Assessment of the Rotorua Te Arawa lakes using LakeSPI - 2014

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Authors/Contributors:

Tracey Burton
John Clayton

For any information regarding this report please contact:

Tracey Burton
Freshwater Ecologist
+64-7-8569 1852
tracey.burton@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
Gate 10, Silverdale Road
Hillcrest, Hamilton 3216
PO Box 11115, Hillcrest
Hamilton 3251
New Zealand

Phone +64-7-856 7026
Fax +64-7-856 0151

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Reviewed by

M. de Winton

Approved for release by

D. Roper

Formatting checked by

Executive summary

NIWA is contracted by Bay of Plenty Regional Council (BOPRC) to assess the ecological condition of 12 Rotorua Te Arawa lakes using LakeSPI (Submerged Plant Indicators). The LakeSPI method provides a quick and cost-effective bio-assessment tool for monitoring and reporting on the ecological condition of lakes. It allows lake managers to assess and report on the status of lakes at an individual, regional or national level; monitor change in a lake or group of lakes over time and prioritise lake management initiatives accordingly (e.g., protection, monitoring, weed surveillance). LakeSPI is recommended by the Ministry for the Environment as one indicator for State of the Environment (SOE) reporting.

Six lakes (Okataina, Rerewhakaaitu, Rotoehu, Rotokakahi, Tarawera and Tikitapu) were surveyed in 2014, and the remainder (Okareka, Okaro, Rotoma, Rotomahana, Rotoiti and Rotorua) were previously surveyed in 2013. This report provides an update on lake ecological condition and considers the changes evident in LakeSPI Indices over a recent time-frame since 2009 (4 to 5 years) and long-term (26-41 years).

LakeSPI results show many of the Rotorua Te Arawa Lakes have undergone significant change over the long-term and continue to be vulnerable to further changes from invasive plants and water quality deterioration. Lakes Rotomahana and Tarawera show the biggest change in lake condition over the long-term on account of impacts from invasive plant species; while the second biggest change to affect the Rotorua Lakes has been from changing water quality in Rotokakahi and Tikitapu.

Present day LakeSPI Indices for lakes in the Rotorua region ranged widely from 18% to 55% with one Rotorua Te Arawa lake assessed as being in ‘high’ condition, ten lakes as ‘moderate’ and one lake categorised as in ‘poor’ condition. None of the 12 Rotorua Te Arawa lakes were recorded in the ‘excellent’ or ‘non-vegetated’ categories.

Lake Rotoma is categorised as being in ‘high’ condition and has been stable. This is an exceptional lake and although it appears to maintain high water quality, it remains under serious threat from potential hornwort invasion. This would have a major detrimental impact on the native character and biodiversity value of this lake.

Lakes Tikitapu, Rotomahana, Okataina, Rerewhakaaitu, Okareka, Okaro, Rotokakahi, Tarawera, Rotorua and Rotoiti are currently ranked as being in ‘moderate’ condition. Lake Tikitapu is showing some signs of recent improvement, however longer term values show a significant reduction in the Native Condition values. Lake Rotomahana has undergone significant change due to invasion by egeria and hornwort and is expected to decrease further in ranking over time. LakeSPI results for Lake Rotomahana show the largest decline recorded in any of the Rotorua lakes since 2008. Lake Okataina appears to maintain high water quality and has been stable, but the presence of hornwort now in the lake poses a serious threat to future lake condition. Lake Rerewhakaaitu currently appears to be in a stable condition with possible early signs of improvement. Although the overall condition of Lake Okareka has remained stable over the long-term, the recent discovery of hornwort in the lake in March 2012 raises concern for future condition. If hornwort becomes established in Lake Okareka we can expect it to displace all native charophyte meadows in this lake. Lake Rotokakahi has shown substantial deterioration over the long-term, but has been more stable recently. Lakes Rotokakahi and Tikitapu, have both seen a reduction in the diversity and extent of native plant communities present, without any direct change in invasive weed

presence or increased performance. Lake Tarawera has remained in a stable state since 2008, following the complete invasion of this lake by hornwort that caused reductions in lake condition over the longer-term. Lake Rotorua has also remained stable, in a moderate condition. Although categorised in moderate condition Lake Rotoiti sits very close to the 'poor' category boundary.

Lake Rotoehu is classified as being in a 'poor' condition. This lake has the lowest LakeSPI Index and the highest Invasive Impact Index recorded for any of the 12 Rotorua Te Arawa lakes. Invasion by hornwort has seen the lake condition decline in the long-term and some small recent changes in invasive status are evident.

Compared to the lakes that have been assessed nationally, the Rotorua region is under-represented in the high (1 lake) to excellent categories. As is the case nationally, most Rotorua Te Arawa Lakes (10 lakes) fell into the group of lakes classified as being in 'moderate' condition. However, the Rotorua Te Arawa Lakes were also under represented in the poor (1 lake) and non-vegetated (no lakes) categories, that tend to represent those with extensive invasion and dominance by one of the country's worst weeds, hornwort, and/or compromised water quality.

Recommendations made in this report are as follows:

To gain further understanding of the overall state of the Bay of Plenty Region, it is suggested that one-off surveys be completed for lakes with no or limited information. Knowing their current condition will provide a better understanding of the regions diversity of lakes and factors that influence macrophyte presence. Benefit of any further longer term monitoring should be considered relative to assessed values and risks.

Additionally, full lake vegetation surveys (Clayton 1983) of the 12 Rotorua Te Arawa lakes have not been carried out since 1988. These full surveys differ from the LakeSPI monitoring method in that they result in a comprehensive species list, as well as detailed information on species frequency and distribution, species cover and height in relation to depth and various other analyses. It is recommended that full vegetation surveys be repeated in combination with new sonar vegetation mapping technology to provide a detailed description of the submerged vegetation in these lakes.

1 Introduction

1.1 Background

Bay of Plenty Regional Council (BOPRC) are responsible for implementing central government's national policy statement for freshwater management to manage freshwaters and land around freshwater in an integrated and sustainable way (http://www.boprc.govt.nz/environment/water/managing-freshwater/). The Rotorua Te Arawa Lakes are stated as priorities under BOPRC's Ten Year Plan 2012-2022 and ongoing monitoring is identified as one of the key features of the long-term implementation program.

Since 2005, NIWA has been contracted by BOPRC to assess the ecological condition of 12 Rotorua Te Arawa lakes using LakeSPI (Submerged Plant Indicators). The LakeSPI method provides a quick and cost-effective bio-assessment tool for monitoring and reporting on the ecological condition of lakes. It allows lake managers to assess and report on the status of lakes at an individual, regional or national level; monitor changes in a lake or group of lakes over time and prioritise lake management initiatives accordingly (e.g., protection, monitoring, weed surveillance). LakeSPI is recommended by the Ministry for the Environment as one indicator for State of the Environment (SOE) reporting.

LakeSPI monitoring of the Rotorua Te Arawa lakes using established baseline sites was first completed between September 2003 and March 2005 (Clayton et al. 2005). Since this time the lakes have been surveyed biennially, ensuring each lake is re-assessed every two years.

This report presents updated LakeSPI results for lakes Okataina, Rerewhakaaitu, Rotoehu, Rotokakahi, Tarawera and Tikitapu assessed in March 2014, and lakes Okaro, Okareka, Rotoiti, Rotoma, Rotomahana and Rotorua last assessed in 2013 (Edwards and Clayton, 2013).

1.2 Study lakes

The lakes assessed in this report are collectively termed the 'Rotorua Te Arawa lakes'. This term refers to the 12 largest lakes in the Rotorua region managed through the Rotorua Te Arawa Lakes Programme, a partnership created by the Bay of Plenty Regional Council, Rotorua District Council and Te Arawa Lakes Trust (www.rotorualakes.co.nz). The 12 Rotorua Te Arawa lakes include: Okareka, Okaro, Okataina, Rerewhakaaitu, Rotoehu, Rotoiti, Rotokakahi, Rotoma, Rotomahana, Rotorua, Tarawera, and Tikitapu. The location of these lakes is indicated in Figure 1.

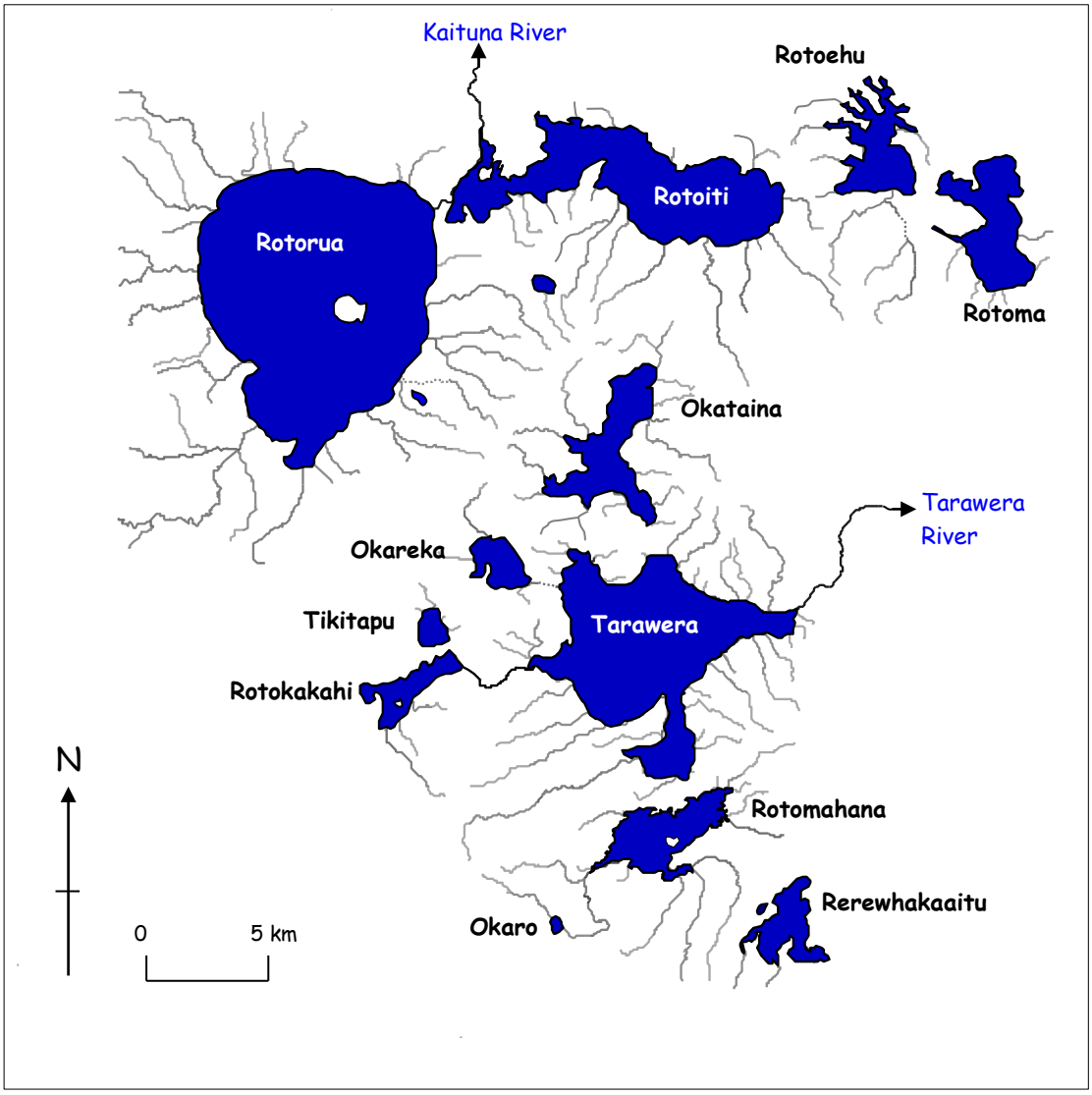


Figure 1: Map showing location of the 12 Rotorua Te Arawa lakes.

In addition to these 12 Rotorua Te Arawa lakes, 3 other lakes (Matahina, Aniwhenua, Pupuwharau) from within the Bay of Plenty Region have also been surveyed and results for these lakes can be found on the LakeSPI web reporting website at www.lakespi.niwa.co.nz.

Table 1: Summary of lake characteristics.

Lake	Maximum Depth (m)	Mean Depth (m)	Size (km^2)	Catchment Area (km^2)
Ōkāreka	33.5	20	3.33	19.6
Ōkaro	18	12.5	0.33	3.9
Ōkataina	78.5	39.4	10.8	59.8
Rerewhakaaitu	15.8	7	5.8	37.0
Rotoehu	13.5	8.2	8.1	49.2
Rotoiti	125	31.5	34.6	123.7
Rotokakahi	32	17.5	4.5	19.7
Rotomā	83	36.9	11.2	27.8
Rotomahana	125	60	9.0	83.3
Rotorua	44.8	11	80.8	508.0
Tarawera	87.5	50	41.7	143.1
Tikitapu	27.5	18	1.5	6.2

1.3 History of the Rotorua Lakes

1.3.1 Geophysical changes

The Rotorua Lakes District contains a diverse range of geologically young water bodies formed from volcanic activity, with the youngest, Lake Rotomahana having been substantially modified and enlarged by the 1886 Tarawera eruption.

Chapman (1970) noted that until the 1900s most of the catchments were densely forested with native trees or covered in manuka scrub. Clearing and planting of *Pinus radiata* forests began in the early 1900s with sawmilling starting around 1940. Farming was slower to prosper on account of “bush sickness” but once the problem of cobalt deficiency was identified and resolved in the mid-1930s, large-scale sheep, beef and dairy farming conversion took place in the late 1940s and 1950s.

Urban development combined with sewage waste disposal, intensification of land uses and tourism have all contributed to nutrient enrichment problems and associated eutrophication of the Rotorua Te Arawa lakes.

1.3.2 Lake vegetation changes

The Rotorua Te Arawa lakes have been significantly affected by changes both in water quality and through the introduction of invasive aquatic plants. Deterioration in the condition of the Rotorua Te Arawa Lakes has been occurring for many years (White 1977, Rutherford 1984, Vincent et al. 1984). Parallel deterioration in the extent of aquatic vegetation and presence of key native submerged species has also been recorded from the 1960s to the 1980s (Coffey & Clayton 1988). Land use practices have led to a progressive deterioration in water clarity, reducing the depth to which vegetation can grow. There are some exceptions to this general trend of deteriorating water quality and clarity as evidenced by Lake Rotoma, which appears to have retained a constant maximum vegetated depth limit since the early 1970s. Lake Rerewhakaaitu saw a period of improved water clarity and a corresponding increase in the depth of submerged vegetation over earlier investigations.

The second important factor affecting the aquatic vegetation in the Rotorua Te Arawa Lakes is the introduction of a range of invasive plant species (Figure 2). The first 'oxygen weed' species (family Hydrocharitaceae) to establish in the Rotorua Te Arawa lakes was *Elodea canadensis*, followed by *Lagarosiphon major*. Elodea is likely to have established in Lake Rotorua during the 1930s, given that the Ngongotaha trout hatchery had 'oxygen weed' in their hatchery around that time and ponds were flushed annually into the Ngongotaha Stream, which flows into the lake (Chapman 1970). By the mid-1950s lagarosiphon had appeared in Lake Rotorua and by 1957 it was recorded in Lake Rotoiti. By the late 1950s major weed problems were apparent in these two lakes, particularly from lagarosiphon. From 1958, large onshore accumulations of weed drift occurred after storms, resulting in an aquatic weed nuisance unprecedented in New Zealand. Lagarosiphon appears to have spread rapidly through many of the Rotorua Te Arawa Lakes, with Lakes Rotoma, Okataina and Tarawera likely to have been colonised in the mid to late 1960s (Coffey 1970, Brown & Dromgoole 1977, Clayton 1982). Invasion of lakes further away from the epicentre of introduction occurred later, with Lake Rerewhakaaitu estimated to have been invaded in the mid-1980s.

Hornwort (*Ceratophyllum demersum*) was first recorded in Lake Rotorua in 1975 and *Egeria densa* in 1983 (Wells & Clayton 1991), and both of these species have continued to spread to other lakes. The impact of egeria on the Rotorua lakes has been less than expected; in contrast to the impact from hornwort, which has exceeded all expectations with this species now ranked as New Zealand's worst widespread submerged aquatic plant pest.

The spread of significant invasive weed species into the remaining Rotorua Te Arawa Lakes is a gradual and on-going process, and there is a strong correlation with boat traffic and lake accessibility, with early weed introduction mainly at boat ramps (Johnstone et al. 1985). Lake Rotomahana was the last of the large lakes to remain relatively weed free which had been attributed to its remote location and difficult public access, but the discovery of egeria and hornwort around boat launching areas in 2007 highlights the ease and speed that invasive weeds can establish. Although Lake Rotokakahi is widely impacted by elodea it is now the only well vegetated Rotorua lake to remain free of the worst invasive weed species (lagarosiphon, egeria and hornwort), primarily attributable to its restricted public access due to its sacred status to Te Arawa.

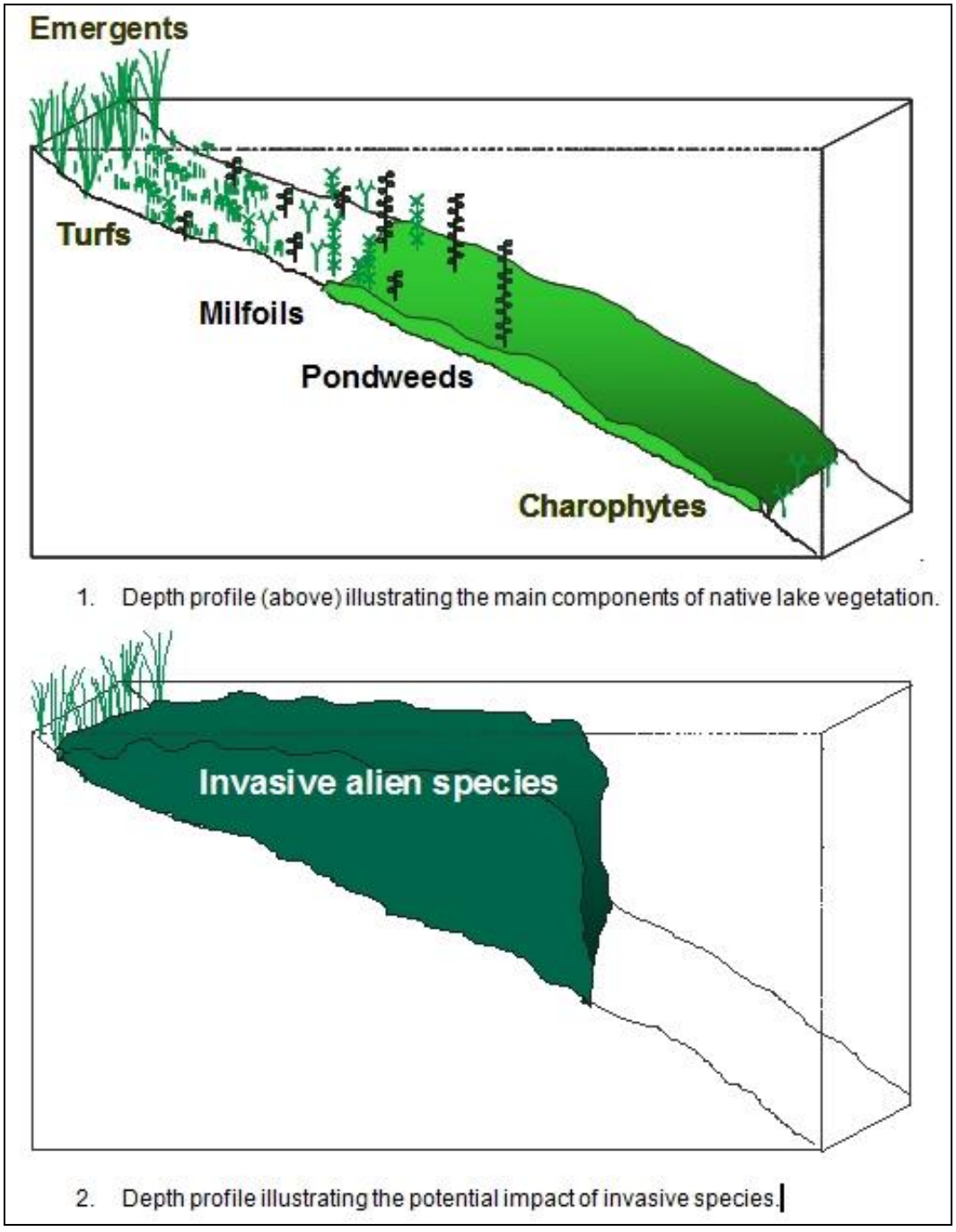


Figure 2: Depth profiles within a lake illustrating the difference between a lake maintaining native plant communities and that which is invaded with invasive weed species.

2 Study methods

2.1 LakeSPI

LakeSPI is a management tool that uses Submerged Plant Indicators (SPI) for assessing the ecological condition of New Zealand lakes and for monitoring trends. 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 & Edwards 2006b).

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

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

2.2 Field surveys

The LakeSPI method was reapplied at five established baseline sites within each of the six lakes re-assessed for this year: Okataina, Rerewhakaaitu, Rotoehu, Rotokakahi, Tarawera and Tikitapu; assessed in March 2014.

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.

2.3 LakeSPI stability

Changes in LakeSPI indices over a recent time-frame, taken as since 2009 (i.e., the last four to five years or three surveys), provide an indication of current stability in lake condition and the direction of any change. Guidelines (Figure 3) based on 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.

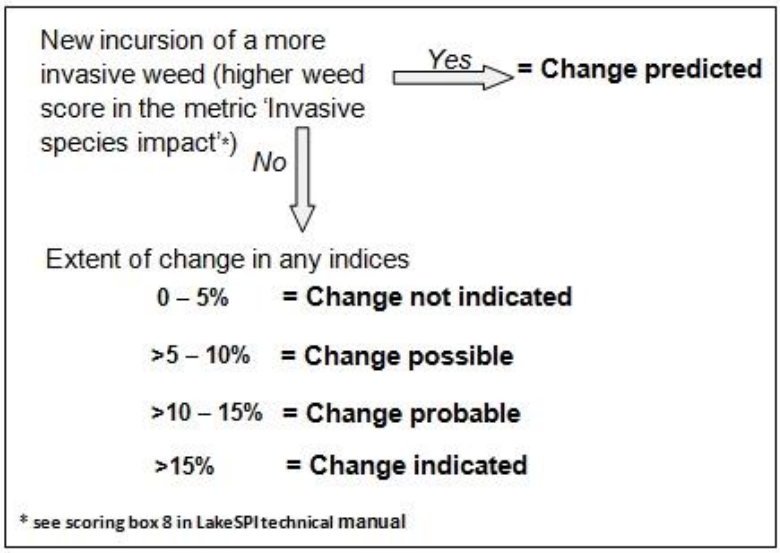


Figure 3: Guidelines for assessing the significance of change in LakeSPI Indices over multiple surveys of a lake.

In addition, the likelihood of an ecologically 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 a significance level $p < 0.05$.

2.4 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

3 Results

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

Table 2: Summary of current LakeSPI indices for 12 Rotorua Te Arawa lakes in order of their overall lake condition (2013 or 2014).

Lake	Most Recent LakeSPI Survey	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)	Overall Condition
Rotoma	16/04/2013	55	57	42	High
Tikitapu	05/03/2014	45	37	40	
Rotomahana	15/04/2013	42	48	59	
Okataina	5/03/2014	40	42	63	
Rerewhakaaitu	4/03/2014	40	53	72	
Okareka	15/04/2013	36	41	70	Moderate
Okaro	15/04/2013	35	25	49	
Rotokakahi	5/03/2014	26	19	77	
Tarawera	4/03/2014	25	29	87	
Rotorua	12/06/2013	23	25	82	
Rotoiti	15/04/2013	21	31	91	
Rotoehu	5/03/2014	18	25	92	Poor

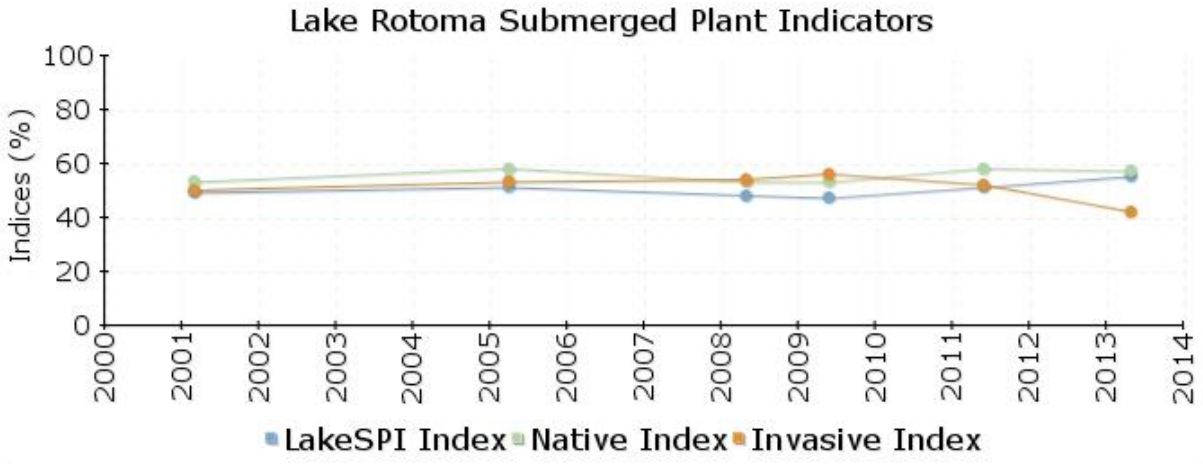
3.1 Lake Rotoma

Lake condition: High

Stability: Stable

Lake ranking: 1st

Lake Rotoma is the highest ranked lake in the Rotorua region and is categorised as being in high ecological condition with a LakeSPI Index of 55% (Figure 4).



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
April 2013	High	55%	57%	42%
May 2011	High	51%	58%	52%
May 2009	Moderate	47%	53%	56%
April 2008	Moderate	48%	53%	54%
March 2005	High	51%	58%	53%
February 2001	Moderate	49%	53%	50%
November 1988	Moderate	50%	52%	47%
January 1973	High	69%	63%	19%

Figure 4: LakeSPI results for Lake Rotoma. LakeSPI Indices expressed as a percentage of lake maximum potential.

LakeSPI scores for lake Rotoma have remained stable over the last 25 years, from 1988 – 2013. An insignificant increase in the LakeSPI Index during the recent survey resulted from lower abundance of the weed lagarosiphon at some baseline sites. Lagarosiphon is still the

dominant invasive plant species in Lake Rotoma, growing down to a maximum depth of 6.1 meters.

The proximity of hornwort in Lake Rotoehu continues to raise particular concern over the risk of spread to Lake Rotoma, with contaminated boat traffic representing the greatest threat.

Historical notes - Lake Rotoma was retrospectively calculated to have a high LakeSPI score in 1973, which reflected the early stage of lagarosiphon invasion and the extensive high cover charophyte meadows in this lake (Clayton 1978). By 1988 the Invasive Impact Index had more than doubled, and the Native Condition Index decreased, which in turn reduced the LakeSPI score for this lake. Since then, changes have been minor. As a result this lake presently has the highest Native Condition Index for any of the lakes and one of the lowest Invasive Impact Indices which contributes to its high LakeSPI ranking.

In 1972 an underwater marker buoy was placed at the bottom boundary of submerged plant growth at one of the five LakeSPI baseline sites. Despite some water level fluctuations since that time this buoy still accurately marks the deepest plant boundary in 2013 after 40 years, which provides good evidence for the stability in water clarity during this period. This confirms that the impact of invasive species on submerged vegetation was the key early driver of change in LakeSPI scores.

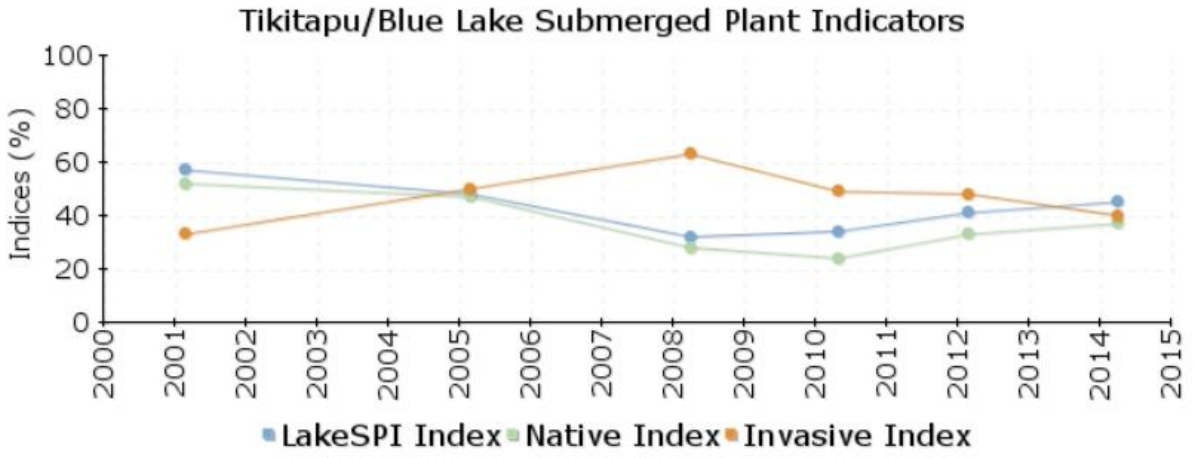
3.2 Lake Tikitapu

Lake condition: Moderate

Stability: Improving?

Lake ranking: 2nd

Lake Tikitapu is categorised as being in moderate ecological condition with a LakeSPI Index of 45% (Figure 5).



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2014	Moderate	45%	37%	40%
February 2012	Moderate	41%	33%	48%
April 2010	Moderate	34%	24%	49%
March 2008	Moderate	32%	28%	63%
February 2005	Moderate	48%	47%	50%
February 2001	High	57%	52%	33%
November 1988	High	63%	75%	47%

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

Some level of recent recovery in lake condition may be indicated, but caution must be used when interpreting recent results. Recent changes in LakeSPI scores are partially driven by the intermittent development of deep water native charophytes at depths of between 16 and

20 m. The variable nature of these charophytes greatly extends the otherwise shallow depth limit of vegetation in Lake Tikitapu which during the 2014 survey was only 2-3 m. Deep water charophytes were present at 3 of the 5 LakeSPI sites in 2014 extending down to a maximum depth of 19.3m. LakeSPI scores further benefited during the most recent survey from deep water charophyte covers exceeding 75% at one site, generating a “charophyte meadow” score for the first time in Lake Tikitapu since 2008.

Lower abundance, cover and depth range of the invasive weed lagarosiphon have recently reduced the Invasive Impact scores although these changes were not quite statistically significant. Lake Tikitapu now has the lowest Invasive Impact Index (40%) of any of the Rotorua Te Arawa lakes.

Longer term however, LakeSPI values show a significant reduction in the Native Condition Index compared to 26 years ago (Figure 5) reflecting a decline in the diversity and extent of the native plant communities present. Unlike most other lakes, this reduction has not been due to the impact from new invasive species.

Historic notes - Past records for Lake Tikitapu also confirm the lake has been deteriorating over time. Brown (1975) stated that charophytes in Lake Tikitapu formed a dense “meadow with 100% ground cover at depths from 4 to 20 m”, with a “dissected meadow” between 20-25 m (Coffey 1970). By the 1988 survey, Clayton et al. (1990) reported “charophyte vegetation was not continuous throughout its reported depth range, with typically few plants found between 11-16 m water depth”, even though covers of up to 100% were still recorded either side of this low cover zone down to a maximum depth of 20.5 m. Since 2008 maximum plant depths across survey sites have been variable, with large un-vegetated areas occurring upslope of any deeper charophyte development.

When the water chemistry of Lake Tikitapu was assessed in the early 1970s it had the lowest alkalinity recorded for any of the Rotorua Te Arawa lakes and it also had low sediment and water nutrient levels (McColl 1972). The reported low alkalinity, calcium and silicon levels may explain the on-going absence of kakahi, the low abundance of snails, koura and planktonic diatoms and even the unusual low stature and lax growth habit of lagarosiphon in this lake.

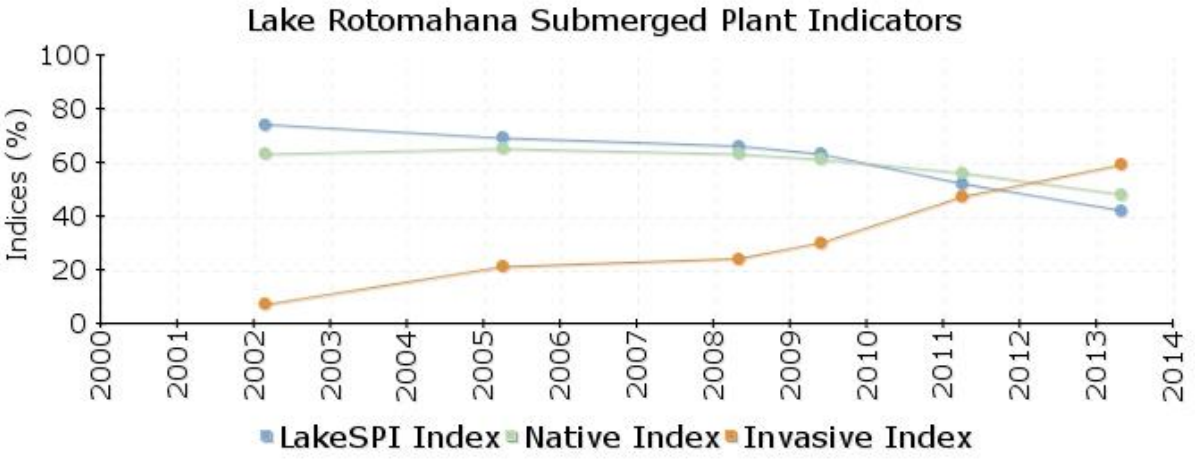
3.3 Lake Rotomahana

Lake condition: Moderate

Stability: Declining

Lake ranking: 3rd

Lake Rotomahana is categorised as being in moderate ecological condition with a LakeSPI Index of 42% (Figure 6).



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
April 2013	Moderate	42%	48%	59%
March 2011	High	52%	56%	47%
May 2009	High	63%	61%	30%
April 2008	High	66%	63%	24%
March 2005	High	69%	65%	21%
February 2002	High	74%	63%	7%
November 1988	High	72%	64%	13%

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

After being the highest ranked lake in the Rotorua region for more than 20 years, declining lake condition has resulted in Lake Rotomahana moving into third rank order. The LakeSPI Index has dropped 24% since 2008 which is the largest change recorded for any of the 12

Rotorua Te Arawa lakes over this recent time frame and Invasive Impact scores have more than doubled. This is largely due to the invasion and continued spread by two of New Zealand's worst aquatic plant species, egeria and hornwort. Discovered for the first time in April 2007, egeria was found to be established in only two areas of the lake, at the north-eastern end and in the southern embayment, while hornwort fragments were found growing amongst native plants in the southern embayment (Clayton & de Winton, 2007; Scholes and Bloxham, 2008). Since then both species have continued to spread, with hornwort now present at 2 of the 5 LakeSPI baseline sites and egeria at all 5 LakeSPI baseline sites. Egeria is now forming intermittent bands of weed growth in shallow waters down to a maximum depth of 6.9 m. The most recently recorded average maximum depth of vegetation (9.3 m) had reduced by more than 2 m since the 2009 survey when aquatic vegetation was recorded down to an average maximum depth of 11.4 m. This reduction in the depth and extent of vegetation is concerning and as both egeria and hornwort continue to further impact on the diversity and quality of indigenous plant communities in Lake Rotomahana, we can expect to see the Native Condition Index decline further while the Invasive Impact Index will continue to increase.

The presence of *Lymnaea auricularia* (ear pond snail), discovered and already widespread during the 2011 survey, suggests an aquarium or ornamental pond source for egeria, hornwort and the ear pond snail, or possibly a deliberate release.

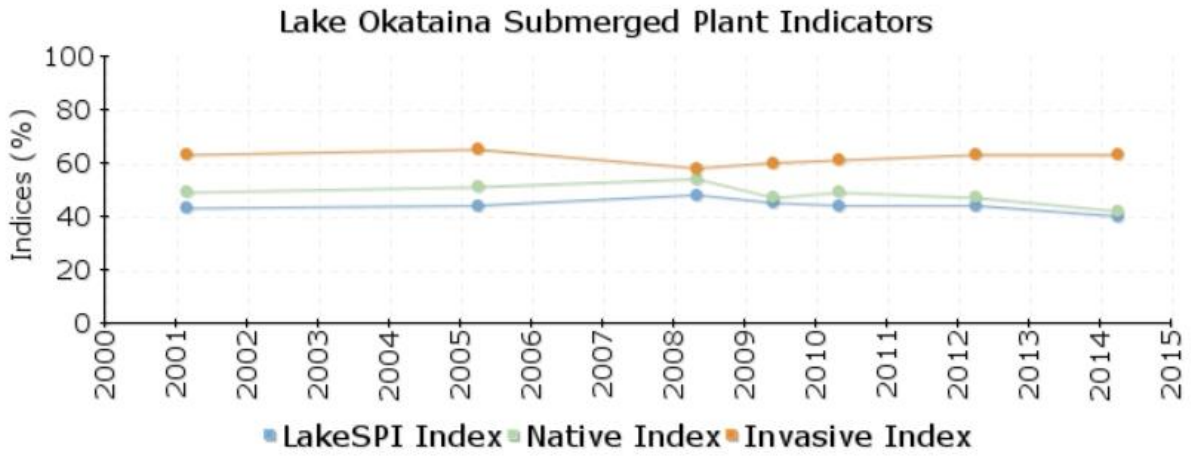
3.4 Lake Okataina

Lake condition: Moderate

Stability: Stable

Lake ranking 4th equal

Lake Okataina is categorised as being in moderate ecological condition with a LakeSPI Index of 40% (Figure 5).



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2014	Moderate	40%	42%	63%
March 2012	Moderate	44%	47%	63%
April 2010	Moderate	44%	49%	61%
May 2009	Moderate	45%	47%	60%
April 2008	Moderate	48%	54%	58%
March 2005	Moderate	44%	51%	65%
February 2001	Moderate	43%	49%	63%
November 1988	Moderate	47%	53%	57%
April 1981	High	51%	57%	53%

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

A moderate LakeSPI index results from the maintenance of native plant communities that are impacted to a degree by the invasive weed lagarosiphon. Native charophyte species formed meadows at 3 out of 5 baseline sites in Okataina in 2014, growing down to a maximum depth of 13.5 m. Lagarosiphon remained the dominant invasive species present, forming high cover weed beds at most sites and generating an Invasive Impact Index of 63%.

A reduction in the depth extent of plant communities was noted in during the 2014 survey, although this was insufficient to cause a significantly change in LakeSPI scores. Because the lake has no outlet, water levels can vary by several metres, so there is potential for water levels to affect the available habitat for submerged vegetation in shallow water, and also the maximum depth extent of plant colonisation. Nevertheless, if water level changes are slow, vegetation can usually compensate by migrating up- and down-slope. BOPRC water level recordings show that lake levels during the 2014 survey were approximately 1m lower than during the 2012 survey and could have influenced the apparent depth reduction. Over the long-term, LakeSPI scores for Lake Okataina have been stable, with only minor fluctuations.

Hornwort continues to pose the most serious threat to the future condition of Lake Okataina. Hornwort was first detected in Lake Okataina in 2007 and was thought to be successfully eradicated. It was not until 2009 that the detection of additional drift fragments led to the discovery of a major hornwort incursion in 2010. Incursion management since this time, using a weed cordon and diquat herbicide, has likely prevented a major spread and impact of hornwort and it is still not yet recorded at any LakeSPI sites. It was however found during the 2014 survey to be established close to one of the LakeSPI sites, in the South Eastern Bay, South of Motuwhetero Island (author's observations). Should hornwort continue to spread, it is likely that we will see a reduction in LakeSPI scores in the future.

Figure 8: Invasive weed bed of hornwort (*Ceratophyllum demersum*) forming a wall of growth 8 m high and growing down to 12 m depth at the south-western end of Lake Okataina in 2010.

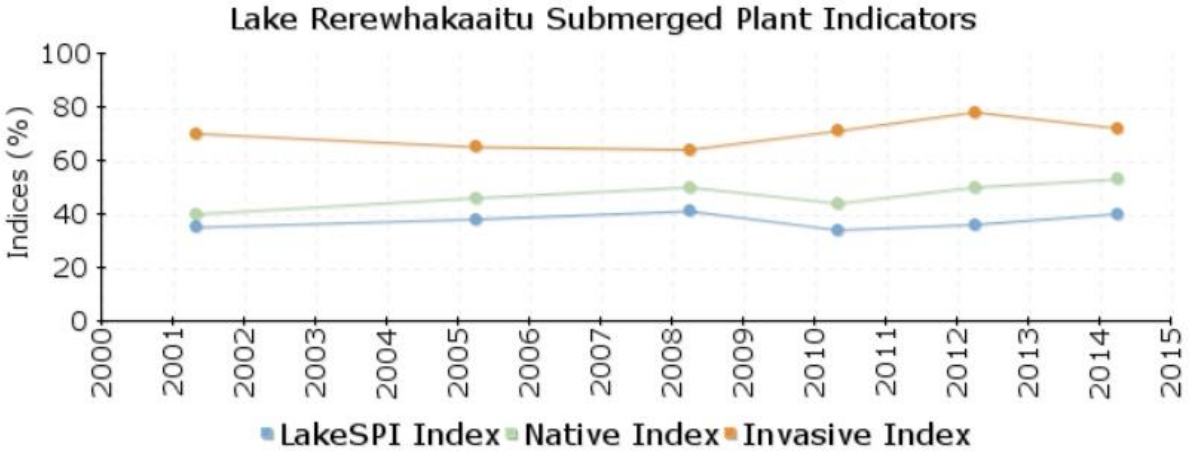
3.5 Lake Rerewhakaaitu

Lake condition: Moderate

Stability: Stable

Lake ranking 4th equal

Lake Rerewhakaaitu is categorised as being in moderate ecological condition with a LakeSPI Index of 40% (Figure 9).



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2014	Moderate	40%	53%	72%
March 2012	Moderate	36%	50%	78%
April 2010	Moderate	34%	44%	71%
March 2008	Moderate	41%	50%	64%
March 2005	Moderate	38%	46%	65%
April 2001	Moderate	35%	40%	70%
November 1988	Moderate	41%	47%	57%
March 1973	High	55%	56%	37%

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

Lake Rerewhakaaitu currently appears to be in a stable condition with possible early signs of improvement. This has followed a period of instability, predominantly due to the impacts from invasion by Lagarosiphon and Egeria.A current LakeSPI Index of 40%, close to what it was in 2008 (Figure 9) followed a small increase in the depth extent of native plants at most sites

and a slight decrease in the depth extent and heights of invasive species during the recent survey.

Egeria densa continues to be the most dominant invasive species in Lake Rerewhakaaitu since 2010, growing down to a maximum depth of 6.2 m and present at all sites. First recorded in the lake in 2000 (Champion et al. 2006), Egeria spread quickly and by the 2010 survey was recorded at all 5 LakeSPI sites. Despite the negative impact from invasive species, native charophyte species were recorded to a maximum depth of 7.0 m in 2014, forming a meadow at all sites. Egeria has the potential to occupy depths to c. 10 m based on its depth extent in other waterbodies, and may impact on this native community in the future.

Historical notes - The submerged vegetation of Lake Rerewhakaaitu was first surveyed in 1973 (Chapman and Clayton 1975) at a time when there was government concern over the degree of eutrophication occurring within several of the Rotorua Te Arawa Lakes. This lake was selected as a candidate for catchment restoration. As a base-line to which future changes could be related, a survey was carried out of the marginal and submerged vegetation using scuba and a submarine. A benthic blue-green algal bloom (*Tolypothrix*, *Lyngbya* & *Oscillatoria*) was prevalent around the lake margin and on plants in shallow water. The submerged vegetation was dominated by native species, with the benign weed *Potamogeton crispus* the only exotic species recorded. None of the problematic 'oxygen weed' species (elodea, lagarosiphon and egeria) or hornwort were present at that time. In 1973 water clarity was low (in water visibility c.1.3 m) and charophytes only grew to a maximum depth of 4.5 – 5 m, with occasional plants to 5.5 metres.

By 1988, Lake Rerewhakaaitu showed two significant changes in the submerged vegetation. Firstly, water clarity improved, enabling charophyte meadows to extend approximately twice as deep (c. 8-9 m). Secondly, lagarosiphon invaded and caused a substantial increase in the Invasive Impact Index, which then increased slightly over the ensuing 20 years to 2008. LakeSPI scores decreased in response to lagarosiphon invasion, while impacts on the Native Condition Index were partly negated by the improved water clarity and extension in charophyte depth limits.

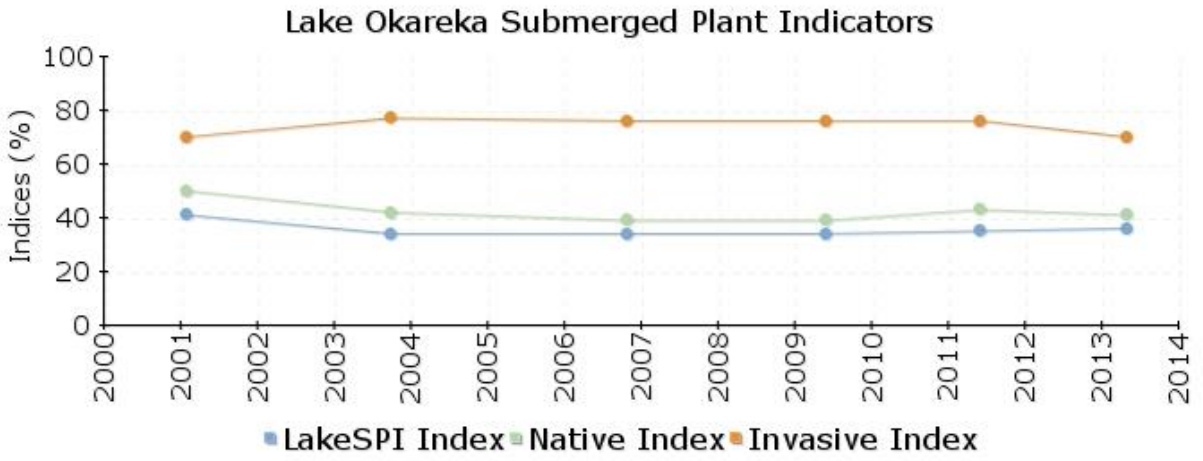
3.6 Lake Okareka

Lake condition: Moderate

Stability: Stable

Lake ranking 5th

Lake Okareka is categorised as being in moderate ecological condition with a LakeSPI Index of 36% (Figure 10).



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
April 2013	Moderate	36%	41%	70%
May 2011	Moderate	35%	43%	76%
May 2009	Moderate	34%	39%	76%
October 2006	Moderate	34%	39%	76%
September 2003	Moderate	34%	42%	77%
January 2001	Moderate	41%	50%	70%
January 1988	Moderate	44%	53%	66%
January 1980	Moderate	40%	49%	67%

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

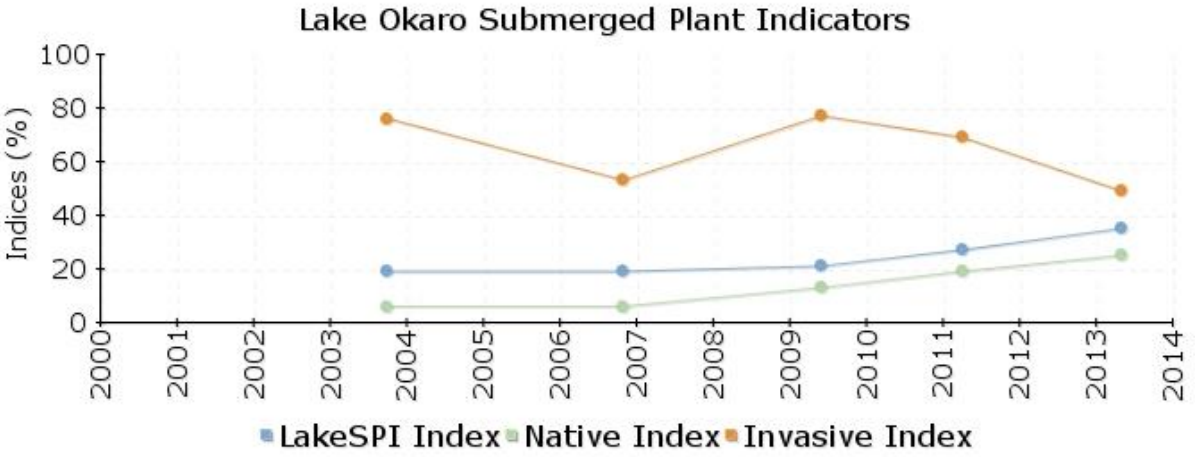
Lake Okareka is currently in a stable condition indicated by the recent LakeSPI indices showing little change since 2008 (Figure 10). Prior to this however, a small increase in the Invasive Impact Index in 2003 due to the establishment of egeria, led to a 10% decrease in the LakeSPI Index.

Egeria was first reported in Lake Okareka in 2000 (Clayton et al. 2005). While not located at any of the 5 LakeSPI baseline sites during the 2001 survey, by 2003 it had spread to 3 sites. Egeria is expected to continue spreading around the lake, displacing lagarosiphon with taller and denser weed growth and occupying a wider depth range. A hornwort incursion in the lake in March 2012 is of concern for the future ecological condition of Lake Okareka, although it has not yet been recorded at LakeSPI sites. Hornwort poses a greater threat to this lake than egeria, with the potential to reduce the LakeSPI Index further, by occupying a deeper range than egeria and by displacing all remaining deep water charophyte meadows.

3.7 Lake Okaro

Lake condition:	Moderate
Stability:	Improving
Lake ranking	6th

Lake Okaro is categorised as being in moderate ecological condition with a LakeSPI Index of 35% (Figure 11).



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
April 2013	Moderate	35%	25%	49%
March 2011	Moderate	27%	19%	69%
May 2009	Moderate	21%	13%	77%
October 2006	Poor	19%	6%	53%
September 2003	Poor	19%	6%	76%
October 1989	Moderate	22%	11%	25%
January 1982	Moderate	31%	29%	67%

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

The degraded nature of Lake Okaro and its fluctuations in water quality and clarity largely account for variations in LakeSPI scores generated for this lake over the long-term, and in the Invasive Impact scores in particular. LakeSPI results since 2008 however, suggest a recent improvement in the condition of Lake Okaro and it is now ranked in moderate condition. Over the recent time-frame, the Native Condition Index has nearly doubled to 25%

and the LakeSPI Index has increased by 21% to 35%. This result may reflect recent efforts by BOPRC to reduce nutrient influx into the lake and nutrient release from hypolimnetic sediments, which might have improved water clarity and resulted in a positive vegetation response. While these improvements are promising, care must be taken when interpreting any kind of recovery in the condition of Lake Okaro at this stage as it is still recognised as a highly variable and sensitive lake system.

Elodea remains the only invasive species reported in Lake Okaro. Historically the hypereutrophic nature of the lake has provided an unfavourable habitat for submerged vegetation. This is reflected in the highly variable cover and depth range of elodea. On several occasions in earlier surveys we have observed rooted elodea beds in shallow water, while from around 2 m depth and deeper all elodea was non-rooted 'drift'. This may well coincide with periods of stratification with anoxia or reduced light at or below a thermocline resulting in root death and shoot detachment.

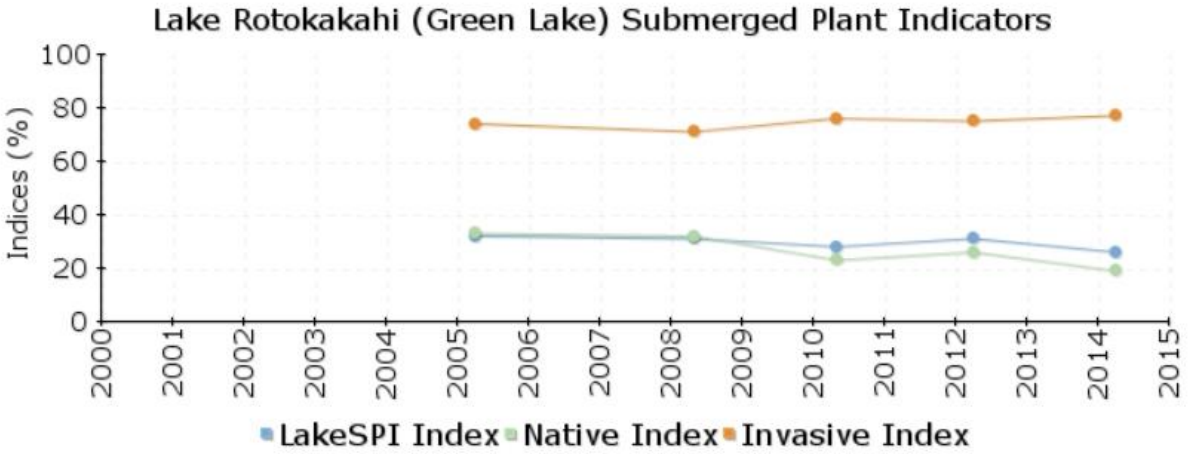
3.8 Lake Rotokakahi

Lake condition: Moderate

Stability: Stable

Lake ranking 7th

Lake Rotokakahi is categorised as being in moderate ecological condition with a LakeSPI Index of 26% (Figure 12).



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2014	Moderate	26%	19%	77%
March 2012	Moderate	31%	26%	75%
April 2010	Moderate	28%	23%	76%
April 2008	Moderate	31%	32%	71%
March 2005	Moderate	32%	33%	74%
November 1988	High	52%	61%	53%

Figure 12: LakeSPI results for Lake Rotokakahi. LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Rotokakahi has undergone one of the largest declines in lake condition as indicated by LakeSPI for any of the 12 lakes over the long-term (Figure 18), with most change taking place prior to 2005. The LakeSPI Index has reduced from 52% in 1988 to only 26% in 2014, whilst the Native Condition Index has also declined significantly largely due to a decline in charophyte meadows over this longer-term time frame. This has occurred even though there has been no new invasive species recorded in this lake. *Elodea canadensis* remains the only

invasive species present and dominates the remaining native vegetation down to a maximum depth of 8.6 m. Small increases in the Invasive Impact scores since 2005 reflect a greater occupancy of the vegetation by elodea as remaining native charophyte meadows have declined.

Overall LakeSPI results for Lake Rotokakahi show that declining condition is not due to invasive weeds, but rather due to a decline in native condition presumably driven by water quality. Additional observations support this conclusion, with filamentous algae prevalent on submerged vegetation and blue-green algal mats often covering sediments beyond the maximum depth of plant growth. These are indicators of enrichment. Nutrient inputs are likely to be entering this lake from the predominantly farmland catchment as well as from sediment nutrient release during summer stratification. Recent deforestation in the catchment may also be a contributing factor.

Lake Rotokakahi, together with Lake Okaro, are the only Rotorua Lakes to remain relatively free of the more invasive weed species.

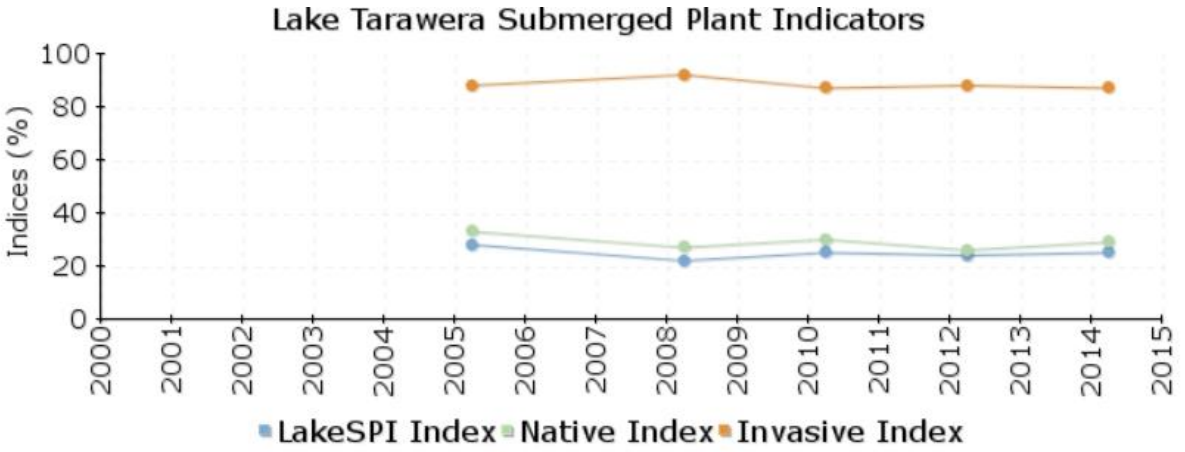
3.9 Lake Tarawera

Lake condition: Moderate

Stability: Stable

Lake ranking 8th

Lake Tarawera is categorised as being in moderate ecological condition with a LakeSPI Index of 25% (Figure 13).



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2014	Moderate	25%	29%	87%
March 2012	Moderate	24%	26%	88%
March 2010	Moderate	25%	30%	87%
March 2008	Moderate	22%	27%	92%
March 2005	Moderate	28%	33%	88%
January 1994	Moderate	41%	50%	70%
November 1988	High	54%	55%	45%

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

Lake Tarawera has remained in a moderate but stable condition since 2010. Prior to this, results show a significant reduction in the LakeSPI Index between 1988 and 2005, driven by the invasion of hornwort. Today hornwort continues to dominate the submerged vegetation in Lake Tarawera down to a maximum depth of 11.8 m, although recent change has been small since the full impact of hornwort has now taken place.

Historical notes - At the time of the 1988 survey, lagarosiphon and elodea were the two dominant invasive weed species in Lake Tarawera. Although hornwort was first recorded in July 1988, it was limited to Kotukutuku Bay near the boat ramp and was not present in any of the survey sites used for LakeSPI. By the time of the 1994 survey, hornwort had spread around much of the lake and had doubled the depth range of invasive vegetation, without displacing lagarosiphon significantly (Wells et al. 1997). By 2005, hornwort was responsible for the widespread displacement of almost all former deep water charophyte meadows in the lake resulting in a significantly lower LakeSPI Index of 28% (Figure 13).

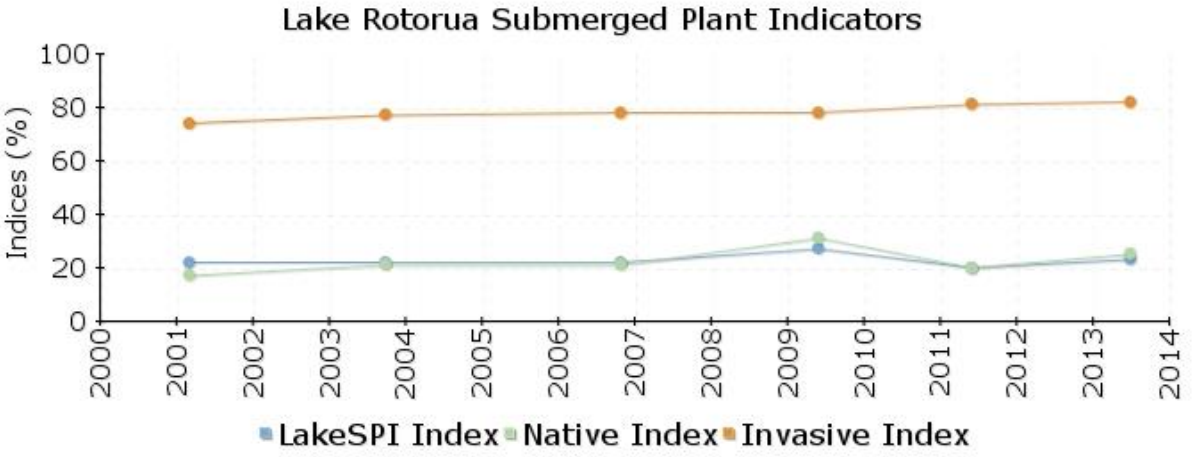
3.10 Lake Rotorua

Lake condition: Moderate

Stability: Stable

Lake ranking 9th

Lake Rotorua is categorised as being in moderate ecological condition with a LakeSPI Index of 23% (Figure 14).



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
June 2013	Moderate	23%	25%	82%
May 2011	Poor	20%	20%	81%
May 2009	Moderate	27%	31%	78%
October 2006	Moderate	22%	21%	78%
September 2003	Moderate	22%	21%	77%
February 2001	Moderate	22%	17%	74%
January 1988	Poor	18%	21%	90%
January 1982	Moderate	27%	23%	68%

Figure 14: LakeSPI results for Lake Rotorua. LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Rotorua has remained in a stable condition long-term, as indicated by LakeSPI. This lake has a large shallow littoral zone subject to considerable wave action, which has the effect of reducing silt build up and helps prevent large surface-reaching weed beds forming around much of the lake margin. The wave washed shallow regions of this lake can support

a wide range of native turf-forming species along with shallow-water charophyte beds. Slight variations in Native Condition Index reflect some variability in the development of these communities from year to year, but these changes are small and have not been sustained.

Historical notes - The early variation in Invasive Impact Index over 1988 to 2001 was attributable to the 'boom and bust' of egeria, which was first recorded in this lake in July 1983 and by 1988 had established weed beds around most of the lake, resulting in a peak Invasive Impact Index of 90%. In 1988 it was estimated that egeria comprised more than 80% of the vegetation in the lake with an area of 440 ha (Wells and Clayton, 1991). In the early 1990s egeria underwent a major decline and has never recovered.

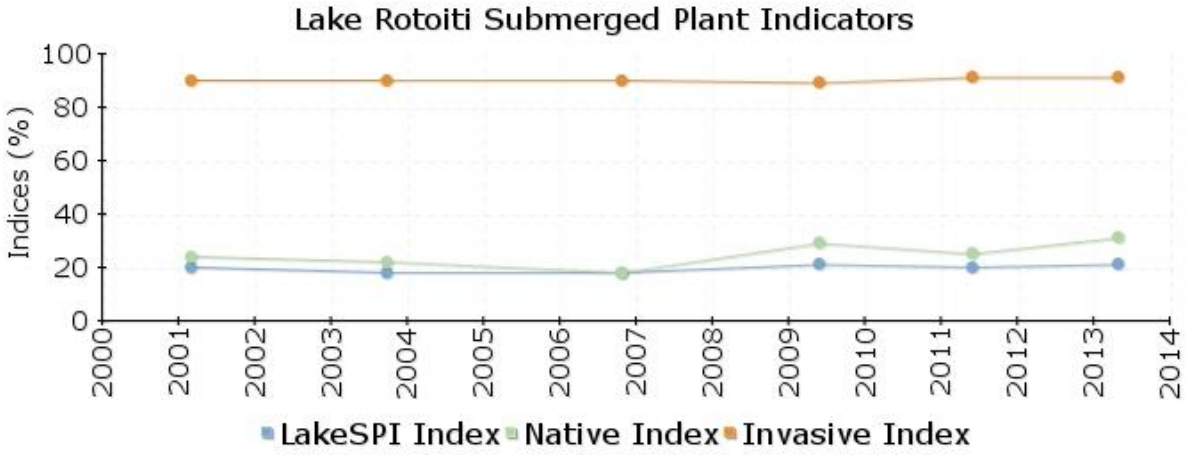
3.11 Lake Rotoiti

Lake condition: Moderate

Stability: Stable

Lake ranking 10th

Lake Rotoiti is categorised as being in moderate ecological condition with a LakeSPI Index of 21% (Figure 15).



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
April 2013	Moderate	21%	31%	91%
May 2011	Poor	20%	25%	91%
May 2009	Moderate	21%	29%	89%
October 2006	Poor	18%	18%	90%
September 2003	Poor	18%	22%	90%
February 2001	Poor	20%	24%	90%
December 1987	Moderate	26%	33%	85%
March 1981	Moderate	26%	33%	82%

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

Lake Rotoiti has consistently had one of the highest Invasive Impact Index scores and continued to have one of the lowest LakeSPI Indices so far recorded for any of the 12 lakes in this region. Development of some deeper charophyte meadows and increases in the Native Condition Index more recently are suggestive of a slight improvement in lake condition.

Lake Rotoiti has a complex morphometry with areas along the northern shoreline that are too steep to support submerged vegetation, making them unsuitable for LakeSPI. The western end of Lake Rotoiti has in the past been predominantly influenced from Lake Rotorua inflows and there had been a progressive decline in submerged vegetation in several arms of Lake Rotoiti such as Okawa Bay, Wairau Bay and Te Weta Bay. Construction of the diversion wall in 2008 to entrain Lake Rotorua inflows down the Kaituna River may have seen a reduction in water quality impacts. However flow-on effects on submerged vegetation are not yet confirmed. Sheltered areas with low water quality are presently often dominated by loose filamentous algae, attached benthic blue-green algal mats and planktonic blue-green algal blooms. The LakeSPI scores indicate poor water quality in this lake.

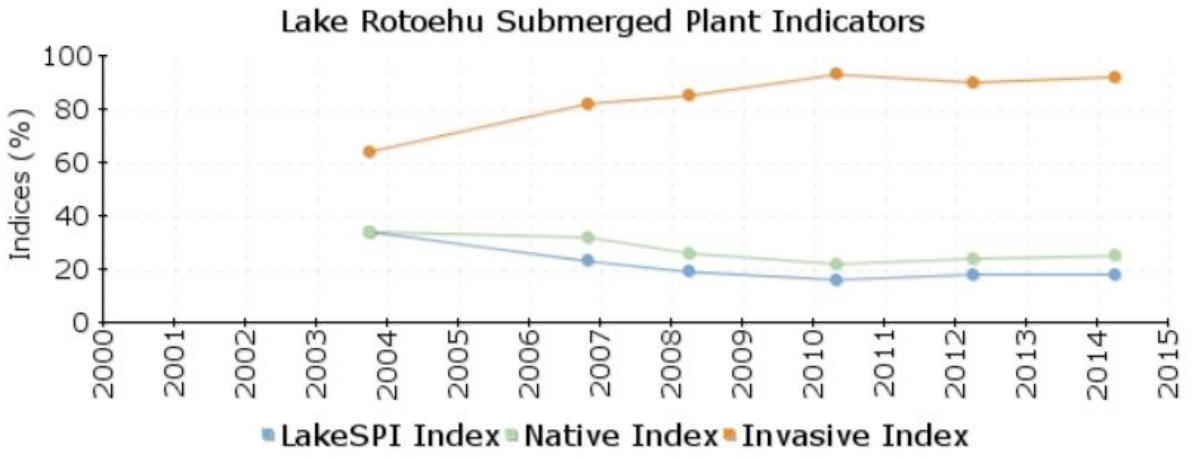
3.12 Lake Rotoehu

Lake condition: Poor

Stability: Stable

Lake ranking 11th

Lake Rotoehu is categorised as being in poor ecological condition with a LakeSPI Index of 18% (Figure 16).



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2014	Poor	18%	25%	92%
March 2012	Poor	18%	24%	90%
April 2010	Poor	16%	22%	93%
March 2008	Poor	19%	26%	85%
October 2006	Moderate	23%	32%	82%
September 2003	Moderate	34%	34%	64%
January 1988	Moderate	30%	34%	81%

Figure 16: LakeSPI results for Lake Rotoehu. LakeSPI Indices expressed as a percentage of lake maximum potential.

Lake Rotoehu has the lowest LakeSPI Index (18%) and the highest Invasive Impact scores (92%) recorded for any of the 12 Rotorua Te Arawa lakes (Figure 16). This reflects a major infestation of hornwort which has spread through the lake resulting in a halving of the LakeSPI Index since the 2003 survey. Hornwort was first recorded in the lake off Otautu Bay in December 2004 (R. Mallinson, BOPRC, pers comm.) and by late summer 2005 it had

formed extensive weed beds around much of the shoreline. Since 2008, LakeSPI results demonstrate the negative impact hornwort is having on native submerged vegetation within the lake as it approaches 'habitat saturation' in this waterbody. Lake Rotoehu remains at the bottom of this group of lakes, categorised as being in 'poor' condition.

On a positive note, given the recent history of poor water quality and frequent blue-green blooms, it is quite possible the development of extensive hornwort beds around the margins of this shallow lake may reduce algal blooms by storing nutrients, despite the other detrimental impacts hornwort will have on littoral condition. Nutrient removal by means of weed harvesting should not only reduce weed impact but also help remove internal lake nutrients. Out of all the Rotorua Te Arawa Lakes, Lake Rotoehu was the only one estimated to have sufficient harvestable weed biomass to potentially reduce the lake nutrient budget by a beneficial amount (Matheson & Clayton 2002).

The discovery of *Lymnaea auricularia* (ear pond snail), well established in Omahota Bay during the 2014 survey marks the second record of this invasive snail in the Rotorua Te Arawa lakes.

Figure 17: Invasive weed (Ceratophyllum demersum) washed up on lake margin of Lake Rotoehu in 2014.

4 Discussion

4.1 Current lake stability

Changes in LakeSPI indices over the recent time-frame (since 2009) have been used to provide an indication of current stability in lake condition and the direction of any change (Table 3).

Table 3: Summary of current LakeSPI results for assessed lakes showing overall condition category, current stability rating, long term changes in condition and an indication of the main impact factor affecting scores.

Lake	LakeSPI Index (%)	Overall Condition	Current Stability (~5 years)	Long term changes (>20 years)	Impact factor
Rotoma	55	High	Stable	No Change	Weed
Tikitapu	45	Moderate	Improving?	Change	Water Quality
Rotomahana	42	Moderate	Deteriorating	Change	Weed
Okataina	40	Moderate	Stable	No Change	Weed
Rerewhakaaitu	40	Moderate	Improving?	Change	Weed
Ōkāreka	36	Moderate	Stable	No Change	Weed
Okaro	35	Moderate	Improvement	No Change	Water Quality
Rotokakahi	26	Moderate	Stable	Change	Water Quality
Tarawera	25	Moderate	Stable	Change	Weed
Rotorua	23	Moderate	Stable	No Change	Water Quality
Rotoiti	21	Moderate	Stable	No Change	Water Quality
Rotoehu	18	Poor	Stable	Change	Weed

Lake Okaro and Tikitapu showed some improvement in LakeSPI scores over this recent timeframe, however these lakes are recognised as being sensitive and variable in nature so care must be taken when interpreting any kind of improvement at this stage. Lake Rerewhakaaitu also shows a small degree of improvement over the short term due to a slight reduction in the development of weed at some baseline sites. Lake Rotomahana, the third highest ranked lake in the Rotorua region, has shown a marked decline in lake condition scores. The LakeSPI Index, has declined from its maximum potential by 21% since 2009 which is the largest change recorded for any of the 12 Rotorua Te Arawa lakes over this 5 year time frame largely due to the continual spread and impact by two of New Zealand's worst aquatic plant species, egeria and hornwort, in the lake. A small deterioration for Lake Rotorua has not been sustained more recently and the lake has returned to a stable state. All remaining Rotorua Te Arawa lakes currently appear to be in a stable condition, with little change in scores, although future change is expected for those at risk from expanding

invasive plants (Lakes Rotoma, Okataina, Okareka). Recent LakeSPI scores for Lake Rotoehu, the lowest ranked Rotorua Te Arawa lake, have changed little as hornwort approaches complete 'habitat saturation'.

4.2 Long term changes

Longer term, many of the Rotorua Te Arawa Lakes have undergone significant change over the last two decades (Table 3, Figure 18).

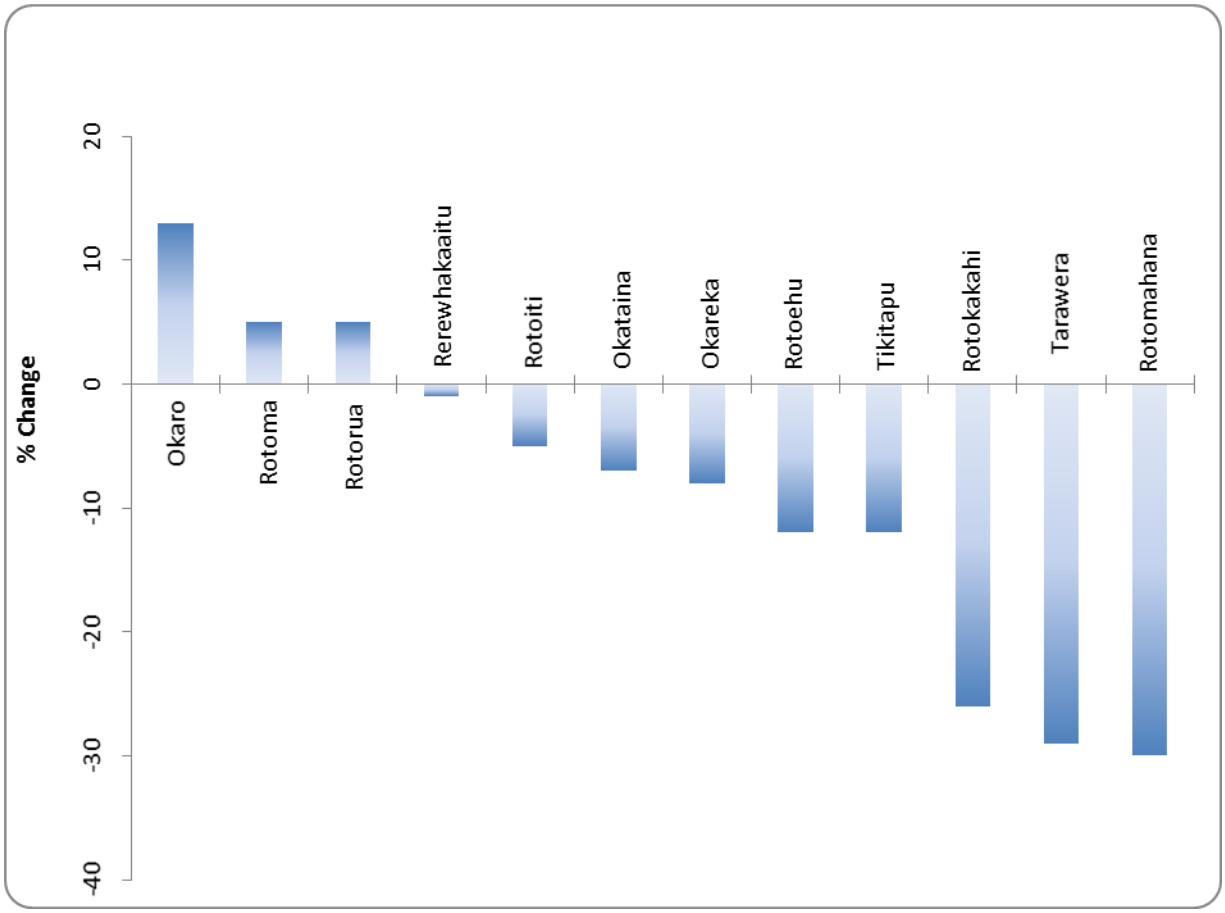


Figure 18: Percentage of change as indicated by the LakeSPI Index over the last 25 years, 1988/1989 to 2013/14.

Lakes Tarawera and Rotomahana show the biggest change in lake condition over the last 24-25 years resulting from invasion by New Zealand's worst submerged plant species. Not only do these species cause physical and biological changes in the lake littoral, they also impact on the amenity and aesthetics of lakes for the public. Invasive weeds also impact negatively on lake condition by excluding native plant communities from depths of less than 6-10 metres with the worst of these invasive species, hornwort, able to out-grow and smother native vegetation to around 15 metres depth. Hornwort is now present in 7 of the 12 Rotorua Te Arawa Lakes and is the dominant invasive weed in lakes Tarawera and Rotoehu. Lake Tarawera is now in a stable state and, since the full impact of hornwort has now taken place, it is not expected to change significantly in the near future. Hornwort is nearing full impact status in Lake Rotoehu also, although we can expect to see some further decline in LakeSPI

scores as hornwort continues to impact negatively on the native vegetation still present. Likewise we can expect to see a further decline in LakeSPI scores for Lake Rotomahana as hornwort continues to spread and occupy a deeper depth range than is currently occupied by egeria, However of most recent concern is the presence of hornwort in Lakes Okareka (detected March 2012) and Okataina (detected March 2010). Based on the potential for hornwort to spread within these lakes and its likely impact, if unable to be controlled, we can expect to see a notable decline in the status of Lakes Okareka and Okataina in years to come.

Lake Rotoma remains at high risk of invasion by hornwort, which would have a major detrimental impact on the native character and biodiversity value of this lake. In 2008 BOPRC established a containment cordon out from the boat ramp at the western end of Lake Rotoma and in July 2010 established a second around the boat ramp at Matahi Spit. It is hoped these nets will act to help contain any hornwort fragments liberated at launch sites by boats or trailers coming from any nearby hornwort infested waterbodies, such as Lakes Rotoehu or Rotoiti, although they will not entirely remove the incursion risk.

Lake Rerewhakaaitu could also be severely impacted by hornwort, but the risk is less imminent on account of its greater distance from nearby infestations and much lower boat traffic.

Next to introduction of invasive plant species, the second biggest change affecting the condition of the Rotorua Te Arawa Lakes is water quality. Lakes Rotokakahi and Tikitapu show the next biggest changes in lake condition over the last 24-25 years and since there has been no new invasive species recorded since full lake surveys begun in 1988, the changes in these lakes are likely to be the result of deteriorating water quality and clarity. LakeSPI metrics (Submerged Plant Indicators) are able to integrate long term changes in water clarity over time and often one of the first signs of deterioration is a retraction of the lower depth limit of plant growth (Schwarz et al. 1999). In many lakes the first valuable plant community to disappear is the charophyte meadow that grows into deeper water and this has been the case in Lake Tikitapu. In 1988 Lake Tikitapu supported extensive charophyte meadows at all 5 LakeSPI sites down to a mean maximum depth of 19.5 m. By 2001 meadows had retracted to a mean maximum depth of 10.3 m and since then, charophyte meadows have only been recorded intermittently at sites.

4.3 National comparison

Compared nationally, the Bay of Plenty Region has no lakes classified as being in ‘excellent’ condition (representing those close to their maximum potential ecological condition) and only one lake classified as being in ‘high’ condition (Figure 19 & 20).

A ‘moderate’ condition category contains the majority of the Rotorua Te Arawa Lakes and contains the largest proportion of lakes nationally. This ‘moderate’ condition group of Rotorua Te Arawa Lakes are representative of those lakes that are impacted in varying degrees by invasive weeds but still retain some native vegetation character

A smaller proportion of lakes nationally are classified as being in a ‘poor’ condition. This group of lakes tends to represent those with extensive invasion and dominance by one of the

country's worst weeds, hornwort, as is the case in Lake Rotoehu, the only Rotorua Te Arawa Lake ranked in this 'poor' category. Three other lakes (Matahina, Aniwhenua, Pupuwharau) surveyed within the Bay of Plenty Region were also included in this category.

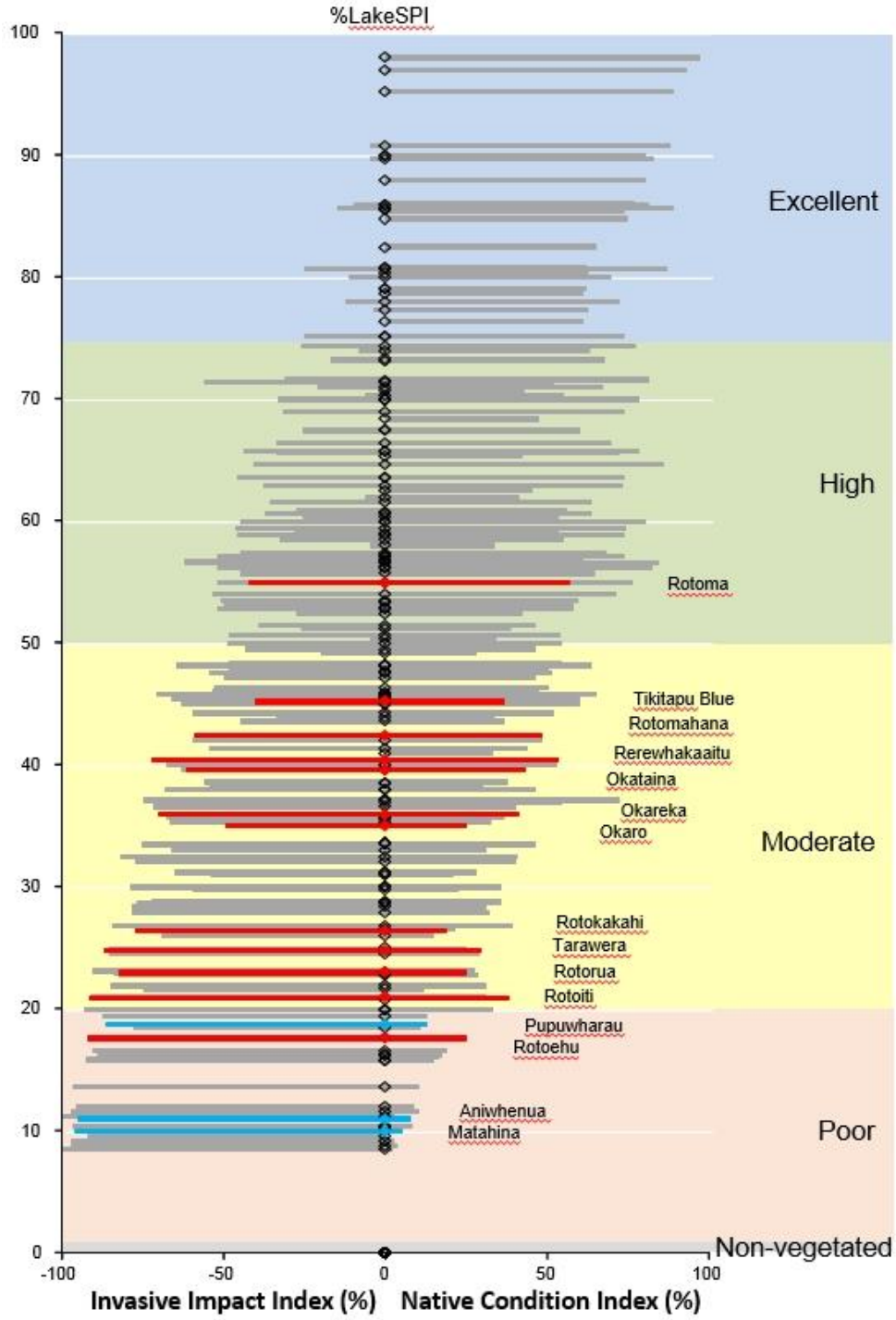


Figure 19: Te Arawa Lakes (red lines) and 3 other lakes in the Bay of Plenty Region (blue lines) are plotted with scores for a total of 244 New Zealand lakes. The most recent LakeSPI scores for lakes for the Rotorua The LakeSPI Index is plotted on the y-axis (points), Native Condition Index as lines to the right and Invasive Impact Index lines to the left of the x-axis. Five categories of LakeSPI condition are indicated by labelled colour bands.

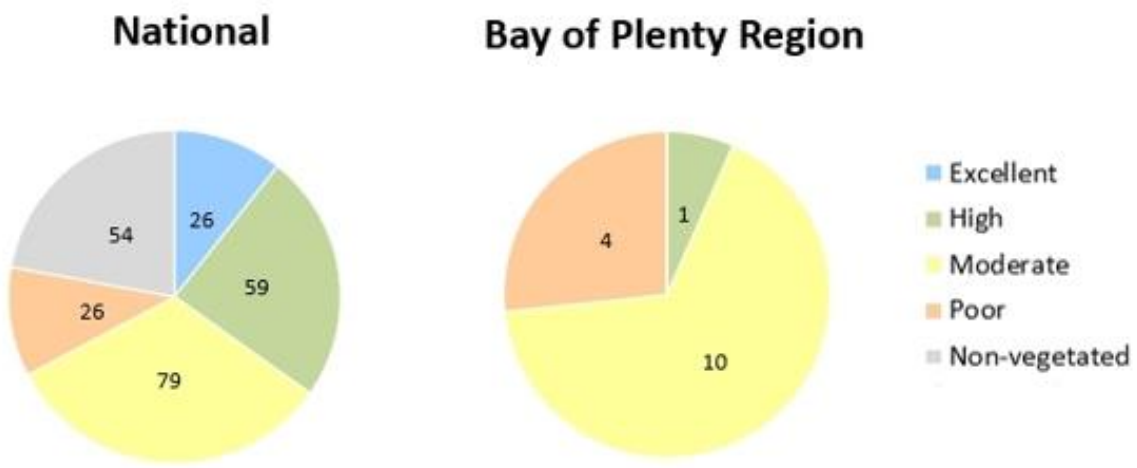


Figure 20: Proportion of lakes that fall into each of five categories of LakeSPI Index for the region (15) and nationally (244), . with number of lakes assessed shown in parenthesis.

5 Conclusions

LakeSPI results show many of the Rotorua Te Arawa Lakes have undergone significant change over the long-term and continue to be vulnerable to further changes from invasive plants and water quality deterioration. Lakes Rotomahana and Tarawera show the biggest change in lake condition over the long-term on account of impacts from invasive plant species; while the second biggest change to affect the Rotorua Lakes has been from changing water quality in Rotokakahi and Tikitapu.

Present day LakeSPI Indices for lakes in the Rotorua region ranged widely from 18% to 55% with one Rotorua Te Arawa lake assessed as being in 'high' condition, ten lakes as 'moderate' and one lake categorised as in 'poor' condition. None of the 12 Rotorua Te Arawa lakes were recorded in the 'excellent' or 'non-vegetated' categories.

Lake Rotoma is categorised as being in 'high' condition and has been stable. This is an exceptional lake and although it appears to maintain high water quality, it remains under serious threat from potential hornwort invasion. This would have a major detrimental impact on the native character and biodiversity value of this lake.

Lakes Tikitapu, Rotomahana, Okataina, Rerewhakaaitu, Okareka, Okaro, Rotokakahi, Tarawera, Rotorua and Rotoiti are currently ranked as being in 'moderate' condition. Lake Tikitapu is showing some signs of recent improvement, however longer term values show a significant reduction in the Native Condition values. Lake Rotomahana has undergone significant change due to invasion by egeria and hornwort and is expected to decrease further in ranking over time. LakeSPI results for Lake Rotomahana show the largest decline recorded in any of the Rotorua lakes since 2008. Lake Okataina appears to maintain high water quality and has been stable, but the presence of hornwort now in the lake poses a serious threat to future lake condition. Lake Rerewhakaaitu currently appears to be in a stable condition with possible early signs of improvement. Although the overall condition of Lake Okareka has remained stable over the long-term, the recent discovery of hornwort in the lake in March 2012 raises concern for future condition. If hornwort becomes established in Lake Okareka we can expect it to displace all native charophyte meadows in this lake. Lake Rotokakahi has shown substantial deterioration over the long-term, but has been more stable recently. Lakes Rotokakahi and Tikitapu, have both seen a reduction in the diversity and extent of native plant communities present, without any direct change in invasive weed presence or increased performance. Lake Tarawera has remained in a stable state since 2008, following the complete invasion of this lake by hornwort that caused reductions in lake condition over the longer-term. Lake Rotorua has also remained stable, in a moderate condition. Although categorised in moderate condition Lake Rotoiti sits very close to the 'poor' category boundary.

Lake Rotoehu is classified as being in a 'poor' condition. This lake has the lowest LakeSPI Index and the highest Invasive Impact Index recorded for any of the 12 Rotorua Te Arawa lakes. Invasion by hornwort has seen the lake condition decline in the long-term and some small recent changes in invasive status are evident.

A summary follows of key points for each lake based on LakeSPI:

Lake Rotoma

- Overall lake condition high.
- Highest Native Condition Index and second lowest Invasive Impact Index in the region.
- An exceptional lake and the best example of extensive charophyte meadows.
- Major threat from hornwort invasion.

Lake Tikitapu

- Overall lake condition moderate and showing possible improvement.
- Major decline in Native Condition Index and LakeSPI scores over the last 26 years independent of any impact from new invasive species.
- Unusual water chemistry may inhibit impact from present and future invasive species.

Lake Rotomahana

- Overall lake condition moderate and declining.
- Egeria and hornwort having a significant impact.
- High Native Condition Index.

Lake Okataina

- Overall lake condition moderate and appears stable.
- Recent invasion by hornwort poses a serious threat to future condition.
- High Native Condition Index.

Lake Rerewhakaaitu

- Overall lake condition moderate and showing possible improvement.
- Invasion by egeria yet to fully influence LakeSPI Index.
- Moderate threat from hornwort invasion.

Lake Okareka

- Overall lake condition moderate and appears stable.
- Invasion by egeria yet to fully influence Invasive Impact Index scores.
- Recent invasion by hornwort poses a serious threat to future condition.

Lake Okaro

- Overall lake condition moderate and showing signs of improvement following lake restoration measures.
- LakeSPI scores variable due to water quality responses by elodea.
- Has one of the lowest Native Condition Indices for any of the Rotorua Te Arawa lakes.

Lake Rotokakahi

- Overall lake condition moderate and stable.
- Major decline in LakeSPI and Native Condition Index over last 26 years.
- No change in elodea status but Invasive Impact Index reflects greater relative occupation of the remaining vegetation by elodea.
- Now the only Rotorua lake (with the exception of Okaro) to remain relatively free of the 3 worst 'high impact' invasive weed species.

Lake Tarawera

- Overall lake condition moderate and stable.
- LakeSPI and Native Condition Index scores have declined significantly over the last 26 years.
- Invasion of hornwort primarily responsible for decline in LakeSPI and Native Condition scores.

Lake Rotorua

- Overall lake condition moderate and stable.
- Slight variations in Native Condition Index reflect some variability in the development of these communities from year to year.

Lake Rotoiti

- Overall lake condition is now moderate but close to the boundary with poor category.
- Has the second highest Invasive Impact Index of the Rotorua Te Arawa lakes.
- LakeSPI Index indicates poor water quality.

Lake Rotoehu

- Overall lake condition poor.
- Hornwort has had a major impact and dominates the submerged vegetation.
- Has the lowest Native Condition Index and the highest Invasive Impact Index of the Rotorua Te Arawa lakes.

6 Recommendations

To gain further understanding of the overall state of the Bay of Plenty Region, it is suggested that one-off surveys be completed for lakes with no or limited information. Knowing their current condition will provide a better understanding of the regions diversity of lakes and factors that influence macrophyte presence. Benefit of any further longer term monitoring should be considered relative to assessed values and risks.

Additionally, full lake vegetation surveys (Clayton 1983) of the 12 Rotorua Te Arawa lakes have not been carried out since 1988. These full surveys differ from the LakeSPI monitoring method in that they result in a comprehensive species list, as well as detailed information on species frequency and distribution, species cover and height in relation to depth and various other analyses. It is recommended that full vegetation surveys be repeated in combination with new sonar vegetation mapping technology to provide a detailed description of the submerged vegetation in these lakes.

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