

The ecological condition of the Rotorua Lakes using LakeSPI-2011



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Authors/Contributors:

Tracey Edwards
John Clayton

For any information regarding this report please contact:

Tracey Edwards
Biologist
Aquatic Plants
+64-7-856 7026
r.wells@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

Approved for release by

M. de Winton

D.Roper

Formatting checked by

A. Bartley

Executive summary

NIWA was contracted by Bay of Plenty Regional Council (BOPRC) to assess the ecological condition of 12 lakes within the Rotorua Region using LakeSPI (Submerged Plant Indicators). LakeSPI was developed according to Ministry for the Environment agreed criteria for freshwater indicators, for the establishment of long-term baselines for Lake State of the Environment reporting and to monitor trends over time. LakeSPI results are presented as a percentage of each lake's maximum scoring potential to enable comparisons between lakes. To identify time trends, each lake has also been assessed using three baseline conditions: Pristine condition (lake plant communities in pre-impacted times), Historical condition (described by historical data) and Present day condition (using most recent data).

LakeSPI results show many of the Rotorua Lakes have undergone significant change over the last two decades and continue to be vulnerable to further changes from invasive plants and water quality deterioration. Lakes Tikitapu, Rotokakahi and Rerewhakaaitu show the biggest change in lake condition over the last 20 years on account of changing water quality or clarity; while the second biggest change to affect the Rotorua lakes has been from the introduction of invasive plant species.

Present day LakeSPI Indices for lakes in the Rotorua region ranged widely from 15% to 51% and using the LakeSPI categories included one lake assessed as being in 'high' condition, eight lakes as 'moderate' and three lakes in 'poor' condition. No Rotorua lakes were recorded in the 'excellent' or 'non-vegetated' categories.

Lake Rotoma is classified as being in 'high' condition. 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 Rotomahana, Okataina, Okareka, Rerewhakaaitu, Tikitapu, Rotokakahi, Okaro and Tarawera are currently classified as being in 'moderate' condition. Lake Rotomahana, while having the second highest overall status, has undergone some significant changes due to the more recent invasion by egeria and hornwort and is expected to decrease in ranking. LakeSPI results for Lake Rotomahana show the largest decline in overall condition recorded in any of the Rotorua lakes over the last 5 to 6 year time frame.

Lake Okataina appears to maintain high water quality but the recent discovery of an established hornwort weed bed from within the lake poses a serious threat to future lake condition. The last 8 years has seen the overall condition of Lake Okareka remain relatively stable but this lake is also under serious threat from hornwort invasion, where the expected outcome would be displacement of all native charophyte meadows. Lake Rerewhakaaitu underwent an improvement in water clarity since the 1970's, which led to an extension in the depth range of native vegetation. For the last 20 years this lake has remained relatively stable, however the continuing spread of egeria and the decline in water clarity and native plant depth limits noted during the last survey now indicates the status of this lake is declining. Lake Tikitapu continues in a state of notable decline on account of changing water

quality and clarity. Lake Rotokakahi also continues to appear in a state of decline due to water quality issues. Over the last 20 years both Lakes Rotokakahi and Tikitapu have seen a reduction in the quality and extent of native plant communities present, without any direct change in invasive species presence or increased performance. Lake Okaro is now classified in 'moderate' condition after a slight improvement in native plant cover and diversity was noted during the recent 2011 survey. Tarawera now remains in a stable state and it is not expected to change in the near future since the full impact of hornwort has now taken place.

Lakes Rotoiti, Rotorua and Rotoehu are classified as being in a 'poor' condition. Lake Rotorua is the only lake to have shown a slight increase in lake condition scores over the past 23 years but remains in a poor condition. Lakes Rotoiti and Rotoehu also remain classified as in 'poor' condition. However, restoration measures on these lakes and others that result in a sustainable improvement in water quality and clarity would be expected to result in improved LakeSPI scores in the future.

Compared nationally, the Rotorua 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. The largest proportion of lakes nationally, including those in the Rotorua Region, fell into the group of lakes classified as being in 'moderate' condition which tended to represent those that are impacted in varying degrees by invasive weeds. A smaller proportion of the Rotorua lakes classified as in 'poor' condition were consistent with others in this group around the country that tended to represent those with extensive invasion and dominance by one of the country's worst weeds, hornwort, or compromised water quality.

Recommendations made in this report are as follows:

All possible measures should be explored for preventing further hornwort transfer (e.g., public education) and establishment into vulnerable lakes, such as Lakes Rotoma and Okareka. Now that Lake Okareka will have a weed cordon in place before the end of this month, it would be worthwhile to survey private ponds in all residences in the catchment to check for hornwort presence since this weed presents a very high risk for the lake.

There may be some merit in assessing some lakes annually. In particular are those lakes where significant changes are taking place either by deterioration (e.g., Tikitapu, Rotokakahi, Rerewhakaaitu) or from improvements (e.g., Okaro, Okareka and Rotoiti) attributable to restoration works such as phosphorus capping and nutrient diversion.

1 Introduction

1.1 Study brief

NIWA was contracted by Bay of Plenty Regional Council (BOPRC) to assess the condition of lakes within the Rotorua Region using LakeSPI (Submerged Plant Indicators); a method that focuses on submerged aquatic plants as indicators of lake ecological condition. The LakeSPI method (Clayton and Edwards 2006a) was developed according to Ministry for the Environment (MfE) agreed criteria for freshwater indicators, for the establishment of long-term baselines for lake SOE reporting, and to monitor trends over time. LakeSPI has been favourably reviewed by MfE describing it as a 'tool offering considerable value to monitor and report on ecological condition' that is 'gaining wide acceptance in New Zealand' (Hamill and Lew 2006), and this method has now been applied by agencies in eight regions of New Zealand. LakeSPI compliments traditional water quality monitoring, such as the Trophic Level Index method (Burns et al. 1999), by providing ecological information.

The contract specifies assessment of 12 lakes with at least six lakes monitored each year to ensure that any given lake is assessed every two years since 2005. LakeSPI monitoring of the Rotorua lakes using established baseline sites was first completed between September 2003 (Edwards & Clayton, 2003) and March 2005 (Clayton et al. 2005), with data used to estimate three conditions for each lake:

1. Pristine condition (lake plant communities in pre-impacted times).
2. Historical condition (described by historical data, including earlier assessments).
3. Present day condition (using most recent data).

This report presents updated results of LakeSPI assessments completed for the 12 Rotorua lakes, with Okataina, Rerewhakaitu, Rotoehu, Rotokakahi, Tarawera and Tikitapu last assessed in April 2010 (Edwards & Clayton, 2010) and Okaro, Okareka, Okataina, Rotoiti, Rotoma, Rotomahana and Rotorua in May or July 2011.

1.2 Study lakes

The lakes assessed in this report are collectively termed the 'Rotorua lakes'. This term refers to the 12 largest lakes in the Rotorua region managed through the Rotorua Lakes Protection and Restoration Action Programme being lakes: Okareka, Okaro, Okataina, Rerewhakaaitu, Rotoehu, Rotoiti, Rotokakahi, Rotoma, Rotomahana, Rotorua, Tarawera, and Tikitapu. The location of these lakes is indicated in Figure 1.

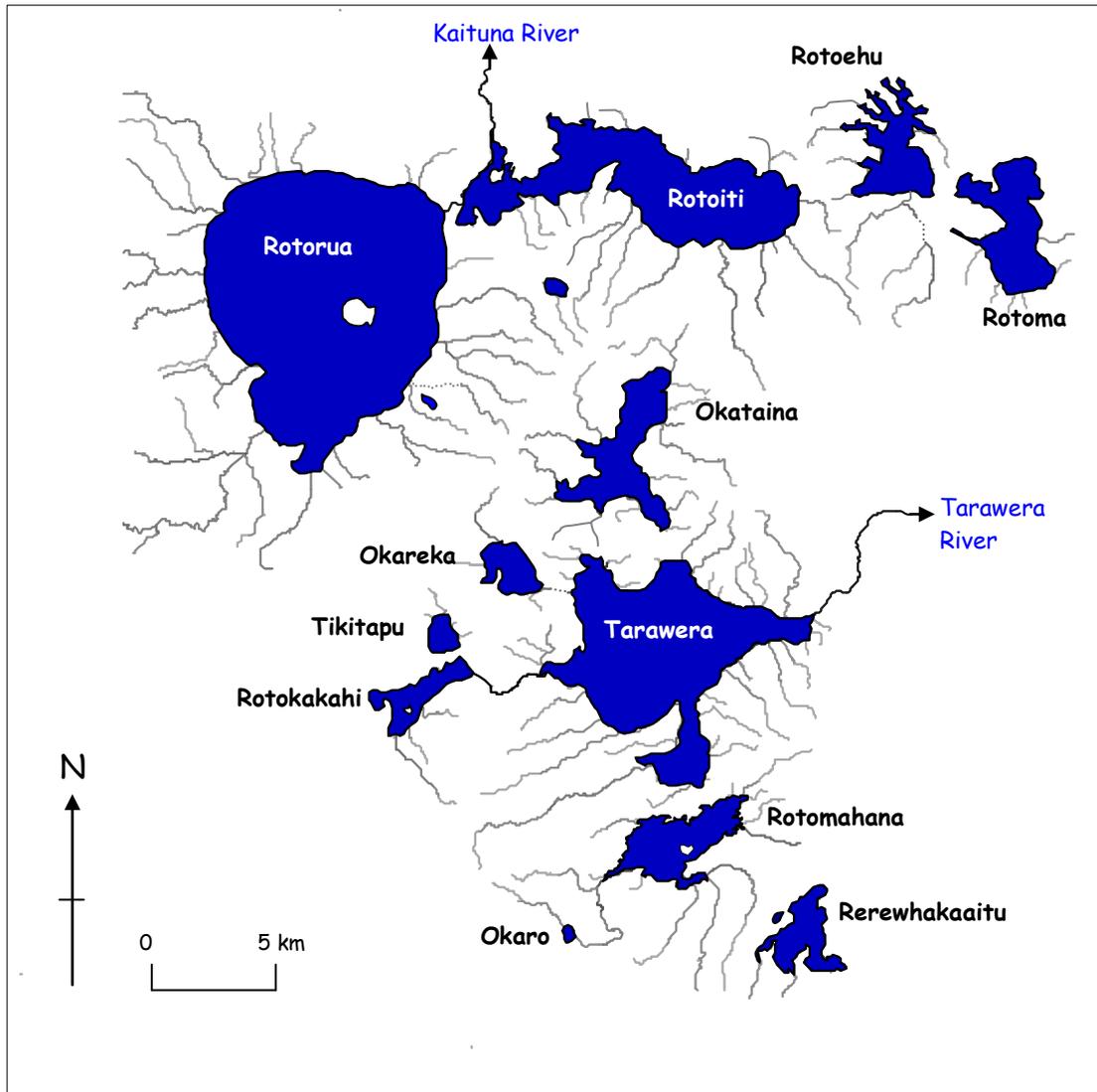


Figure 1: Map showing location of the 12 Rotorua lakes.

Table 1: Summary of lake characteristics.

Lake	Maximum Depth (m)	Mean Depth (m)	Size (km ²)	Catchment Area (km ²)
Okareka	33.5	20	3.33	19.6
Okaro	18	12.5	0.33	3.9
Okataina	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
Rotoma	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 lakes.

1.3.2 Lake vegetation changes

The Rotorua 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 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 Lakes is the introduction of a range of invasive plant species. The first 'oxygen weed' species (family Hydrocharitaceae) to establish in the Rotorua 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 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 Lakes is a gradual and on-going process, and there is a strong correlation with boat traffic and lake accessibility, with 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.

2 Study methods

2.1 LakeSPI

LakeSPI takes advantage of the usefulness of submerged plants as indicators (Clayton and Edwards 2006b). This includes their ease of observation, plants ability to integrate conditions over time, and a sensitivity to catchment based impacts in the littoral zone. LakeSPI also provides a direct measure of the impact by alien invasive weeds.

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).

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 quality 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.

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%.

2.2 Lake surveys

During this reporting period, observations were made at five standard baseline sites in each of the selected lakes: Okaro, Okareka, Okataina, Rotoiti, Rotoma, Rotomahana and Rotorua. At each site, scuba divers swam from the lake shore to the deepest extent of the vegetation. Depth extent (± 0.1 m using a dive computer) was defined as the cut-off for 10% plant cover, with 75% cover for charophyte ‘meadows’. The presence and depth extent of key native plant communities were noted, and their combined proportional contribution to the vegetation was estimated. The presence of any of 10 invasive weeds was also noted, together with their depth extent, the nature of weed cover, height, and overall proportional contribution to the vegetation.

For full LakeSPI method details, the LakeSPI Technical Report and User Manual can be viewed at <http://www.niwascience.co.nz/ncwr/tools/lakespi>. An online LakeSPI web reporting system (www.lakespi.niwa.co.nz) enables ready access to results in a form suitable for lake monitoring purposes and trend reporting.

2.3 Baselines

To help put the LakeSPI indices into context, each lake has been assessed using three different conditions: Pristine, Historical and Present day.

1. Pristine condition

This baseline usually describes the best possible lake condition, which in most New Zealand lakes would be what it theoretically was in pre-impacted times. However, because of the volcanically young history of the Rotorua lakes and impacts from geological events including earthquakes and eruptions along with fluctuating water levels in the last 150 years, the baseline used in this capacity would not be so relevant. This condition assumes that any lake in a pristine, undisturbed state would have supported a diverse range of submerged plant communities and have had no invasive plant species. A 'pristine condition' baseline allows lake managers to better compare present day lake condition with what the lake once would (or could) have been.

2. Historical condition

The LakeSPI method can be applied to available historic vegetation survey data using key vegetation information from macrophyte data in FBIS (Freshwater Biodata Information System - fbis.niwa.co.nz). Additional information on the nature of vegetation cover, proportion of native to invasive vegetation and the depth boundary for 10% cover was estimated from examination of the original survey sheets. Reference to historical LakeSPI scores allows changes over the last few decades to be followed. Prior application of the LakeSPI method for monitoring also provides a time trend against which to gauge recent changes.

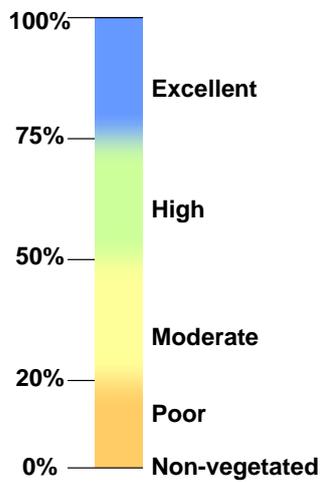
3. Present day condition

Present day condition was calculated for each lake based on the most recent survey data. These assessments provide managers with a benchmark for monitoring future changes and can help to assess the effectiveness of catchment and lake management initiatives.

2.4 Lake categories

For the purposes of ranking and discussing results, lakes have been categorised into five main groups based on the LakeSPI Index. Lakes are grouped as being in an 'excellent', 'high', 'moderate', 'poor', or 'non-vegetated' condition (Figure 2). These new lake groupings support an MfE initiative to ensure national consistency in terminology and reporting and allow for better comparisons of lakes nationally and regionally.

LakeSPI Indices **Categories of ecological condition**



Note: These categories are imposed on a continuum scale of scores; therefore we recognise some flexibility in the placement of lakes with scores close to the transition between categories. Lake placement in these cases will be made using expert opinion based on the current status of the lake and the pressures exerted on it.

Figure 2: LakeSPI indices categorise lakes into five lake condition groups.

2.5 Lake stability

Changes in LakeSPI indices over the last five years (or survey used that is closest to the five year timeframe) have been used to provide an indication of current stability in lake condition and direction of any change. The stability of lakes over this five year time frame, is indicated either as being stable ($\pm 3\%$), declining ($> -3\%$) or improving ($> +3\%$).

3 Results

Table 2 presents LakeSPI results for each lake, with the indices given 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 lakes in order of their overall lake condition (2010 or 2011).

Lake	Most Recent LakeSPI Survey	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)	Overall Condition
Rotoma	11/05/2011	51	58	52	High
Rotomahana	11/05/2011	50	53	47	
Okataina	07/04/2010	44	51	62	
Okareka	11/05/2011	35	43	76	
Rerewhakaaitu	07/04/2010	34	45	71	Moderate
Tikitapu	07/04/2010	34	24	49	
Rotokakahi	08/04/2010	28	23	76	
Okaro	31/03/2011	27	19	69	
Tarawera	31/03/2010	25	30	87	
Rotoiti	12/05/2011	20	25	91	
Rotorua	21/07/2011	20	20	81	Poor
Rotoehu	07/04/2010	15	22	93	

3.1 Lake Rotoma



Lake condition: High

Stability: Stable

Lake ranking: 1st

Table 3: LakeSPI results for Lake Rotoma. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine		98	97	0
	1973	69	63	19
	1988	54	57	41
Historical data	2001	52	54	44
	2005	52	58	51
	2008	48	53	54
	2009	47	53	56
Present day	2011	51	58	52

Lake Rotoma is now the highest ranked lake in the Rotorua region after lake condition values have remained relatively stable over the last 23 years, from 1988 – 2011. In 1973 Lake Rotoma had a high LakeSPI score, which reflected the early stage of lagarosiphon invasion and the extensive high cover charophyte meadows in this lake. By 1988 the Invasive Impact Index had more than doubled, which in turn reduced both the Native Condition Index and LakeSPI score for this lake. Since then, Invasive Impact scores have increased more gradually, with smaller changes occurring to the Native Condition Index or LakeSPI score. As a result this lake presently has the highest Native Condition Index for any of the lakes and one of the lowest Invasive Impact Index 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 after almost 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 has been the key driver of change in LakeSPI scores over that time.

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.

3.2 Lake Rotomahana



Lake condition: Moderate

Stability: Declining

Lake ranking: 2nd

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

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine		94	90	0
	1988	72	64	13
	2002	73	61	7
Historical data	2005	70	66	19
	2008	66	63	24
	2009	63	61	30
Present day	2011	50	53	47

After being the highest ranked lake in the Rotorua region for more than 20 years, declining lake condition values have resulted in Lake Rotomahana sliding into second position. The LakeSPI Index has declined by 20% since 2005 which is the largest change recorded for any of the 12 Rotorua lakes over this 5 to 6 year time frame and Invasive Impact scores have more than doubled. This is largely due to the recent 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 egeria now present at all 5 LakeSPI baseline sites (2 sites more than 2009) and forming bands of weed growth down to a depth of 8.5 m. The most recently recorded average maximum depth of vegetation (8.1 m) had reduced by more than 3 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.

Of interest during the recent 2011 survey was the presence of *Lymnaea auricularia* (ear pond snail), recorded for what is believed to be the first time within a natural New Zealand waterbody. This snail is known from within the aquarium/pond trade and their large numbers and widespread distribution around the lake indicates that they may have been present for some time, perhaps 5 or more years. Their increase in numbers and dispersal around the lake would have likely been much slower than that for egeria and hornwort, which would account for their later discovery. If this proposed timing is correct it suggests that egeria, hornwort and the ear pond snail could all have been introduced at the same time and by means other than boat transfer, such as an outdoor pond overflow or by deliberate release.

3.3 Lake Okataina



Lake condition: Moderate

Stability: Stable

Lake ranking 3rd

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

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine		94	90	0
Historical data	1981	51	57	53
	1988	47	53	57
	2005	44	51	65
	2008	48	54	58
	2009	45	47	60
Present day	2010	44	51	62

The discovery of an established bed of hornwort during the most recent 2010 survey poses a serious threat to the future condition of Lake Okataina. Hornwort fragments were found at the south-west end of the lake, with a search of the surrounding area revealing an established hornwort weed bed (Figure 3) growing in the middle bay west of Motuwhetero Island (authors pers obs.). Because only a couple of hornwort shoots were recorded from one of the five LakeSPI baseline sites, the Invasive Impact Index and other indices have not yet been greatly affected.

Previously an established hornwort plant was successfully eradicated from the lake in 2007, but from 2009 onwards additional fragments were located that suggested a possible established incursion within the lake. The location of the current find in a popular anchorage site suggests an association with boating activity, while the size of the colony suggests it has been present for some time and subsequent dispersal to other locations within the lake is likely. Further hornwort growth remains a major threat to Lake Okataina.

In the past 29 years (from 1981 to 2010), LakeSPI scores for Lake Okataina have been reasonably stable, with only minor fluctuations. Care must be taken in interpreting small

variations, as the lake has no outlet and water levels can vary by several metres. Although lake level changes tend to be quite slow, they can still affect the available habitat for submerged vegetation in shallow water and the corresponding adjustments in the maximum depth of charophyte colonisation may be slower.



Figure 3: 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.

3.4 Lake Okareka



Lake condition: Moderate

Stability: Stable

Lake ranking 4th

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

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine		94	90	0
	1980	40	49	67
	1988	44	53	66
Historical data	2001	41	50	70
	2003	34	42	77
	2006	34	39	76
	2009	34	39	78
Present day	2011	35	43	76

Lake Okareka currently appears to be in a stable condition indicated by the recent LakeSPI indices showing little change over the last 8 years, from 2003 to 2011. Prior to this however, a 10% decrease in the LakeSPI Index between 1988 and 2003, resulted from a decline in the quality of native plant communities present, indicated by the Native Condition Index, and an increase in the Invasive Impact Index over the same time frame.

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 and during the most recent survey it was well established at 4 of the 5 sites. As egeria continues to spread around the lake, displacing lagarosiphon with taller and denser weed growth and occupying a wider depth range, we can expect to see the LakeSPI Index decline further. Despite the spread of egeria around the lake, hornwort still poses a major threat to Lake Okareka with the potential to reduce the LakeSPI even further, by occupying a deeper range than egeria and by displacing all remaining deep water charophyte meadows.

3.5 Lake Rerewhakaaitu



Lake condition: Moderate

Stability: Declining

Lake ranking 5th

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

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine		94	92	0
	1973	55	58	37
Historical data	1988	41	48	57
	2005	38	47	65
	2008	41	52	64
Present day	2010	34	45	71

After remaining relatively stable from 1988 to 2008, the most recent LakeSPI assessment shows a decline in the overall condition of Lake Rerewhakaaitu. Increased Invasive Impact scores reflect the wider impacts that egeria is now having upon the lake; and apparent decreases in water quality (author pers obs.) and retraction in charophyte depth limits are concerning for the future state of this lake.

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 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 specimens 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 has 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. As a result LakeSPI Indices remained relatively stable over the 20 years from 1988 to 2008.

Egeria was first recorded in Lake Rerewhakaaitu in 2000 (Champion et al. 2006). By 2008 egeria was present at 2 of the 5 LakeSPI baseline sites and by the recent 2010 survey, had spread to all 5 sites, causing an incremental rise in the Invasive Impact score. Egeria is expected to have an increased negative impact on overall LakeSPI condition in years to come.

The recent 2010 survey also showed a retraction in the maximum depth of charophyte meadows (charophytes >75% cover) from a mean depth of 7.9 m in 2008 to only 3.8 m in 2010. This appears to be associated with reduced water clarity noticed at the time of this survey and suggests that low water clarity has been sustained in Rerewhakaaitu for a timeframe of months or more.

3.6 Lake Tikitapu



Lake condition: Moderate

Stability: Declining

Lake ranking: 6th

Table 8: LakeSPI results for Lake Tikitapu. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine		94	90	0
	1970	70	77	33
Historical data	1988	63	75	47
	2005	46	45	50
	2008	32	28	63
Present day	2010	34	24	49

The LakeSPI Index shows a reduction of 29% over the last 22 years to 2010 indicating that the condition of Lake Tikitapu has deteriorated faster than the other 11 Rotorua Lakes over this same period. Unlike the other lakes this decline is not due to the impact from new invasive species but from a substantial decline in the quality and extent of the native plant communities present.

Historic records for Lake Tikitapu confirm a lake that 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. The mean maximum depth of native plant growth at survey sites further decreased from 12.4 m in 2005, 8.8 m in 2008, to only 2 m in 2010 resulting in a 21% decline in the ‘Native Condition Index’ over the last 5 years.

A notable decrease in the Invasive Impact Index from the 2010 survey is another indicator of the lakes changing condition. Prior to this last survey a continued increase in Invasive Impact scores occurred due to the existing invasive vegetation having a greater relative impact on

overall vegetation status, rather than any new invasive plant introductions or spread of existing invasive plants.

The trend of decreasing LakeSPI condition in Lake Tikitapu indicates on-going deterioration in the water quality and clarity of this lake at an alarming rate. Recently, Burns et al. (2005) reported that anoxia is occurring in bottom waters, possibly triggering phosphorous release in this phosphorous limited lake. A deep chlorophyll layer of was reported above the thermocline (David Hamilton, Waikato University, pers comm. 2008) that may have had a negative impact on the previously deep-water charophyte meadows. Subsequently, the widespread decline in native charophyte meadows could have contributed to further decline in water quality due to the loss of their beneficial sediment and water stabilisation influences (Donk & van de Bund 2002, Blindow et al. 2002).

When the water chemistry of Lake Tikitapu was assessed in the early 1970s it had the lowest alkalinity recorded for any of the Rotorua 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 diatoms and even the unusual low stature and lax growth habit of lagarosiphon in this lake.

3.7 Lake Rotokakahi



Lake condition: Moderate

Stability: Declining

Lake ranking 7th

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

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine		94	90	0
Historical data	1988	52	61	53
	2005	35	36	71
	2008	31	32	71
Present day	2010	28	23	76

Lake Rotokakahi has undergone the second largest decline behind Lake Tikitapu shown for any of the 12 lakes over the same 22 year time period. The LakeSPI Index has almost halved with a 24% reduction from 1988 to 2010, whilst the Native Condition Index has also decreased by 38% largely due to a decline in charophyte meadows. This has occurred even though there has been no change in the dominant invasive species (*Elodea canadensis*) in this lake; although the relative impact of invasive presence on overall submerged vegetation has increased. The declining condition of Lake Rotokakahi, like Lake Tikitapu, is not due to invasive weeds but rather a decline in native condition presumably due to a change in water quality. Additional observations support this in Lake Rotokakahi, 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 poor lake health. 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 logging in the catchment appears to have further increased lake turbidity since the last 2008 LakeSPI survey. A decline in oxygen content in deeper water has been noted by David Hamilton (Waikato University pers comm.), which is consistent with hypolimnetic nutrient enrichment taking place. Lake Rotokakahi is now the only Rotorua Lake to remain relatively free of significant invasive weed species.

3.8 Lake Okaro



Lake condition: Poor
 Stability: Improving
 Lake ranking 8th

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

State	Year	LakeSPI	Native	Invasive
		Index (%)	Condition Index (%)	Impact Index (%)
Pristine		94	89	0
	1982	31	29	67
Historical data	1989	29	15	30
	2003	19	6	76
	2006	19	6	53
	2009	21	13	77
Present day	2011	27	19	69

The degraded nature of Lake Okaro and its wide fluctuations in water quality and clarity account largely for the variation in LakeSPI scores, in particular in the Invasive Impact scores, generated for this lake over the last 29 years. The most recent LakeSPI results, however, are indicating a small improvement in the condition of Lake Okaro and it is now ranked in 'Moderate' condition. This result may reflect recent efforts by Environment Bay of Plenty to reduce nutrient influx into the lake and nutrient release from hypolimnetic sediments, which may well be helping to improve water clarity and be resulting in a positive vegetation response.

Over the last 5 years the Native Condition Index has more than doubled to 19% (still the lowest Native Condition value for any of the 12 Rotorua lakes) and the LakeSPI Index has increased by 8% to 27%. 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 and the hypereutrophic nature of the lake continues to provide an unfavourable habitat for submerged vegetation. This is reflected in the highly variable cover and depth range of elodea, both seasonally and annually. It is also likely to explain root lyses (root death and detachment) in elodea beds from periods of oxygen stress and anoxia. 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 has appeared as non-rooted 'drift'. This may well coincide with periods of shallow stratification with severe anoxia below the thermocline resulting in root death and shoot detachment.

3.9 Lake Tarawera



Lake condition: Moderate

Stability: Stable

Lake ranking 9th

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

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine		94	90	0
	1988	41	50	70
Historical data	1994	22	30	89
	2005	28	33	88
	2008	22	27	92
Present day	2010	25	30	87

Lake Tarawera remains in a moderate condition and is not expected to change in the near future since the full impact of hornwort has now taken place.

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). The high Invasive Impact Index recorded in 1994 (89%) has remained almost the same and Tarawera has one of the highest Invasive Impact Index scores of the 12 Rotorua lakes. The LakeSPI Index declined by 19% in only 6 years from 1988 to 1994 and has remained low since that time. This was the largest LakeSPI decline for any of the Rotorua lakes over such a short time frame. The Native Condition Index also declined substantially from 1988 to 1994 and has remained low, with hornwort responsible for widespread displacement of almost all the former deep-water charophyte meadows.

3.10 Lake Rotoiti



Lake condition: Poor
 Stability: Stable
 Lake ranking: 10th equal

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

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine		94	90	0
	1981	26	33	82
	1988	26	33	85
Historical data	2001	20	24	90
	2003	18	22	90
	2006	18	18	90
	2009	21	29	89
Present day	2011	20	25	91

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. Small changes in the Native Condition and LakeSPI values reflect the variable condition of native charophyte meadows (>75% cover) at some baseline sites, growing to a maximum depth of only 3.5 m during the recent survey.

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 to entrain Lake Rotorua inflows down the Kaituna River may see reduced water quality impacts, especially in this area. However flow-on effects on submerged vegetation is not yet clear. 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.

3.11 Lake Rotorua



Lake condition: Poor
 Stability: Stable
 Lake ranking: 10th equal

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

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine		94	90	0
	1982	27	23	68
	1988	18	21	90
Historical data	2001	22	17	74
	2003	22	21	77
	2006	22	21	78
	2009	27	31	78
Present day	2011	20	20	81

Lake Rotorua is presently in a poor but stable condition similar to that recorded 29 years ago 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. These shallow plant communities, however, can be ephemeral in nature, especially when subjected to seasonal storms like those that occurred prior to the 2011 LakeSPI survey of Lake Rotorua. As a result charophyte meadows (>75% cover) were present at only 2 of the 5 LakeSPI baseline sites during the 2011 survey, compared to 4 sites in 2009 which resulted in a higher Native Condition Index.

Prior to the recent 2011 survey, the LakeSPI scores and Native Condition Index did not change a lot over the last 27 years from 1982 to 2009. The variable Invasive Impact Index over this same period 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, which is reflected in the Invasive Impact Index from 2001 declining from the 1988 peak.

3.12 Rotoehu



Lake condition: Poor
 Stability: Declining
 Lake ranking 12th

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

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine		89	88	0
	1988	33	33	73
Historical data	2003	34	34	64
	2006	22	32	82
	2008	18	26	85
Present day	2010	15	22	93

Lake Rotoehu now has the lowest LakeSPI Index (15%) and the highest Invasive Impact score (93%) recorded for any of the 12 Rotorua lakes. This is a direct reflection of a major infestation of hornwort which has spread through the lake resulting in a 19% decline in the LakeSPI Index since the 2003 survey. Hornwort was first recorded in the lake off Otautu Bay in December 2004 (R. Mallinson, EBoP, pers comm.) and by late summer 2005 there were extensive weed beds along much of the shoreline. The most recent LakeSPI results show the negative impact hornwort is having on native submerged vegetation within the lake and Lake Rotoehu remains in the bottom group of 3 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 detrimental impact hornwort will have on littoral condition. Nutrient removal by means of weed harvesting may not only reduce weed impact but also help remove stored nutrients. Out of all the Rotorua 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). A total of 600 tonnes of hornwort was harvested and removed from Lake Rotoehu over a 4 week period from April to May 2008, which equated to removal of 720 Kg of nitrogen and 96 Kg of phosphorous (R. Mallinson EBoP, pers comm.).

4 Discussion

Long term changes

Many of the Rotorua Lakes have undergone significant change over the last two decades (Figure 4) and continue to be vulnerable to further changes from invasive plants and water quality deterioration. The submerged plant indicators used in LakeSPI provide an effective and alternative means to being able to assess these changes and monitor trends over time.

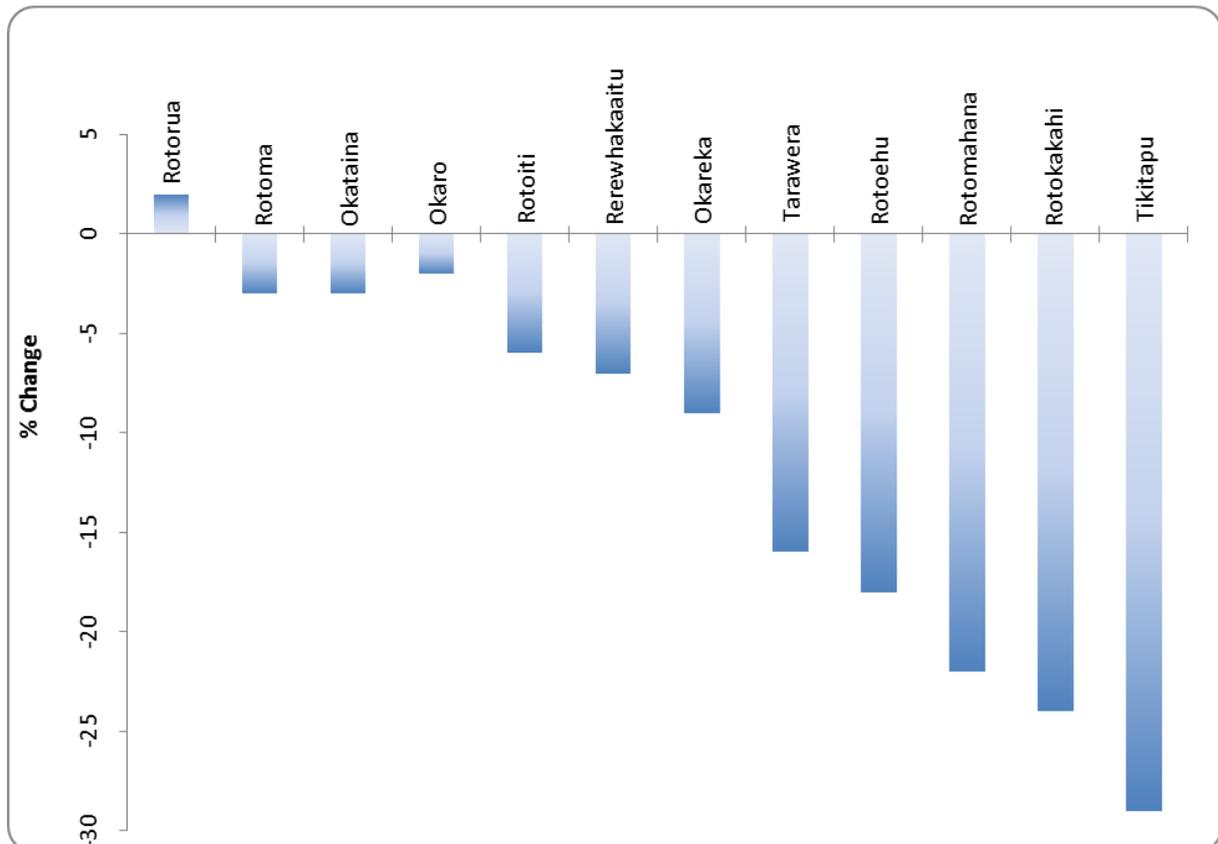


Figure 4: Percentage of change as indicated by the LakeSPI Index over the last 23 years, 1988 to 2010/11.

Lakes Tikitapu and Rotokakahi show the biggest change in lake condition over the last 20 years resulting from a notable reduction in the quality and extent of native submerged vegetation present in the lakes. There has been no new invasive species in either lake since full lake surveys in 1988, so these changes are likely the result of deteriorating water quality and clarity. Submerged plants are able to integrate long term changes in water clarity and nutrient status 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 depth of 19.5 m. By 2008, charophyte meadows ($\geq 75\%$ cover) were found at only one LakeSPI site with remnants ($\leq 5\%$ cover)

found at one other and by 2010, charophyte meadows had disappeared and the mean maximum depth of plant growth (inclusive of invasive species) had declined to only 3.6 m.

Next to water quality, the second biggest change affecting the condition of the Rotorua Lakes is the introduction of invasive plant species. Invasive species tend to impact negatively on lake condition by displacing native plant communities to around a depth of 6-10 metres with the worst of these invasive species, hornwort, able to out-grow and smother native vegetation to around 15 metres. Hornwort is now present in 6 of the 12 Rotorua Lakes and is the dominant invasive species in 2 of these lakes, Tarawera and Rotoehu. Lake Tarawera now remains in a stable state and it is not expected to change much in the near future since the full impact of hornwort has now taken place. 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. Lake Rotomahana is also showing signs of declining condition on account of egeria and hornwort invasion. Already vulnerable to change on account of low water clarity and the limits this posed on the extent of native submerged vegetation, Lake Rotomahana has undergone the largest decline in LakeSPI scores recorded for any of the 12 Rotorua lakes over the last 5-6 year time frame and the third biggest change in overall long term condition (Figure 4). We can expect to see lake values decline further as egeria and hornwort continue to spread and displace the native vegetation in this lake. Lake Okataina is the most recent lake to report an incursion of hornwort and while measures are being taken to prevent further spread of hornwort around the lake, we might also expect to see a notable decline in the status of Lake Okataina in years to come.

Lakes Rotoma and Okareka remain at risk of invasion by hornwort, which would result in a major decline in LakeSPI scores based on their potential for invasion and the impact that this species would have on their present vegetation status. Lake Rerewhakaaitu could also be severely impacted, but the risk is less imminent on account of its greater distance from nearby hornwort infestations and much lower boat traffic. In 2008 EBoP 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. It is recommended that a similar containment cordon should be considered a priority for the boat ramp at Lakes Okareka.

National comparison

Compared nationally, the Rotorua Region have 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 5).

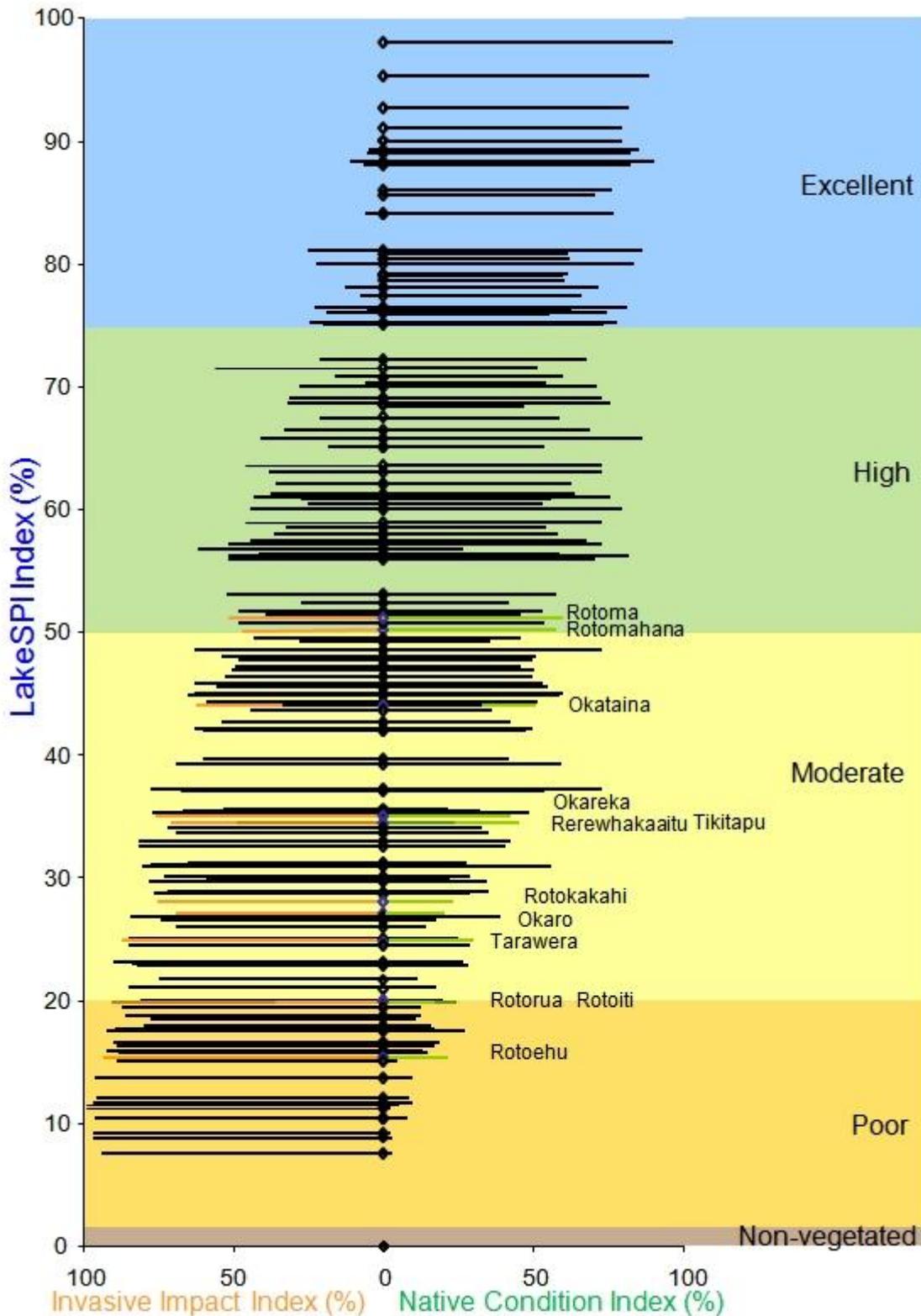


Figure 5: Current LakeSPI scores for 215 New Zealand lakes showing LakeSPI Index, Native Condition Index (right hand bars), and Invasive Impact Index (left hand bars).

A 'moderate' condition category contains the majority of the Rotorua Lakes and contains the largest proportion of lakes nationally. This 'moderate' condition group of lakes are representative of those lakes that are impacted in varying degrees by invasive weeds.

A smaller proportion of the Rotorua Lakes 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 for 2 of the 3 Rotorua Lakes ranked in this 'poor' category. Water quality issues that have created unfavourable conditions for submerged plant growth are also often represented in this group of 'poor' condition lakes (e.g., Lake Okaro).

5 Conclusions

LakeSPI results have provided valuable inter-lake comparisons and show many of the Rotorua Lakes having undergone significant change over the last two decades while continuing to be vulnerable to further changes from invasive plants and water quality deterioration. As well as providing a cost effective monitoring tool for regional and national reporting requirements, LakeSPI information is also used to prioritise management objectives such as for surveillance strategies, appropriate protection measures for high value lakes and potential restoration objectives for degraded lakes.

The Rotorua lake ranked as being in 'high' condition is Rotoma. Lake Rotoma is now the highest ranked lake in the Rotorua region and appears to maintain good water quality. It does however remain under serious threat from potential hornwort invasion which would have a major detrimental impact on the native character and biodiversity value of this lake.

Lakes Rotomahana, Okataina, Okareka, Rerewhakaaitu, Tikitapu, Rotokakahi, Okaro and Tarawera are currently ranked as being in 'moderate' condition. Lake Rotomahana has shown the largest decline in lake condition over the last 5-6 year time frame of any of the Rotorua lakes. This is largely due to the introduction and spread of invasive species which has more recently seen the Invasive Impact Index more than double. Lake Okataina has been relatively stable. However, the recent discovery of an established bed of hornwort poses a serious threat to the future stability and condition of Okataina. Lake Okareka also remains relatively stable but has a high risk of hornwort invasion, where the expected outcome would be displacement of all native charophyte meadows. Lake Rerewhakaaitu after remaining relatively stable now shows signs of declining lake condition. Increased invasive impacts from egeria and changes noted in water quality that are impacting on charophyte depth limits and are of concern for the future state of this lake. Lake Tikitapu continues in a state of notable decline on account of changing water quality and clarity although there have been no new invasive species since the first full lake survey in 1988. Lake Rotokakahi also continues to appear in a state of decline due to water quality issues. Over the last 20 years, both Lakes Rotokakahi and Tikitapu have seen a reduction in the quality and extent of native plant communities present, without any direct change in invasive species presence or performance. A slight improvement was noted in scores for Lake Okaro during the 2011 survey and it is now classified in 'moderate' condition. This reflects an increase in native plant cover and diversity, and a corresponding decrease in invasive plant covers during the recent survey. Lake Tarawera also falls into this 'moderate' condition category and its condition is not expected to change in the near future since the full impact of hornwort has now taken place.

Lakes Rotoiti, Rotorua and Rotoehu are classified as being in a 'poor' condition and are not expected to move from this position in the near future. Lake Rotorua is the only lake to have shown a slight increase in lake condition scores over the past 23 years (Figure 4) but remains in a poor condition. Lakes Rotoiti and Rotoehu also remain classified as in 'poor' condition and are not expected to move from this position in the near future. However, restoration measures on these lakes and others that result in a sustainable improvement in

water quality and clarity would be expected to result in improved LakeSPI scores in the future.

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

Lake Rotoma

- Overall lake condition high and appears stable.
- LakeSPI scores stable with the highest Native Condition Index and one of the lowest Invasive Impact Index.
- An exceptional lake and the best example of extensive charophyte meadows.
- Major threat from hornwort invasion.

Lake Rotomahana

- Overall lake condition now moderate and declining.
- Recent invasion by egeria and hornwort having a significant impact.
- High Native Condition Index and lowest Invasive Impact Index of any lake.

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 Okareka

- Overall lake condition moderate and likely to decline.
- Invasion by egeria yet to fully influence Invasive Impact Index scores.
- Major threat from hornwort invasion.

Lake Rerewhakaaitu

- Overall lake condition moderate and now declining.
- Invasion by egeria yet to fully influence Invasive Impact Index scores.
- Water clarity and depth of native charophyte plant growth had considerably improved since 1973 but the 2010 survey now indicates decline.
- Moderate threat from hornwort invasion.

Lake Tikitapu

- Overall lake condition moderate and declining.

- Major decline in Native Condition Index and LakeSPI scores over the last 22 years independent of any impact from new invasive species.
- Unusual water chemistry may inhibit impact from present and future invasive species.

Lake Rotokakahi

- Overall lake condition moderate and declining.
- Major decline in LakeSPI and Native Condition Index over last 20 years.
- No change in elodea but invasive impact accentuated by decline in native plant communities.
- Now the only Rotorua lake (with the exception of Okaro) to remain relatively free of the worst 'high impact' invasive weed species.

Lake Okaro

- Overall lake condition moderate and variable.
- Unstable LakeSPI scores due to variable water quality and seasonal response of elodea. Possible signs of some improvement following lake restoration measures.
- Has the lowest Native Condition Index for any of the lakes.

Lake Tarawera

- Overall lake condition moderate and likely to be stable in the immediate future.
- LakeSPI and Native Condition Index scores have declined significantly over the last 22 years.
- Invasion of hornwort primarily responsible for decline in LakeSPI and Native Condition scores.

Lake Rotoiti

- Overall lake condition poor.
- Has one of the highest Invasive Impact Indices of the Rotorua lakes.
- LakeSPI Index indicates poor water quality.

Lake Rotorua

- Overall lake condition poor and variable.
- Only lake to have shown a slight increase in lake condition scores over the past 22 years.

Lake Rotoehu

- Overall lake condition poor and declining.
- Recent invasion by hornwort is having a major impact.
- Has one of the highest Invasive Impact Index of the Rotorua lakes.

6 Recommendations

All possible measures should be explored for preventing further hornwort transfer (e.g., public education) and establishment into vulnerable lakes, such as Lakes Rotoma and Okareka. Now that Lake Okareka will have a weed cordon in place before the end of this month, it would be worthwhile to survey private ponds in all residences in the catchment to check for hornwort presence since this weed presents a very high risk for the lake.

There may be some merit in assessing some lakes annually. In particular are those lakes where significant changes are taking place either by deterioration (e.g., Tikitapu, Rotokakahi, Rerewhakaaitu) or from improvements (e.g., Okaro, Okareka and Rotoiti) attributable to restoration works such as phosphorus capping and nutrient diversion.

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