Freshwater ecology: Lake Submerged Plant Indicators (LakeSPI) survey

Version 1.0

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Contents

Department of Conservation
Te Papa Atawhai

Synopsis

Lake Submerged Plant Indicators (LakeSPI) is a survey method for monitoring and assessing the ecological condition of New Zealand lakes, developed by Clayton & Edwards (2006a,b,c). This survey protocol was developed to provide a tool for robust assessment of lake condition, using submerged plants as ecological indicators. LakeSPI has been developed for New Zealand ecosystems and differs from macrophyte bioassessment approaches for lakes in other countries in that the impacts of invasive exotic weeds are also incorporated to reflect this major additional anthropogenic pressure (de Winton et al. 2012). The method also enables changes in lake condition to be monitored over time and for robust comparisons to be made between lakes.

A technical report on the development of LakeSPI (Clayton & Edwards 2006a) and a user manual (Clayton & Edwards 2006b) detailing the method are available on the National Institute of Water and Atmospheric Research (NIWA) LakeSPI website[1] and provide a high level of detail about implementing this method. An account of the method has been published (Clayton & Edwards 2006c) and LakeSPI results for 195 New Zealand lakes have also been explored (de Winton et al. 2012).

The LakeSPI method is based on the quantitative assessment of key features of aquatic plant structure and composition within a lake. The data collected using the LakeSPI method is then used to generate three LakeSPI indices: a Native Condition Index which characterises the status of native vegetation within a lake, an Invasive Impact Index which captures the degree of impact from invasive weed species, and the LakeSPI Index that provides an overall indicator of lake ecological condition. The LakeSPI method has been developed for use in all lakes, except those where environmental conditions such as high altitude, salinity, or pH affect the development of typical submerged vegetation.

LakeSPI data is typically collected using scuba diving along transects of the lake profile at five representative sites within a lake. For very shallow lakes it may be possible to carry out the LakeSPI method by snorkelling. A standard LakeSPI datasheet is used to collect all the information required to generate site scores for 11 component metrics that are used in the calculation of the LakeSPI indices. Initial 'baseline' site selection for a lake is important as care needs to be taken to ensure sites are representative and not unduly influenced by variables such as inflows, outflows, steep profiles, wave direction or other disturbances. Site selection should also consider any existing vegetation information for a lake. At each site, a compass bearing is taken to set the transect line at right angles to the lake shore. In most cases this bearing will guide the diver to the gradient of steepest decent and to the maximum depth of plant growth in the lake. Once the compass bearing has been established, it is recommended that the diver then swims along the transect line, making general observations about the site. The formal survey can then be carried out while swimming back along the transect line from the deepest point to the lake shore. Waterproof LakeSPI field sheets prompt the diver to record the necessary plant information.

[1] www.lakespi.niwa.co.nz

The method requires the surveyor to identify plants to a community, genus or species level, although specialist knowledge is not required and users can be guided by 'LakeSPI plant identification sheets' (docdm-908168). Where identification of a key species is in doubt, a specimen should be taken for confirmation.

The appropriate interval for LakeSPI surveys depends upon the perceived stability of the lake and the needs of the lake manager. For stable lakes, an interval of 5 years is adequate, while annual or twice-yearly surveys may be required for lakes with a high likelihood of change. Generally, an interval shorter than 6 months to a year between surveys is not required because lake vegetation already integrates conditions for plant growth over the time scale of several months to years. Although LakeSPI surveys can be carried out at any time of the year, it is recommended that summer and autumn months are preferable since plant growth is often at its seasonal best and water temperatures are more favourable for scuba diving.

Assumptions

- Native plant species and high plant diversity represent healthier lakes or higher lake condition.
- Invasive plant species are undesirable due to their potential to displace natives and to adversely affect ecological condition.
- Maintaining an exotic plant community in good condition is preferable to total collapse of the vegetation community leading to algal dominance.
- The deeper the submerged plants are able to grow, the better the ecological condition of the lake.
- Sites surveyed in a lake are representative samples of the wider submerged plant community in that lake.

Advantages

- LakeSPI is a cost-effective tool and once the standard skills are met, the method is straightforward to apply.
- LakeSPI is an established tool, with existing data available for many lakes throughout New Zealand in a national database that is administered by NIWA.
- Where sufficient historical data is available for a lake, indicative LakeSPI indices can be generated for comparison with present day condition.
- The LakeSPI method is robust against user bias when protocols are followed.
- LakeSPI delivers data that is directly applicable to lake ecosystem management and conservation.

Disadvantages

- The method requires scuba-diving skills and qualifications, with the exception of very shallow lakes.

- For bigger lakes a certified boat and boat operator is required, which may present resourcing issues in some situations.
- The method requires a minimum of three people.
- The LakeSPI method cannot be used to assess lakes where the submerged vegetation community is affected by unusual physical or chemical variables.
- Sensitivity of the method to change in vegetation depth limits is restricted in shallow lakes that are completely vegetated.

Suitability for inventory

This method is not particularly suitable for inventory of the aquatic plant community in a lake. While the identification of 11 invasive plants is required to species level, native plants are recorded only at a genus or community level.

Suitability for monitoring

- This method is suitable for monitoring changes in the submerged plant community in a lake over two or more surveys, with longer time frames of monitoring at appropriate intervals allowing better detection of trends in lake condition.
- The LakeSPI method is able to be replicated, and changes in lake plant community composition and structure are detectable.
- The method has been designed to enable robust assessment of the effectiveness of lake ecosystem management actions.

Skills

- A scuba-diving qualification is necessary in order to carry out the diving required for this method.
- To meet Occupational Safety and Health standards, any scuba divers employed to carry out the LakeSPI method must meet DOC standards. The following standard operating procedures (SOPs) must be followed:
  - ‘Scientific diving: one page SOP’ (docdm-673798)
  - ‘Snorkelling: one page SOP’ (docdm-673820)
  - ‘Scientific diving and snorkelling: technical document’ (docdm-237640)
- Depending on the lake size, a suitably qualified boat operator may also be required to skipper a boat for diver transport and safety. Any use of boats must be in accordance with DOC standards for both boat operators and vessels.
- A basic level of aquatic plant identification skills is required for accurate data collection.

Resources

- A minimum of three people are recommended to carry out this method, two qualified divers and at least one safety person (the safety person can also be the boat operator if a boat is being used).
- Scuba-diving equipment is required to carry out this method. In particular, an accurate depth gauge is important for recording vegetation data in relation to the depth profile and a compass is an essential piece of equipment to aid underwater navigation.
- Divers will require a plastic clipboard, 'LakeSPI field sheets' (docdm-929916) printed on waterproof paper, and a 2B pencil for underwater use.
- Laminated 'LakeSPI plant identification sheets' (docdm-908168) are a useful resource for keeping on the boat.
- It is recommended that each diver have a short graduated line with a lead weight attached for measuring the height of weed beds.
- Plastic zip-lock bags, plastic jars and waterproof labels are useful for collecting plant samples that may require further identification.
- For lakes where a boat is being used, it is recommended that the boat has all the standard safety equipment as well as a depth sounder and sonar equipment. Sonar technology that can record lake-bed profiles and indicate the presence of benthic vegetation is particularly useful for selection of baseline survey sites on lakes without prior vegetation information.
- A handheld GPS and digital camera are important tools for recording the location of a new survey site and to enable accurate relocation of that site in the future.
- Laminated maps showing LakeSPI baseline sites should be available on the lake as well as a marker pen to record additional information on the maps.

Minimum attributes

Consistent measurement and recording of these attributes is critical for the implementation of the method. Other attributes may be optional depending on your objective. For more information refer to Full details of technique and best practice.

DOC staff must complete a 'Standard inventory and monitoring project plan' (docdm-146272).

A LakeSPI field sheet (docdm-929916) has been developed by NIWA (see Appendix A) to ensure the necessary information is recorded for each site. In order for the LakeSPI metric scores and indices to be generated, the method needs to be carried out in full.

Data storage

In the field, survey information is recorded on waterproof LakeSPI field sheets. Each field sheet has a section at the top for recording basic information such as date, site location, and GPS waypoints and includes space at the bottom for additional site notes and a profile drawing. Any other comments regarding the site should also be recorded on the field sheet.

Copies of completed survey sheets should be forwarded to the survey administrator as soon as possible after the survey. All hardcopies of field sheets and field notes need to be labelled and retained in a project file, and it is recommended they be scanned electronically for storage. Data should also be entered into electronic form as soon as possible after the fieldwork is completed.

For this method, it is recommended that data be provided to the LakeSPI database administered by NIWA. This is a national repository created for the purpose of entering and processing LakeSPI data, which ensures the correct calculation of indices, safe-keeping of data with regular back-up, and optional uploading to the LakeSPI web-reporting pages for public accessibility to results. Scanned LakeSPI field sheets can be sent to the national LakeSPI coordinator for entry.[2] Results will then be emailed back to the survey administrator in electronic format as Microsoft Excel spreadsheets and pdf reports, while the LakeSPI database is currently supported in a Microsoft Access environment.

LakeSPI scores can also be calculated manually using step-by-step guidance from the LakeSPI user manual. If undertaking manual entry of LakeSPI data, the electronic spreadsheet should contain all the same fields as in the field sheet, in similar format to avoid confusion. All electronic spreadsheets should have a notes sheet where relevant information and comments can be recorded. In particular, each user, beginning with the diver who enters the data into the field sheet, should record details of any changes to the data, including when and why they were made. Particular care must be taken not to inadvertently alter spreadsheet calculations, and cell references.

LakeSPI field sheets, electronic spreadsheets, calculations and analyses should be labelled so that these different data remain linked, can be retained on the project file, and where possible incorporated into an electronic file system and backed up (disk or hard-drive) for security.

Analysis, interpretation and reporting

Seek statistical advice from a biometrician or suitably experienced person prior to undertaking any analysis.

Calculation of LakeSPI variables

The LakeSPI Technical Manual (Clayton & Edwards, 2006a) outlines how field sheet data are converted into LakeSPI scores. For each site that is surveyed, the LakeSPI scoring system generates three indices to describe lake condition:

- The Native Condition Index
- The Invasive Impact Index

[2] Email: lakespi@niwa.co.nz

- The LakeSPI Index

This calculation is performed within NIWA's LakeSPI database (custom-built Microsoft Access database) thereby ensuring standardised and error-free results. However, manual calculations are possible using the scoring boxes provided in the Technical Manual. It is recommended that data are processed as soon as possible after the lake survey, in case any clarification or other information needs to be sought from the surveyors.

Figure 1 lists the 11 component metrics, where site observations from the field sheets are translated to a metric score. Scores are then summed to generate site sub-totals for each index. Note that the LakeSPI Index includes a combination of selected scores from the other indices, with the scores from the Invasive Impact Index being reversed in recognition of the negative influence on lake condition (i.e. a high invasive score becomes a low lake condition score).

Summed site scores for the Native Condition Index and LakeSPI Index are then normalised according to the depth of a lake, which dictates the maximum scoring potential of several of the metrics. These indices are therefore expressed as a percentage of a lake's maximum scoring potential, i.e. approximately the pre-European condition, with the Invasive Impact Index indicating the degree of deviation from maximum scoring potential. Maximum scoring potential of a lake can be calculated using the depth calibration table in the Technical Manual. The final index values for the lake are calculated as the average of the site values.

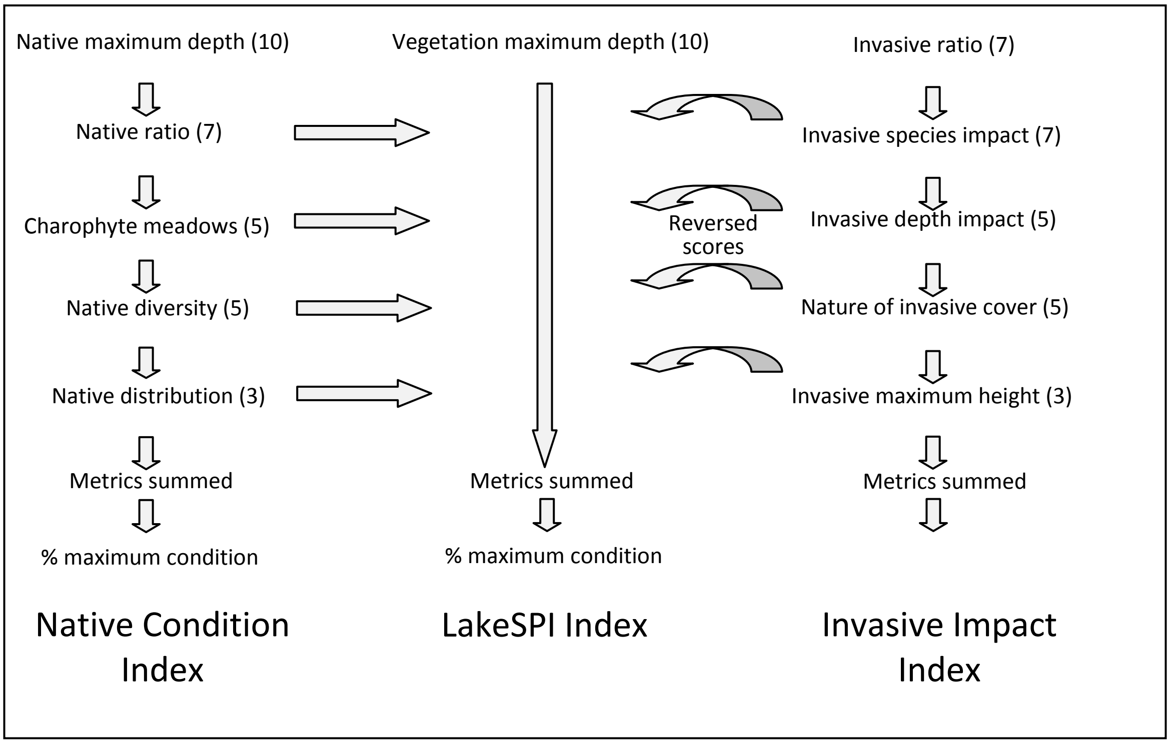


Figure 1. Contribution of the 11 LakeSPI metrics to the 3 LakeSPI indices, with maximum metric score in parenthesis.

For the manual method of calculating LakeSPI metric scores and indices, the process for the component steps is outlined in Figure 2.

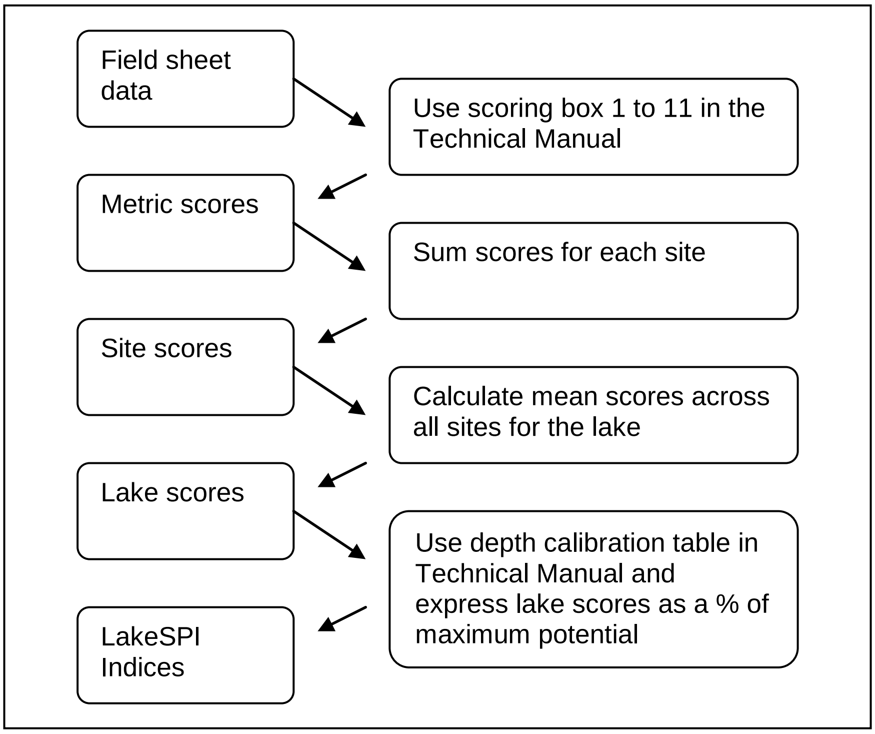


Figure 2. Flow chart showing steps in generating the final LakeSPI Indices for a lake.

Reporting LakeSPI status

The combination of values for the three LakeSPI indices provides a description of the lakes status at the time of survey, and enables comparisons with the positions of other lakes along a scale in LakeSPI condition (see 'Case study B').

For ease of reporting LakeSPI status, five lake condition categories (Excellent, High, Moderate, Poor, Non-vegetated) have been developed to support a Ministry for the Environment initiative for national consistency in terminology and reporting. Lakes are classified according to the value of their LakeSPI Index:

- > 75% = Excellent
- > 50% to 75% = High
- > 20% to 50% = Moderate
- > 0% to 20% = Poor
- 0% = Non-vegetated

Reporting LakeSPI trends

LakeSPI users may wish to set their own threshold for recognised change in LakeSPI status of lakes. For example, a change in lake condition class from ‘High’ to ‘Moderate’ may not be considered acceptable for high country glacial lakes. Other recognised ecological change may involve a new incursion by a more invasive weed, which signals future change in LakeSPI scores with time, although an immediate large change in scores may not be evident.

General guidelines (Figure 3) have been developed by NIWA to give a scale of probabilities for change in lake condition with the extent of change in the LakeSPI indices over multiple surveys. These guidelines, based on expert judgement, have considered variation by different observers and the response of LakeSPI scores to major ecological events in lakes.

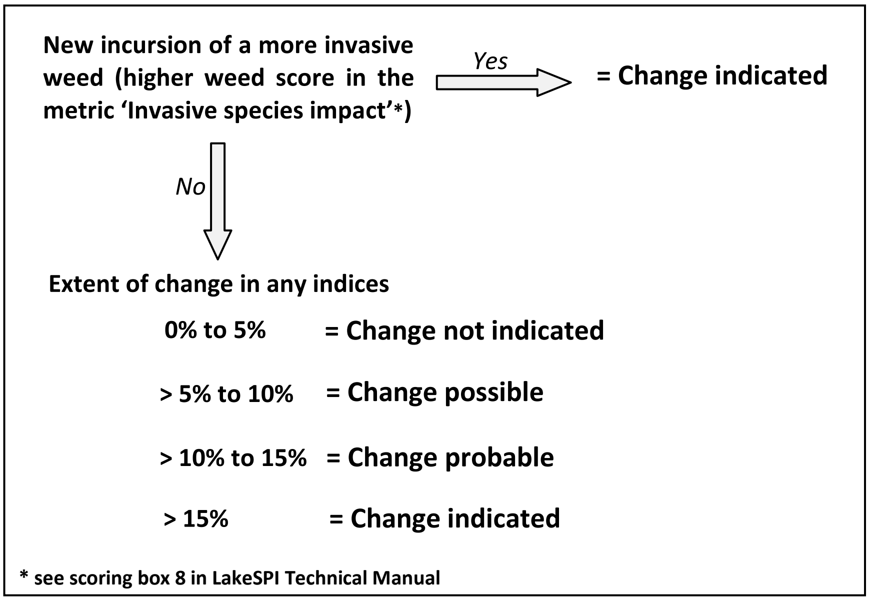


Figure 3. Guidelines for assessing the significance of change in LakeSPI Indices over multiple surveys of a lake.

Statistical approaches for LakeSPI trends are at the discretion of the user. However, we suggest these should incorporate both the magnitude and direction of change in indices values for all surveyed sites in a lake.

LakeSPI web-reporting resources

On contributing data to the LakeSPI database, DOC may also choose to authorise lake results to be uploaded to the publically accessible LakeSPI reporting system[3]. These pages (under development) would enable users to generate a ‘report’ to display the current status of a lake, and earlier survey results if available, as well as acknowledging the agencies that have contributed the data. The latest lake surveys available from the LakeSPI database may be utilised in a ‘lakes summary report’. For example, a lakes status may be viewed against a national overview of available lake

[3] www.lakespi.niwa.co.nz

scores. The advantage of this automated reporting system will be consistency and correctness of results, and public availability of processed results for viewing or to download.

Case study A

Case study A: assessing herbicide trial in Lake Otamateroa

Synopsis

LakeSPI can be used to track the ecological outcomes for lakes from both the invasion of exotic aquatic weeds and also the results of active weed management. In this example, LakeSPI was applied to assess results of a herbicide trial in Lake Otamatearoa.

Lake Otamatearoa (Figure 4) is a small (10 ha) dune lake in the Waikato Region, and is privately owned. It has conservation values, including the presence of threat-status plant species, and has been the site of DOC-led plant species translocations (Wildland Consultants 2011). This lake is the only one in the Āwhitu area to have been invaded by the exotic weed hornwort (*Ceratophyllum demersum*), one of the worst submerged weeds for ecological impacts in waterways (Champion & Clayton 2000) and designated as a 'National Interest Pest' in the South Island.

Figure 4. Lake Otamatearoa, an Āwhitu dune lake.

Lake Otamatearoa provided a potential site to trial the use of endothall, a herbicide registered for use in aquatic situations since 2005, in controlling or potentially eradicating hornwort. Impact on non-target aquatic vegetation was expected to be no more than minor.

Objectives

Application of the LakeSPI method before and after two whole-of-lake treatments with endothall sought to identify ecological outcomes, such as removal of hornwort dominance and recovery of key native plant communities, with the ultimate aim being the eradication of this weed. The context for the magnitude of change in ecological condition was also sought by considering results of previous LakeSPI assessments and the retrospective application of the method to available historic vegetation accounts.

Sampling design and methods

Five baseline sites had been established for the lake in 2004, when a LakeSPI survey was commissioned by Environment Waikato as part of suite of ecological indicators for shallow lakes in the region (Neilson et al. 2007; Edwards et al. 2010). A small lake without defined inflows or outflows, the vegetation composition in Lake Otamatearoa was previously found to be largely homogenous. Therefore sites had been selected at access points situated approximately equidistantly around the lake edge. Sites were documented by GPS and photo-points.

Baseline sites were resurveyed prior to and following hornwort treatment with endothall. At each site, divers recorded key vegetation features from the lake edge to the deepest plant extent, which in the case of this shallow lake corresponded to the maximum depth of the lake (between 3.2 and 4.3 m depending on water level).

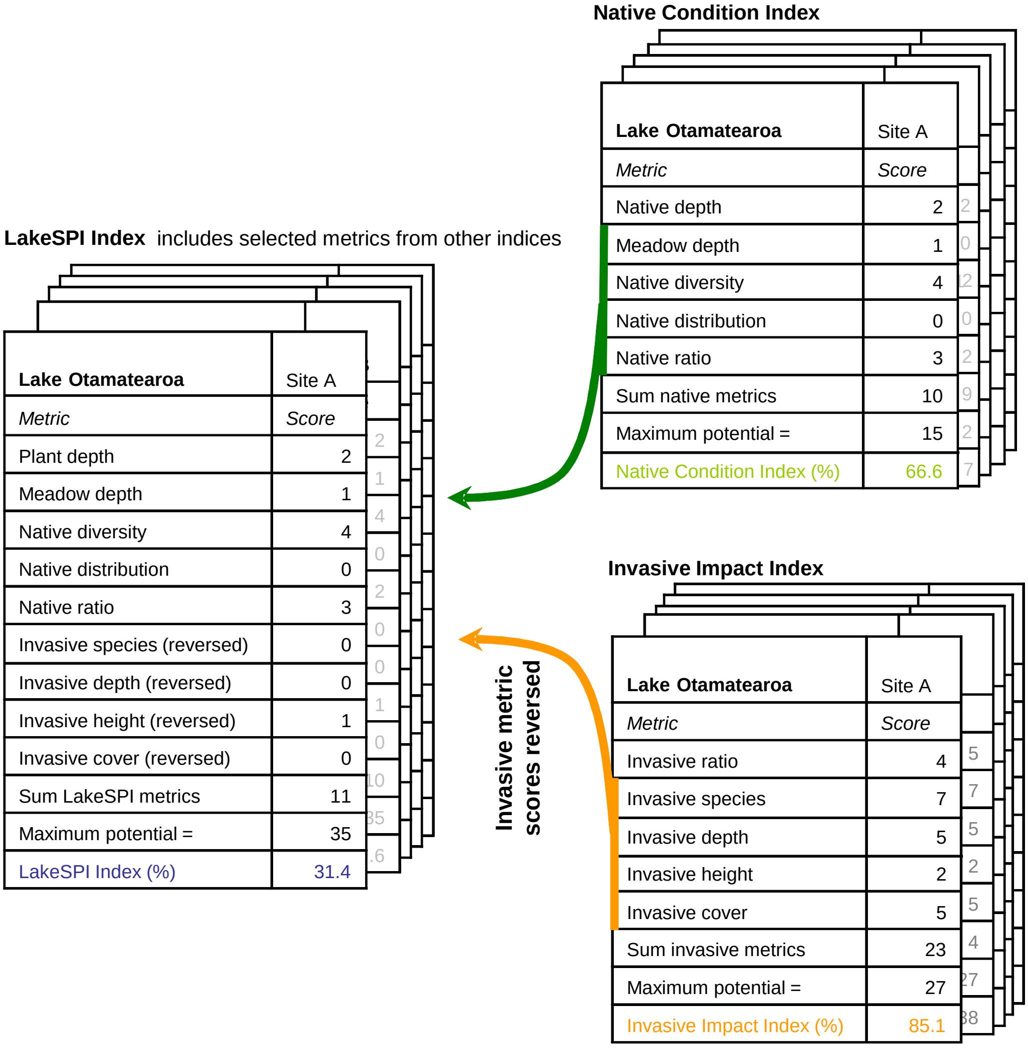
To provide scores for Native Condition, divers recorded the presence of up to four native plant communities (emergents, milfoils, pondweeds and charophytes). The depth extent of charophyte 'meadows' (forming covers of 75% or more in a 2 m^2 area) was measured, as was the maximum depth extent of native vegetation that exceeded a 10% cover in any 2 m^2 area. The overall ratio of lakebed occupation by native species, as opposed to invasive plant species, was also estimated for each of the sites.

To provide scores for Invasive Impact, weeds recorded at Lake Otamatearoa were scored according to an *a priori* ranking, where the presence of top ranked weed only, in this case hornwort, was recorded. The maximum height of each invasive species was estimated, and the maximum cover of invasive vegetation in any 2 m^2 area was described, with categories ranging from occasional plants to a closed cover. The maximum depth extent of any invasive vegetation that exceeded a 10% cover in any 2 m^2 area was measured. The ratio of occupation by invasive species was estimated as above.

Diver measurements and observations at each site were entered into NIWA's LakeSPI database (see 'Data storage') which automatically generates scores for each LakeSPI metric and calculates three overall indices (Figure 5). The LakeSPI Index combined key features of the other two indices, but incorporated reversed scores from the Invasive Impact Index in recognition of the reduced contribution of invasive weeds to lake ecological condition (Figure 5). Overall scores for the lake are an average of the 5 sites.

Indicative LakeSPI scores can also be generated from historical accounts of lake vegetation provided there is sufficient information. In this case, a detailed map and a description of vegetation features was made in 1950 based on observations and grapnel drags in Lake Otamatearoa by Cunningham et al. (1953). Detailed observations were also made in 1986 by NIWA staff (unpublished records).

Observations translated to scores
↓
Site metrics summed
↓
Maximum potential score calculated
↓
Index % calculated
↓
Results = average of 5 baseline sites



Native Condition Index

Lake Otamatearoa	Site A
Metric	*Score*
Native depth	2
Meadow depth	1
Native diversity	4
Native distribution	0
Native ratio	3
Sum native metrics	10
Maximum potential =	15
Native Condition Index (%)	66.6

LakeSPI Index includes selected metrics from other indices

Lake Otamatearoa	Site A
Metric	*Score*
Plant depth	2
Meadow depth	1
Native diversity	4
Native distribution	0
Native ratio	3
Invasive species (reversed)	0
Invasive depth (reversed)	0
Invasive height (reversed)	1
Invasive cover (reversed)	0
Sum LakeSPI metrics	11
Maximum potential =	35
LakeSPI Index (%)	31.4

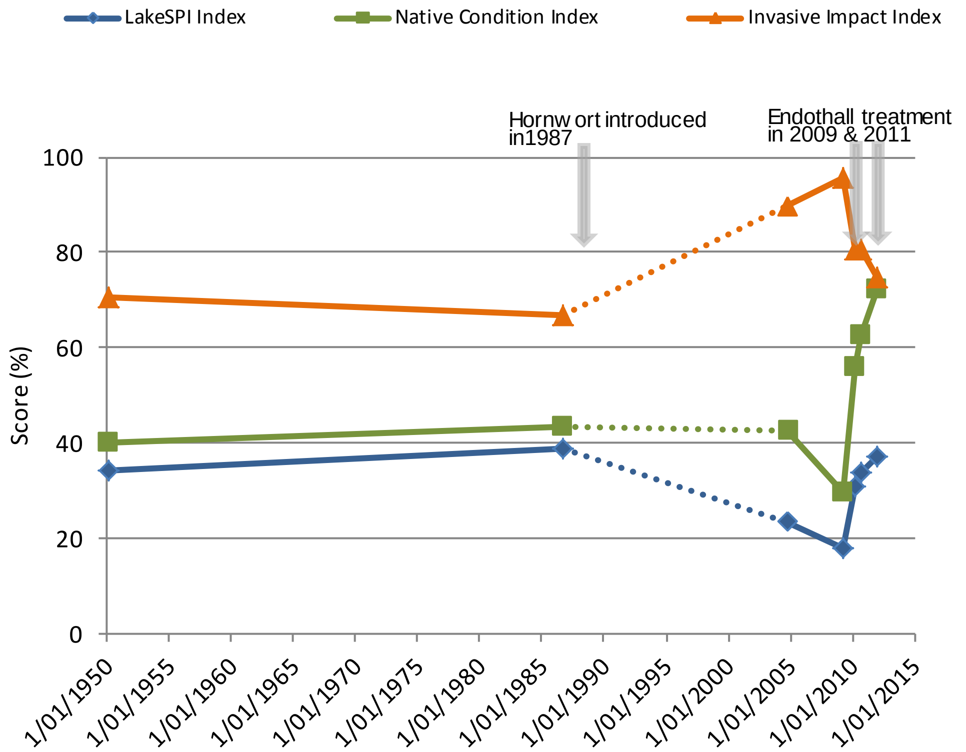
Invasive Impact Index

Lake Otamatearoa	Site A
Metric	*Score*
Invasive ratio	4
Invasive species	7
Invasive depth	5
Invasive height	2
Invasive cover	5
Sum invasive metrics	23
Maximum potential =	27
Invasive Impact Index (%)	85.1

Figure 5. Observations from five sites are translated to LakeSPI scores and indices are calculated as a percentage of the maximum potential for the lake.

Results

Prior to endothall treatment in late September 2009, LakeSPI results showed the lake to be dominated by the invasive weed, hornwort. Each metric of the Invasive Impact Index scored highly to give a score of 95.6% (Figure 6). In contrast, the low Native Condition Index of 29.3% (Figure 6) at this time reflected constrained native vegetation occupancy and depth extent, although up to four native plant community types were recorded. The LakeSPI Index integrated the low native scores and the reversed high invasive scores to give an overall score of 17.7% (Figure 6).



Year	Vegetation	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
1800s	Pristine state	97.1	93.3	0.0
24/01/1950	*E. canadensis* present	34.3	40.0	70.4
11/08/1986	*E. canadensis* present	38.6	43.3	66.7
18/10/2004	Hornwort dominant	23.4	42.7	95.6
09/03/2009	Pre-herbicide	17.7	29.3	95.6
08/03/2010	5 months post-herbicide	30.9	56.0	80.7
20/10/2010	13 months post-herbicide	33.7	62.7	80.7
18/01/2012	7 months post-herbicide	37.1	72.0	74.8

Figure 6. Time-series of LakeSPI Indices showing the response of scores to hornwort invasion and to a subsequent herbicide treatment.

In early March 2010, 5 months after the first herbicide treatment, LakeSPI metrics recorded reduced cover and lake occupancy of invasive vegetation that led to a 15% reduction in the Invasive Impact Index (Figure 6). At the same time the depth extent and occupancy of native vegetation increased so that the Native Condition Index and LakeSPI Index almost doubled (Figure 6).

A second whole-of-lake treatment with endothall was made in June 2011 in an unsuccessful attempt to eradicate the small remaining biomass of hornwort. Only a small additional reduction in the Invasive Impact Index was achieved, with hornwort continuing to be recorded at low covers from all sites, together with a slight expansion in other invasive species (*Elodea canadensis*, *Potamogeton crispus* and *Utricularia gibba)*. The Native Condition Index continued to increase as native plants expanded to areas and depths previously occupied by hornwort.

Historically, the lake vegetation had a long stable period (Figure 6) from at least 1950 when the less weedy exotic *Elodea canadensis* was present (Cunningham et al. 1953), until 1987 when hornwort was first recorded (de Winton et al. 2009). Subsequent assessments reflect the greater ecological impact that hornwort has exerted.

In conclusion, LakeSPI showed endothall treatment was capable of reducing hornwort dominance and promoting the recovery of native vegetation character. The difference in LakeSPI indices between assessments prior to and after the sequence of herbicide treatments was 19% to 43% magnitude, indicating that significant ecological change had occurred. There was no evidence of off-target herbicide effects on native vegetation character. This is in keeping with other trials showing selective control of several invasive weeds using endothall, with a range of native plant species showing substantially lower sensitivity.

Limitations and points to consider

LakeSPI was appropriate to track the general response of lake vegetation to herbicide treatment, but additional observations were required to track outcomes for the threat status plants recorded at the lake. A targeted survey established no off-target herbicide impacts on lake edge populations of *Myriophyllum robustum*, *Ranunculus macropus* or the submerged *Utricularia australis*.

Timing is important when using LakeSPI to track the outcomes of active weed management. In the example above, sufficient time had elapsed (in this case 5–7 months) after herbicide application for weed bed decay and for native vegetation to expand. In contrast, application of LakeSPI to assess the use of grass carp to remove invasive vegetation in water bodies is not recommended until the influence of fish on overall lake vegetation is removed.

References for case study A

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Case study B

Case study B: measuring the ecological condition of the Kai Iwi lakes

Synopsis

LakeSPI assessment of lake ecological condition can be used to rank lake values on a regional or national basis, and to set lake management priorities. Although LakeSPI measures lake condition based on submerged plant indicators, results can be used to complement other values such as uniqueness of water body type, threat species status, cultural importance and/or public usage.

Northland Regional Council (NRC) has commissioned LakeSPI surveys on selected lakes contributing towards wider native biodiversity value monitoring (Wells & Champion 2011). As a component of this programme, the Kai Iwi group of lakes—Kai Iwi, Waikere and Taharoa—are surveyed using LakeSPI at intervals of approximately 5 years. LakeSPI was used both to detect possible adverse influences on lake ecological condition, and also to compare the status of lakes both regionally and nationally.

Objectives

LakeSPI was applied to measure the ecological condition of the Kai Iwi lakes, their stability, native biodiversity value, and regional and national status. This was achieved by regular assessments, and interpretation of results within the context of available nationwide LakeSPI results.

Sampling design and methods

The three lakes are situated on consolidated dunes, with the largest being Lake Taharoa at 197 ha in size and the two smaller lakes being approximately 20 ha. Lake Taharoa and Waikere both exceed 30 m in depth; Lake Kai Iwi has a maximum depth of 16 m. Baseline LakeSPI sites were selected based on historical knowledge on the lakes' vegetation and sought to incorporate typical vegetation while avoiding localised conditions or unusual features. Although the lakes have only minor inflows, with no outflows, sites that were avoided included the drain connection between lakes Kai Iwi and Taharoa, and a poorly vegetated bay in Lake Taharoa (the 'sin-bin').

Plant maximum depth in Lake Taharoa (and sometimes Lake Waikere) frequently exceeded 20 m in depth which is the maximum depth for diver observations as required by the LakeSPI method. This is a practical limitation for the safety of divers, but is also sufficient to distinguish those exceptional lakes that have extremely high water clarity allowing vegetation to develop past 20 m of depth.

Other diver observations were made according to the method and translated to scores and indices upon entry to NIWA's LakeSPI database (Figure 5). In addition to this, results are described according to five LakeSPI categories ranging from 'non-vegetated (LakeSPI score 0%), to 'excellent' (LakeSPI score > 75%). The LakeSPI method is also retrospectively applied to historical vegetation data, where sufficient detail exists, and all LakeSPI results for each lake were extracted to build a time-sequence of results. These results are then compared to the latest assessments of all New Zealand lakes to determine rankings of the Kai Iwi lakes on a regional and national basis.

Results

Current status

Overall lake condition was 'high' for Lake Kai Iwi, and 'excellent' for both Lake Waikere and Lake Taharoa (Table 1). All three lakes had extensive native submerged vegetation, with maximum depth records exceeding 20 m in lakes Waikere and Taharoa and reaching 12.6 m in Lake Kai Iwi. This translated to Native Condition Index values ranging between 66% and 77% (Table 1). Impacts by exotic invasive weeds were negligible to low, with an Invasive Impact Index of approximately 20% for the two smaller lakes and just 6% for Lake Taharoa. The low scoring for invasive impact was driven by the presence of relatively benign, seed-spread exotic species, *Utricularia gibba* and *Juncus bulbosus*, which had a variable influence on vegetation character.

Table 1. Current status of the Kai Iwi lakes according to the most recent LakeSPI assessment.

Lake	LakeSPI category	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Kai Iwi	High	69.4	65.9	22.2
Waikere	Excellent	75.2	74.0	20.0
Taharoa	Excellent	84.0	77.3	5.9

Change over time

Plotting LakeSPI results by date shows the lakes have been relatively stable (< 10% change in indices), (Figure 7), with the exception of the most recent time frame between assessments (2007 to 2011) for lakes Kai Iwi and Waikere. This most recent change reflects the response of the

Invasive Impact Index to the introduction of *U. gibba* in the lakes and subsequent widespread establishment of this weed at low levels.

Changes were also influenced somewhat by fluctuations in the maximum depth limits of vegetation in the lakes, which may relate to the development of thermocline gradients in water temperature, clarity and oxygen status.

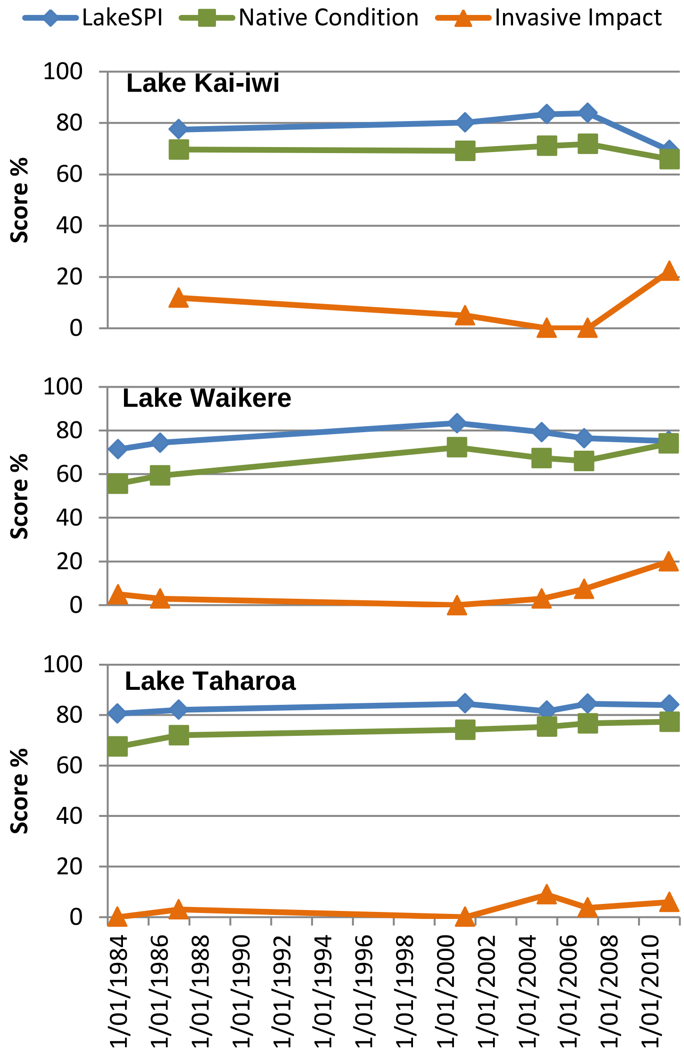

Figure 7. Time sequence of LakeSPI Indices for the Kai Iwi lakes over the last 26 years, based on LakeSPI assessments.

Regional and national comparison

Table 2 provides the rankings of the Kai Iwi lakes out of 47 Northland Region lakes, and rankings out of 215 lakes assessed nationally using the LakeSPI index. Results show that the Kai Iwi lakes rank amongst the approximate top third of Northland lakes and rank amongst the top 20% of all assessed lakes nationally. This demonstrates the good ecological condition of a number of the Northland lakes; in particular, Lake Taharoa, which ranks highly as the best example of a clear-water lake with deep vegetation (24 m) in the North Island.

Table 2. National and regional rankings of the Kai Iwi lakes according to LakeSPI Index.

Lake	Regional ranking (47 lakes)	National ranking (215 lakes)
Kai Iwi	17th	40th
Waikere	14th	31st
Taharoa	6th	13th

Figure 8 presents the national rankings in a format which allows the status of each lake to be viewed relative to other lakes nationally, whilst also showing the relative contribution of the Native Condition Index and Invasive Impact Index to the overall scores. For example, lakes Taharoa and Waikere share a high Native Condition Index score (right hand red bar) and a modest Invasive Impact Index score (left hand red bar) with the other lakes in the 'excellent' category of ecological condition.

Results shown in this format confirm that the Kai Iwi lakes rank highly in terms of lake ecological condition on both a regional and national basis. Management initiatives aimed to protect or enhance the ecological values of the lakes were then able to be rationalised and prioritised on the basis of identified values. For example, these lakes are now sites of an annual weed surveillance programme, with native biodiversity values monitored every 5 years, and further emphasis on lake water quality and catchment nutrient sources (Wells & Champion 2011).

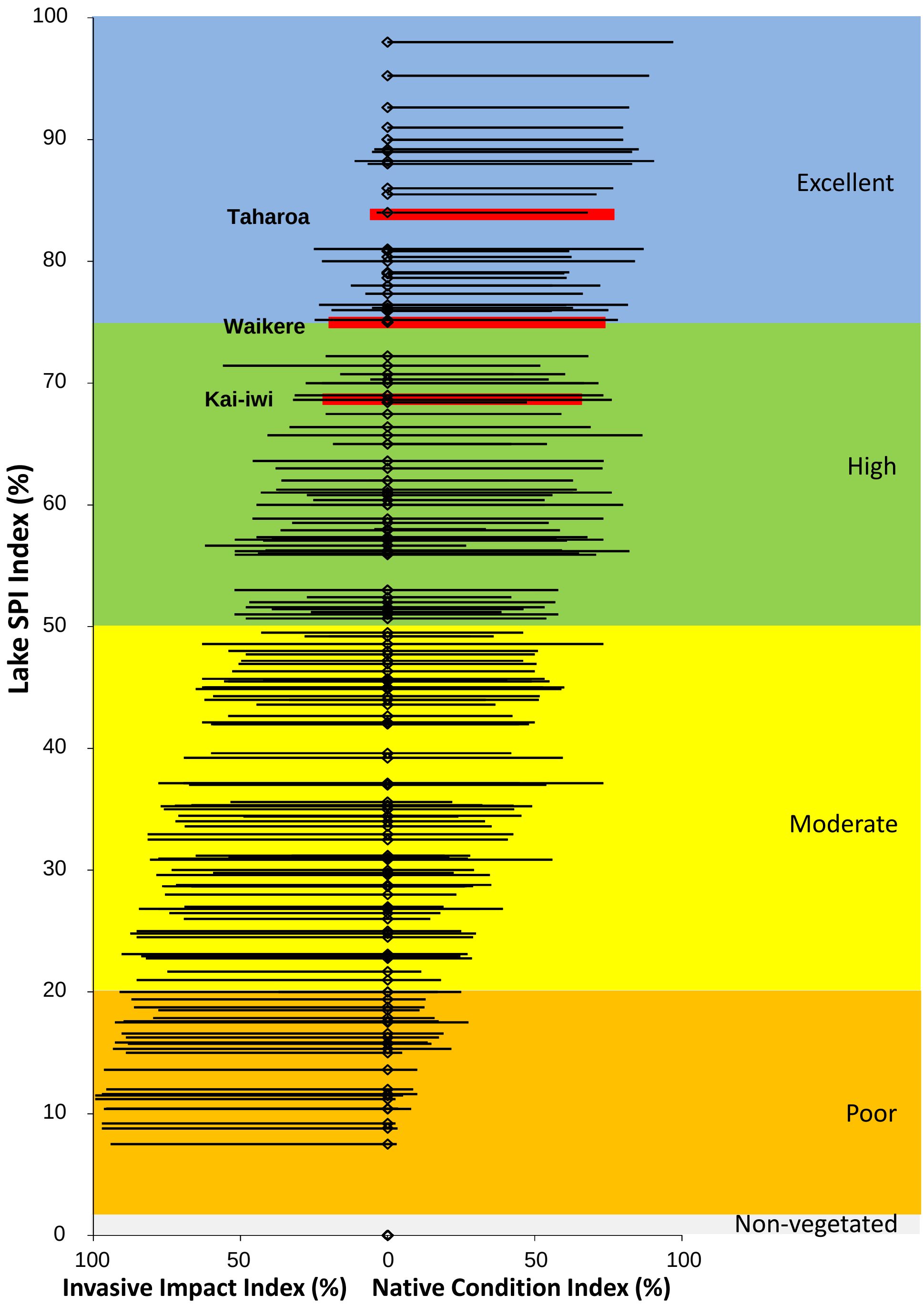

Figure 8. The Kai Iwi lakes (red lines) plotted against the most recent scores for 215 New Zealand lakes together with five categories of LakeSPI condition. LakeSPI Index is plotted on the *y*-axis, Native Condition Index and Invasive Impact Index, respectively, on the right and left of the *x*-axis.

Limitations and points to consider

LakeSPI was designed to measure the departure of lake submerged vegetation from an expected or potential state, based on a range of ubiquitous vegetation features common to the majority of

New Zealand lakes. As such, it does not detect special or unusual vegetation features that represent specific ecological values, e.g. unique community assemblages, populations of threat status species. Nevertheless, higher ecological condition indicated by the application of LakeSPI can be considered an additional value for setting management priorities.

References for case study B

Wells, R.; Champion, P. 2011: Northland lakes ecological status 2011. Prepared for Northland Regional Council, Whangarei. NIWA Client Report HAM2011-096. 310 p.

Full details of technique and best practice

The LakeSPI user manual (Clayton & Edwards 2006b) is available online.[4] It is strongly recommended that you read the user manual before undertaking a LakeSPI survey to monitor the ecological condition of lakes. The user manual gives clear user-friendly guidance on how to carry out the field assessment and how to generate the LakeSPI indices.

Rather than replicating or condensing the user manual here, readers are directed to Sections 4 and 5 of the document, which outline how to carry out a LakeSPI survey (including how to fill in the field sheets correctly) and how to use the field data to generate the LakeSPI scores.

The LakeSPI technical report (Clayton & Edwards 2006a) is also available online[5] and explains the concepts behind the LakeSPI method, interpretation of the method and management applications.

References and further reading

Clayton, J.; Edwards, T. 2006a: A method for monitoring ecological condition in New Zealand lakes: technical report version 2. NIWA Project: CRBV062, National Institute of Water & Atmospheric Research Ltd., Hamilton. 66 p.

Clayton, J.; Edwards, T. 2006b: A method for monitoring ecological condition in New Zealand lakes: user manual version 2. NIWA Project: CRBV062, National Institute of Water & Atmospheric Research Ltd., Hamilton. 49 p.

Clayton, J.; Edwards, T. 2006c: Aquatic plants as environmental indicators of ecological condition in New Zealand lakes. *Hydrobiologia 570*: 147–151.

de Winton M.D.; Clayton, J.S.; Edwards, T. 2012: Incorporating invasive weeds into a plant indicator method (LakeSPI) to assess lake ecological condition. *Hydrobiologia* (DOI) 10.1007/s10750-012-1009-0.

[4] http://www.niwa.co.nz/sites/default/files/import/attachments/lakespi_manual.pdf
[5] http://www.niwa.co.nz/sites/default/files/import/attachments/lakespi_report.pdf

Appendix A: LakeSPI field sheet

LAKE:
SITE: A B C D E
DATE:
SURVEYOR:
PROFILE LENGTH: <25m 25–100m >100m
GPS:
SITE DESCRIPTION:

NATIVE VEGETATION

MAXIMUM DEPTH

	NATIVES (>10% cover)
	CHAROPHYTE MEADOWS (> 75% cover)

NATIVE PRESENCE

☑		>5 m
	Emergents	
	Turf Plants	
	Charophytes	
	Isoetes	
	Milfoils	
	Pondweeds	

RATIO (%)

	< 5
	6 – 25
	26 – 50
	51 – 75
	76 – 95
	> 95

INVASIVE VEGETATION

INVASIVE MAXIMUM DEPTH (>10% cover)

INVASIVE SPECIES

HEIGHT (m)		= 100%
	Elodea	
	Egeria	
	Lagarosiphon	
	Ceratophyllum	
	Hydrilla	
	Pot. crispus	
	Juncus bulbosus	
	Ranunculus tri.	
	Vallisneria spp.	
	Utricularia gibba	

RATIO (%)

	< 5
	6 – 25
	26 – 50
	51 – 75
	76 – 95
	> 95

NATURE OF INVASIVE COVER

	OCCASIONAL
	COMMON
	OPEN CANOPY
	PARTLY CLOSED
	CLOSED

MUSSELS **KOURA**

OTHER BIOTA NOTED (eg snails, fish, algae)

COMMENTS (profile sketch, land use)

Appendix B: DOC documents are referred to in this method

docdm-929916	LakeSPI field sheet
docdm-908168	LakeSPI plant identification sheets
docdm-237640	Scientific diving and snorkelling: technical document
docdm-673798	Scientific diving: one page SOP
docdm-673820	Snorkelling: one page SOP
docdm-146272	Standard inventory and monitoring project plan