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TE RAUHĪTANGA TAIAO

Assessment of the ecological condition of 32 lakes in the Auckland Region using LakeSPI

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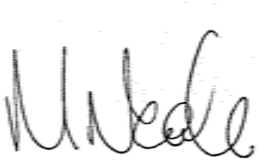

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Assessment of the ecological condition of 32 lakes in the Auckland Region using LakeSPI

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Prepared for
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1 Executive Summary

The Auckland Regional Council (ARC) contracted NIWA to assess the ecological condition of 32 lakes within the Auckland 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. A three phase exercise was undertaken for the ARC that identified lakes with sufficient information to assess current condition using LakeSPI (Phase 1), carried out LakeSPI surveys for additional lakes selected by the ARC (Phase 2) and prepared a report detailing all LakeSPI information for the Auckland Region's lakes (Phase 3).

Three LakeSPI indices were generated from key features of submerged vegetation structure and composition: a 'Native Condition Index' where higher values indicate better lake condition based on the diversity, depth extent and quality of indigenous plant communities; an 'Invasive Condition Index' where higher values show greater impact from invasive weed species and a lower lake condition; and a 'LakeSPI Index' which provides an overall indication of lake condition with higher values indicating better lake condition.

LakeSPI indices were expressed as a percentage of a lake's maximum scoring potential to enable comparisons between lakes. To identify time trends, each lake has also been assessed using three different baselines: 'Pristine' (or 'Potential Condition'), 'Historical' (using available information) and 'Present day'.

Present day LakeSPI Indices for lakes of the region ranged widely from 0% to 90% and were categorised into four groups comprising:

1. An 'Excellent' group of six lakes that scored a LakeSPI Index >60%. These lakes, ranked in order from best, were Poutoa, Tomarata, Mangatawhiri, Pokorua, Ototoa, and Wairoa.
2. A 'Good' group of eight lakes that scored a LakeSPI Index of 20 – 60%. These lakes were Waitakere, Cossey's, Upper Huia, Whatihua, Lower Huia, Pupuke, Silver Hills, and Small Pehiakura.
3. A 'Poor' group of seven lakes that scored a LakeSPI Index <20%. These lakes were Okaihau, Wainamu, Big Pehiakura, Kuwakatai, Te Kanae, Kawaupaku, and Kereta.
4. A 'Non vegetated' group of eight lakes, that did not exceed the threshold vegetation abundance (10% cover) for application of the LakeSPI method, received a default of 0%. These lakes were Mangatangi, Hays Creek, Karaka, Paekawau, Slipper, Spectacle, Upper Nihotupu, and Western Springs.

Three lakes were not assessed due to unsuitability for the LakeSPI method (Piripoua, Ngakaru), or because of poor visibiity conditions for survey (Lower Nihotapu).

Lakes not classified as being in 'Excellent' condition were further assessed to determine the major contraint on LakeSPI values and vegetation development. Of these lakes:

- Ten lakes were significantly impacted by invasive submerged weeds (Invasive Condition Index >75%) due to dominance by hornwort (*Ceratophyllum demersum*), *Egeria densa*, and/or *Vallisneria gigantea*.
- Six lakes, mostly 'Non vegetated', possessed poor water clarity at the time of survey that was likely responsible for the poor development and depth extent of submerged vegetation. Western Springs was not vegetated on account of stocking of grass carp for weed control purposes.
- Eight Watercare Reservoirs in the Waitakere and Hunua Ranges were clearly influenced by the amplitude, duration and direction of water level change in the year prior to survey. However the LakeSPI indices reflected the recent stability of water levels during the few months prior to survey.

Recent changes in LakeSPI indices were also assessed to provide an indication of current stability of lake condition. Of the 29 lakes that were suitable for LakeSPI assessment, only seven appeared to be in a stable condition with ≤2% change in LakeSPI indices. Six lakes showed an improvement in lake condition with Lakes Tomarata and Pokorua showing a >30% increase in LakeSPI indices. A further six lakes showed declining lake condition with three of these lakes showing a >20% reduction in LakeSPI indices. Lack of historical vegetation descriptions limit the assessment of stability for the remaining ten lakes. All lakes except Lake Poutoa showed a reduction in condition from 'pristine' condition.

Comparisons of LakeSPI results for 161 New Zealand lakes emphased the high number of lakes in the Auckland Region that are extensively invaded by the worst ranked invasive submerged weeds. Auckland has also the second highest ranking for the proportion of lakes in a region which are non vegetated (LakeSPI Index of 0%).

Priority rankings of lakes for future monitoring are presented, that integrate both the current condition of lakes and the extent and immediacy of threats facing water body condition. A schedule for LakeSPI monitoring of the Auckland lakes is recommended with a sampling frequency of 2 years for three high priority lakes, 3-4 years for six moderate priority lakes and 5-10+ years for most other waterbodies.

2 Introduction

2.1 Study brief

Auckland Regional Council (ARC) are preparing a State of the Environment (SOE) report for the Auckland Region in 2009 and wish to include information on the regions lakes. The LakeSPI (Submerged Plant Indicators) method to assess the ecological condition of lakes (Clayton and Edwards 2006) 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 in a recent report 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' (MFE 2006). This method has now been applied by agencies in seven regions of New Zealand. LakeSPI compliments traditional water quality monitoring, such as the Trophic Level Index method (Burns and Bryers 2000), by providing ecological information. For example, LakeSPI focuses on the littoral edges of lakes where human interaction is the greatest and where impacts from inflowing water quality is most apparent (Clayton and Edwards 2006).

The ARC contracted NIWA to assess the condition of 32 lakes within the Auckland Region using LakeSPI. It was recognised that different levels of submerged plant information existed for lakes of the region, ranging from full LakeSPI assessments carried out in the last 5 years, to limited or older information, to no available information at all. Because of this variable data availability, a three-step project was undertaken:

- Phase 1 - Desktop exercise. LakeSPI scores were generated for lakes in the region where suitable data was available from submerged vegetation surveys carried out in the last 5 years.
- Phase 2 - Where there was insufficient information, or a likelihood that available information was not current, then LakeSPI surveys were undertaken for additional lakes selected by the ARC.
- Phase 3 - This report was prepared to provide a 'one-stop' source of LakeSPI information for the regions lakes. LakeSPI scores for each lake are reported here, accompanied by a brief description of vegetation character, and impacts or threats that may be facing these lakes (Section 4). Current LakeSPI scores are collated and ranked in order, together with an explanation of the main characteristics driving each score, while historical and 'pristine' scores are also considered to identify time trends in condition (Section 5). Finally, recommendations are provided on priorities and schedules for future LakeSPI monitoring of lakes based on their apparent stability, value, and perceived threats (Section 6).

2.2 History of lakes of the Auckland Region

The Auckland Region has approximately 72 water bodies of 1 ha in size or greater (Lake Environmental variables database, Snelder *et al.* 2006), ranging in size from small ponds to several large flooded valleys which serve as reservoirs for Auckland City reticulated water supply. Lake types in the region can be categorised depending on where they are situated and how they were formed. These types include sand dune lakes along the western and eastern coasts, water bodies of volcanic origin in the city of Auckland and constructed reservoirs for water storage and abstraction, mainly in the Waitakere and Hunua Ranges.

Prior to people arriving in New Zealand, naturally formed lakes would have been in their natural 'pristine' state. Periodic disruption to lake condition would have occurred with natural disturbances, such as volcanic activity, flood events or from dynamic dune processes. Changes in lake condition also took place as the lakes aged, with key influences being changing climatic conditions, changes in catchment vegetation and progressive nutrient enrichment associated with increased productivity. Native submerged plant communities were likely present in all natural lake types as evidenced by early botanists. For example, Cheeseman collected six species of native charophyte from Lake Pupuke in 1884 (Wood and Mason 1977) and Cunningham *et al.* (1953) reported extensive native plant communities in five coastal dune lakes within the region.

The reservoirs of the Waitakere and Hunua Ranges were dammed from stream valleys between the early 1900's and 1970's. Newly constructed water bodies are often rapidly colonised by submerged plants that are spread from seed by waterfowl, so that vegetation can develop to a similar extent and diversity to natural systems over a relatively short time.

The early history of land settlement, scale of land use change and proximity to a large population centre meant that lakes in the Auckland Region may have been especially vulnerable to change. Three major factors cause the accelerated decline in ecological condition of lakes: (1) declining water quality; (2) invasive plant species; and (3) invasive fish species.

Declining water quality typically results from the conversion of forested lake catchments to agriculture, exacerbated by associated drainage of wetlands and removal of lake-margin vegetation, fertiliser application to pasture, and further impacts from farming activities which, collectively, lead to accelerated nutrient enrichment and siltation. The result is increased productivity at an unnatural rate and dominance of phytoplankton over submerged plants so that lakes may ultimately become de-vegetated and turbid.

In recent years there has been widespread liberation of invasive exotic fish such as rudd and koi carp, which have contributed significantly to the deterioration in water quality (Rowe 2007) and the decline of submerged vegetation. Juvenile stages of many invasive exotic fish, and some adult stages, feed on zooplankton and so may release planktonic algae from the grazing control exerted by zooplankton (Rowe 2007). Exotic fish also contribute increased sediment resuspention in lakes and can reduce plant

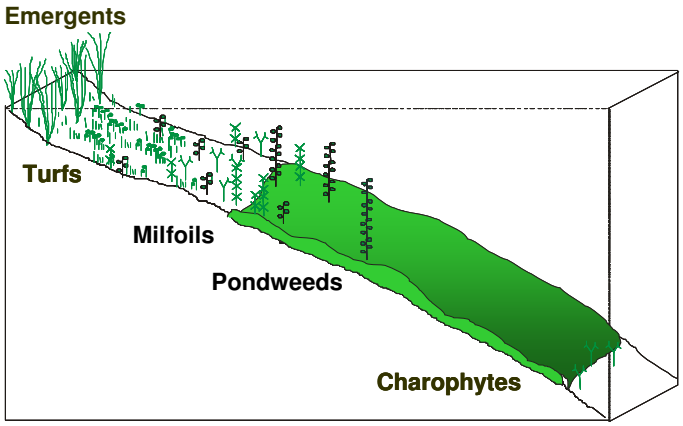
cover (Rowe 2007). Herbivorous rudd directly graze on submerged vegetation (de Winton *et al.*, 2003), whilst exotic fish are also implicated in preventing the re-establishment of vegetation from propagules, which contributes to the present poor status of many turbid de-vegetated lakes.

Thirdly, there has been extensive invasion of most lakes by submerged weed species that have largely displaced native submerged vegetation. The earliest recorded weed introduction was *Elodea canadensis*, which arrived in New Zealand in the late 1800s and was subsequently spread around much of the country. Cheeseman (1886) recorded the early establishment of *Vallisneria gigantea* (as *V. spiralis*) in Lake Pupuke, although the species has not spread from this site. Successively more competitive submerged weeds established in New Zealand lakes, firstly *Lagarosiphon major*, then *Egeria densa* and *Ceratophyllum demersum*. Their combined effect has led to the virtual loss of submerged native plants from many lakes. Subsequent rapid and widescale declines in the abundance of weed-dominated vegetation, particularly *E. densa* (Champion 2002), has occurred in fifteen or more New Zealand lakes including Lake Wainamu in Auckland Region (de Winton *et al.*, 2007). In de-vegetated lakes, high biomass algal growth or re-suspension of bottom sediments often reduces water clarity to the point where aquatic plants have not re-established.

2.3 Lake vegetation changes

In a pristine state, lakes in the Auckland Region would have once contained a diverse range of native plant species to a depth determined by water clarity or the maximum depth of the lake (Figure 1). For very shallow lakes (i.e., <5-10 m depth) it is likely that plant growth would have occurred across the entire lake bottom at some stage during their development and maturation. Today, there are relatively few lakes that remain in an all-native vegetated state.

Figure 1.
Depth profile illustrating the main components of native lake vegetation.



With the introduction of invasive submerged plant species during the mid 1900's, native plants in most lakes were displaced by invasive weed species, often forming tall monospecific weed beds (Figure 2), which were then especially vulnerable to subsequent decline and dominance by phytoplankton or turbid water conditions (Figure 3). Although invasive species are not favourable in terms of overall lake condition, the presence of any submerged plants in a lake is preferable to none, because they mitigate many of the symptoms of eutrophication (e.g., lock-up nutrients, maintain water clarity, compete with phytoplankton).

Figure 2.
Depth profile illustrating the potential impact of invasive species.

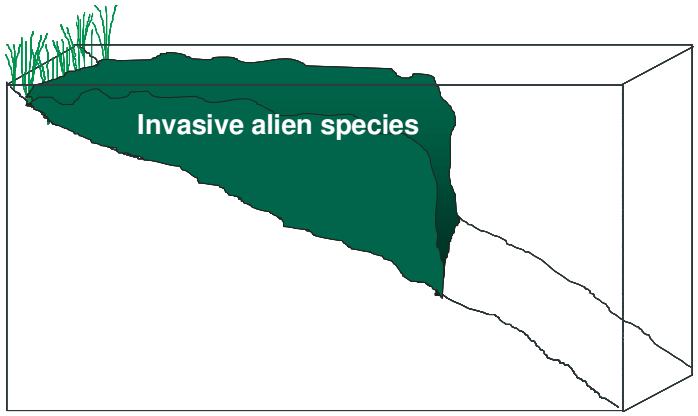
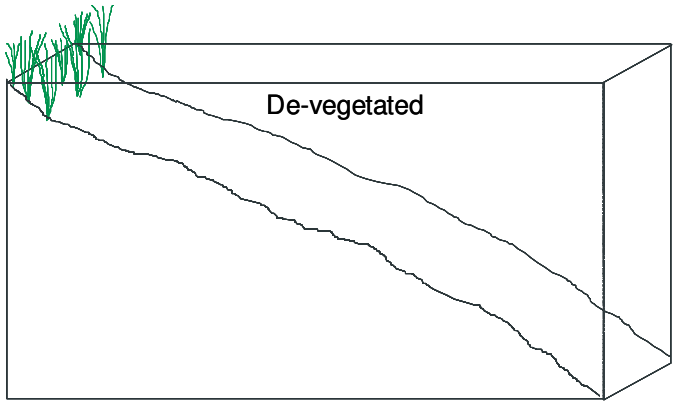


Figure 3.
Depth profile illustrating a de-vegetated lake.



2.4 Plants as indicators of lake condition

Submerged plants have a number of advantages that favour their use as indicators of lake condition. For example, they are predominantly rooted or anchored to the bed of lakes. They are also macroscopic and perennial in nature, and together these features make them easy to observe, sample and identify. This contrasts with many other biota that can be highly mobile (e.g., fish) or difficult to sample, measure or identify (e.g., plankton).

Submerged plants also effectively integrate the range of environmental conditions supporting plant growth over an extended period of time prior to survey. This contrasts with other physio-chemical methods (e.g., water chemistry and Secchi disc), which may change markedly over short time periods and require frequent measurements throughout the year.

In lakes where the littoral zone (lake margin to maximum plant depth) represents a large proportion of the lake area (e.g., small shallow dune or peat lakes), the open water (or centre lake) condition can have quite different water quality and ecological condition compared to the littoral zone. Given the importance of the littoral zone to the overall ecological state and recreational value of many lakes it is important to monitor the ecological well-being and biological functioning of the littoral zone where submerged plants tend to dominate.

Increased sediment and nutrient loading from catchment activities, and displacement of native vegetation by invasive alien plant species are major influences on lake ecology and condition. The submerged plant indicators used in LakeSPI provide an effective means of assessing these impacts.

3 Study methods

3.1 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 in lake ecological condition. Key features of aquatic plant 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 submerged vegetation.

'Invasive Condition 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 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 are taken to represent healthier lakes or better lake condition, while invasive plants are ranked for undesirability based on their displacement potential and degree of measured ecological impact (Clayton & Edwards 2006).

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

A complete description of measured characteristics is given in the technical report and user manual at www.niwascience.co.nz/ncwr/tools/lakespi.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.

3.2 Baselines

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

1. **Pristine condition or potential condition**

Pristine condition describes the best possible condition for a lake, as it theoretically would have been in pre-european times. Because suitable pre-impact submerged vegetation records are not available for most lakes, for the purpose of establishing a pristine baseline we have adopted the limitation posed by lake depth as the maximum scoring potential for lakes. 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 alien plant species. Characteristics of vegetation structure and species composition are extrapolated from lake vegetation characteristics where given by early botanists (e.g., Cunningham *et al.*, 1953), or from unimpacted examples of similar lakes.

In the case of constructed reservoirs a pristine condition is not applicable as in its original state it would have existed as a stream system. In these cases a best potential condition is estimated in a similar way to pristine condition, but based on current reservoir depth. A 'pristine condition' or 'potential condition' baseline allows lake managers to better compare present day lake condition with what the lake once would have been, or could be.

2. **Historical condition**

The LakeSPI method can be applied to available historic vegetation survey data. Sources of information include published accounts, unpublished reports, and macrophyte data in FBIS (Freshwater Biodata Information System – www.fbis.niwa.co.nz). The limitations of source information are considered in these assessments with FBIS data providing the most reliable and comprehensive information (see information sources below). Reference to historical LakeSPI scores allows changes over the last few decades to be followed.

3. **Present day condition**

Present day conditions were calculated for each lake based on the most recent survey data (within the last 5 years). These assessments provide managers with information on present condition, a benchmark for monitoring future changes and can help to assess the effectiveness of catchment and lake management initiatives.

3.3 Vegetation description sources

Data for the LakeSPI assessments have been collected from a variety of sources including published accounts of historical vegetation condition. Historical data was obtained from Cunningham *et al.* (1953), where plant grab samples were used to indicate vegetation distribution and composition on bathymetrical maps and to note dominant plant species in the text and tables. The limitations of such remote sampling include a level of uncertainty over vegetation detection and lack of information about plant covers, therefore we have made some assumptions based on our knowledge of plant development in lakes of similar vegetation composition.

Unpublished vegetation reports were also used to generate scores, for example, Gibbs *et al*. (1999) undertook snorkel obsevations at limited sites for six Auckland lakes that are useful in confirming vegetation presence and changes in composition or weed status.

Historical NIWA macrophyte data held in FBIS provides the most reliable data for generating historical LakeSPI scores. Key information on vegetation composition was obtained from FBIS and 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 (NIWA unpublished data).

Present day assessments were generated from recent LakeSPI surveys at these lakes (last 5 years), or if lacking, from surveys conducted specifically for this project (Table 1).

Table 1.

Lake grid refererence (New Zealand Transverse Mercator Projection), size, and most recent survey date for 32 lakes assessed in the Auckland Region using LakeSPI, from available information (Phase 1) or from surveys carried out specifically for this assessment.

Lake Name	East NZTM	North NZTM	Size (km^2)	Phase	Current survey date
Karaka	1715596	5947634	0.024	1	03/11/2005
Kawaupaku	1730005	5915818	0.098	1	07/11/2007
Ngakuru	1718966	5942560	<0.01	1	03/11/2005
Okaihau	1728437	5925300	0.057	1	04/11/2005
Ototoa	1710843	5958624	1.066	1	06/11/2007
Paekawau	1727957	5927300	0.032	1	04/11/2005
Pehiakura (Small)	1743468	5883335	<0.01	1	02/08/2005
Pehiakura (Big)	1743356	5883698	0.043	1	02/08/2005
Piripoa	1719447	5941811	<0.01	1	03/11/2005
Pokorua	1744927	5882495	0.259	1	02/08/2005
Poutoa	1718287	5944643	<0.01	1	03/11/2005
Wainamu	1730872	5916363	0.150	1	07/11/2007
Whatihua	1748113	5873293	0.039	1	02/08/2005
Cosseys	1787547	5897211	1.132	2	21/10/2008
Hays Creek	1779564	5895634	0.139	2	21/10/2008
Kereta	1714422	5949693	0.236	2	31/10/2008
Kuwakatai	1710982	5956779	0.278	2	31/10/2008
Lower Huia	1739409	5905887	0.470	2	30/10/2008
Lower Nihotupu	1743462	5908545	0.511	2	30/10/2008
Mangatangi	1796196	5891451	1.544	2	21/10/2008
Mangatawhiri	1791615	5894449	1.239	2	21/10/2008
Pupuke	1757588	5928039	1.038	2	28/10/2008
Silver Hill	1740040	5988528	0.149	2	29/10/2008
Slipper	1746657	5995739	0.090	2	29/10/2008
Spectacle	1746747	5994660	0.438	2	29/10/2008
Te Kanae	1715290	5951255	0.056	2	31/10/2008
Tomarata	1748358	5993318	0.144	2	29/10/2008
Upper Huia	1736672	5908072	0.180	2	30/10/2008
Upper Nihotupu	1739105	5909722	0.102	2	30/10/2008
Wairoa	1789201	5892920	0.943	2	21/10/2008
Waitakere	1735885	5914673	0.253	2	30/10/2008
Western Springs	1753629	5918586	0.074	2	31/10/2008

3.4 Additional information

Extreme water level fluctuations (i.e., >2 m) can influence vegetation development and depth distribution depending on the amplitude, temporal pattern of change and the timing of vegetation investigations in relation to water level history. Where large fluctuations were known (i.e., Watercare managed reservoirs) we obtained water level data as background information.

Interpreting LakeSPI scores against extreme water level fluctuations can be problematic, especially when fluctuations are of an episodic rather than seasonal pattern. For example, an under estimated LakeSPI score is likely where the speed of lake draw down exceeds the rate that plants respond by colonising downwards from the bottom limit. Conversely, LakeSPI scores can be artificially high where rapid water level increase means plants persist at depths beyond their natural survival range. However, where a history of water level change is known it may be possible to correct scores or otherwise acknowledge the direction of possible artifacts.

The presence of exotic fish, particularly herbivorous rudd (*Scardinius erythrophthalmus*) and koi carp (*Cyprius carpio*) was also noted where relevant as these fish are known to have deleterious impacts upon the development of submerged vegetation.

4 Results

LakeSPI results for each lake have been presented in the form of a table identifying the LakeSPI Index, Native Condition Index, and Invasive Condition Index. Indices are presented as a percentage of each lake's maximum scoring potential and can be interpreted as follows:

HIGHER LakeSPI Index = Better lake condition.

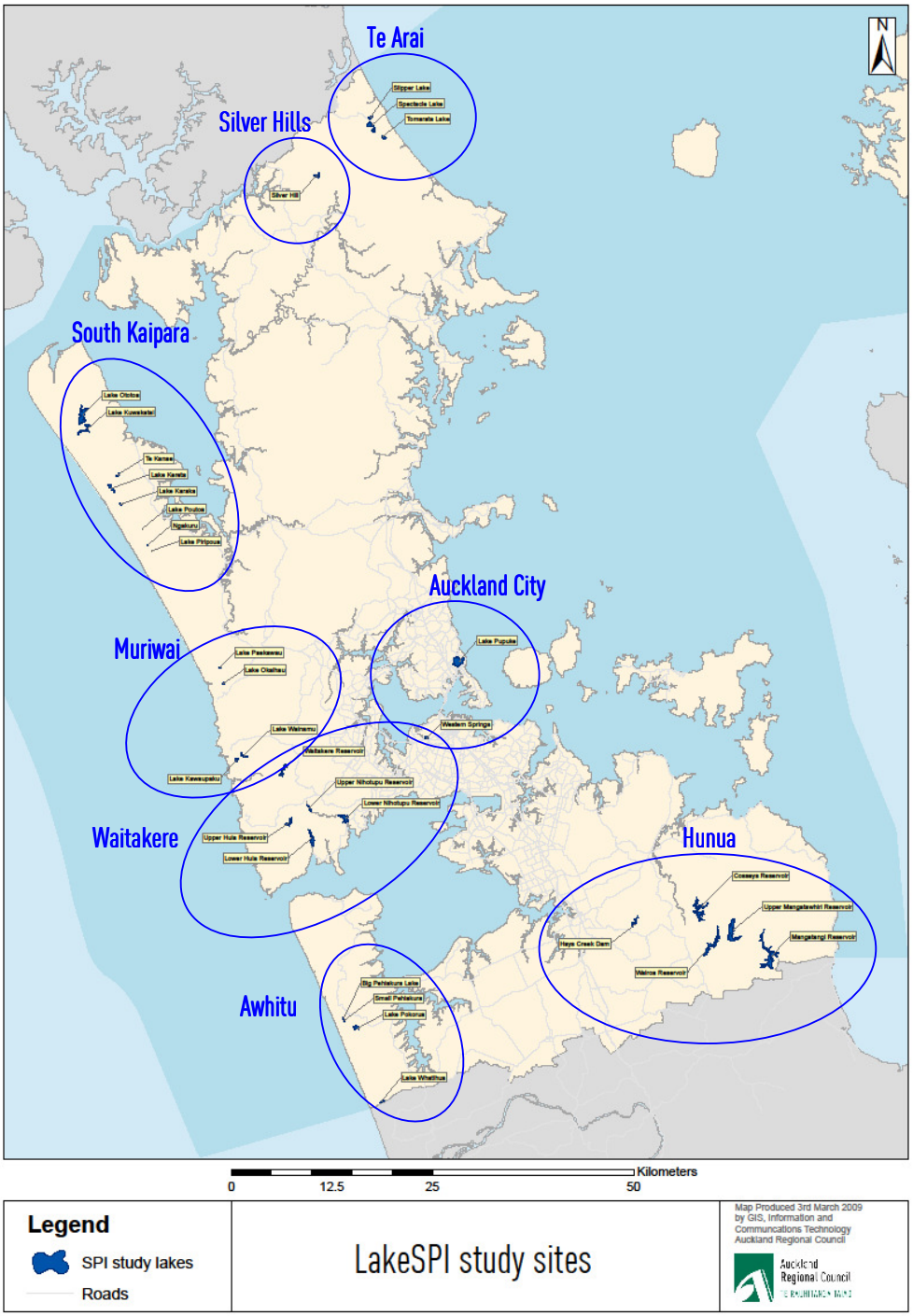
HIGHER Native Condition Index = Better lake condition.

LOWER Invasive Condition Index = Better lake condition.

Descriptions of present day lake condition based on LakeSPI results, together with historic descriptions where available, are presented below by grouping lakes under eight geographical headings (Figure 4). The Te Arai Lakes include Tomarata, Spectacle and Slipper; the Silver Hills Reservoir is grouped separately; South Kaipara group contains Lakes Ototoa, Kuwakatai, Te Kanae, Kereta, Karaka, Poutoa, Ngakaru and Piripoua; the Muriwai group are Lakes Paekawau, Okaihau, Wainamu and Kawaupaku; Auckland City Lakes are Lake Pupuke and Western Springs; the Waitakere group are Waitakere, Upper Nihotupu, Lower Nihotupu, Upper Huia and Lower Huia Reservoirs; the Awhitu Lakes are Big and Small Pehiakura, Pokorua and Whatihua; and the Hunua group are Cosseys, Hays Creek, Upper Mangatawhiri, Wairoa and Mangatangi Reservoirs. Within each geographical group, lakes are presented in order of decreasing LakeSPI scores.

Species lists based on the most recent survey for each lake are presented in the appendix.

Figure 4.
Geographical groupings of Auckland Region lakes.



4.1 Te Arai Lakes

4.1.1 Lake Tomarata

Lake condition:	**Excellent**
Stability:	**Improving**
Lake Max Depth (m):	**6**
Lake type:	**Dune**

Currently the high LakeSPI Index of 78% (Table 2) reflects native plant dominance, the absence of invasive weeds, and the relatively deep extent of vegetation. Beds of native charophytes were recorded to depths of up to 4.3 m and were present at all survey sites around the lake. Marginal emergent vegetation was well developed except at those sites in the north-east where steep sand dunes extended into the lake.

In the past Lake Tomarata has recorded fluctuations in submerged vegetation presence. In 1988 charophyte vegetation was recorded to 6 m depth and generated a similar LakeSPI score to 2008 (Table 2), but was impacted slightly by the presence of the invasive weed *Juncus bulbosus*. However, in 1989 loss of the charophyte bottom cover was reported (ARWB 1990) and submerged vegetation remained absent in 1999 (Gibbs *et al.*, 1999) with a subsequent default LakeSPI score of 0% (Table 2). Loss of submerged vegetation was attributed to a possible flood event decreasing water clarity and / or grazing by the herbivorous fish rudd which had been known in the lake since 1975 (Cadwallader, 1978). The subsequent recovery of submerged vegetation suggests conditions for submerged plant growth have improved since 1999.

Table 2.

LakeSPI results for Lake Tomarata. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		95	90	0
Historical data	1988	73	58	11
	1999	0	0	0
Present day	2008	78	56	0

4.1.2 Lake Spectacle

Lake condition:	**Non vegetated**
Stability:	**Stable**
Lake Max Depth (m):	**7**
Lake type:	**Dune**

Lake Spectacle has not had submerged vegetation on the three occasions it has been surveyed (1988, 1999, 2008), and therefore has received a default LakeSPI Index of 0% (Table 3). In 1999, the lake was reported as having the worst water quality of seven Auckland Lakes assessed (Gibbs *et al.*, 1999) and submerged plants were effectively excluded by low water clarity (<1 m Secchi Disc depth) and floating sudds of marginal vegetation that extended out over 2 m in depth. Herbivorous rudd are known to have been present in this lake since 1979 (FBIS).

Table 3.

LakeSPI results for Lake Spectacle. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		95	90	0
Historic data	1988	0	0	0
	1999	0	0	0
Present day	2008	0	0	0

** The 1988 result is based on 2 sites, 1999 on 1 site and 2008 on 3 sites.*

4.1.3 Lake Slipper

Lake condition:	**Non vegetated**
Stability:	**Stable**
Lake Max Depth (m):	**5.3**
Lake type:	**Dune**

Lake Slipper is connected to Lake Spectacle via a wide drainage channel. Both lakes are likely to have similar water quality issues and like Lake Spectacle, Lake Slipper has been devoid of submerged vegetation during 1988 and 2008 surveys. This has resulted in a LakeSPI Index of 0% (Table 4).

Table 4.

LakeSPI results for Lake Slipper. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		95	90	0
	1988	0	0	0
Present day	2008	0	0	0

** The 1988 result is based on only 1 site and 2008 on 2 sites.*

4.2 Silver Hill Reservoir

Lake condition:	**Good**
Stability:	**-**
Lake Max Depth (m):	**13.5**
Lake type:	**Reservoir**

A modest LakeSPI Index of 30% (Table 5) reflects the restricted depth of vegetation around the lake and presence of the invasive pondweed *Potamogeton crispus*, which dominated at some sites. Overall, pondweeds formed a narrow fringe, extending from the flooded pasture edge at 0.5 m depth to a maximum of 2.1 m depth. Individual, tall-growing clumps of the alien *Aponogeton distachyus* were also present to 2.4 m depth. This irrigation reservoir was constructed in the early 1990's and the submerged vegetation present is comprised of species commonly spread from seed by waterfowl and often dominant in isolated farm dams.

Table 5.

LakeSPI results for Silver Hill Reservoir. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Potential condition		98	96	0
Present day	2008	30	22	59

4.3 South Kaipara Lakes

4.3.1 Lake Poutoa

Lake condition:	**Excellent**
Stability:	**-**
Lake Max Depth (m):	**1.6**
Lake type:	**Dune**

Lake Poutoa had a LakeSPI Index of 90% (Table 6), the highest LakeSPI Index identified for any of the Auckland lakes. This was a result of the proportional depth extent of native submerged vegetation in this very shallow lake, with little impact from invasive species. Charophyte meadows together with native pondweeds, grew from 0.8 to 1.5 m depth but were largely excluded from the shallow margins to 1 m depth by floating mats of the sprawling marginal weed *Ludwigia peploides* (Champion and de Winton 2005). The invasive species *Juncus bulbosus* was limited to the margins and had a minimum impact on the lake.

Lake Poutoa is one of a series of shallow waterbodies running along the coastal dunes south from Lake Kereta. This lake together with Lakes Karaka, Ngakaru and Piripoua were marked on recent topographic maps (Map Toaster Topo, Version 4.00.194, 2007) as 'dry', although earlier maps (NZMS260 Sheet Q10, Helensville, Edition 1 1980) showed lakes as a series of basins holding water. Lake Poutoa is likely to have undergone major reductions in water levels over time, which makes it difficult to assign a meaningful LakeSPI score without information on its original bathymetry. The lake is known to dry out to little open water (J. Bendall pers comm. 2005) and the presence of drowned and emergent dead trees also suggest past water level changes. Nevertheless, the submerged plant community of Lake Poutoa suggests a high ecological condition for a shallow lake of its type.

Table 6.

LakeSPI results for Lake Poutoa. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		97	93	0
Present day	2005	90	82	5.6

** The 2005 survey is based on only 2 sites.*

4.3.2 Lake Ototoa

Lake condition:	**Excellent**
Stability:	**Stable**
Lake Max Depth (m):	**27.5**
Lake type:	**Dune**

To date the lake has had an excellent and stable ecological condition on account of its native plant communities and water quality conducive to vegetation development. LakeSPI Indices for Lake Ototoa remained high (70-74%) and changed little over the last 23 years (Table 7).

During 2007 native charophyte meadows were recorded to a maximum of 12.5 m. Emergents, native turf species and milfoils were present at some sites and the native pondweed *Potamogeton cheesemannii* was recorded for the first time. Invasive species *Juncus bulbosus* and *Utricularia gibba* were also recorded for the first time from some survey sites, but had a negligable impact on the native vegetation.

The invasive species hornwort (*Ceratophyllum demersum*) was found in the isolated north-west arm of the lake in 2007 but it was not recorded at survey sites and so was not reflected in the LakeSPI scores. Despite initiatives to contain and eradicate the hornwort infestation, it was confirmed from several sites within the main body of the lake in March 2009 (Mike McMurtry, ARC, pers comm.). Without further intervention, hornwort is expected to expand and replace the charophyte vegetation, and substantial reductions in future LakeSPI Indices are anticipated.

In 2005 meadows of charophytes grew to between 7.1 and 9.7 m depth with low covers extending to 10 m (de Winton *et al.*, 2005a). Emergents fringed the shore and short turf plants were found where the emergents had an open growth. The minor weed *Ottelia ovalifolia* was noted as present in shallow water at some shorelines.

In 1984 charophyte meadows were recorded to 9.5 m depth at the southern end of the lake (Tanner *et al.*, 1986). Emergent, turf and milfoil species were also recorded at some sites, and the only weed species was *O. ovalifolia.* A similar vegetation in 1988 included charophyte beds to 10 m depth.

Lack of historical information prior to 1984 has restricted our ability to generate historical LakeSPI scores for earlier survey dates. Cunningham *et al.* (1953) did not show the presence of submerged species on their 1950 vegetation map for the lake (as Lake Rototoa), although a native charophyte was noted as dominant within a sheltered bay. Charophytes were recorded by Green (1975) as abundant along the southern lake edge to depths of 10-15 m so we can only assume that submerged

vegetation was present during the 1950 survey but was missed by the plant grab method of sampling employed by Cunningham *et al*. (1953).

We also noted that herbivorous rudd were present at the lake (Rowe 2007) and represent a potential disturbance pressure on the submerged vegetation.

Table 7.

LakeSPI results for Lake Ototoa. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		96	93	0
	1984	74	57	0
Historical data	1988	71	51	0
	2005	70	51	0
Present day	2007	72	60	8.1

** The 2007 survey used different sites to those used in previous years.*

4.3.3 Lake Kuwakatai

Lake condition:	**Poor**
Stability:	**Improving**
Lake Max Depth (m):	**15**
Lake type:	**Dune**

Lake Kuwakatai has a low LakeSPI Index of 11% (Table 8) due to the high level of invasive impact (Invasive Index 99%) by the weed hornwort (*Ceratophyllum demersum*). Beds of hornwort extended from the lake edge to 8 m depth at complete cover, with lower covers recorded to 10.1 m depth (de Winton *et al.*, 2008). Beds grew up to 6.5 m height and were surface-reaching in shallow areas. Four other submerged plants were restricted in distribution to limited shallow areas. Emergent marginal plants were well developed along the northern and eastern shorelines, but scattered along the southern shoreline.

LakeSPI Indices generated from a limited earlier survey in 1999 were lower (4%), as hornwort beds were reported over a more restricted depth range to 2.5 m (Gibbs *et al.*, 1999). Previously, in 1988, no submerged plants were recorded giving a default LakeSPI score of 0%. At this time, the lake waters were described as milky, and emergent plants formed a floating sudd over depths of up to 3 m.

In 1950 native charophytes were recorded to 4 m depth in the south-east of the lake and less than 2 m depth within the shallow northern arm (Cunningham *et al.*, 1953). A generated LakeSPI Index of 68% based on this historic description reflects a moderate native character, absence of invasive weeds and a modest vegetation depth extent.

In 2008, hornwort weed beds were well developed despite challenging water clarity conditions with frequent algal blooms and the presence of the potentially damaging fish, koi carp and rudd (de Winton *et al.*, 2008).

Table 8.

LakeSPI results for Lake Kuwakatai. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		96	93	0
	1950	68	44	0
Historical data	1988	0	0	0
	1999	4	0	96
Present day	2008	11	5	99

** The 1999 results are based on only 1 site. The 1988 result is based on 3 baseline sites.*

4.3.4 Te Kanae Lake

Lake condition:	**Poor**
Stability:	**-**
Lake Max Depth (m):	**18**
Lake type:	**Dune**

The lake at Te Kanae Road had a low LakeSPI Index (10%) and one of the highest Invasive Condition Indices (96%) reflecting the high invasive impact hornwort is having on the lake (Table 9). Hornwort formed beds up to 3 m in height that extended from the margin of emergent plants to a maximum of 6.6 m depth, and drifting shoots from these beds were noted on the lake bed to depths exceeding 12 m. The only other submerged plants seen were a native milfoil and fragments of the invasive weed *Utricularia gibba* at one site only.

Koi, rudd and tench (*Tinca tinca*) have been liberated to the lake (Grant Leighton, landowner, pers comm. 2008) and a large koi, together with signs of sediment disturbance, was observed during the survey. Koi carp are frequently incompatable with significant submerged vegetation on account of direct plant disturbance (Crivelli 1983) and impacts on water quality (Rowe 2007). However, the fact that this lake has dense sandy substrates, and that non-rooted hornwort is less susceptable to physical disturbance, may explain why vegetation destruction has not been severe.

Table 9.

LakeSPI results for Te Kanae Road Lake. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		96	93	0
Present day	2008	10	4	96

4.3.5 Lake Kereta

Lake condition:	**Poor**
Stability:	**Declining**
Lake Max Depth (m):	**2.3**
Lake type:	**Dune**

The very low LakeSPI Index of 8% (Table 10) results from the high level of invasion by hornwort (Invasive Condition Index of 94%). The entire lake bed to 2.3 m depth was covered by hornwort with only occasional holes or areas of lower cover. Beds averaged 0.5 to 2 m high and were surface reaching in shallow areas. Emergent marginal plants generally fringed the lake to 0.3 m depth and a few plants of a native milfoil and charophyte species were limited to a shallow sand bank within the lake. Scums from an algal bloom had accumulated along the central western shore.

A similar LakeSPI Index of 13% was generated from a survey in 1999 (Table 10) which described hornwort dominance for the first time (Gibbs *et al.*, 1999). Conversely, in 1988 the lake scored highly (70%) due to a vegetation dominated by native milfoils to 1.3 m depth only impacted to a limited extent by the invasive weed *Potamogeton crispus* (Invasive Condition Index of 6%). This native vegetation existed until at least the early 1990's (Gibbs *et al.*, 1999). In 1950 the lake was deeper (maximum bathymetry 5 m) and a native vegetation dominated by charophytes, pondweeds and milfoils was recorded to 4 m depth (Cunningham *et al.*, 1953). The corresponding high LakeSPI Index of 85% (Table 10) reflects the extent of native submerged vegetation and lack of any invasive plant at that time.

Table 10.

LakeSPI results for Lake Kereta. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		95	90	0
	1950	85	70	0
Historical data	1988	70	47	6
	1999	13	15	93
Present day	2008	8	3	94

** The 1999 results are based on 1 site. The 1988 result is based on 3 baseline sites.*

4.3.6 Lake Karaka

Lake condition:	**Non vegetated**
Stability:	**-**
Lake Max Depth (m):	**1.3**
Lake type:	**Dune**

Submerged plants did not exceed a 10% cover in Lake Karaka resulting in a default LakeSPI Index of 0% (Table 11). Only occasional shoots of native pondweeds were recorded to 0.3 m, and extensive areas in shallow water were bare, although diverse and well developed emergent plants fringed the lake (Champion and de Winton 2005).

Table 11.

LakeSPI results for Lake Karaka. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		97	93	0
Present day	2005	0	0	0

** The 2005 survey is based on only 3 sites.*

4.3.7 Lakes Ngakuru and Piripoua

Lake condition:	**Not suitable for LakeSPI**
Stability:	
Lake Max Depth (m):	**<1.5**
Lake type:	**Dune**

These lakes were represented by a series of shallow (usually<1.5 m) basins that had a mixture of marginal and submerged plants to <0.3 m depth. These included native milfoils and pondweeds at variable covers (Champion and de Winton 2005). Their shallow nature and the difficulty in distinguishing a true submerged plant community from marginal and ephemeral amphibious species means these lakes are not suitable for the LakeSPI method of assessing ecological condition.

4.4 Muriwai Lakes

4.4.1 Lake Okaihau

Lake condition:	**Poor**
Stability:	**-**
Lake Max Depth (m):	**9.5**
Lake type:	**Dune**

The invasive weeds hornwort and *Egeria densa* have had a marked impact on Lake Okaihau resulting in a LakeSPI Index of 18% (Table 12). Hornwort was recorded at variable covers to a maximum depth of 3.9 m, and scattered shoots of *E. densa* were present to 2.2 m depth (Champion and de Winton 2005). Native vegetation character was limited to clumps of native milfoils to 1.8 m and low covers of a native turf plant at 0.2 m depth. Water lilies (*Nymphaea* sp.) were dominant in some shallow areas. Turbid water, and possibly the presence of rudd (adult fish recorded in 1974; Cadwallader 1978), may account for poor development of submerged vegetation.

In 1950 Cunningham *et al.* (1953) recorded native pondweeds and charophytes to depths of 4 m, resulting in the high LakeSPI Indices of 79% for that time (Table 12).

Table 12.

LakeSPI results for Lake Okaihau. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		95	91	0
Historical data	1950	79	59	0
Present day	2005	18	16	80

**The 2005 results are based on 2 sites*

4.4.2 Lake Wainamu

Lake condition:	**Poor**
Stability:	**Declining**
Lake Max Depth (m):	**15**
Lake type:	**Dune**

Egeria densa formed a continous band around the margin of this lake during the 2007 survey, resulting in a high Invasive Condition Index of 85% and LakeSPI Index of 16% (Table 13). High cover beds of *E. densa* formed from the edge of the emergents to 5 m depth, grew to a height of 4.2 m and were surface-reaching in places (de Winton *et al.*, 2007). Native charophytes formed patches between 2.5 and 3.5 m and the invasive weed *Utricularia gibba* formed entangling growths over plants to 2.3 m depth. Additional exotic species were *Myriophyllum aquaticum* and *Otellia ovalifolia* (de Winton *et al.*, 2007).

During the 2005 survey, *E. densa* weed beds had lower covers and extended to a lesser depth of 3.8 m, while native charophyte meadows were common (de Winton *et al.*, 2005b) resulting in a higher LakeSPI Index of 24%. The 2005 assessment was made at a time when vegetation in the lake was recovering from an extended devegetated period from 1999, during which a default LakeSPI value of 0% applied.

Prior to the vegetation decline, a low LakeSPI Index of 9% generated from 1995 data reflected the greatest impact from *E. densa* (Invasive Condition Index of 93%), when weed beds occupied almost all available habitat in the lake to a depth of 4 m.

In 1991, prior to the establishment of *E. densa* in Lake Wainamu, the submerged vegetation was predominantly native with a shallow zone of native pondweeds and deeper charophyte meadows to 4.5 m depth (Champion 1995). During this time the invasive weed *Utricularia gibba* was widespread but had a minimal impact. The 1991 LakeSPI Index of 60% reflected the predominantly native character of the lake at that time.

Re-establishment of extensive *E. densa* beds similar to that recorded in 1995 raises the possibility of another vegetation decline, due to the apparent instability of this invasive vegetation.

Table 13.

LakeSPI results for Lake Wainamu. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		96	93	0
Historical data	1991	60	41	15
	1995	9	0	93
	1999	0	0	0
	2005	24	22	73
Present day	2007	16	16	85

4.4.3 Lake Kawaupaku

Lake condition:	**Poor**
Stability:	**Declining**
Lake Max Depth (m):	**22**
Lake type:	**Dune**

LakeSPI indices for Lake Kawaupaku remained similar between the 2004 and 2007 surveys with LakeSPI Indices of 14% and 10% respectively (Table 14). During both of these surveys the Invasive Condition Indices have also remained high (81% and 89% respectively) due to the high level of invasive impact that *Egeria densa* is having on the lake. *E. densa* weed beds commonly grew from ≤1 m to 4 m depth, with lower weed covers found to 6 m depth. Flowering beds of surface reaching *E. densa* were also noted as common near the lake margins during the recent 2007 survey. The only other submerged plant species seen during the recent survey was one clump of a native charophyte species resulting in a low Native Condition Index of 3%. A dense algal bloom was also noted as present in surface layers of the water column during this survey (de Winton *et al.*, 2007).

E. densa was first recorded during the 2004 survey, when no native vegetation was seen during this limited survey. It is of interest to note that the landowner noted *E. densa* introduction coincided with the release of coarse fish (Champion and de Winton 2005).

Prior to *E. densa* invasion, in 1971, the submerged vegetation of Lake Kawaupaku was dominated by native pondweeds and charophyte meadows to 7 m depth (NIWA data). Other submerged species recorded included a native turf plant and the minor weed *Otellia ovalifolia*. A relatively high LakeSPI Index of 69% was generated at this time due to the extensive presence of native vegetation and absence of notable invasive weeds.

Table 14.

LakeSPI results for Lake Kawaupaku. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		96	93	0
Historical data	1971	69	49	0
	2004	14	0	81
Present day	2007	10	3	89

**The 2004 result is based on only 1 site.*

4.4.4 Lake Paekawau

Lake condition:	**Non vegetated**
Stability:	**-**
Lake Max Depth (m):	**3+**
Lake type:	**Dune**

No submerged vegetation was recorded giving a default LakeSPI score of 0% (Table 15), although native milfoils were a component of amphibious marginal vegetation at the extreme lake edge (Champion and de Winton 2005). Poor water clarity due to the dark-stained and turbid waters is likely responsible for the current absence of submerged vegetation. This lake was once infested by the floating weed *Salvinia molesta*, which was detected in 1988 and has since been eradicated (MAF unpublished records). At that time the lake have posed a poor habitat for submerged plants due to shading.

Table 15.

LakeSPI results for Lake Paekawau. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		97	93	0
Present day	2005	0	0	0

4.5 Auckland City Lakes

4.5.1 Lake Pupuke

Lake condition:	**Good**
Stability:	**Improving**
Lake Max Depth (m):	**58**
Lake type:	**Volcanic**

Lake Pupuke had a LakeSPI Index of 30% (Table 16) that was influenced by the large number of invasive weed species present, although native character was still discernable and the depth of vegetation extended to 11.4 m. Eelgrass (*Vallisneria gigantea*) was the dominant invasive weed forming a band of near complete cover from around 1 to 9.2 m depth. Limited charophyte meadows were present beyond the eelgrass beds to a maximum of 11.4 m depth, and native milfoils sometimes formed a band in shallow water to 3.5 m depth. Other invasive weeds included patches of high cover *Egeria densa* to 8.9 m, scattered plants to patches of *Lagarosiphon major* to 5.3 m depth, scattered plants of *Potamogeton crispus* to 4.9 m, and the rarely encounted *Elodea canadensis*.

A LakeSPI Index of 26% was generated from the last of three surveys over 1980-1982 that documented the early invasion by *E. densa* (Coffey and Clayton 1987). This lower historic score reflected a lesser vegetation extent (9 m maximum depth) and lower representation of charophyte meadows in deep water than currently. Although *E. densa* was thought to be a potential dominant based on the rate of invasion over 1980-1982, little other change has been seen in the composition of the vegetation and the Invasive Condition Indix was similar to 2008 (Table 16).

Table 16.

LakeSPI results for Lake Pupuke. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		98	97	0
Historical data	1985	26	21	76
Present day	2008	30	35	79

4.5.2 Western Springs Lake

Lake condition:	**Non vegetated**
Stability:	**-**
Lake Max Depth (m):	**2.9**
Lake type:	**Volcanic**

Western Springs scored a LakeSPI Index of 0% (Table 17) on account of the almost complete absence of submerged vegetation. Submerged plants were restricted to aquatic mosses, including the 'Nationally Endangered' species *Fissidens berteroi* (Hitchmough 2005), that were growing attached to volcanic rocks used in revetment walls and elsewhere within the lake. *F. berteroi* is locally recorded elsewhere in Auckland City from spring-fed waterways at Onehunga Springs, Meola Creek and Motions Creek which originates from Western Springs Lake (Bodmin and Wells 2009).

Western Springs has a long history of weed invasion and weed management. In the mid 1960s the lake was infested by *Salvinia molesta* (Johnstone 1972) and the development of sumerged vegetation varied with the degree of invasion by this floating fern until it was eventually eradicated in the mid 1980's. In 1968, when *S, molesta* was actively cleared, *Egeria densa* dominated the entire lake and *Elodea canadensis*, native pondweeds, milfoils and a charophyte were recorded to at least 2 m depth (Johnstone 1972). At this time the lake would have had a LakeSPI Index of 29%. In 1980 the lake was still dominated by *E. densa* together with *Potamogeton crispus* (NIWA data). Most recently in the 1990's, grass carp (*Ctenopharyngodon idella*) were stocked to remove weeds and continued grass carp presence explains the current absence of significant submerged vegetation. Accordingly, LakeSPI has a limited potential to describe lake condition while grass carp determine vegetation development.

Table 17.

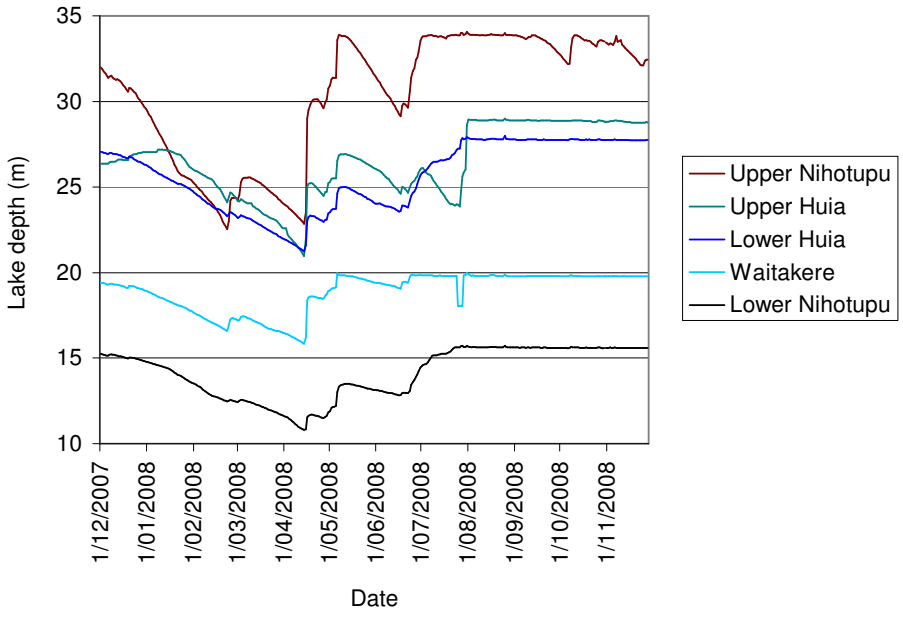
LakeSPI results for Western Springs Lake. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		95	90	0
Historical data	1968	29	50	78
Present day	2008	0	0	0

4.6 Waitakere Reservoirs

The Waitakere Reservoirs are managed for water supply and typically undergo rapid water level increases driven by precipitation and slower draw-down by water abstraction and evaporation (Figure 5). The range in water levels during 334 days prior to the October 2008 LakeSPI survey showed Upper Nihotupu Reservoir had the greatest fluctuation of 11.5 m, Upper Huia fluctuated by up to 8.1 m, Lower Huia by 6.8 m, Lower Nihotupu by 4.9 m, and Waitakere Reservoir had the lowest fluctuations of 4.1 m (Figure 5). The reservoirs showed a pattern of declining water levels to mid-April 2008 followed by a series of rapid water level increases. Waitakere Reservoir had a period of approximately 6 months prior to the LakeSPI survey when water level was relatively stable. Upper and Lower Nihotupu Reservoirs had a stable period of about 4 months, and Upper and Lower Huia Reservoirs had stable water level period of 3 months prior to the survey (Figure 5).

Figure 5.
Amplitude of water level fluctuations (m) for the Waitakere reservoirs in relation to their depth over the period from 01/12/2007 to 28/11/2008 (Watercare Services Limited data). The LakeSPI survey was in late October 2008.



4.6.1 Waitakere Reservoir

Lake condition:	**Good**
Stability:	**Stable**
Lake Max Depth (m):	**19.7**
Lake type:	**Reservoir**

Waitakere Reservoir was the highest scoring of this group of reservoirs, with a LakeSPI Index of 51% (Table 18) resulting from the presence of extensive charophyte meadows to 6.9 m depth, moderately impacted by a shallow band (<4 m) of the weed *Juncus bulbosus* (Invasive Condition Index of 39%). Patches of native milfoil were also common. Two other invasive weeds observed included one plant of *Ranunculus trichophyllus* and fragments of *Utricularia gibba* stranded on the dam structure outside of the survey sites. All three invasive species are spread by waterfowl. The high cover charophyte meadows began at between 2.5 and 3.8 m depth, within the range of water level fluctuation of 4.1 m and suggesting the 6-month period of stable water levels prior to the survey was sufficient for charophyte expansion.

A LakeSPI Index of 49% was generated from limited data collected in 1982. At this time a diverse charophyte assemblage (four species) was abundant to 3 m depth. A shallower band of native milfoils was recorded to 2.2 m depth, commonly with pondweeds and the invasive weed *Juncus bulbosus* to 1.5 m.

Table 18.

LakeSPI results for Waitakere Reservoir. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Potential condition		96	93	0
Historic data	1982	49	38	33
Present day	2008	51	46	39

** 1982 scores were based on a general reconnoitre*

4.6.2 Upper Huia Reservoir

Lake condition:	**Good**
Stability:	**Stable**
Lake Max Depth (m):	**33.1**
Lake type:	**Reservoir**

The submerged vegetation was dominated by the weed *Juncus bulbosus*, resulting in a moderately high invasive Condition Index (53%) and modest LakeSPI Index of 36% (Table 19). Spread from seed by water fowl, *J. bulbosus* is less invasive than most other submerged weeds, but in the Upper Huia Reservoir it formed the highest covers of any plant species and was recorded to the maximum vegetation depth of 5.5 m. Native milfoils also commonly contributed to the vegetation, but no charophytes were recorded. All submerged vegetation was within the range of water level fluctuations experienced over the preceding year.

An identical LakeSPI Index was recorded in 1982, although native vegetation was more abundant at that time. The submerged vegetation was dominated by native milfoils and the turf plant *Glossostigma* sp. was common to 4 m depth, with *Juncus bulbosus* described as common to 4.5 m depth. Native pondweeds, and the invasive weed *Ranunculus trichophyllus* were occasional, but charophytes were rare.

Table 19.

LakeSPI results for Upper Huia Reservoir. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Potential condition		96	93	0
Historic data	1982	36	33	56
Present day	2008	36	22	53

** 1982 scores were based on a general reconnoitre*

4.6.3 Lower Huia Reservoir

Lake condition:	**Good**
Stability:	**Declining**
Lake Max Depth (m):	**33.5**
Lake type:	**Reservoir**

A LakeSPI Index of 31% (Table 20) reflected the paucity of submerged vegetation, limited depth extent and minor impact by the weed *Juncus bulbosus* (Invasive score 33%). The most common submerged plants were native milfoils, the alien marginal plant *Ludwigia palustris*, and *J. bulbosus*. Highest plant covers were <3 m depth, with the deepest plants recorded at 3.6 m. Charophytes were present but not common. Remains of terrestrial shrubs were recorded to 4.6 m, which is in keeping with the 6.8 m increase in water level over the preceeding months and suggests that the submerged vegetation recorded was made up of recently colonised plants.

Data from a limited survey in 1982 suggested a higher LakeSPI Index of 68%. At the time of this survey no invasive weed species were noted, with native charophte meadows extending to a depth of 3.5 m, native milfoils and pondweeds also common, and one pondweed species being recorded to 5 m depth.

Table 20.

LakeSPI results for Lower Huia Reservoir. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Potential condition		96	93	0
Historic data	1982	68	47	0
Present day	2008	31	23	33

** 1982 scores were based on a general reconnoitre*

4.6.4 Upper Nihotupu Reservoir

Lake condition:	**Non vegetated**
Stability:	**Stable**
Lake Max Depth (m):	**33.9**
Lake type:	**Reservoir**

No submerged plants were recorded from the Upper Nihotupu Reservoir and it received a default LakeSPI Index of 0% (Table 21). The extreme water level fluctuations in this reservoir (11.5 m) are likely to exclude significant vegetation development. Likewise, no submerged species were recorded in 1982 (NIWA data).

Table 21.

LakeSPI results for Upper Nihotupu Reservoir. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Potential condition		96	93	0
Historic data	1982	0	0	0
Present day	2008	0	0	0

** 1982 scores were based on a general reconnoitre*

4.6.5 Lower Nihotupu Reservoir

Lake condition:	**Unassessed**
Stability:	**-**
Lake Max Depth (m):	**18.4**
Lake type:	**Reservoir**

A LakeSPI assessment could not be made in 2008 because of high water turbidity due to slip in a tributary catchment severely limited divers observations. We were able to confirm the presence of plants to 4 m depth, with apparent bare sediment at 5 m, the deepest extent investigated, however reliable LakeSPI indices could not be generated. Whilst recent water level fluctuations (4.9 m) were amongst the lowest in this group of lakes, additional light stress on plants from high turbidity raises doubts for the survival of deep submerged vegetation.

Limited vegetation data collected in 1982 derived a LakeSPI Index of 46% (Table 22). At this time native charophyte meadows ranged from the lake edge to 2.1 m depth and native milfoils and the invasive weed *Juncus bulbosus* were occasionally encountered stranded above the water level.

Table 22.

LakeSPI results for Lower Nihotupu Reservoir. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Potential condition		96	93	0
Historic data	1982	46	29	37
Present day	2008	-	-	-

** 1982 scores were based on a general reconnoitre*

4.7 Awhitu Lakes

4.7.1 Lake Pokorua

Lake condition:	**Excellent**
Stability:	**Improving**
Lake Max Depth (m):	**6**
Lake type:	**Dune**

Lake Pokorua is one of the highest ranked of the Auckland lakes scoring a LakeSPI Index of 76% (Table 23). This is on account of the lake still maintaining a well developed native plant community with charophyte meadows recorded to a depth of 3.3 m and an open canopy of native pondweeds growing down to 3 m depth. *Egeria densa* was recorded at 75% cover to 3 m depth at one of the survey sites (Champion and de Winton 2005).

Earlier, in 1988, *E. densa* was much more abundant (Invasive Condition Index 76%) and had a significant impact on the lake vegetation (LakeSPI Index 37%) with high cover weed beds recorded from 2 to 3.8 m depth. The same native submerged species were recorded during this earlier survey, but charophytes were reduced in cover and/or depth range.

In 1950 Cunningham *et al.* (1953) recorded native pondweeds dominant to between 4 and 6 m depth, with charophytes present to between 2 and 4 m depth. Based on this survey a high LakeSPI Index of 97% was generated reflecting native vegetation that covered much of the bed of the lake.

The recent improvement was driven by a reduction in the impact of *E. densa*. It could be that the lake underwent a vegetation decline event prior to the 2005 survey and the predominance of native plants reflected their superior ability to recolonise from seed reserves compared to *E. densa*, which is reliant on vegetative reproduction. Although *E. densa* continues to pose an ongoing threat to the native vegetation, it is restricted in its distribution at the moment.

Table 23.

LakeSPI results for Lake Pokorua. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		97	93	0
Historical data	1950	97	93	0
	1988	37	63	76
Present day	2005	76	82	23

** The 2005 survey is based on 4 baseline sites*

4.7.2 Lake Whatihua

Lake condition:	**Good**
Stability:	**Improving**
Lake Max Depth (m):	**11**
Lake type:	**Dune**

Lake Whatihua generated a modest LakeSPI Index of 33% which is a reflection of the significant native character of vegetation that remains in the lake even though *Egeria densa* is having a marked impact (Table 24). *E. densa* commonly formed complete cover weed beds up to 3 m tall from the edge of marginal reeds to 6.8 m depth (Champion and de Winton 2005). Another weed, *Elodea canadensis* made a minor contribution to the invasive character of the submerged vegetation. Despite these impacts the lake still had significant native character, with deeper meadows of charophytes recorded from 7 m to 7.2 m depth, and a diverse assemblage of plants in the shallow zone shoreward of the emergent reed beds. A total of ten native submerged species were recorded from this lake.

A slightly lower LakeSPI Index of 23% was generated from the survey of one site in 1987 when, with the exception of an absence of the deeper charophyte meadows, a similar vegetation was recorded. A much higher LakeSPI Index of 80% was generated from a 1950 survey by Cunningham *et al.* (1953), where charophytes were recorded to 8 m depth and invasive weed species were absent.

Table 24.

LakeSPI results for Lake Whatihua. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		95	92	0
Historical data	1950	80	63	0
	1987	23	25	89
Present day	2005	33	43	81

**The 1987 survey is based on 1 site and 2005 survey is based on 4 baseline sites.*

4.7.3 Lake Pehiakura (Small)

Lake condition:	**Good**
Stability:	**-**
Lake Max Depth (m):	**5.3**
Lake type:	**Dune**

A LakeSPI Index of 25% (Table 25) for the smaller of the two Pehiakura lakes resulted from the dense beds of invasive *E. densa* recorded between 1.3 to 5.3 m depth (Invasive Condition Index 85%). Some native character remained (Native Condition Index 25%), where good covers of native milfoils, turf plants (*Glossostigma* sp.) and a charophyte were found in depths <1.3 m between the clumps of emergent reeds (Champion and de Winton 2005).

Table 25.

LakeSPI results for Lake Pehiakura (Small). LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		95	90	0
Present day	2005	25	25	85

**The 2005 survey is based on 2 baseline sites.*

4.7.4 Lake Pehiakura (Big)

Lake condition:	**Good**
Stability:	**-**
Lake Max Depth (m):	**5.6**
Lake type:	**Dune**

The larger Pehiakura Lake had a LakeSPI Index of 15% (Table 26), lower than the smaller Pehiakura Lake, as *Egeria densa* was the only submerged plant recorded (Invasive Condition Index 89%). Large *E. densa* beds were recorded from 1.6 to 5.4 m depth while an almost continuous band of emergent plant species grew around the lake margin to a depth of 1.6 m (Champion and de Winton 2005).

Table 26.

LakeSPI results for Lake Pehiakura (Big). LakeSPI Indices expressed as a percentage of lake maximum potential.

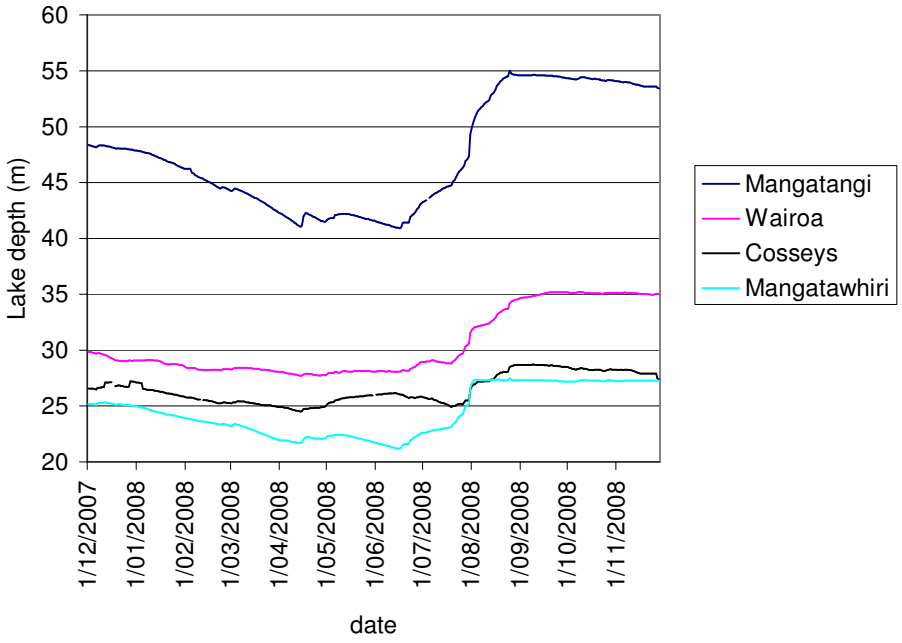
State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Pristine		95	90	0
Present day	2005	15	5	89

**The 2005 survey is based on 3 baseline sites.*

4.8 Hunua Reservoirs

The Hunua Reservoirs provide water supply to Auckland. With the exception of Hays Creek Reservoir which has a stable water level, the reservoirs undergo fluctuations driven by precipitation, water abstraction and evaporation. Over the 325 days prior to the October 2008 survey (Figure 3) water levels initially declined slowly to mid-April, stablilised, then rapidly increased from late June (or late July for Cosseys Reservoir) to late August (or early August for Mangatawhiri Reservoir). The subsequent period of stable water level prior to the survey was 2.6 months for Mangatawhiri Reservoir, and 1.8 months for the other reservoirs. The range in fluctuation prior to the survey ranged from 14.1 m for Mangatangi Reservoir, 7.5 m for Wairoa, 6.3 m for Mangatawhiri, and 4.2 m for Cosseys Reservoir.

Figure 3.
Amplitude of water level fluctuations (m) for the Hunua reservoirs in relation to their depth over the period from 01/12/2007 to 28/11/2008 (Watercare Services Limited data). The LakeSPI survey was in late October 2008.



4.8.1 Mangatawhiri Reservoir

Lake condition:	**Good**
Stability:	**Improving**
Lake Max Depth (m):	**35.6**
Lake type:	**Reservoir**

The upper Mangatawhiri Reservoir had the highest LakeSPI ranking of the Hunua Reservoirs (76%) on account of the depth extent of native charophytes that formed high cover meadows down to 10.4 m depth (Table 27). The shallow edge of these meadows began at 6 m depth, corresponding with the water level rise of 6.3 m recorded prior to the survey. Native milfoils and pondweeds were a minor vegetation component found in shallower depths than the charophyte meadows and no invasive submerged weeds were recorded.

A slightly lower LakeSPI Index of 68% was generated from the 1990 vegetation survey (Table 27), when charophyte meadows were recorded to 6.5 m and native pondweeds to 5 m depth. Using a general description of submerged vegetation in 1982, a similar score of 72% was based on abundant charophytes to 6.2 m and pondweeds to 3 m depth.

Table 27.

LakeSPI results for Mangatawhiri Reservoir. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Potential condition		96	93	0
Historical data	1982	72	53	0
	1990	68	47	0
Present day	2008	76	61	0

** 1982 scores were based on a general reconnoitre*

4.8.2 Wairoa Reservoir

Lake condition:	**Excellent**
Stability:	**Stable**
Lake Max Depth (m):	**40.3**
Lake type:	**Reservoir**

A high LakeSPI Index of 66% (Table 28) resulted from the presence of native plant communities growing down to a moderate depth in the absence of any invasive plant species. Beds of native charophytes began at 6.3 to 7.1 m and extended to 8.6 m depth, with occasional plants recorded as deep as 11.7 m. Native milfoils and pondweeds were sometimes present in mid-depths of 3 to 8.2 m and terrestrial vegetation was noted to 4.4 m depth. An increase in water level of 7.5 m prior to the survey would account for the transition from terrestrial to obligately submerged plants seen between 4.4 and around 7 m depth.

An identical LakeSPI score was generated from the 1990 survey, when charophyte beds were present from the lake edge to 5.5 m depth. Based on a general description of vegetation in 1982 the lake scored 66%, with pondweeds and milfoils in shallow water to 1.5 m and charophytes common to 3 m depth. At the time of the 1982 survey a rapidly lowering water level (reported at 2 m per day) had also stranded vegetation above the waterline.

Table 28.

LakeSPI results for Wairoa Reservoir. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Potential condition		96	93	0
Historical data	1982	66	43	0
	1990	68	46	0
Present day	2008	68	47	0

** 1982 scores were based on a general reconnoitre*

4.8.3 Cossey's Reservoir

Lake condition:	**Good**
Stability:	**Declining**
Lake Max Depth (m):	**35.1**
Lake type:	**Reservoir**

The LakeSPI Index of 49% (Table 29) reflected the largely native vegetation character in Cossey's Reservoir that, although it was low in cover and depth extent, had only minimal impact by invasive *Juncus bulbosus*. The sparse submerged vegetation comprised of native charophytes and milfoils while *J. bulbosus* was present at some of the sites. Submerged plants were recorded to 5.6 m depth although most growth was less than 3.3 m, and innundated terrestrial plants were noted to 2.6 m. The water level increase of 4.2 m prior to the 2008 survey was not clearly reflected in the depth distribution of the submerged vegetation.

A higher LakeSPI Index of 71% was generated from a 1990 vegetation survey, driven by higher covers of charophytes that extended to a maximum depth of 7.5 m and the absence of invasive weed species. An intermediate LakeSPI Index of 64% was generated from a general reconoitre of submerged vegetation in 1982, when charophytes were abundant to 5 m depth, native pondweeds and milfoils common to abundant to 2.5 m, and *J. bulbosus* was occasionally recorded to a depth of 1 m.

The reduction in LakeSPI scores since 1990 (Table 29) reflects a reduction in the covers and depth extent of native submerged plants. This may be related to a dam reconstruction in the early 2000's, which saw reservoir volume reduced by <50% (Watercare Caretaker, pers comm. 2002). Associated water level reduction, desiccation of submerged vegetation, slumping/erosion of aquatic sediment and possible impacts on water clarity might explain the lack of vegetation re-development. Additionally, herbivorous rudd are known from the reservoir (Baker *et al.*, 2008) and have elsewhere been implicated in the removal of native plant material (de Winton *et al.*, 2003).

Table 29.

LakeSPI results for Cossey's Reservoir. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Potential condition		96	93	0
Historical data	1982	64	50	15
	1990	71	51	0
Present day	2008	49	28	20

** 1982 scores were based on a general reconnoitre*

4.8.4 Mangatangi Reservoir

Lake condition:	**Non vegetated**
Stability:	**Declined**
Lake Max Depth (m):	**54.6**
Lake type:	**Reservoir**

Small patches of native charophytes were recorded between 13.1 and 15.4 m depth and native milfoils from 6 to 8.5 m. However, these plants were considered to be remnants of previous vegetation after innundation by a 14.1 m rise in water level prior to the 2008 survey, as it is doubtful these patches would survive the maintainance of high levels recorded over the subsequent three or more months (Figure 3). This together with the sparse nature of plant growth (≥10% cover at only one of three sites investigated) results in a LakeSPI Index of 0% (Table 30).

In 1990 submerged vegetation comprised native charophytes and pondweeds to a maximum depth of 4.5 m. At this time plant cover was not complete due to the steep slopes, unstable sediment and observed wave re-suspension of fine silt. However the moderately high LakeSPI Index of 64% generated from this survey indicates the native character of vegetation and depth extent of development. A similar score of 62% generated from an earlier (limited) description of vegetation in 1982 also resulted from charophyte meadows recorded to 2.5 m depth and abundant pondweeds to 2 m depth.

Table 30.

LakeSPI results for Mangatangi Reservoir LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Potential condition		96	93	0
Historical data	1982	62	37	0
	1990	64	39	0
Present day	2008	0	0	0

** 1982 scores were based on a general reconnoitre*

4.8.5 Hays Creek Reservoir

Lake condition:	**Non vegetated**
Stability:	**-**
Lake Max Depth (m):	**20.7**
Lake type:	**Reservoir**

Hays Creek Reservoir received a LakeSPI Index of 0% (Table 31) on account of the low presence of submerged vegetation. Only occasional charophyte plants were encountered at≤10% cover; below the threshold for generating LakeSPI scores. The low water clarity, with a turbid, 'milky' appearance, suggests light availability restricted submerged vegetation development. However, the presence of koi carp known from the reservoir is implicated both for impacts on water clarity (Rowe 2007) and direct impacts on submerged plants (e.g., Crivelli 1983). In contrast to the other Hunua Reservoirs, Hays Creek has a stable water level.

Table 31.

LakeSPI results for Hays Creek Reservoir. LakeSPI Indices expressed as a percentage of lake maximum potential.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)
Potential condition		96	93	0
Present day	2008	0	0	0

5 Discussion

5.1 Current lake condition

Lakes of the Auckland Region displayed a wide range of current LakeSPI scores from having no submerged vegetation (0%) to a maximum LakeSPI Index of 90%. For the purposes of ranking and discussing these results, lakes have been categorised into four main groups according to their current LakeSPI Index as:

Excellent: scoring >60%.

Good: soring 20 - 60%

Poor: soring <20%

Non vegetated: scoring 0%

Good, Poor and Non Vegetated categories were futher divided based on the apparent impacting factor influencing the score, as *weed* invasion (Invasive Condition Index >70%), vegetation development limited by *water quality*, or by *water level* fluctuations (Table 32).

Table 32.

Summary of current LakeSPI results for assessed lakes with overall condition category and an indication of the main impact factor on scores.

Lake	LakeSPI Index (%)	Native Condition Index (%)	Invasive Condition Index (%)	Overall condition	Impact factor
Poutoa	90	82	5.6	Excellent	
Tomarata	78	56	0	Excellent	
Mangatawhiri	76	61	0	Excellent	
Pokorua	76	82	23	Excellent	
Ototoa	72	60	8.1	Excellent	
Wairoa	66	47	0	Excellent	
Waitakere	51	46	39	Good	Water Level
Cossey's	49	28	20	Good	Water Level
Upper Huia	36	22	53	Good	Water Level
Whatihua	33	43	81	Good	Weed
Lower Huia	31	23	33	Good	Water Level
Pupuke	30	35	79	Good	Weed
Silver Hills	30	22	59	Good	Water Quality
Small Pehiakura	25	25	85	Good	Weed
Okaihau	18	16	80	Poor	Weed
Wainamu	16	16	85	Poor	Weed
Big Pehiakura	15	5	89	Poor	Weed
Kuwakatai	11	5	99	Poor	Weed
Te Kanae	10	4	96	Poor	Weed
Kawaupaku	10	3.3	89	Poor	Weed
Kereta	8	3	94	Poor	Weed
Mangatangi	0	0	0	Non vegetated	Water Level
Hays Creek	0	0	0	Non vegetated	Water Quality
Karaka	0	0	0	Non vegetated	Water Quality
Paekawau	0	0	0	Non vegetated	Water Quality
Slipper	0	0	0	Non vegetated	Water Quality
Spectacle	0	0	0	Non vegetated	Water Quality
Upper Nihotupu	0	0	0	Non vegetated	Water Level
Western Springs	0	0	0	Non vegetated	Grass Carp

5.1.1 Excellent condition lakes

Six lakes generated a LakeSPI index >60% (Table 32). These were Lake Tomarata (Te Arai), Lakes Poutoa and Ototoa (South Kaipara), the Mangatawhiri and Wairoa Reservoirs (Hunua Ranges) and Lake Pokorua (Awhitu). High LakeSPI indices reflected either substantial native vegetation character (Native Condition Index ≥60%), and/or the absence of invasive submerged weeds. Out of this group only Lake Pokorua had an Invasive Condition Index over 10% (Figure 5) due to the presence of *Egeria densa*, although the impact of this weed on the lake was minimal.

It is noted that LakeSPI and Native Condition indices for Mangatawhiri and Wairoa Reservoirs (Hunua Ranges) may be slightly inflated because vegetation may not have compensated for recent water level increases by retracting to shallower water at the

time of the survey. Nevertheless, these waterbodies would still rank highest out of all the Watercare reservoirs assessed and if meaningful adjustments could be made based on water level change the scores are still only likely to change by <10%.

5.1.2 Good condition lakes

Eight lakes generated LakeSPI indices between 20% and 60% (Table 32) due to the quality of submerged native vegetation present in these lakes with varying degrees of impact by invasive species (Figure 5). Waitakere, Cossey's, and the Upper and Lower Huia Reservoirs were mildly impacted by invasive weeds (Invasive Condition index between 20-55%), but water level fluctuations were the primary driving force behind the moderate depth extent and development of vegetation. Lakes Whatihua, Pupuke and the smaller Pehiakura Lake were strongly impacted by invasive weeds (Invasive Condition index 79% to 85%), but also retained strong remnant native character (Native Condition Index 25% to 43%). The development of submerged vegetation at the reservoir at Silver Hill Road was restricted to a shallow depth range (2.1 m depth) due to low water clarity and light limitation for plant growth, and this limitation exacerbated the impact of a minor weed (Invasive Condition Index 59%).

5.1.3 Poor condition lakes

Seven lakes with LakeSPI indices between 8% and 18% were grouped as being in 'poor' condition (Table 32) as all were heavily impacted by the major invasive weeds hornwort (*Ceratophyllum demersum*) and/or *Egeria densa* (Invasive Condition Index 80-99%). These species are amongst the top three ranked submerged plant species in New Zealand for 'weediness' (Champion and Clayton 2000) and are capable of completely replacing native elements in the vegetation.

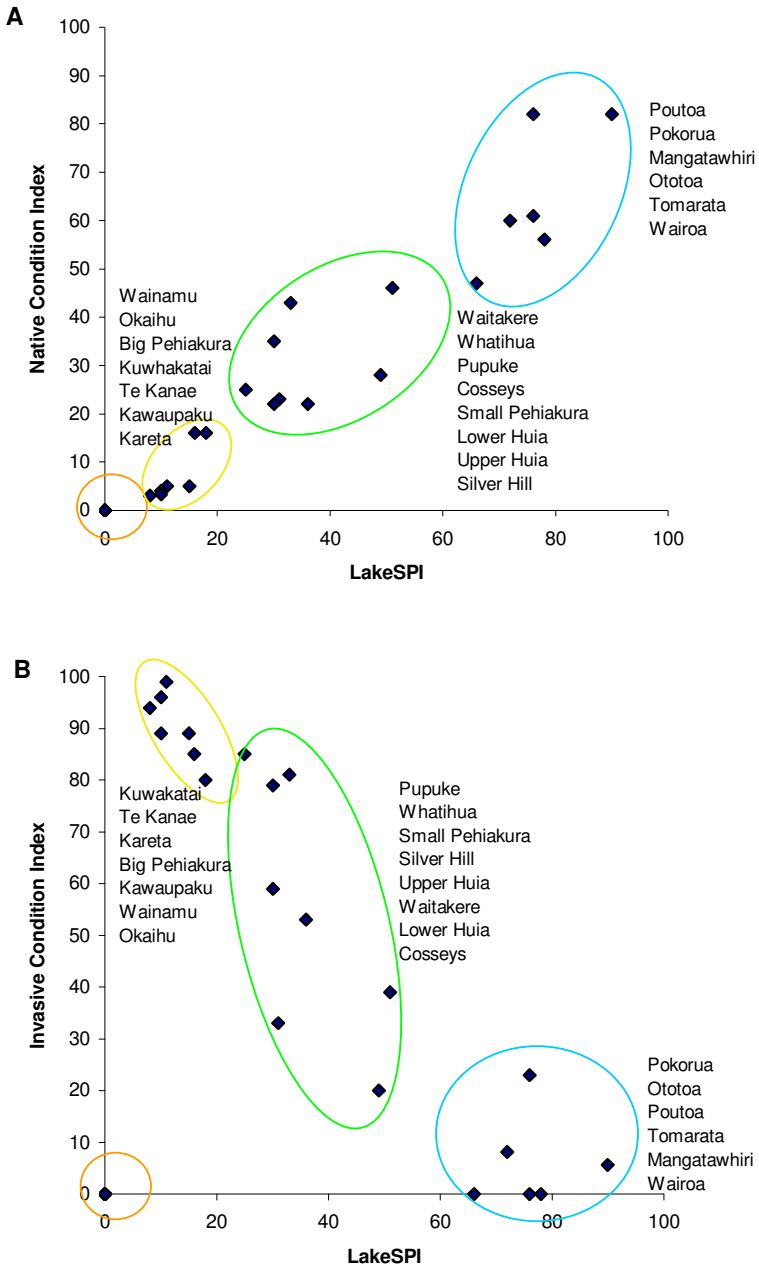
5.1.4 Non vegetated lakes

Eight lakes did not record adequate vegetation development to a level where the LakeSPI method could be applied (i.e., <10% cover recorded at most survey sites) and therefore scored a LakeSPI Index of 0% (Table 32). Nevertheless, the absence of significant vegetation also indicates an impacted condition for these lakes.

With the possible exception of Watercare managed lakes with strongly fluctuating levels like the Upper Nihotupu and Mangatangi Reservoirs, the expected condition of lakes would be vegetated. In the case of Western Springs Lake the management initiative of stocking grass carp to control weeds is responsible for vegetation absence and native vegetation recovery would be expected upon removal or death of the fish. The outcome of subsequent re-vegetation on the rare moss *F. berteroi* is not known. For the remaining five lakes it is apparent that water quality is a major constraint for plant growth via low water clarity and light limitation. Additional stresses in these lakes may exist in the form of grazing or disturbance by exotic fish.

Figure 5.

Relationship between LakeSPI index and **A**) Native Condition index and **B**) Invasive Condition index for lakes of the Auckland Region distinguishing four lake categories of *Excellent* (blue ring) *Good* (green ring), *Poor* (yellow ring) and *Non vegetated* (orange ring). Lake names listed in ascending order for Native or Invasive Condition.



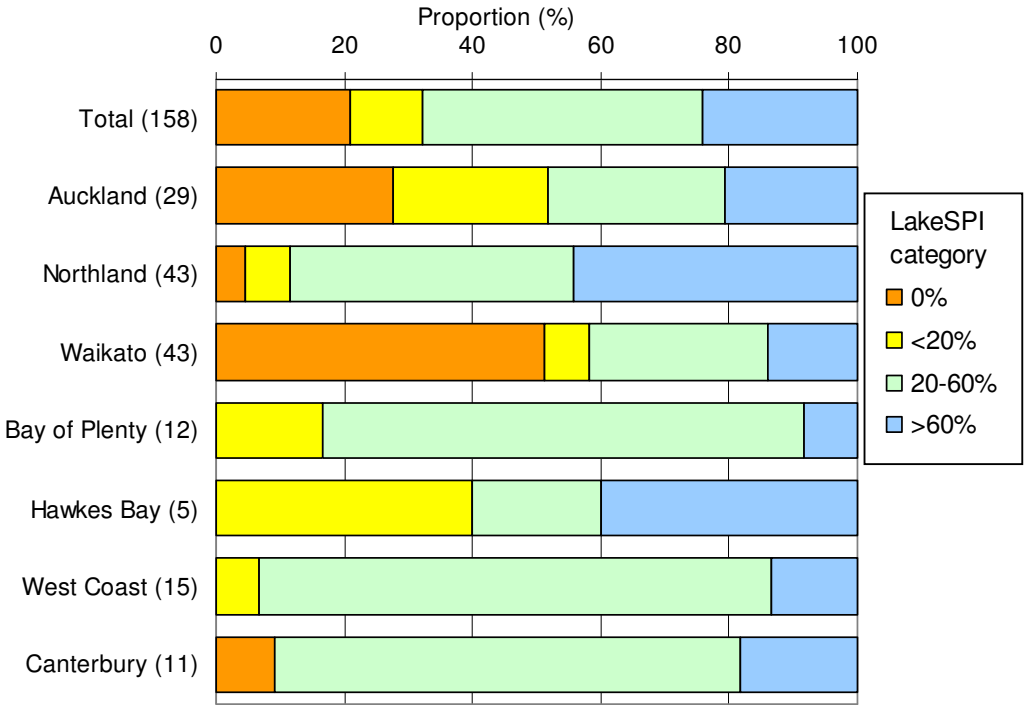
5.1.5 National comparison

Comparing the categories of lake condition identified for the Auckland Region to current LakeSPI Indices for lakes within other regions of New Zealand (Figure 6) shows:

- The proportion of Auckland lakes with a LakeSPI Index >60% is within the middle of the range shown by other regions.
- Auckland lakes have a lower proportion of lakes with a LakeSPI Index of 20-60 % than lakes of other regions, with the exception of Hawke's Bay.
- The proportion of lakes in the region with LakeSPI Indices <20% is also higher than all regons except Hawke's Bay, and reflects the high number of lakes that are extensively invaded by the worst ranked invasive submerged weeds.
- Auckland region is second to Waikato Region in the proportion of lakes which do not possess significant submerged vegetation and score a LakeSPI Index of 0%.

This comparison is a simple overview of LakeSPI Indices for lakes within other regions of New Zealand and does not take into account the wide range of the types of lakes sampled. In this regard we note that the high proportion of water supply reservoirs in the region (10/32 lakes assessed) may influence comparisons. For example, reduced public access for recreational activities in the reservoirs means none are extensively weed invaded, however, the extent of water level fluctuation undoubtedly contributes to the number of non-vegetated waterbodies in the region.

Figure 6.
Proportion of lakes that fall into each of four categories of LakeSPI Index, showing total and regional differences, with number of lakes assessed shown in parenthesis.



5.2 Stability in lake condition

Changes in LakeSPI indices between the last two assessment dates for each lake has been used to provide an indication of the current stability in lake condition and the direction of any change. Of the 29 lakes that were suitable for LakeSPI assessment, only seven appeared to be in a stable condition, with changes of ≤2% (Table 33).

Six lakes showed an improvement in their LakeSPI indices, although four of these lakes improved by <10%. The two lakes that showed a substantial improvement (>30% increase) were Lake Tomarata, which had been recolonised by native plants following a vegetation decline event, and Lake Pokorua, where *E. densa* had lost dominance since the earlier assessment.

A further six lakes showed declining lake condition between the last two assessments. Three of these lakes showed a reduction of >20%, and a further three showed minor deterioration of between 4% and 10%.. The status of Watercare managed waterbodies were influenced by the timing of assessments in relation to the temporal pattern of water level fluctuation. In the case of apparent reductions in the condition of Mangatangi, Lower Huia and Cossy's Reservoirs these are driven by the extent and

timing of water level fluctuations, and possibly additional factors of water clarity and exotic fish disturbance in the case of Cossey's reservoir.

Lack of previous vegetation descriptions limits the assessment of stability for the remaining ten lakes with recent LakeSPI assessments.

With the possible exception of Lake Poutoa, all lakes show deterioration from their likely pristine condition to current condition. Vegetation descriptions for five lakes from 1950 (Cunningham *et al.*,1953) gave LakeSPI indices of 10% to 28% lower than pristine state, or an identical score to the pristine state in the case of Lake Pokorua.

Table 33.

Lakes ranked in order of change in LakeSPI Index during the last two assessments. A dash (-) indicates no suitable historical assessment.

Lake	Current LakeSPI	Stability	Change (%)
Tomarata	78	Improving	+78
Pokorua	76	Improving	+39
Whatihua	33	Improving	+10
Mangatawhiri	76	Improving	+8
Kuwakatai	11	Improving	+7
Pupuke	30	Improving	+4
Ototoa	72	Stable	+2
Waitakere	51	Stable	+2
Wairoa	66	Stable	0
Upper Huia	36	Stable	0
Slipper	0	Stable	0
Spectacle	0	Stable	0
Upper Nihotupu	0	Stable	0
Mangatangi	0	Declining	-64
Lower Huia	31	Declining	-37
Cossey's	49	Declining	-22
Wainamu	16	Declining	-8
Kereta	8	Declining	-5
Kawaupaku	10	Declining	-4
Poutoa	90	-	
Silver Hills	30	-	
Small Pehiakura	25	-	
Okaihau	18	-	
Big Pehiakura	15	-	
Te Kanae	10	-	
Western Springs	0	-	
Hays Creek	0	-	
Karaka	0	-	
Paekawau	0	-	
Lower Nihotupu	Not suitable for LakeSPI assessment		
Ngakuru	Not suitable for LakeSPI assessment		
Piripoua	Not suitable for LakeSPI assessment		

6 Conclusions and recommendations

Priorities for future monitoring of lakes in the Auckland Region were considered (Table 34) based on the current lake condition, lake stability, any outstanding or special values represented within the lake vegetation, and the perceived extent and immediacy of threats that presented a risk to the future condition of the lakes. For example, higher scoring lakes have a greater potential for deterioration compared to already impacted lakes so tended to receive a higher priority for future monitoring. This was also considered, along with the risk of future weed invasion to a lake based on proximity to weed sources, access to, and usage of lakes, and their vulnerability to further invasion. Non vegetated lakes have a low risk of invasion due to highly restricted habitat availability for submerged plants, while several lakes already have maximal development of the worst available weed species. At least two lakes (Tomarata and Wainamu) have undergone submerged vegetation decline events, with subsequent deterioration in water quality. Risk of vegetation decline is considered highest for heavily invaded water bodies where weed beds occupy much of the water column. Elsewhere vegetation decline has proved especially likely in the case of lakes invaded by *Egeria densa* (Champion 2002), with 26.4% of the New Zealand lakes invaded by *E. densa* subsequently undergoing a decline event (de Winton *et al.,* 2009).

In setting priorities we have not considered ameliorative works that have been suggested for several lakes and their catchments. However, we recognise that the proposed schedule for monitoring indicated in Table 34 should be bought forward if a large change is known for any lake or its catchment.

LakeSPI results indicating lake condition can contribute to a priortization of the regions lakes for management or for restoration activities. Other information required for such an assessment are the percieved values for lakes (possibly including community/social importance) and the likely threats facing the lakes. The highest priority for management would be those water bodies of high value, that are in good condition (i.e., high LakeSPI scores, good water quality) which are at risk from identified threats.

Table 32.

Priority ranking for lakes for future monitoring that integrates both the current condition of lakes and the extent and immediacy of threats facing water body condition. A schedule for timing of monitoring for the lakes using LakeSPI is suggested.

Lake	Priority	LakeSPI schedule
Ototoa	High	2 yrs
Tomarata	High	2 yrs
Pokorua	High	2 yrs
Whatihua	Moderate	3-4 yrs
Pupuke	Moderate	3-4 yrs
Wainamu	Moderate	3-4 yrs
Kawaupaku	Moderate	3-4 yrs
Small Pehiakura	Moderate	3-4 yrs
Big Pehiakura	Moderate	3-4 yrs
Kuwakatai	Moderate	3-4 yrs
Te Kanae	Low-moderate	5 yrs
Poutoa	Low-moderate	5 yrs
Silver Hill	Low-moderate	5 yrs
Cossey's	Low	5-10 yrs
Lower Nihotupu	Low	Baseline assessment still required
Mangatawhiri	Low	5-10 years
Wairoa	Low	5-10 years
Waitakere	Low	5-10 years
Upper Huia	Low	5-10 years
Lower Huia	Low	5-10 years
Mangatangi	Low	5-10 years
Okaihau	Low	5-10 years
Karaka	Low	5-10 years
Kereta	Low	5-10 years
Slipper	Low	5-10 years
Spectacle	Low	5-10 years
Paekawau	Low	5-10 years
Western Springs	Low	Reassessment after grass carp are removed
Upper Nihotupu	Low	10+ years
Hays Creek	Low	10+ years

6.1 Summary information

To assist in setting prorities, summary information for each lake in ranked priority for monitoring is presented below in bullet point form and includes:

- A conclusion on the current lake condition, and stability (where known).
- The main influences on lake condition.
- Identification of any outstanding or special ecological values.
- Perceived major threats to lake condition and the level of risk of deterioration.

Lake Ototoa

- Excellent lake condition and appears stable.
- Outstanding example of diverse native plant communities.
- Large deterioration expected as hornwort expands in distribution and impact.

Lake Tomarata

- Excellent lake condition following recent improvement.
- Native charophyte vegetation has recovered since 1999 and is well developed.
- Risk of invasive weed introduction is high, together with possible impacts from adverse catchment events and exotic fish.

Lake Pokorua

- Excellent lake condition with improvement since 1988.
- *Egeria densa* has decreased in influence and the vegetation retains considerable native character.
- Risk of future *E. densa* dominance.

Lake Whatihua

- Good lake condition and improving slightly with native vegetation still represented.
- The lake recorded a high diversity of native plants despite dominance by invasive *Egeria densa*.

- The lake faces a moderate risk of increased *E. densa* dominance, which is more likely if water quality deteriorates in the future.

Lake Pupuke

- In good condition with signs of slight improvement in water quality indicated by the development and depth extent of charophyte meadows.
- The most immediate threat is hornwort introduction, which elsewhere has proven competitive against a *Vallisneria* species similar to the dominant weed in Lake Pupuke.

Lake Wainamu

- In poor condition and deteriorating due to re-established dominance by *Egeria densa*.
- Large weed-beds increase the potential risk of another vegetation decline event and subsequent stabilisation in a turbid condition.

Lake Kawaupaku

- In poor condition due to almost total invasion by *Egeria densa*, with a slight deterioration due to continued expansion by that species.
- Vulnerable to a vegetation decline event on account of unstable *E. densa* vegetation and water quality issues.

Lake Small Pehiakura

- In good condition but with extensive *Egeria densa* beds.
- Moderate risk of vegetation decline due inherently unstability *E. densa* weed beds.

Lake Big Pehiakura

- In poor condition due to complete invasion by *Egeria densa*.
- Moderate risk of vegetation decline due inherently unstability *E. densa* weed beds.

Lake Kuwakatai

- In a poor lake condition but shows signs of slight improvement in water clarity.

- Heavily invaded by hornwort.
- Moderate risk of further deterioration due to a vegetation decline event.

Lake Te Kanae

- Poor lake condition is driven by almost complete invasion by hornwort.
- Level of stability is unknown but a limited catchment area and relatively deep lake depth is likely to buffer the lake against a rapid deterioration.

Lake Poutoa

- Excellent lake condition for a shallow waterbody.
- At low-moderate risk of drainage/drying and subsequent replacement of submerged vegetation by alien marginal plants.

Silver Hill Reservoir

- Good condition on account of significant native vegetation but limited plant development on account of poor water quality and possibly young age of this waterbody.
- Low to moderate risk of invasion by additional weed species.

Cossey's Reservoir

- In good condition but showing signs of recent deterioration.
- Level of submerged vegetation development restricted despite a more moderate water level regime than other Hunua reservoirs.
- Low risk of rapid deterioration unless an extreme water level regime is adopted.

Lower Nihotupu Reservoir

- Requires a baseline assessment to be made.
- Current condition not known, but risk of rapid deterioration likely to be similar to that assessed for other Waitakere reservoirs (low).

Mangatawhiri Reservoir

- Excellent lake condition with signs of slight improvement.
- High native character without invasive weeds.
- Low risk of rapid deterioration unless an extreme water level regime is adopted.

Wairoa Reservoir

- Excellent lake conditon and apparently stable.
- Moderately high native character with absence of invasive weeds.
- Low risk of rapid deterioration unless an extreme water level regime is adopted.

Waitakere Reservoir

- In good condition and apparently stable.
- Largely native and indicative of good water quality, with only moderate impacts from the current water level regime.
- The reservoir has a low risk of rapid deterioration unless an extreme water level regime is adopted.

Upper Huia Reservoir

- Currently in good condition and apparently stable.
- Largely native vegetation, but somewhat restricted development due to relatively recent recolonisation following water level fluctuations.
- Low risk of rapid deterioration unless an extreme water level regime is adopted.

Lower Huia Reservoir

- In good condition but signs of deterioration due to invasive weeds and restricted vegetation development from relatively recent recolonisation following water level fluctuations.
- Low risk of rapid deterioration unless an extreme water level regime is adopted.

Mangatangi Reservoir

- Non vegetated lake condition with deterioration apparent since 1990, however extreme water level fluctuations account for recent change.
- Vegetation re-development is expected (signalling improved lake condition) unless an extreme water level regime is adopted.

Lake Okaihau

- Currently in poor condition with limited vegetation development mostly by invasive weeds.

- Low risk of rapid further deterioration.

Lake Karaka

- This lake had no vegetation suggesting poor water quality.
- Substantial wildfowl value is recognised on account of diverse marginal emergent vegetation.
- Further deterioration is unlikely.

Lake Kereta

- Currently in a poor condition and deterioraing due to extensive invasion by hornwort.
- Risk of vegetation decline is lessened by the lakes extreme shallow nature.

Lake Slipper

- Stable in a non vegetated condition since at least 1988.
- Highly impacted currently so risk of further deterioration is low.
- Changes only likely after amelioration works in the catchment.

Lake Spectacle

- Stable in a non vegetated condition since at least 1988.
- Highly impacted currently so risk of further deterioration is low.
- Changes only likely after amelioration works in the catchment.

Lake Paekawau

- The lake had no vegetation, apparently due to water quality restrictions for submerged plant growth
- Further deterioration is unlikely.

Western Springs

- Currently non vegetated due to stocking of the herbivorous grass carp as a weed management intiative.
- LakeSPI indices have a limited potential to describe lake condition while grass carp are present.

- A high risk of weed re-introduction will exist following grass carp removal.

Upper Nihotupu Reservoir

- Non vegetated but stable.
- Extent of water level fluctuations exclude development of submerged vegetation.

Hays Creek

- Non vegetated condition.
- Further deterioration unlikely.

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9 Appendix

Species lists for most recent lake surveys, indicaticating native or exotic status of species.

Te Arai Lakes

Lake Tomarata 29/10/2008

Chara australis	Native
Nitella pseudoflabellata	Native
Chara fibrosa	Native
Nitella leonhardii	Native
Eleocharis sphacelata	Native
Baumea articulata	Native
Typha orientalis	Native

Lake Spectacle 29/10/2008

Eleocharis sphacelata	Native
Baumea articulata	Native
Typha orientalis	Native
Baumea juncea	Native

Lake Slipper 29/10/2008

Baumea articulata	Native
Baumea juncea	Native
Eleocharis sphacelata	Native
Typha orientalis	Native

Silver Hills Reservoir 29/10/2008

Aponogeton distachyus	Exotic
Ludwigia palustris	Exotic
Potamogeton cheesemanii	Native
Potamogeton crispus	Exotic
Potamogeton ochreatus	Native

South Kaipara Lakes

Lake Poutoa 3/11/2005

Azolla pinnata	Exotic
Chara australis	Native
Eleocharis sphacelata	Native
Juncus bulbosus	Exotic
Landoltia punctata	Exotic
Ludwigia peploides	Exotic
Myriophyllum propinquum	Native
Myriophyllum triphyllum	Native
Persicaria decipiens	Native
Potamogeton ochreatus	Native

Lake Ototoa 6/11/2007

Apodasmia similis	Native
Baumea arthrophylla	Native

Baumea articulata	Native
*Ceratophyllum demersum**	Exotic
Chara australis	Native
Chara fibrosa	Native
Chara globularis	Native
Eleocharis sphacelata	Native
Glossostigma elatinoides	Native
Juncus articulatus	Exotic
Juncus bulbosus	Exotic
Lilaeopsis novae-zelandiae	Native
Myriophyllum triphyllum	Native
Nitella aff. *cristata*	Native
Nitella hyalina	Native
Nitella leonhardii	Native
Nitella pseudoflabellata	Native
Persicaria decipiens	Native
Potamogeton cheesemanii	Native
Ruppia polycarpa	Native
Schoenoplectus tabernaemontani	Native
Triglochin striata	Native
Typha orientalis	Native
Utricularia gibba	Exotic

*ARC record March 2009

Lake Kuwakatai 31/10/2008

Apodasmia similis	Native
Baumea juncea	Native
Centella uniflora	Native
Ceratophyllum demersum	Exotic
Eleocharis acuta	Native
Eleocharis sphacelata	Native
Glossostigma submersum	Native
Ludwigia palustris	Exotic
Myriophyllum triphyllum	Native
Schoenoplectus tabernaemontani	Native
Typha orientalis	Native

Te Kanae Road Lake 31/10/2008

Baumea articulata	Native
Ceratophyllum demersum	Exotic
Eleocharis acuta	Native
Eleocharis sphacelata	Native
Hydrocotyle sp.	
Ludwigia palustris	Exotic
Ludwigia peploides	Exotic
Myriophyllum propinquum	Native
Persicaria decipiens	Native
Ranunculus amphitrichus	Native
Schoenoplectus tabernaemontani	Native
Typha orientalis	Native
Utricularia gibba	Exotic

Lake Kereta 31/10/2008

Baumea articulata	Native
Ceratophyllum demersum	Exotic
Eleocharis acuta	Native
Isolepis prolifer	Native
Ludwigia palustris	Exotic
Ludwigia peploides	Exotic
Myriophyllum triphyllum	Native
Nitella hyalina	Native
Nymphaea sp.	Exotic
Schoenoplectus tabernaemontani	Native
Typha orientalis	Native
Zizania latifolia	Exotic

Lake Karaka 3/11/2005

Baumea articulata	Native
Carex sp.	
Cyperus sp.	
Eleocharis acuta	Native
Eleocharis sphacelata	Native
Isolepis prolifer	Native
Juncus articulatus	Exotic
Landoltia punctata	Exotic
Ludwigia palustris	Exotic
Ludwigia peploides	Exotic
Myriophyllum propinquum	Native
Polygonum sp.	
Potamogeton cheesemanii	Native
Potamogeton ochreatus	Native
Schoenoplectus tabernaemontani	Native
Typha orientalis	Native
Zizania latifolia	Exotic

Lake Ngakuru 3/11/2005

Azolla pinnata	Exotic
Ludwigia palustris	Exotic
Ludwigia peploides	Exotic
Myriophyllum propinquum	Native

Lake Piripoa 3/11/2005

Azolla pinnata	Exotic
Juncus sp.	
Ludwigia palustris	Exotic
Ludwigia peploides	Exotic
Myriophyllum propinquum	Native
Potamogeton cheesemanii	Native
Potamogeton ochreatus	Native

Muriwai Lakes
Lake Okaihau 4/11/2005

Bolboschoenus fluviatilis	Native
Ceratophyllum demersum	Exotic
Egeria densa	Exotic
Eleocharis sphacelata	Native
Glossostigma elatinoides	Native
Isolepis prolifer	Native
Ludwigia palustris	Exotic
Myriophyllum triphyllum	Native
Nymphaea sp.	Exotic

Lake Wainamu 7/11/2007

Azolla pinnata	Exotic
Baumea articulata	Native
Carex sp.	
Chara australis	Native
Chara fibrosa	Native
Chara globularis	Native
Egeria densa	Exotic
Eleocharis acuta	Native
Eleocharis sphacelata	Native
Galium palustre	Exotic
Isachne globosa	Native
Landoltia punctata	Exotic
Ludwigia peploides	Exotic
Myriophyllum aquaticum	Exotic
Nitella aff. *cristata*	Native
Nitella pseudoflabellata	Native
Otellia ovalifolia	Exotic
Schoenoplectus tabernaemontani	Native
Typha orientalis	Native
Utricularia gibba	Exotic

Lake Kawaupaku 7/11/2007

Baumea arthrophylla	Native
Baumea articulata	Native
Carex sp.	
Chara australis	Native
Egeria densa	Exotic
Eleocharis acuta	Native
Eleocharis sphacelata	Native
Isachne globosa	Native
Landoltia punctata	Exotic
Nasturtium officinale	Exotic
Persicaria decipiens	Native
Phormium tenax	Native
Ranunculus amphitrichus	Native
Typha orientalis	Native

Lake Paekawau 4/11/2005

Eleocharis sphacelata	Native
Glossostigma elatinoides	Native

Isolepis prolifer	Native
Ludwigia palustris	Exotic
Myriophyllum propinquum	Native
Myriophyllum triphyllum	Native
Nymphaea sp.	Exotic
Typha orientalis	Native

Auckland City Lakes
Lake Pupuke 28/10/2008

Chara australis	Native
Chara globularis	Native
Egeria densa	Exotic
Elodea canadensis	Exotic
Lagarosiphon major	Exotic
Myriophyllum triphyllum	Native
Nitella hyalina	Native
Nitella pseudoflabellata	Native
Potamogeton crispus	Exotic
Vallisneria gigantea	Exotic

Western Springs Lake 31/10/2008

Amblystegium riparium	Native
Fissidens berteroi	Native
Iris pseudacorus	Exotic

Waitakere Reservoirs
Waitakere Reservoir 30/01/2008

Centella uniflora	Native
Chara australis	Native
Eleocharis acuta	Native
Eleocharis sphacelata	Native
Juncus bulbosus	Exotic
Ludwigia palustris	Exotic
Myriophyllum propinquum	Native
Nitella aff. *cristata*	Native
Nitella leonhardii	Native
Nitella pseudoflabellata	Native
Potamogeton cheesemanii	Native
Potamogeton ochreatus	Native
Ranunculus trichophyllus	Exotic

Upper Huia Reservoir 30/10/2008

Baumea sp.	Native
Centella uniflora	Native
Glossostigma elatinoides	Native
Juncus bulbosus	Exotic
Ludwigia palustris	Exotic
Myriophyllum propinquum	Native
Myriophyllum triphyllum	Native
Potamogeton ochreatus	Native
Typha orientalis	Native

Unidentified moss

Lower Huia Reservoir 31/10/2008

Callitriche sp.	
Centella uniflora	Native
Eleocharis sphacelata	Native
Galium palustre	Exotic
Glossostigma elatinoides	Native
Juncus bulbosus	Exotic
Ludwigia palustris	Exotic
Myriophyllum propinquum	Native
Nitella aff. *cristata*	Native
Nitella pseudoflabellata	Native
Potamogeton cheesemanii	Native
Zannichellia palustris?	Native

Upper Nihotapu Reservoir 30/11/2008

Lower Nihotupu Reservoir 30/11/2008

Ludwigia palustris	Exotic

Awhitu Lakes

Lake Pokorua 2/08/2005

Chara australis	Native
Egeria densa	Exotic
Eleocharis sphacelata	Native
Nitella aff. *cristata*	Native
Potamogeton ochreatus	Native
Typha orientalis	Native

Lake Whatihua 2/08/2005

Apium nodiflorum	Exotic
Azolla pinnata	Exotic
Chara fibrosa	Native
Chara globularis	Native
Egeria densa	Exotic
Eleocharis acuta	Native
Eleocharis sphacelata	Native
Elodea canadensis	Exotic
Glossostigma submersum	Native
Lilaeopsis ruthiana	Native
Lilaeopsis ruthiana	Native
Ludwigia palustris	Exotic
Myriophyllum propinquum	Native
Myriophyllum triphyllum	Native
Nasturtium officinale	Exotic
Nitella aff. *cristata*	Native
Nitella hyalina	Native
Otellia ovalifolia	Exotic
Potamogeton cheesemanii	Native
Potamogeton ochreatus	Native

Ricciocarpus natans	
Schoenoplectus tabernaemontani	Native

Lake Small Pehiakura 2/08/2005

Egeria densa	Exotic
Eleocharis acuta	Native
Eleocharis sphacelata	Native
Glossostigma submersum	Native
Lemna minor	Native
Lotus pedunculatus	Exotic
Myriophyllum triphyllum	Native
Nitella hyalina	Native
Schoenoplectus tabernaemontani	Native

Lake Big Pehiakura 2/08/2005

Baumea articulata	Native
Egeria densa	Exotic
Eleocharis sphacelata	Native
Schoenoplectus tabernaemontani	Native
Typha orientalis	Native

Hunua Reservoirs

Mangatawhiri Reservoir 21/10/2008

Centella uniflora	Native
Chara australis	Native
Eleocharis sphacelata	Native
Galium palustre	Exotic
Juncus sp.	
Ludwigia palustris	Exotic
Myriophyllum propinquum	Native
Nitella aff. *cristata*	Native
Potamogeton cheesemanii	Native
Potamogeton ochreatus	Native

Wairoa Reservoir 21/10/2008

Carex sp.	
Chara australis	Native
Myriophyllum propinquum	Native
Nitella aff. *cristata*	Native
Nitella pseudoflabellata	Native
Potamogeton cheesemanii	Native
Potamogeton ochreatus	Native

Cosseys Reservoir 21/10/2008

Centella uniflora	Native
Galium palustre	Exotic
Glossostigma submersum	Native
Juncus bulbosus	Exotic
Juncus sp.	
Ludwigia palustris	Exotic
Myosotis sp.	

Myriophyllum propinquum	Native
Myriophyllum propinquum	Native
Nitella aff. *cristata*	Native
Nitella pseudoflabellata	Native
Ranunculus flammula	Exotic

Mangatangi Reservoir 21/10/2008

Chara australis	Native
Myriophyllum propinquum	Native
Nitella aff. *cristata*	Native

Hays Creek Reservoir 21/10/2008

Nitella aff. *cristata*	Native