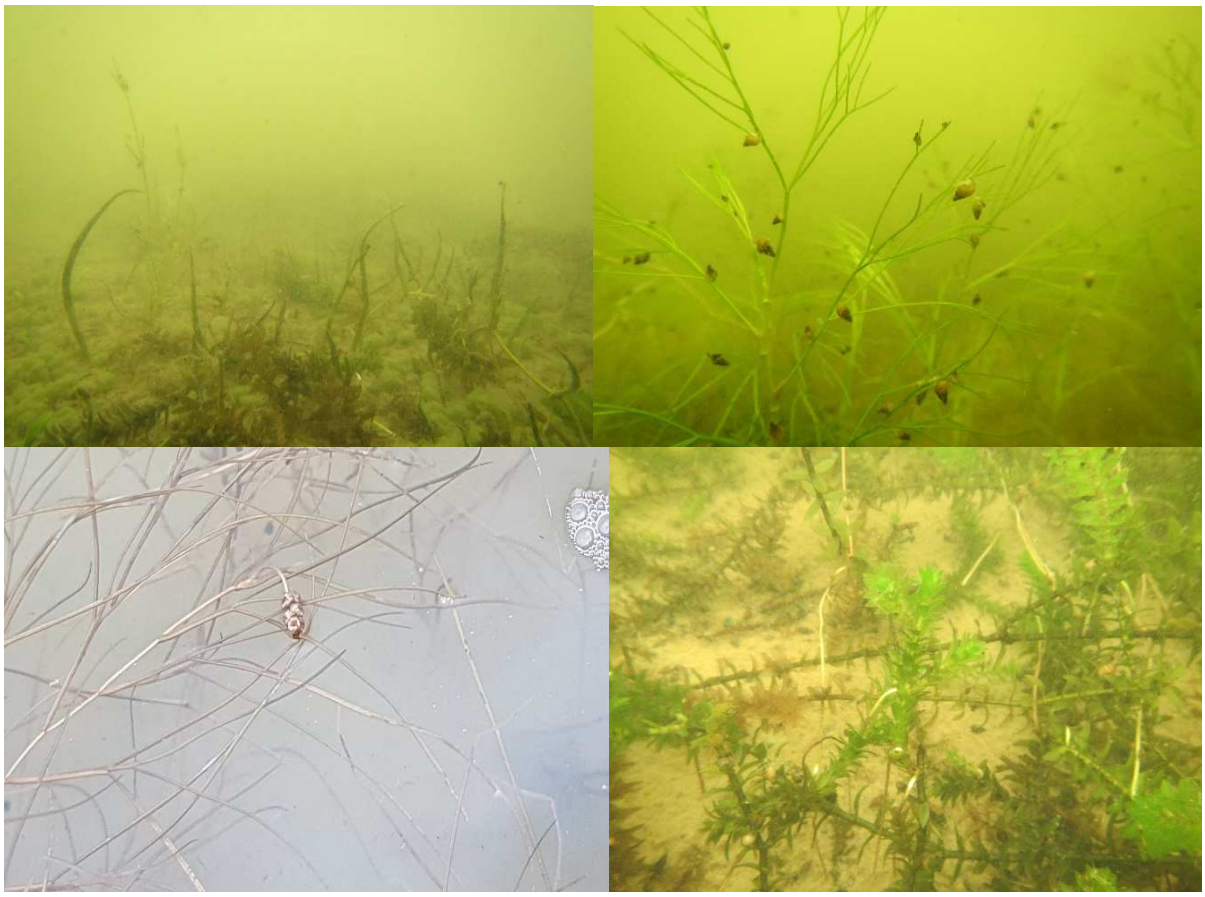
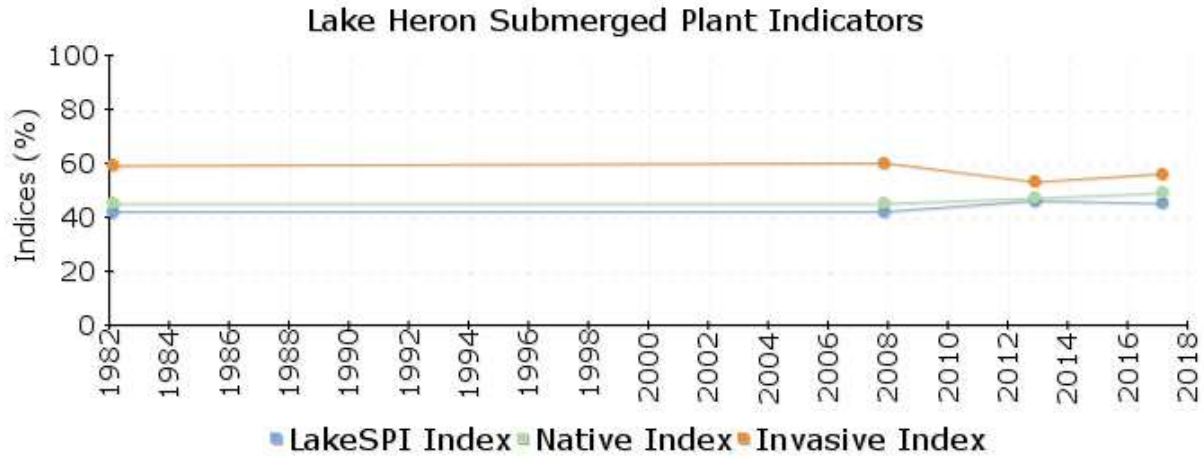


Figure 14: Submerged vegetation in Lake Emma. Clockwise from top left: sparse turf plants; water buttercup; elodea colonising shallow substrate; fruiting *Stuckenia pectinata*.

3.7 Lake Heron

Lake condition:	Moderate
Lake ranking	27
Stability	Stable



	Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
	February 2017	Moderate	45%	49%	56%
	November 2012	Moderate	46%	47%	53%
	November 2007	Moderate	42%	45%	60%
*	February 1982	Moderate	42%	45%	59%

**NB sites at different locations to subsequent surveys*

Figure 15: LakeSPI results for Lake Heron. LakeSPI indices expressed as a percentage of lake maximum potential.

Lake Heron remained categorised in a moderate ecological condition in 2017 according to a LakeSPI Index of 45% (Figure 15). The LakeSPI Indices did not vary significantly between any of the survey years; 2007, 2012 or 2017 and vegetation composition has remained very similar.

In 2017 *Elodea canadensis* formed a short (<1 m tall), closed canopy bed at most sites. Up to five native submerged plant community types were also recorded (Figure 16). The vegetation was notable for its diverse assemblage of nine charophyte species (Table A-1). Charophyte meadows (≥75% cover) found deeper than the main elodea bed, comprised of a complex zonation pattern of intergrading species. Native milfoil (*Myriophyllum triphyllum*) and pondweeds (*Potamogeton ochreatus*, *P. cheesemanii*) were common at generally low covers and <5 m depth. Turf plants were recorded at the shallow margins of all sites, and high cover swards of quillwort (*Isoetes alpina*) occurred at most sites. Didymo (*Didymosphenia geminata*) was observed on shallow rocks at the south-western shoreline, but not on deeper vegetation.

Repeated patterns of spatial variability in submerged vegetation between survey sites were observed in all surveys. For instance, greater vegetation depths have always been recorded in the north-east arm (1.5 to 3.3 m deeper), where spring inflows have been observed. This natural variability is unusual in one waterbody and may reduce sensitivity for detecting significant future change.

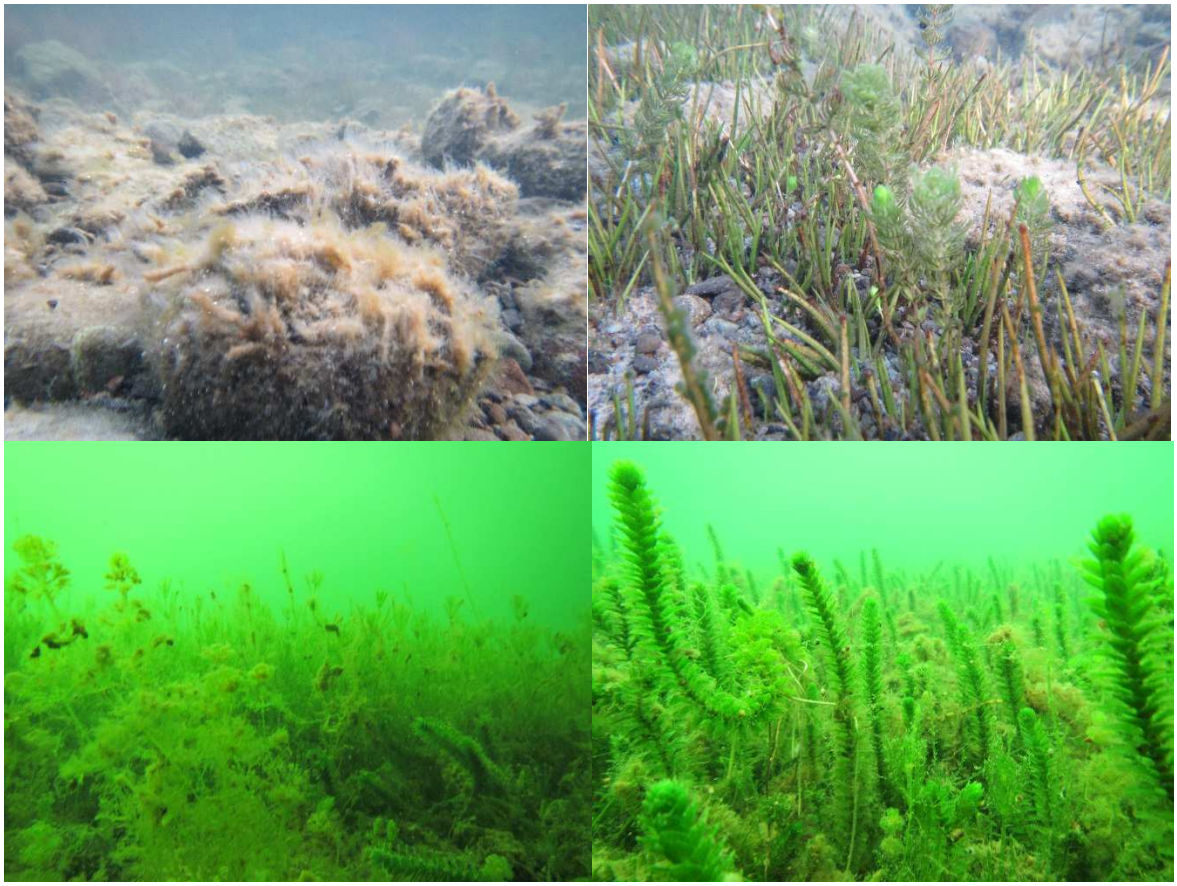
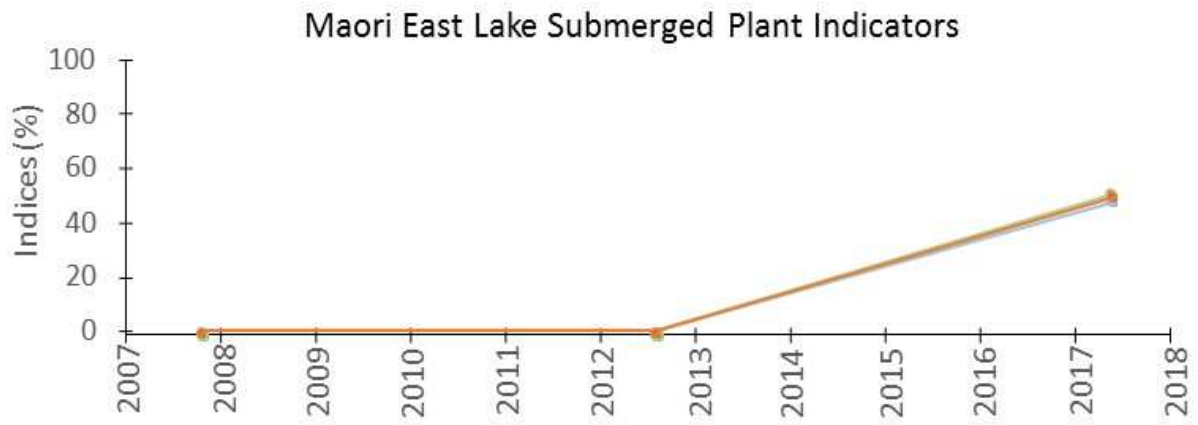


Figure 16: Submerged vegetation in Lake Heron. Clockwise from top left: didymo *Didymosphenia geminata* on shallow wave-washed boulders; quillworts *Isoetes alpina* growing in coarse shallow gravel; open canopy elodea beds; deeper charophyte meadows at the depth limit of elodea.

3.8 Maori East Lake

Lake condition:	Moderate
Lake ranking	25
Stability	Improving



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
February 2017	Moderate	47%	50%	49%
November 2012	Moderate	46%	45%	19%
November 2007	Non-vegetated	0%	0%	0%

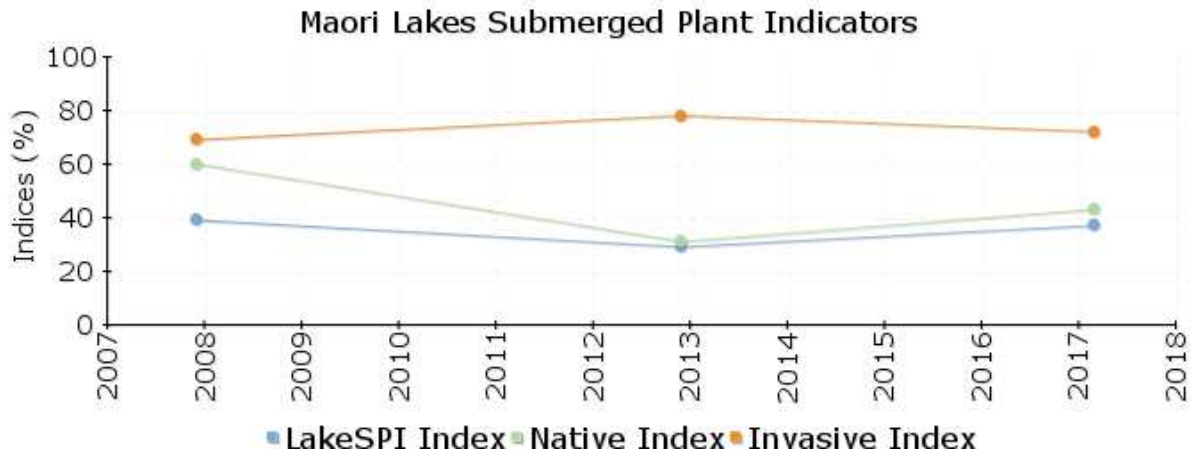
Figure 17: LakeSPI results for Maori East Lake. LakeSPI indices expressed as a percentage of lake maximum potential.

In 2017, Maori East lake was categorised in a moderate ecological condition with a LakeSPI Index of 47% (Figure 17). This result was significantly higher than the 2012 or 2007 LakeSPI Index, when an extremely sparse submerged vegetation fell below the 10% cover threshold, generating a default LakeSPI Index of 0%.

During the recent 2017 survey, a limited community of turf plants comprising three species (Table A-1) was recorded from the shallow margin at the vehicle access site. Across the shallow bed of the lake (to 0.7 m depth), taller vascular plants were recorded that included the invasive weed elodea, and native plants, *Ruppia polycarpa* and pondweed (*Potamogeton ochreatus*). As noted in 2012, the low stature of these plants (≤0.2 m) might suggest browsing and uprooting by waterfowl or wave action in this shallow lake, which has loose flocculent sediments. Didymo was previously reported from Maori East Lake, but was not observed during the 2017 or 2012 surveys.

3.9 Maori West Lake

Lake condition:	Moderate
Lake ranking	32
Stability	Stable



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
February 2017	Moderate	37%	43%	72%
November 2012	Moderate	29%	31%	78%
November 2007	Moderate	39%	60%	69%

Figure 18: LakeSPI results for Maori West Lake. LakeSPI indices expressed as a percentage of lake maximum potential.

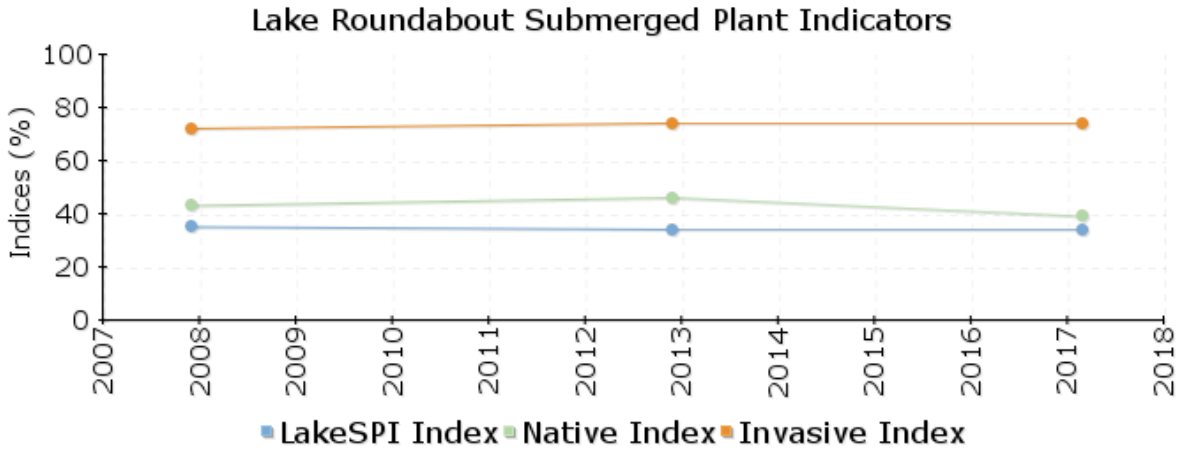
In 2017, Maori West Lake remained categorised in a moderate ecological condition with a LakeSPI Index of 37%, which was similar to the result in 2007 (Figure 18). Although the LakeSPI Index varied by c. 10% between successive surveys, variability between the sites meant this change was not statistically significant.

In 2017 submerged vegetation (Figure 19) was recorded across the entire bottom of the lake to a maximum depth of 1.9 m. The exotic weed elodea dominated the vegetation, but patches of native charophytes and pondweeds were common (Table A-1).

Figure 19: Submerged vegetation types in Maori West Lake. Clockwise from top left: the charophyte, *Chara australis*; *Elodea canadensis*; Pondweed (*Potamogeton ochreatus*) emerging from elodea; a mosaic of these species.

3.10 Lake Roundabout

Lake condition:	Moderate
Lake ranking	35
Stability	Stable



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
February 2017	Moderate	34%	39%	74%
November 2012	Moderate	34%	46%	74%
November 2007	Moderate	35%	43%	72%

Figure 20: LakeSPI results for Lake Roundabout. LakeSPI indices expressed as a percentage of lake maximum potential.

In 2017 Lake Roundabout remained categorised in moderate condition with a LakeSPI Index of 34% (Figure 20). Results were similar to those recorded in both 2007 and 2012, with no significant changes identified.

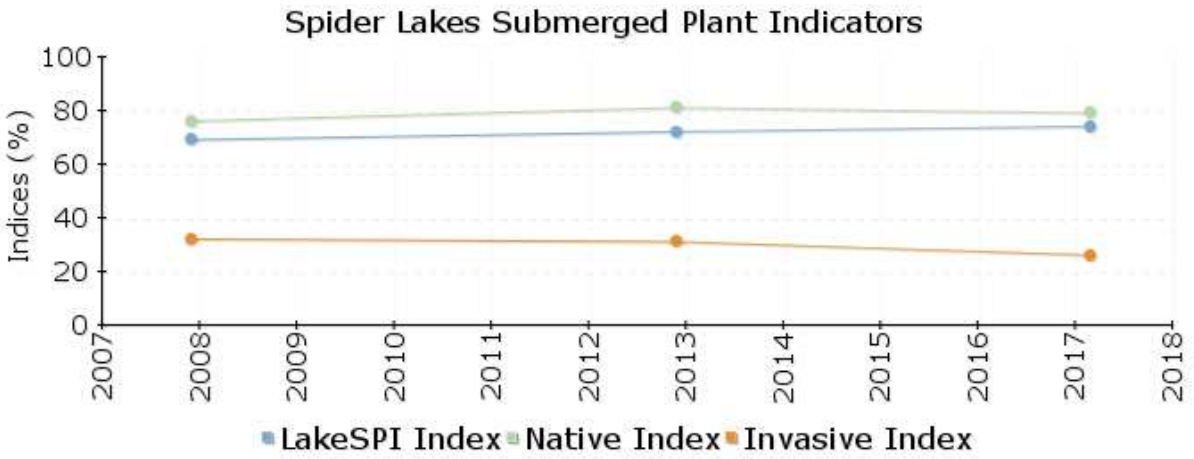
During the recent 2017 survey the water clarity appeared to be low, but on closer inspection was found to comprise a dense bloom of the introduced cladoceran *Daphnia pulex*. Submerged vegetation extended over most of the lake bed to the maximum lake depth of 1.5 m at the time of the survey, although bare patches were common. *Elodea canadensis* was the dominant plant species forming closed canopy beds that were <1 tall. The introduced water buttercup (*Ranunculus trichophyllus*) also formed some patches in the shallows.

The same four native community types were recorded as in previous surveys (Table A-1). Milfoil (*Myriophyllum triphyllum*) was co-dominant with elodea in places, while pondweed (*Potamogeton ochreatus*) was common. A single charophyte species (*Chara australis*) was recorded at low cover only. Turfs were common at the lake edge.

During the 2017 survey the presence of the introduced ear pond snail (*Radix auricularia*) was reconfirmed, and the large size of freshwater mussels (*Echyridella menziesii*) noted.

3.11 Spider Lake

Lake condition:	High
Lake ranking	8
Stability	Stable



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
February 2017	High	74%	79%	26%
November 2012	High	72%	81%	31%
November 2007	High	69%	76%	32%

Figure 21: LakeSPI results for Lake Spider Lake. LakeSPI indices expressed as a percentage of lake maximum potential.

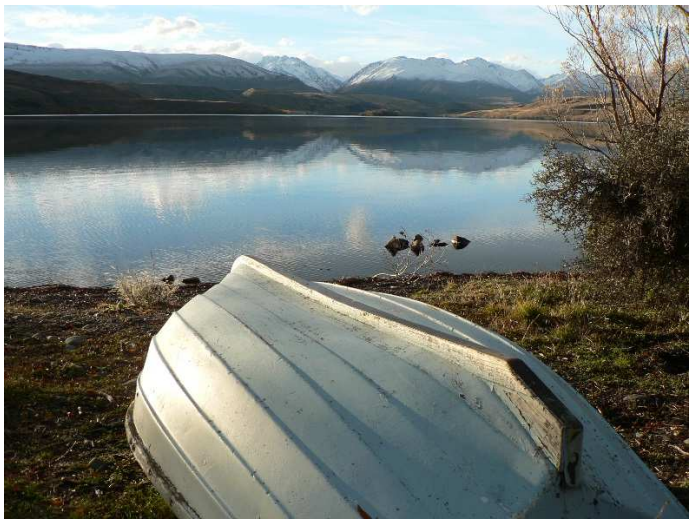
In 2017, Spider Lake remained categorised in a high ecological status with a LakeSPI Index of 73.5% (Figure 21). Low water levels observed during the recent survey meant that the eastern basin was very shallow (0.3 m deep) but still maintained a submerged plant community, while the main basin was 0.7 m depth. Results showed no significant changes in LakeSPI Indices since 2012 or 2007.

Both basins of the lake in 2017 had exposed margins covered by amphibious turf plants and flocculent mud in deeper central areas (Figure 22). Nevertheless, all components of the previously described submerged vegetation were present (Table A-1). High cover meadows of charophytes present in the main basin were comprised of *Chara fibrosa* (Figure 22), with additional charophyte species scattered at low covers. Native milfoils and pondweeds also contributed to the vegetation in deeper areas. The only invasive weeds present were *Elodea canadensis* and *Ranunculus trichophyllus* which comprised a minor part of the vegetation.

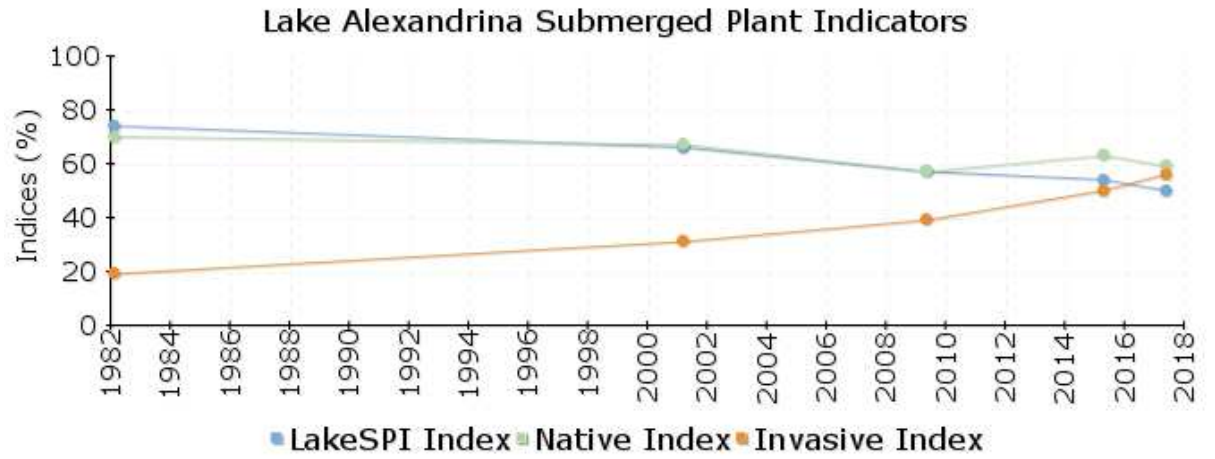
Figure 22: Submerged vegetation at Spider Lake. Clockwise from top: exposed turf and shallow water at the east of the main basin; floating leaves of pondweed (*Potamogeton cheesemanii*); an extracted bunch of the charophyte *Chara fibrosa*; edge of a milfoil patch.

4 Waitaki LakeSPI Results

4.1 Lake Alexandrina



Lake condition:	High
Lake ranking	20
Stability	Stable



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
May 2017	High	51%	60%	56%
April 2015	High	54%	63%	50%
May 2009	High	57%	57%	39%
* March 2001	High	66%	67%	31%
* February 1982	High	74%	70%	19%

**Results indicative only*

Figure 23: LakeSPI results for Lake Alexandrina. LakeSPI indices expressed as a percentage of lake maximum potential.

In 2017, Lake Alexandrina remained categorised in a high ecological condition with a LakeSPI Index of 51% (Figure 23). There were no significant changes in this Index from 2009 or 2015, however the 2015 and 2017 values for the Invasive Impact Index were significantly higher than in 2009. Earlier scores from 2001 and 1982 could not be directly compared due to the different location of sites and are indicative only.

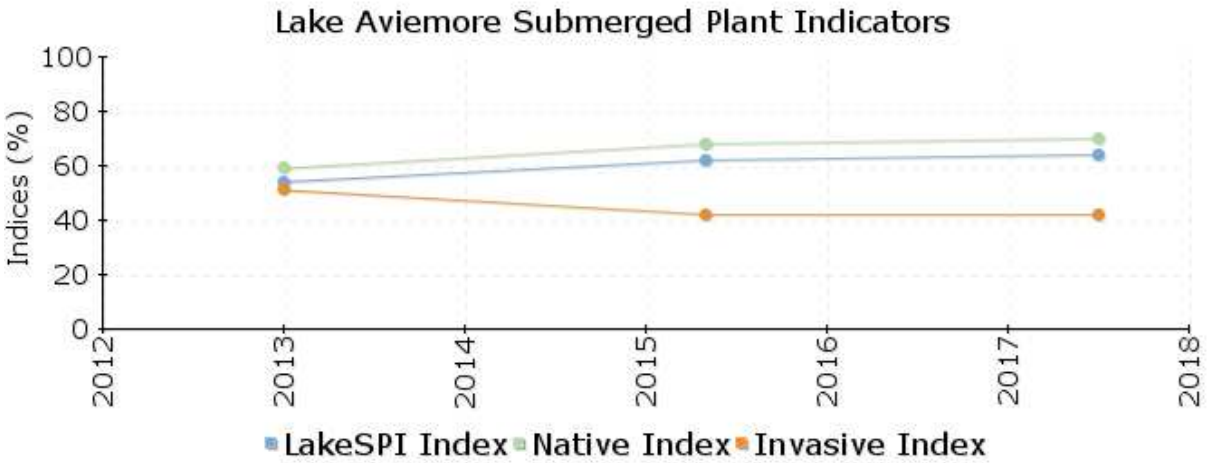
Most recently (2017) vegetation was recorded to an average of 10.6 m depth, which was similar to 2015 (10.8 m) but a little deeper than 2009 (9.4 m). In 2017, the deepest vegetation at all sites comprised charophyte meadows (≥75 cover) of *Chara australis* to an average depth of 10.3 m.

Up to five types of native submerged plant communities were observed in 2017. Five additional charophyte species were recorded in addition to *C. australis* (Table A-2). Native milfoil (*Myriophyllum triphyllum*) was common at low covers to c. 4 m depth. Pondweeds included locally dominant beds of *Potamogeton ochreatus* that extended to an unusually deep depth of 6.8 m, and lower covers of *P. cheesemannii* in <5 m. Quillwort (*Isoetes alpina*) formed a sward in shallow water at all sites, while turf plants were also common in shallow water <3 m depth.

Earlier survey results suggest the invasive weed *Elodea canadensis* has increased in development over time, with higher areas and covers after 2009 leading to a significantly higher Invasive Impact Index. In 2017 elodea was the most dominant plant species in the lake. Elodea formed closed-canopy beds to an average depth of 6.3 m, occupying ≤50% of the vegetated area. Introduced water buttercup (*Ranunculus trichophyllus*) was also commonly observed.

4.2 Lake Aviemore

Lake condition:	High
Lake ranking	12
Stability	Stable



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
June 2017	High	64%	70%	42%
April 2015	High	62%	68%	42%
December 2012	High	54%	59%	51%

Figure 24: LakeSPI results for Lake Aviemore. LakeSPI indices expressed as a percentage of lake maximum potential.

In 2017, Lake Aviemore remained categorised in a high ecological condition with a LakeSPI index of 64% (Figure 24). No changes were apparent in LakeSPI Indices between any of the surveys, despite the apparent lower scoring associated with the 2012 survey.

Elodea canadensis and introduced water buttercup (*Ranunculus trichophyllus*) were the only invasive weed species recorded in all three surveys. *Lagarosiphon major* is known to be present in the upper areas of Lake Aviemore and upstream Lake Benmore, however an intensive management programme appears to have prevented this weed from establishing in the main basin of the lake to date.

In 2017, elodea dominated the mid-depth vegetation. It was recorded at all sites and generally formed a low-growing (<1 m tall) band of high cover in mid-depths to 6.5 m depth. Water buttercup formed localised beds in the shallows or was scattered in mid-depths. Results for these invasive species are similar to that observed previously.

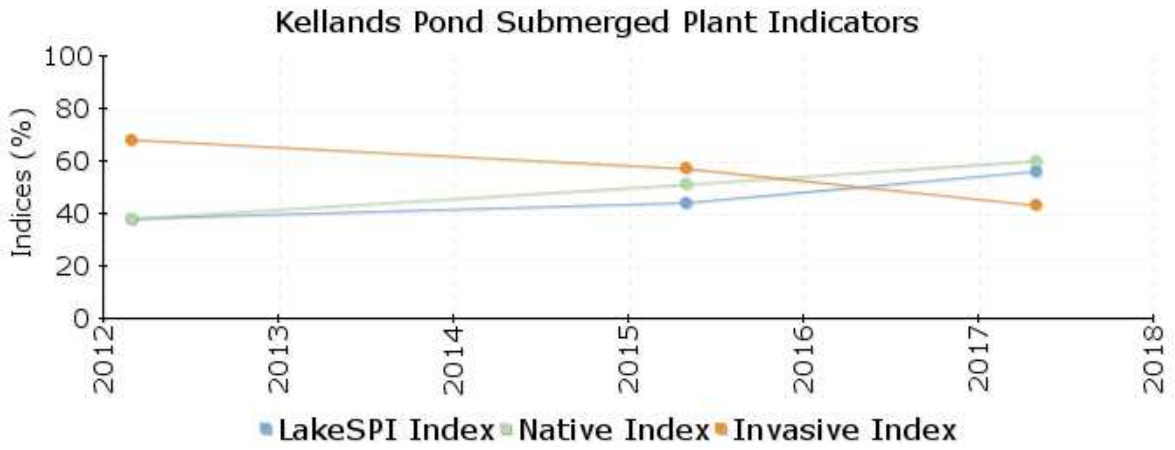
Most recently submerged vegetation was recorded to an average of 14.4 m, compared to 14.5 m recorded in 2015 and 12.7 m in 2012. The deepest vegetation comprised charophyte meadows (≥75% cover) dominated by *Chara australis* (Figure 25) or *Nitella leonhardii.* Five other charophyte species also contributed to the vegetation in 2017 (Table A-2).

In addition to charophytes, three other native plant communities were represented. Pondweeds comprised *Potamogeton cheesemanii* and *P. ochreatus* (Figure 25), the latter exceeding 5 m depth at all sites and recorded to an unusually deep maxima of 7.1 m. Milfoil (*Myriophyllum triphyllum*) also exceeded 5 m depth at some sites. Turf plants were present in shallow water (<3 m depth) at all sites, with *Eleocharis pusilla* the dominant species. Quillwort (*Isoetes alpina*) was not recorded in 2017, yet was noted at some sites in 2015 and 2012.

Figure 25: Submerged vegetation in Lake Aviemore. *Elodea canadensis* co-existing with pondweed, *Potamogeton ochreatus* (left) and deep water charophyte meadows of *Chara australis* (right).

4.3 Kellands Pond

Lake condition:	High
Lake ranking	19
Stability	Improving



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
April 2017	High	56%	60%	43%
April 2015	Moderate	44%	51%	57%
February 2012	Moderate	38%	38%	68%

Figure 26: LakeSPI results for Kellands Pond. LakeSPI indices expressed as a percentage of lake maximum potential.

In 2017, Kellands Pond was categorised in a high ecological condition for the first time with a LakeSPI Index of 56% (Figure 26). A status change from the previous moderate condition in 2012 and 2015 suggests improvement, although this change was not quite statistically significant for the LakeSPI Index. In contrast, the 2017 Native Condition Index was significantly higher than either of the 2012 and 2015 values, with the 2015 Native Condition Index also being significantly higher than the 2012 result.

The significantly increasing Native Condition Index over 2015 and 2017 was driven by greater occupancy of the vegetation by native plants and extensions in the depths of native plants, especially charophyte meadows (≥75% cover). Five charophyte species were recorded in 2017 (Table A-2).

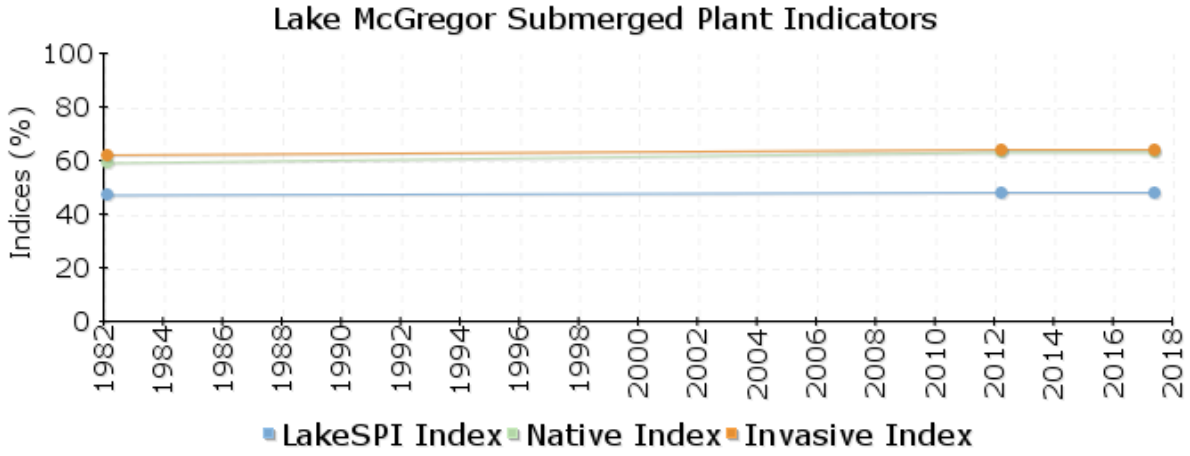
Native milfoils and pondweeds recorded in 2017 (Table A-2) included locally abundant beds of *Myriophyllum triphyllum* and *Potamogeton ochreatus*. The margins of this small sheltered waterbody were commonly occupied to 0.5 m depth by open growths of the small emergent reed*, Eleocharis acuta*. Immediately deeper to 1.5 m depth was a turf plant community of up to five species (Table A-2), usually dominated by *Eleocharis pusilla*.

The invasive weed *Elodea canadensis* was spatially variable in development in 2017, ranging from occasional plants to closed-canopy cover and occupying between <5% and 50% of the vegetated area at sites. Previous surveys recorded a generally greater development of elodea, with survey results in 2012 showing elodea formed the major proportion of the vegetated area and deepest plant depth limit. Introduced water buttercup *(Ranunculus trichophyllus*) is the only other weed to be recorded (2017 and 2012 surveys) from Kellands Pond (Figure 27). In 2017, divers observed a bloom of introduced freshwater jellyfish (*Craspedacusta sowerbii*), also noted in this waterbody previously.

Figure 27: Submerged vegetation and alien jellyfish in Kellands Pond. Clockwise from top left: shallow-growing charophytes; water buttercup; mixed stands of native milfoil and elodea; jellyfish.

4.4 Lake McGregor

Lake condition:	Moderate
Lake ranking	23
Stability	Stable



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
May 2017	Moderate	48%	63%	64%
March 2012	Moderate	48%	63%	64%
* February 1982	Moderate	47%	59%	62%

**Results indicative only*

Figure 28: LakeSPI results for Lake McGregor. LakeSPI indices expressed as a percentage of lake maximum potential.

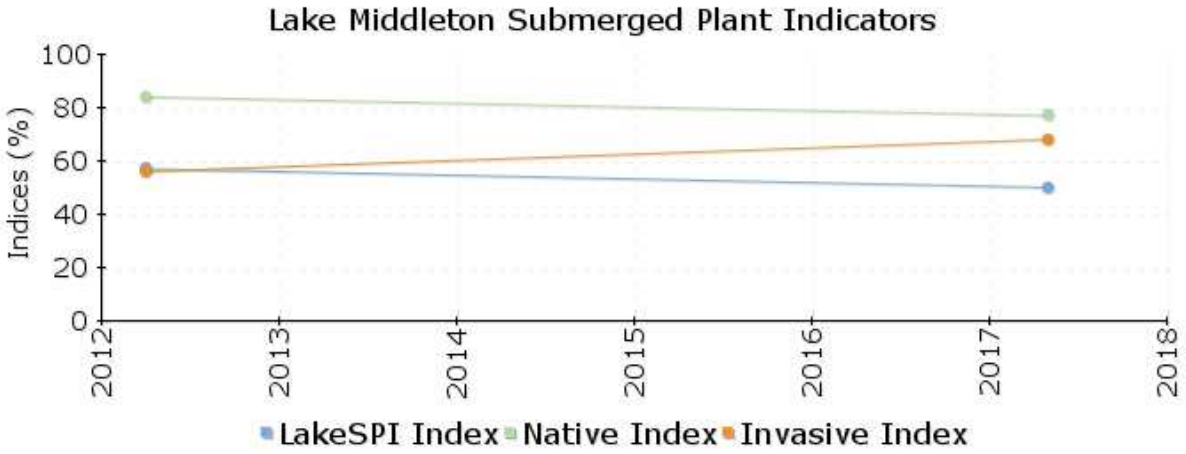
In 2017, Lake McGregor was categorised in a moderate ecological condition with a LakeSPI Index of 48% (Figure 28). There were no significant differences in any LakeSPI Indices from results obtained in 2012. Whilst earlier results from 1982 are also similar to results in 2017, they cannot be directly compared due to differences in site locations and are indicative only.

The moderate LakeSPI condition reflects the influence of the invasive weed *Elodea canadensis*, which in 2017 formed closed-canopy beds to between 6 and 6.4 m depth. Introduced water buttercup (*Ranunculus trichophyllus*) was also present in shallow water (<3 m) at some sites.

Up to five native submerged community were recorded in Lake McGregor in 2017. Charophyte meadows (≥75% cover) dominated by *Chara australis* were recorded at all sites to an average of 7.5 m depth in 2017. An additional four charophyte species were recorded (Table A-2) with *Chara globularis* and *C. fibrosa* being locally dominant in shallow water <2 m). Two native pondweeds (Table A-2) were common, with *Potamogeton ochreatus* recorded to >5 m depth at all sites. Shallow water areas were dominated by two native milfoils (Table A-2) were also common. Quillwort (*Isoetes alpina*) and the turf plant *Lilaeopsis ruthiana* dominated the shallow water vegetation (< 2 m deep) with several other turf species contributing (Table A-2).

4.5 Lake Middleton

Lake condition:	High
Lake ranking	21
Stability	Stable



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
April 2017	Moderate	50%	77%	68%
March 2012	High	57%	84%	56%

Figure 29: LakeSPI results for Lake Middleton. LakeSPI indices expressed as a percentage of lake maximum potential.

In 2017, Lake Middleton had a high ecological condition with a LakeSPI Index of 50% (Figure 29). No significant changes in LakeSPI Indices were detected between 2012 and 2017. A vegetation survey of four sites in 1989 cannot be directly compared, but was indicative of a LakeSPI Index of 67%, Native Condition Index of 82% and an Invasive Impact Index of 37%.

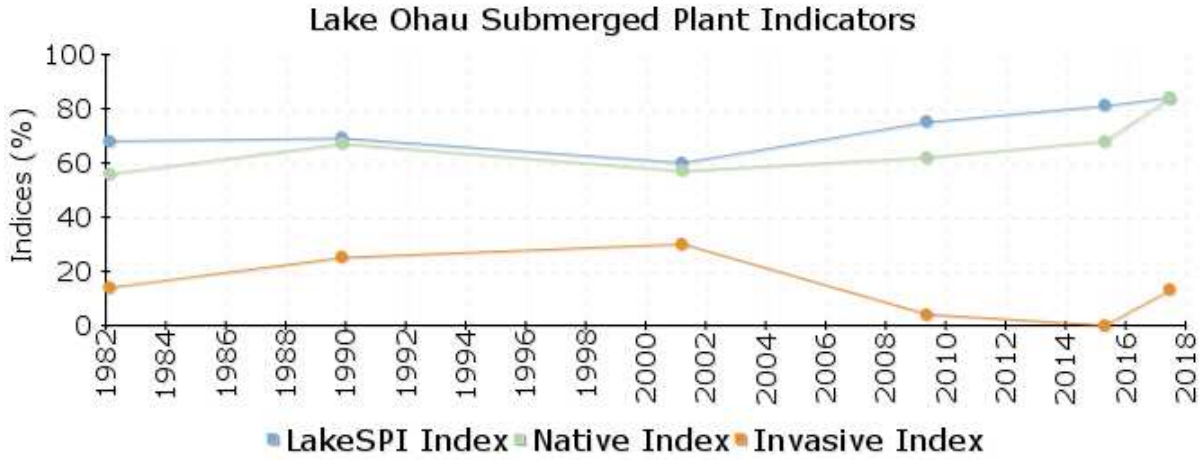
Elodea canadensis is the only invasive weed to be recorded from Lake Middleton. Most recently (2017) elodea formed closed-canopy beds and extended to depths between 5.2 and 5.5 m, usually occupying between 26 to 50% of the vegetated area at sites. Multiple survey results suggest an expansion by elodea over time in terms of cover and depth range. Elodea is now the deepest growing vegetation in Lake Middleton.

Despite the dominance of Lake Middleton by elodea up to five native submerged plant communities were recorded contributing to relatively high Native Condition Index in 2017, as in 2012 (Figure 29).

Charophyte meadows (≥75% cover) were present shallower than the main elodea bed in 2017 to depths of between 2.9 and 4.3 m. These meadows were dominated by high covers of *Chara australis*, together with locally abundant *C. fibrosa* and *Nitella pseudoflabellata*. Low covers of a milfoil and a pondweed (Table A-2) were associated with these meadows. Swards of quillwort (*Isoetes alpina*) were common in shallow water to 2.5 m depth, and accompanied in the upper part of the depth range by lower cover turf species (Table A-2).

4.6 Lake Ohau

Lake condition:	Excellent
Lake ranking	6
Stability	Improving



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
June 2017	Excellent	84%	84%	13%
April 2015	Excellent	81%	68%	0%
May 2009	High	75%	62%	4%
* March 2001	High	60%	57%	30%
* November 1989	High	69%	67%	25%
* February 1982	High	68%	56%	14%

**Results indicative only*

Figure 30: LakeSPI results for Lake Ohau. LakeSPI indices expressed as a percentage of lake maximum potential.

In 2017, Lake Ohau remained in an excellent ecological condition with a LakeSPI Index of 84% (Figure 30). There was no significant change in the LakeSPI Index from 2015, but an earlier improvement was significant between 2009 and 2015. In contrast, the Native Condition Index in 2017 shows a significant improvement from both 2015 and 2009.

This improvement in Native Condition Index is due to native charophytes being recorded above threshold covers (i.e., ≥10% cover for depth extent or ≥75% cover for meadows) to greater depths. The average depth limit for charophytes in 2017 was 16.9 m and charophyte meadows were recorded at all five surveyed sites to between 10 and 15.2 m depth. In 2015, the equivalent vegetation depth extent was 14.2 m and charophyte meadows were present at three sites, compared to a 9.5 m depth extent and charophyte meadows recorded at two sites in 2009. These results suggest an ongoing increase in long-term water clarity an improved light climate for vegetation development at depth.

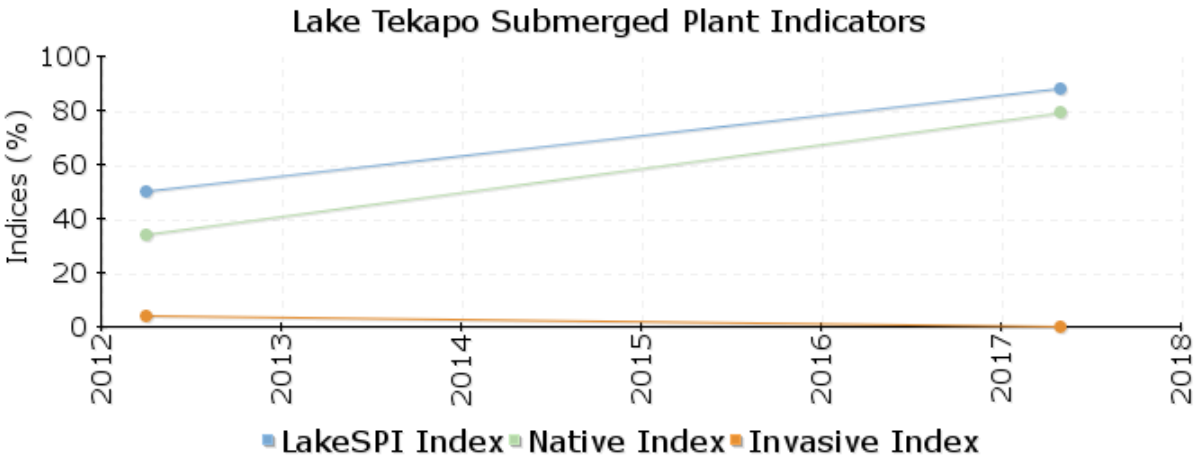
Up to five native submerged vegetation community types were recorded in 2017. Charophyte meadows were dominated by *Nitella claytonii* in deeper water and *Chara globularis or Nitella pseudoflabellata* in mid-depths. Five additional charophyte species also contributed to the vegetation composition in 2017 (Table A-2). A feature of Lake Ohau was the unusually depth extent recorded for several native plant community types in all surveys. Milfoil (*Myriophyllum triphyllum*), pondweed (*Potamogeton cheesemanii*) and quillwort (*Isoetes alpina*) were all recorded to in excess of 5 m in 2017, with quillwort recorded to 10 m depth. In contrast, turf plant species (Table A-2) occupied the usual shallow water range of <2 m depth.

Elodea canadensis has remained a minor component of the submerged vegetation in Lake Ohau during the last three surveys, being either absent from sites or recorded as occasional and occupying <5% of the vegetated area.

Submerged bryophytes were recorded in Lake Ohau in 2017, both in the shallows and in deep water to 28 m, but they do not contribute to the LakeSPI assessment method due to their limitation to deep, high clarity lakes.

4.7 Lake Tekapo

Lake condition:	Excellent
Lake ranking	4
Stability	Improving



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
April 2017	Excellent	88%	79%	0%
March 2012	Moderate	50%	34%	4%

Figure 31: LakeSPI results for Lake Tekapo. LakeSPI indices expressed as a percentage of lake maximum potential.

In 2017, Lake Tekapo was categorised in excellent ecological condition with a LakeSPI Index of 88% (Figure 31). There have been significant increases in the LakeSPI Index and Native Condition Index since 2012, when Lake Tekapo was assessed in a moderate condition.

The current (2017) excellent condition of Lake Tekapo reflects the deep extent of vegetation (≥10 % cover) to an average of 20.2 m and the presence of charophyte meadows (≥75 % cover) at all sites to an average of 17.4 m depth. Previously in 2012 the average depth of vegetation extent was 7.8 m and charophyte meadows were not recorded. These changes suggest the long-term water clarity has increased and the light climate has increased to support plant growth at greater depth.

Four charophyte species (Table A-2) were represented in 2017, with *Nitella claytonii* dominant in deeper water and *N. pseudoflabellata* or *Chara globularis* in mid-depths. Also contributing to native diversity was the widespread presence of milfoil (*Myriophyllum triphyllum*) and occasional pondweed (*Potamogeton cheesemanii*) which extended deeper than 5 m. One feature of large, wave-exposed Lake Tekapo is the absence of shallow water plant communities (e.g., no turfs or quillwort) and the deep depth minima for submerged vegetation (≥3 m depth in 2017).

Elodea canadensis was not encountered in 2017, but previously in 2012 this invasive weed was described as occasional at one site only and occupied <5% of the vegetated area.

Figure 32: The dominant submerged vegetation in Lake Tekapo. Charophyte meadows at 15 m comprising *Nitella claytonii* and *N. pseudoflabellata*.

5 LakeSPI discussion

5.1 Regional comparison of current status

Thirty-eight lakes of the Canterbury Region have now been surveyed using LakeSPI, with Lake Benmore split into separate assessments of the Ahuriri and Haldon Arms. Seven lakes have been assessed in the excellent category of lake ecological condition according to LakeSPI. This category includes Lakes Coleridge, Tennyson, Hawdon and Ida in addition to the three recently surveyed lakes listed in Table 4. Fourteen lakes have been assessed in the high LakeSPI category including Lakes Lyndon, Masonette, Mason, Sumner, Selfe, Taylor, Pearson and Waitaki, in addition to the six recently surveyed lakes Table 4). Sixteen Canterbury lakes fell into the moderate category. These include Katrine, Sarah, Georgina, Evelyn, Grasmere, Benmore (Ahuriri and Haldon Arms), Wairepo Arm and Sheppard and eight recently surveyed lakes (Table 4). Only Lake Denny was categorised in the poor category according to LakeSPI.

Table 4: Summary of current (2017) LakeSPI results. List of surveyed lakes showing: category, scores for LakeSPI Indices, surveyed lake ranking within the Canterbury Region in ascending order of condition and perceived stability based on successive surveys.

Lake_name	Category	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)	Rank in Canterbury Region*	Stability
Donne	Excellent	94	86	0	1	Stable
Tekapo	Excellent	88	79	0	4	Improving
Ohau	Excellent	84	84	13	6	Improving
Spider	High	74	79	26	8	Stable
Camp	High	65	66	31	10	Stable
Aviemore	High	64	70	42	12	Stable
Kellands Pond	High	56	60	43	19	Improving
Alexandrina	High	51	60	56	20	Stable
Middleton	High	50	77	68	21	Stable
Clearwater	Moderate	49	54	49	22	Stable
McGregor	Moderate	48	63	64	23	Stable
Maori East	Moderate	47	50	49	25	Improving
Heron	Moderate	45	49	56	27	Stable
Maori West	Moderate	37	43	72	32	Stable
Emma	Moderate	35	38	71	34	Stable
Roundabout	Moderate	34	39	74	35	Stable
Emily	Moderate	28	25	74	38	Stable
Denny	Poor	13	9	37	39	Deteriorating

**Based on LakeSPI Index value to 1 decimal place.*

The operational Canterbury Land and Water Regional Plan Volume 1[1] sets out fresh water outcomes for Canterbury lakes by 2030 in Table 1b of that document. The current LakeSPI status of lakes is compared to those outcomes in Table 5. Note that 'natural state waterbodies' (Ō Tū Wharekai lakes in DOC estate) are included in the comparison in the absence of recognised criteria for meeting a 'natural state'. On this basis 18 Canterbury lakes currently have a LakeSPI status below the desired outcomes.

[1] https://www.ecan.govt.nz/your-region/plans-strategies-and-bylaws/canterbury-land-and-water-regional-plan/

Table 5: Current LakeSPI status of thirty-eight Canterbury lakes compared to fresh water outcomes identified in the operational Canterbury Land and Water Regional Plan.

Management unit	LakeSPI (minimum grade)	Lakes currently meeting criteria	Lakes not currently meeting criteria
Natural state waterbodies*	Lakes are maintained in a natural state		
Large high country lakes	Excellent	Coleridge, Tennyson, Hawdon Tekapo, Ohau	Sumner, Heron*
Small to medium sized high country lakes	High	Ida, Donne*, Lyndon, Masonette, Mason, Selfe, Taylor, Pearson, Spider*, Camp*, Alexandrina, Middleton	Katrine, Sarah, Georgina, Evelyn, Grasmere, Sheppard, Clearwater*, McGregor, Maori East*, Maori West*, Emma*, Roundabout*, Emily*, Denny*
Artificial lakes – on-river	High	Waitaki, Aviemore	Benmore (Ahuriri and Haldon Arms), Wairepo Arm
Artificial lakes – others	Suitable for the purpose of the lake	Kellands Pond (previously suggested criteria of high)	

**Lakes within land that is administered for conservation purposes by the Department of Conservation*

5.2 National comparison of current status

The sample set of surveyed lakes in the region is unlikely to be proportionally representative of all the waterbody types, for instance no lowland lakes are included. Therefore, the following comparison must be interpreted with care.

According to results to date, the Canterbury Region has a higher proportion of lakes in the excellent, high and moderate LakeSPI category than is the case nationally (Figure 33). In contrast, lakes in poor condition are less represented in the region, and currently there are no lakes in the lowest quality category (non-vegetated) according to LakeSPI.

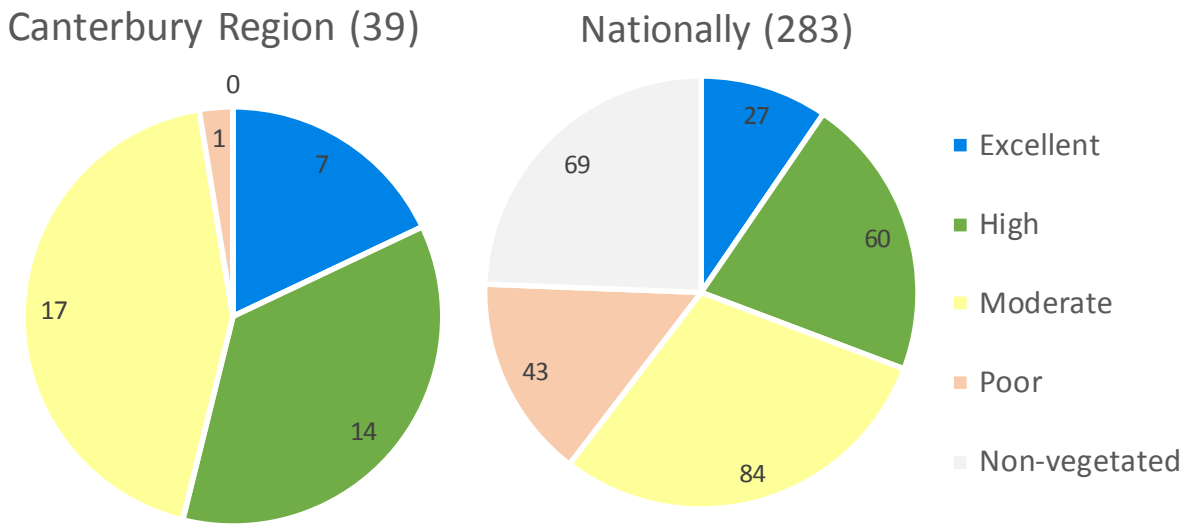


Figure 33: Composition of lakes in LakeSPI categories for the Canterbury Region and nationally. Number of lakes surveyed is given in total and for each category.

The distribution of LakeSPI Indices of the recently surveyed lakes (2017) is graphed with all surveyed lakes in Figure 34.

5.2.1 Ō Tū Wharekai lakes

Of note is the excellent LakeSPI Index for Lake Donne, placing it in the top four highest scoring lakes in New Zealand to date (Figure 34). Lake Donne is scored on a par with lakes such as Wakatipu because it scores near the maximum (pristine) state possible for this shallow tarn. A diverse vegetation extended across the entire bottom of Lake Donne, with only two submerged plant communities unrecorded (charophyte meadows and Isoetes) and a complete absence of any invasive weed species.

Lakes Spider and Camp were categorised in the high category for ecological condition according to LakeSPI. Both these lakes had invasive weed species present, but impacts were minor. Native submerged vegetation was particularly diverse in Spider Lake, with similarities to nearby Lake Donne. These attributes placed Spider Lake close to the national position for Lake Waikaremoana. Lake Camp also had a well-developed diversity of native submerged vegetation, although the absence of an *Isoetes* community and restricted depth limits provided a slight penalty for LakeSPI results.

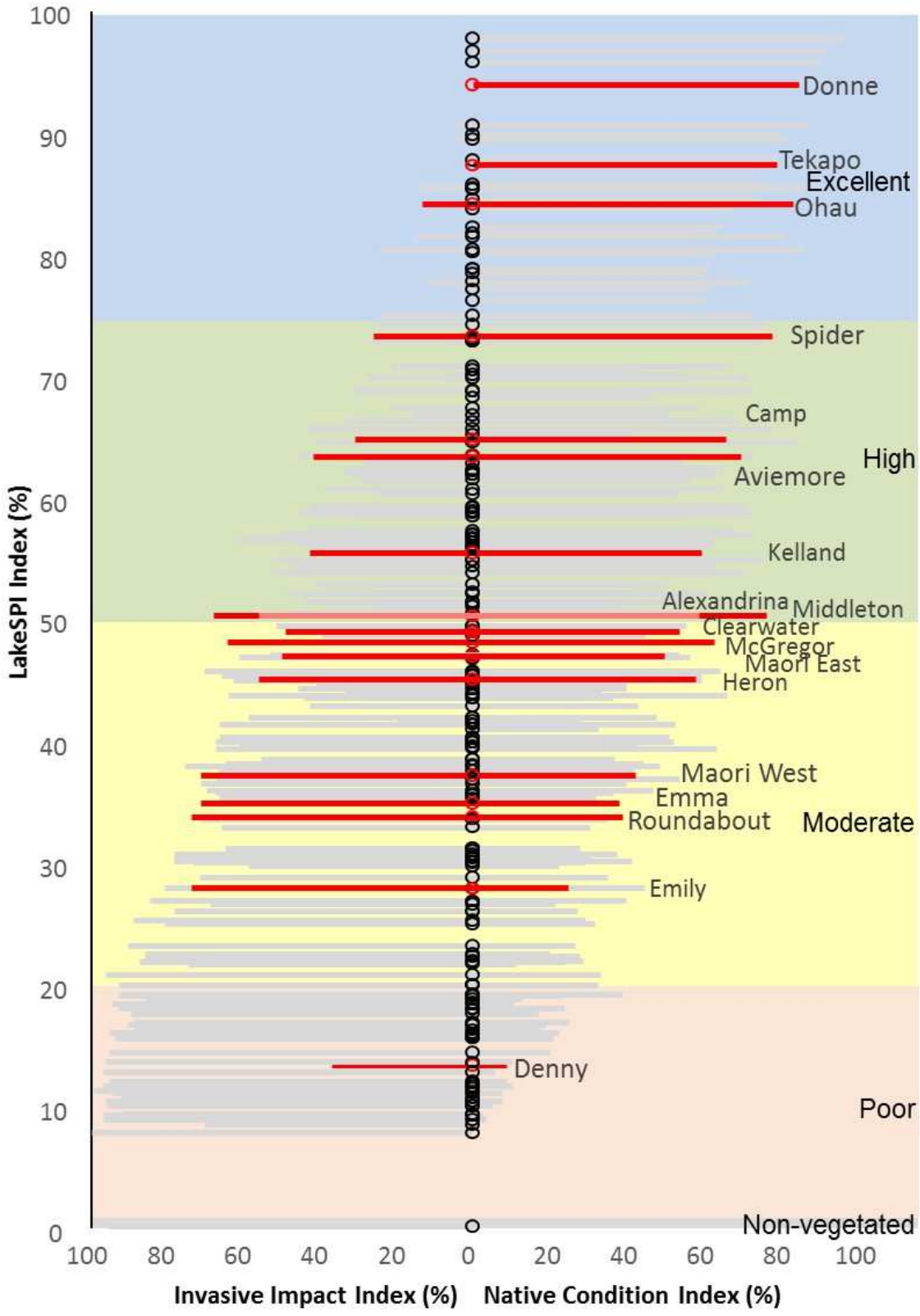


Figure 34: LakeSPI results for the 18 Canterbury lakes (red) surveyed in 2017, graphed with results for 283 New Zealand lakes (grey). The most recent LakeSPI Index is plotted on the y-axis (red points), Native Condition Index plotted as lines to the right and Invasive Impact Index lines to the left of the x-axis. Five categories of LakeSPI condition are indicated by labelled colour bands.

The majority of Ō Tū Wharekai lakes are placed in the moderate category based on the LakeSPI Index (Figure 34). These lakes could be distinguished between those where invasive weeds had a major impact (Invasive Impact Index >70%; Maori West, Emma, Roundabout, Emily) or those where restrictions to native vegetation appeared to be other than invasive weeds (Clearwater, Maori East, and some bays of Heron). Plant depth restrictions for Lake Clearwater and Lake Heron are likely due to water clarity, and for Maori East due to interactions with disturbance and a flocculent substrate providing a poor plant anchorage.

Lake Denny falls within the poor LakeSPI category. This is due to a very restricted development of vegetation in terms of depth and diversity, added to a major influence by the invasive weed elodea. Interestingly, this lake falls into the same category as many North Island lakes that have an almost exclusive occupation by invasive weeds (e.g., lower Waikato hydro-lakes).

5.2.2 Waitaki Lakes

Lakes Tekapo and Ohau were categorised as having excellent ecological condition according to LakeSPI and are within the top 15 scoring lakes in the country. Both lakes have a deep vegetation extent (> 15 m) and no or minor impacts from invasive weeds.

Lake Aviemore and Kellands Pond are within the high category for LakeSPI, but while they have similar levels of moderate weed invasion, the Native Condition Index was higher for Lake Aviemore due to the greater depth extent of vegetation and presence of charophyte meadows. Lakes Alexandrina and Middleton had an almost identical LakeSPI Index close to the lower boundary for the high condition category (LakeSPI Index of 50%). This position reflected equal influences of Native Condition Index (positive for LakeSPI) and Invasive Impact Index (Negative for LakeSPI). They score similarly to Lake Okareka in the Rotorua Lakes. Lakes McGregor also has near equal Native Condition Index and Invasive Impact Index, but fall into the moderate category for LakeSPI due to a constrained depth extent for vegetation.

5.3 Changes in status

5.3.1 Ō Tū Wharekai lakes

The majority of the Ō Tū Wharekai lakes have been stable over successive surveys from 2007, 2012 and 2017 (Table 4). The exceptions have been a deterioration detected for Lake Denny (and possibly for Maori West Lake) and an improvement for Maori East Lake. Deterioration at Lake Denny is likely to be linked to the poor water clarity observed in 2017. Considerations of land use changes (e.g., land use change observed during the 2017 visit) or other influences within the catchment of this lake are recommended. We cannot speculate on the improvement seen at Maori East Lake except to note there has likely been better growth conditions and/or reduced disturbance that has enabled greater plant colonisation of the lake bed.

The most recent survey of the Ō Tū Wharekai lakes was undertaken in February, where previous surveys have been undertaken in November. Vegetation differences attributed to the change of survey season are minor and relate mostly to plant heights and fruiting status. The LakeSPI metric most potentially influenced is measures of weed height, however, there was little evidence for increased stature of elodea over previous surveys. We did note lower water levels (as reduced depth) for a number of the small lakes and tarns. LakeSPI uses broad depth categories for scoring and there were no penalties apparent in scoring these shallower systems.

5.3.2 Waitaki Lakes

The majority of Waitaki lakes have remained stable between surveys, with the exception of detected improvement for Lakes Tekapo, Ohau and Kellands Pond. Lakes Tekapo and Ohau (with Lake Pukaki) are located at the head of the Waitaki system and fed by glaciers in Aoraki/Mount Cook National Park. There is evidence to suggest the retreat of glaciers and/or climate change results in greater light penetration in lakes because the input of glacial flour is reduced (Rose et al. 2014, Parker et al. 2008). Alternatively, recent meteorological variation may have reduced inorganic inputs. An improved long-term (> months) water clarity would account for the expansion in depth extent and development of the deepest plant community of charophytes in these lakes.

The improvement in Kellands Pond, little influenced by inputs of glacial flour, may reflect improved water clarity or a more stable environment for plant growth, resulting in the apparent increase in occupation by native plants and increased charophyte meadows.

6 Weed surveillance

No new weed incursions were detected at any of the weed surveillance sites. Brief commentary on the individual surveillance sites is given below.

6.1 Ō Tū Wharekai lakes

6.1.1 Camp

Most of the shallow bay at the boat ramp located at the north-west of the lake was checked by snorkel divers, including the enclosed swimming area with floating platform. High water clarity allowed for effective observation, however, a well-developed, tall vegetation hindered observation in some areas.

6.1.2 Clearwater

A 50 m length of shoreline either side of the boat ramp west of the camp ground was checked by snorkel/scuba to 3 m depth. This site is a relatively exposed area with hard substrates and cobble and low vegetation in the shallows. Water clarity was adequate for observations, but was noticeable reduced by wave action and sediment resuspension at the margin.

6.1.3 Additional lakes

None of the remainder of the Ō Tū Wharekai lakes had formal boat launch sites. In these cases, surveillance was carried out at the most obvious entry point for water craft/swimmers based on vehicular access points. A combination of shoreline searches and snorkel searches of the shallow margins were completed.

6.2 Waitaki Lakes

6.2.1 Aviemore

Following the establishment of lagarosiphon in the upper Aviemore system (Loch Laird and riverine portion) additional surveillance was carried out by NIWA outside of the standard sites (Sutherland and Clayton 2014) in August 2017. These checks occurred after the full shoreline surveillance and control works undertaken in February to May 2017 by contractors working for the LINZ-Meridian lagarosiphon management programme. Inspections of bottom lining of lagarosiphon at the upstream Islands in the riverine section lead to c. 20 small plants being removed by NIWA. In Loch Laird one small colony of lagarosiphon was removed from c. 70 m west of the boat ramp. A c. 2 km snorkel tow along the southern riverine bank south of Otematata did not locate any lagarosiphon, suggesting contractors efforts in removing single colonies from this area have been effective.

Surveillance of sites 3, 4, 5 and 6 were completed using free snorkelling from road access points as weather limited boat navigation. Site 2 could not be completed due blocked access (road works).

6.2.2 Alexandrina

The surveillance area incorporates the shorefront of the settlement area and boat ramp together with the point of outflow to Lake McGregor. A shoreline and wading search and scuba searches were made in this area.

6.2.3 Haldon Arm (Lake Benmore)

Four sites in the upper Haldon Arm were able to be completed using snorkel tows due to good water clarity conditions, supplemented by boat surface view in the enclosed boat harbour of Site 2.

The four sites in the mid-arm were not completed due to poor weather conditions and will be completed with spring 2017 surveillance.

6.2.4 Kellands Pond

Both sides of the culvert running between Kellands Pond and Wairepo Arm were checked by a snorkel tow along the shoreline.

6.2.5 McGregor

Surveillance sites comprise the area adjacent to the inflow from Lake Alexandrina and outflow to Lake Tekapo. A combination of scuba spot dives and snorkel tows were used to cover both these areas.

6.2.6 Middleton

The access points at the northern and southern shorelines were checked. Scuba/snorkel divers (depending on depth) using scooters provided good surveillance coverage at the boat ramp area. The northern recreational area and informal boat ramp was covered by snorkel divers in the shallows and sot dives by scuba divers.

6.2.7 Ohau

All four sites were covered using a combination of shoreline searches, snorkel tows along longer shorelines and scuba divers on scooters around access points structures such as boat ramps or beach launch areas.

6.2.8 Ruataniwha

Free snorkel and snorkel with scooter was used to cover the enclosed boat launch sites along the northern shoreline A shoreline search was completed along foreshore by Kate Cameron Drive. A snorkel tow was undertaken around the perimeter of the Site 4 bay on the southern shore.

6.2.9 Tekapo

The surveillance site along the shoreline in front of the township is very wave exposed and comprises hard packed substrate with no macrophyte vegetation. This makes surveillance quick and effective but this does not represent a likely location for establishment of new weeds. With indicated increase in water clarity (Section 4.7) increases in weed establishment risk for this lake are possible. A shallow bay adjacent to the outflow from Lake McGregor was suggested for surveillance only in the event of a weed incursion in Lakes Mc Gregor or Alexandrina.

6.2.10 Wairepo Arm

A snorkel tow was made around the periphery of the arm.

6.2.11 Waitaki

Water clarity was extremely poor due to high winds at the time of the scheduled work. While site 3 was able to be completed, effectiveness of surveillance under poor conditions was questionable. Sites 1 and 2 were not completed.

7 Recommendations

- Carry out a LakeSPI survey in both arms of the Lake Benmore (Ahuriri and Haldon), which are overdue according to the schedule in Table 6: The lakes would add further data for identifying trends for lake clarity in the upper Waitaki system.
- Lake Waitaki LakeSPI and surveillance was unable to be completed in 2017 due to weather conditions and will be added to any commissioned work for 2018.
- Complete LakeSPI surveys for Craigieburn lakes that are due or overdue for survey according to the schedule in Table 6: These are Lakes Evelyn, Ida, Lyndon, Pearson, Hawdon, Grasmere and Sarah.
- Review the surveillance sites for Lake Aviemore and Waitaki in light of recent lagarosiphon incursions in the upstream riverine section of Lake Aviemore.
- Identify possible best practice protective works at Lake Denny to safeguard water quality (i.e., complete fencing, plant the steep, eroded southern face, review of land use practices in catchment).

Table 6: Recommended LakeSPI and weed surveillance schedule for Canterbury waterbodies.

Lake	LakeSPI assessment date	Recommended resurvey	Surveillance status	Recommended surveillance frequency
Alexandrina	2017	2022	High value, low risk	Biennial (due 2019)
Aviemore	2017	2022	High risk	6 monthly
Benmore - Haldon Arm	Jan 2012	2014	Weed control activities	6 monthly
Benmore - Ahuriri Arm	2013	2015	Weed control activities	6 monthly
Camp	2017	2022	High risk	Annual
Clearwater	2017	2022	High value, low risk	5- yearly (due 2022)
Coleridge	2014	2019	High risk	Annual
Denny	2017	2022	Low risk	5- yearly (due 2022)
Donne	2017	2022	Low risk	5- yearly (due 2022)
Emily	2017	2022	Low risk	5- yearly (due 2022)
Emma	2017	2022	Low risk	5- yearly (due 2022)
Evelyn	2014	2016	Low risk	5- yearly (due 2017)
Georgina	2015	2020	Low risk	3 -yearly (due 2018)
Grasmere	2013	2018	Low risk	5- yearly (due 2018)
Hawdon	2013	2018	High value, low risk	5- yearly (due 2018)
Heron	2017	2022	Moderate risk	3 -yearly (due 2020)
Ida	2010	2015	Low risk	5- yearly (due 2017)
Katrine	2016	2021	High value, low risk	5- yearly (due 2021)
Kellands	2017	2022	Moderate risk	Annual
Lyndon	2013	2018	High value, low risk	5- yearly (due 2018)
Maori West	2017	2014	Low risk	5- yearly (due 2022)
Maori East	2017	2022	Low risk	5- yearly (due 2022)
Mason	2016	2021	High value, low risk	5- yearly (due 2021)
McGregor	2017	2022	Moderate risk	Annual
Middleton	2017	2022	High risk	Annual
Ohau	2017	2022	High risk	Annual
Pearson	2013	2018	High risk	Annual
Roundabout	2017	2022	Low risk	5- yearly (due 2022)
Ruataniwha	-	-	High risk	Annual
Sarah	2013	2016	Low risk	3- yearly (due 2017)
Selfe	2014	2019	High value, low risk	5- yearly (due 2020)
Sheppard	2016	2021	Low risk	5- yearly (due 2021)
Spider	2017	2022	Low risk	5- yearly (due 2022)
Sumner	2016	2021	High value, low risk	5- yearly (due 2021)
Taylor	2016	2021	High value, low risk	5- yearly (due 2021)
Tekapo	2017	2022	Low risk	Annual
Tennyson	2012	2017	High value, low risk	5- yearly (due 2017)
Waitaki	2015	2018*	High risk	6 monthly
Wairepo Arm	2014	2016	High risk	Annual

**Unable to be completed in 2017 and deferred to 2018.*

8 Acknowledgements

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9 References

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Appendix A Table of aquatic plant species records

Table A-1: Aquatic plant species recorded in the Ō Tū Wharekai lakes in 2017.

Species	Camp	Clearwater	Denny	Donne	Emily	Emma	Heron	Maori East	Maori West	Roundabout	Spider
Turf plants											
Crassula sinclairii	✓										
Eleocharis acuta											✓
Eleocharis pusilla		✓			✓		✓	✓			✓
Elatine gratioloides		✓		✓	✓		✓				
Glossostigma diandrum					✓		✓	✓		✓	✓
Isoetes alpina		✓			✓	✓	✓				
Lilaeopsis ruthiana	✓	✓		✓	✓	✓	✓			✓	✓
Pilularia novae-hollandiae					✓						
Ranunculus limosella	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Utricularia dichotoma					✓						
Tall vascular plants											
**Elodea canadensis*	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Myriophyllum triphyllum	✓	✓		✓		✓	✓		✓	✓	✓
Myriophyllum propinquum				✓							✓*
Potamogeton cheesemanii	✓	✓		✓	✓		✓		✓		✓
Potamogeton ochreatus		✓		✓		✓	✓	✓		✓	✓
**Ranunculus trichophyllus*						✓				✓	✓*
Ruppia polycarpa	✓			✓			✓	✓			✓
Stuckenia pectinata						✓					
Charophytes											
Chara australis	✓	✓				✓	✓		✓	✓	✓
Chara fibrosa	✓	✓		✓			✓				✓
Chara globularis	✓	✓					✓				

Species	Camp	Clearwater	Denny	Donne	Emily	Emma	Heron	Maori East	Maori West	Roundabout	Spider
Nitella claytonii							✓				
Nitella sp. aff. *cristata*		✓					✓				
Nitella hyalina	✓	✓				✓	✓		✓		✓
Nitella leonhardii	✓	✓									
Nitella masonae						✓					
Nitella pseudoflabellata	✓	✓		✓			✓		✓		✓
Nitella stuartii							✓				
Nitella tricellularis	✓			✓			✓				

*Invasive weeds.

Table A-2: Aquatic plant species recorded in the Waitaki lakes in 2017

Species	Alexandrina	Aviemore	Kellands	McGregor	Middleton	Ohau	Tekapo
Turf plants							
Crassula sinclairii							
Eleocharis acuta			✓				
Eleocharis pusilla		✓	✓	✓			
Elatine gratioloides		✓	✓			✓	
Glossostigma elatinoides	✓						
Glossostigma diandrum	✓	✓	✓	✓	✓	✓	
Hydrocotyle hydrophila							
Isoetes alpina	✓			✓	✓	✓	
Lilaeopsis ruthiana	✓	✓	✓	✓	✓	✓	
Limosella lineata							
Myriophyllum pedunculatum							
Pilularia novae-hollandiae							
Ranunculus limosella			✓	✓	✓		
Utricularia dichotoma							
Tall vascular plants							
Elodea canadensis	✓	✓	✓	✓	✓	✓	
Myriophyllum triphyllum	✓	✓	✓	✓	✓	✓	✓
Myriophyllum propinquum			✓	✓	✓	✓	
Potamogeton cheesemanii	✓	✓	✓	✓	✓	✓	✓
Potamogeton ochreatus	✓	✓	✓	✓			
Ranunculus trichophyllus	✓	✓	✓	✓			
Ruppia polycarpa							
Charophytes							
Chara australis	✓	✓	✓	✓	✓	✓	✓
Chara fibrosa	✓			✓	✓	✓	
Chara globularis	✓	✓	✓	✓		✓	✓

Species	Alexandrina	Aviemore	Kellands	McGregor	Middleton	Ohau	Tekapo
Nitella claytonii		✓				✓	✓
Nitella sp. aff. *cristata*		✓	✓				
Nitella hyalina	✓	✓		✓		✓	
Nitella leonhardii		✓	✓			✓	
Nitella masonae							
Nitella pseudoflabellata	✓	✓	✓	✓	✓	✓	✓
Nitella stuartii	✓						
Nitella subtilissima							
Nitella tricellularis						✓	
Unidentified bryophytes	✓					✓	