Northland Lakes Strategy

Prepared for Northland Regional Council

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Contents

Tables

Figures

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Executive summary

Northland Regional Council (NRC) sought technical advice from NIWA, via a medium Envirolink advice grant, to assist it to develop and implement a comprehensive regional strategy for the management of Northland's unique lakes resource.

Northland lakes are of national and international significance, with dune lakes the predominant lake type. Northland has the greatest number of dune lakes nationally, and most probably internationally, and represents a large proportion of warm, lowland New Zealand lakes still with relatively good water quality. These lakes and their surrounding wetland margins support a range of endemic endangered species providing the only known habitat, or the national strongholds for a range of biota. Perhaps the most outstanding character of these lakes is the currently limited impact of invasive species on their biota, which is unparalleled in any other region of mainland New Zealand.

Using results of previous NIWA studies 76 lakes were evaluated in this strategy, with all but seven being dune lakes. These seven lakes were classed as lakes of volcanic or alluvial origin, or man-made dams. The dune lakes were classified according to their origin including perched dune lakes and coastal deflation hollows both typically with tea-stained water (e.g., Lake Mokeno), window lakes with clear spring-fed water (e.g., Lake Taharoa), lakes formed by mobile dunes damming valleys or basins (e.g., Lake Humuhumu), marine contact lakes (e.g., Waitahora Lagoon) and ephemeral pools in mobile sands (e.g., Te Arai Pond). Lakes were further classified based on soil age and geographical area, with a total of 27 lake groups.

Ecological values were assessed for each lake including habitat size, buffering, water quality, aquatic vegetation diversity and integrity, presence of endangered and key species and connectivity. Thirty four lakes were classed as Outstanding, High or High-Moderate. The Outstanding lakes were Lakes Taharoa, Humuhumu, Waikere, Rotokawau (Pouto), Mokeno, Kai-Iwi, Ngatu, Wahakari, Kanono, Waiporohita, Waihopo and Morehurehu.

Despite the high ecological values provided by many Northland lakes the status of these water bodies is not secure. Pressures and threats identified and evaluated include biosecurity threats (aquatic weeds, pest fish and their risk of spread), eutrophication pressures from land use such as pasture and pine forestry and predominance of planktonic algal blooms and water level fluctuations, especially dropping lake levels. Only seven of the 76 lakes were assessed to be subjected to low levels of pressure/threat.

Additional assessment of the following pressures/threats is recommended:

- Potential biosecurity impact of lakes from eel fishing/diggers/drainage networks/sources of pests from water bodies other than lakes.
- Impact of nitrogen fixing plants in the catchment on nitrogen loading to lakes (especially the Kai-Iwi lakes).
- Impact of harvesting pine plantations in the catchment on the release of nutrients through death of mycorrhizae and erosional and aeolian mobilisation of nutrients to lakes.
- Impact of drought cycles on mobilisation of nutrients.

- Specific impact of land use practices on lake ecological condition, including:
  - Subdivisions and effluent treatment (e.g., septic tanks).
  - Harvesting of buried kauri logs and impact on water level.
  - Comparative nutrient run-off from cropping, e.g., avocado, maize, kumara, squash etc., and pastoral land use e.g., dairying, intensive beef, low density dry stock etc.
- Although catchment size is estimated based on a topographical model, catchments within sandy soils may well be much larger due to more extensive occluded aquifers. Quantification of land-use impacts on each lake requires an accurate assessment of catchment extent.

The current annual monitoring of 28 lakes for TLI and 10-12 lakes for LakeSPI and other ecological condition is recommended to be continued at a minimum, or preferably expanded to include all lakes ranked in the top three Ecological Value classes and best representative lakes of each remaining class (a minimum of 43 lakes). From this annual monitoring, trends in the ecological condition and impact of pressures can be ascertained and also the rates at which changes are occurring.

Continued surveillance for early detection of pest plant incursions in six high risk lakes is also recommended. Species loss is also an important indicator of lake pressure. For example, *Isoetes* sp. aff. *kirkii* was last found in Lake Omapere and is now apparently extinct in the wild, surviving only as plants collected in 1996 and cultivated at NIWA. Loss of *Utricularia australis* from many of the lakes that comprise the national stronghold of this plant has occurred over the past decade and is likely to increase its threat status to Nationally Critical.

Additional monitoring of relevance to lake ecological health assessment could include:

- On-going assessment of land use practices to produce a risk profile of each land use type and identify nutrient enrichment hot-spots.
- Establishment of water level gauges in lakes where water level decline/increase is suspected.
- Explore alternative means to assess pressures e.g., identification of nutrient enrichment of lakes by remote sensing.

Decline in condition indicated by the monitoring programme of Northland lakes need to be followed up by further investigations into the causes of these changes and exploration of potential management to mitigate or ameliorate these. Some major biosecurity management initiatives such as the eradication programmes for hornwort and lagarosiphon have been undertaken and appear to be progressing towards their goals.

A Northland Lake Strategy should be adopted by NRC. This plan would integrate activities carried out by four separate groups within NRC (land management, biosecurity, monitoring and policy/planning). As such, the benefits of a coordinated response will lead to both increased effectiveness and efficiency of NRC activities, and allow better reasoning of lake protection measures and clarify the potential impacts of land management practices and also

assist in applications for central government assistance to protect these internationally important assets. This strategy is likely to lead to more co-ordinated management actions, and better environmental outcomes and should also influence actions and policy/plans of other stakeholders including DOC, Northland Fish & Game, iwi and territorial authorities. NRC will use the strategy to advise landowners and stakeholders about the special status of water bodies on their property, through direct advice and/or farm/forestry management plans, leading to community support and additional protection of these lakes.

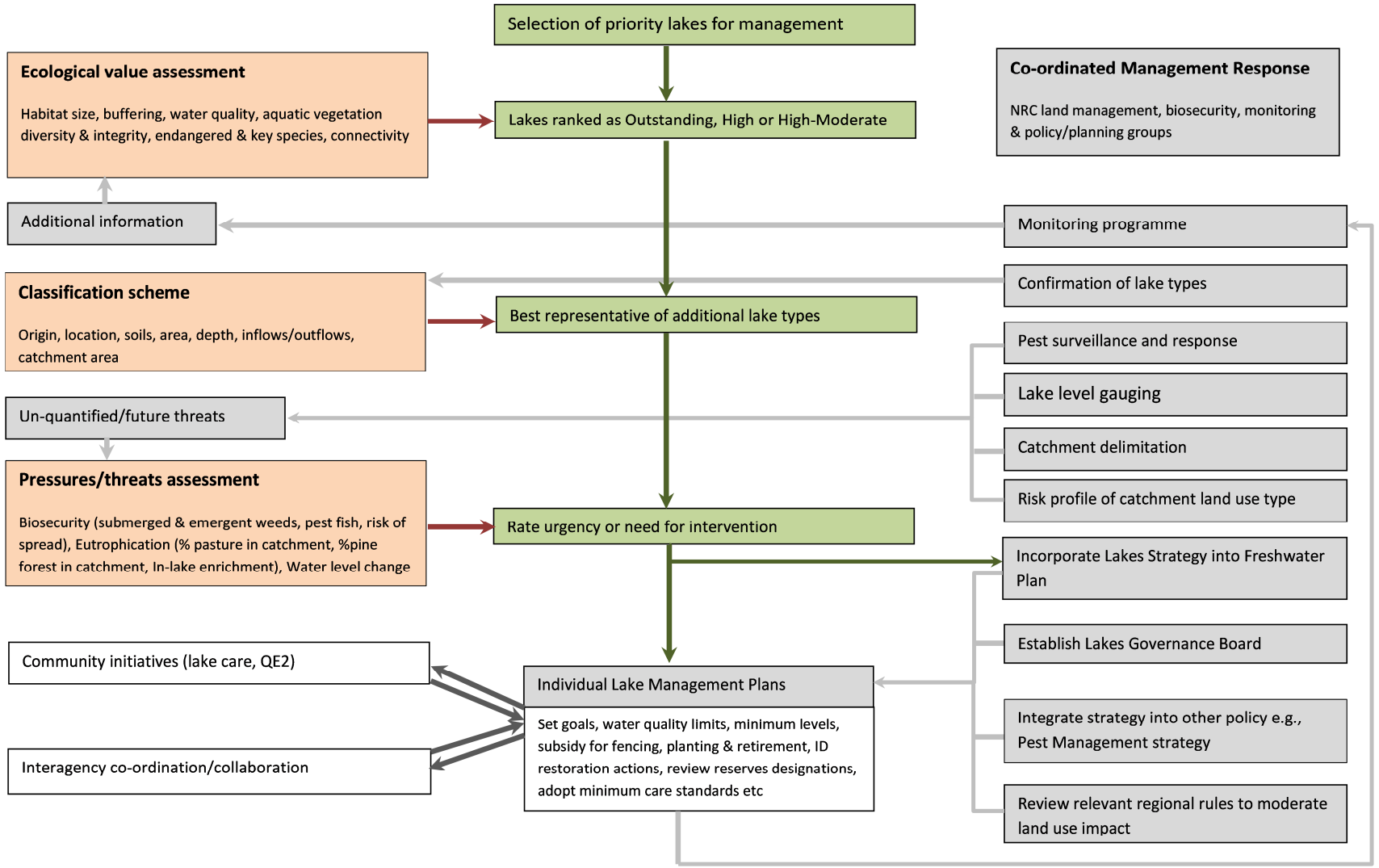
Management actions can include:

- Identify land tenure in the catchment of high value lakes and maintain a register of ownership.
- Identify if protection of the lake is effective where the catchment is within DOC or District Council reserves.
- Install weed cordons at high risk boat entry sites to reduce the risk of weed fragments establishing from boat trailers.
- Undertake strategic eradication of pest species.
- Carry out eradication of new incursions detected through the surveillance programme.
- Carry out a publicity campaign about the spread of aquatic weeds and pests (e.g., Check Clean Dry) and also educate the public on preventing impacts of nutrient enrichment (e.g., constructed wetlands, riparian retirement etc.).
- Restrict high-impact land uses in sensitive parts of the catchments of high-risk lakes (especially oligotrophic and mesotrophic lakes that are most likely to deteriorate as a result of nutrient enrichment).
- Encourage the development of Farm Environmental Management Plans and Best Practise for landowners farming in high value lake catchments.
- Encourage and possibly assist in finance of community initiatives such as riparian fencing, restoration planting, riparian management and pest control.
- Attempt to restore and enhance populations of endangered lake biota.

Individual management plans should be developed for each high value lake.

A framework for the Northland Lake Strategy is presented below. This identifies components of the strategy described in this report and also future actions to be undertaken by NRC.

Framework for Northland Lakes Strategy



1 Introduction

Northland Regional Council (NRC) sought technical advice from NIWA, via a medium Envirolink advice grant, to assist it to develop and implement a comprehensive regional strategy for the management of Northland's unique lakes resource.

Northland has over 400 freshwater lakes, many of which are coastal dune lakes. Other lake types include volcanic lakes, those created by lava flows damming streams or flooded craters, and man-made lakes (dams and reservoirs). As part of routine business, the NRC currently monitors water quality for 28 lakes in Northland, carries out annual pest surveillance monitoring of eight at-risk lakes, and has a five year programme in conjunction with NIWA to measure ecological condition (mainly plant based) of 85 lakes. The NRC is also undertaking catchment protection and/or incursion response on an ad hoc basis.

However, there is currently no overarching strategy which guides these actions, measures their effectiveness and identifies priorities and resources needed for on-going work. As a result, actions are undertaken in isolation and are often reactive, and therefore their effectiveness is likely to be limited. NRC state that there has never been an attempt to classify Northland dune lakes into their range of types based on their history of formation and how they function. Some are in a relatively pristine condition, with minimal impacts from pest species and catchment activities. However, recent declines in many of these water bodies have been detected and a coordinated approach to lakes management is required.

This Northland regional lake management strategy provides:

- An overview of the national and international significance of Northland lakes.
- A classification system for Northland lakes.
- A measurement of lake values and ranking of Northland lakes based on these values.
- Identification of threats and pressures, and assessment of these for each lake.

It will assist in the development of a management template to guide the prioritisation of actions, and help achieve the most efficient and effective management approach possible combining management of water quality, biodiversity values and biosecurity. The template will also facilitate measurement of the consequent environmental outcomes both in the intermediate and long term.

2 Significance of Northland lakes

The majority of lakes considered in this strategy are dune lakes, associated with coastal dunes or other older sand deposits. Dune lakes are internationally uncommon, occurring in New Zealand, on the eastern coastline of Australia, the Florida Panhandle and Pacific Northwest of the USA, Madagascar, the Netherlands and UK (Hadwen 2002; Porter 2009). Dune lakes are probably most abundant in New Zealand; comprising the third most numerous lake type (15%) and the most numerous North Island lake type (35%) with a total of 106 lakes (Lowe & Green 1987), the majority being on the west coast especially in Northland. Most dune lakes are small (<0.5 km^2 in area) and shallow (<10 m deep), but Northland has the largest and deepest lake of this type, Lake Taharoa (Mosley 2004).

In addition to their international rarity, the Northland dune lakes represent a large proportion of warm, lowland New Zealand lakes with relatively good water quality (Sorrell et al. 2006; Verburg et al. 2010). Verburg et al. (2010) compared water quality for each region and showed 14 Northland lakes were either oligotrophic or mesotrophic, compared with only one lake each within Auckland and Waikato Regions, with similar temperatures and elevations to Northland. One of the oligotrophic lakes, Lake Te Kahika is apparently unique, a clear water lake with very acid water (pH <4). Only regions of New Zealand with higher elevation and deeper, bigger lakes in cooler climates (e.g., Canterbury) have more lakes of higher water quality.

These Northland lakes and their surrounding wetland margins support a range of endemic endangered species providing the only known habitat, or the national strongholds for a range of biota. These include Northland mudfish, dune galaxias, dwarf inanga, *Utricularia australis*, *Trithuria inconspicua* and *Thelypteris confluens*. The abundance of dune lakes and associated wetlands, although discontinuous, collectively provide important habitat for a number of threatened and regionally significant birds including the Nationally Critical Australasian bittern and other rare species such as NZ dabchick, spotless crake and North Island fernbird (Conning & Holland 2003). The recent survey of Lake Omapere (Wells & Champion 2012) reported populations of two critically endangered plants *Ophioglossum petiolatum* and *Centipeda minima* subsp. *minima* on the lake margin and this volcanic lake now supports the highest number of threatened species known in Northland, despite its recent history of vegetation decline and poor water quality.

Perhaps the most outstanding character of these lakes is the currently limited impact of invasive species (especially weeds such as hornwort, egeria, lagarosiphon and elodea and pest fish including koi carp, catfish and perch) on their biota, which is unparalleled in any other region of mainland New Zealand. Tanner et al. (1986) highlight this and, despite some more recent incursions, their suggestion that representative lakes are worthy of active protection is still valid. Verburg et al. (2010) noted that around half (13 out of 27) lakes sampled using LakeSPI with the highest category “Excellent” were located in Northland. A primary driver for this score is the lack of pest plant impact compared to the majority of New Zealand lakes. For more details see Section 6.1.

3 Selection of lakes and their classification

Spread sheets of information relevant to Northland lakes were obtained from NRC (in 2001) and from the Freshwater Ecosystems of NZ (FENZ) geo-database (Leathwick et al. 2010). NRC had developed a spread sheet of lakes present within their region, with 227 lakes identified with an area ≥ 1ha, with a further 188 lakes smaller than this. However, these lakes include a number of artificial water bodies such as dams and reservoirs that are outside the scope of the current strategy, which focusses on natural water bodies. FENZ include 258 water bodies ≥ 1ha. Since 2005 NIWA has been undertaking surveys of Northland lakes (Champion et al. 2005; Wells et al. 2006; 2007; Wells & Champion 2008; 2009; 2010; 2011; 2012) and a total of 76 out of the 86 surveyed lakes were selected for this exercise based on their natural condition (Table 3-1). Any other natural Northland lakes not included in the current selection process should be identified from NRC and/or FENZ databases and reconnaissance of their lake values included in future field sampling programmes.

Adoption of the FENZ lakes classification system was not seen as appropriate for the purposes of a lake management strategy because resolution of lake types in Northland was too coarse for the 76 selected lakes (only 4 lake types at level 5), and 11 of the lakes were defined as wetlands (FENZ geo-database).

The 76 selected lakes include six lakes which are not included in the FENZ database because of their size (< 1 ha) or saline influence (Waitahora Lagoon). Lakes are sorted from north to south in four areas; Aupouri Peninsula, central and eastern Northland including Karikari Peninsula, western lakes from Dargaville to Waipoua and the Pouto Peninsula. NRC and FENZ identifiers are included in this table.

Table 3-1: List of Northland lakes and their NRC and FENZ numbers. n - indicates no FENZ number allocated.

Lake Name	NRC no	FENZ LID
Aupouri Peninsula		
Waitahora Lagoon	3	n
Waitahora Lake	4	24434
Te Werahi Lagoon	6	21450/21444/21448
Ngakaketa North/Te Paki	13	21434
Ngakaketa	14	21433
Te Paki dune	15	19585
Austria	22	19567
Ngatuwhete	23	19576
Pretty	24	19559
Waipara/Dead	25	19575
Te Kahika	29	24633
Te Kahika South	30	24632
Kihona	31	24621
Morehurehu	32	24628
Morehurehu South 1	33	n
Wahakari	35	24620

Morehurehu South 2	36	n
Taeore	38	24619
Te Arai Ephemeral Wetland/Pond	46	n
Te Arai Lake	47	24594
Salt	48	24605
Bulrush	49	24596
Waihopo	78	24511
Waiparera	102	13467
Katavich	103	13466
Forest Lake/Deans Swamp	114	18720
Yelavich	105	13463
Ngakapua	115 & 117	18717/18718
Rotokawau	116	18719
Carrot/Ngakapua West	118	23690
Ngatu	120	23691
West Coast Rd	121	23689
Little Gem	123	n
Heather	125	23682
Rotoroa	126	23681
Mini/Split	130	23676
Waimimiha North	136	23660
Waimimiha South	137	23657
Karikari Peninsula, central and east Northland		
Rotokawau West	95	24422
Rotokawau East	96	24423
Waiporohita	99	24415
Rotopokaka	104	19509
Omapere	173	23721
Owhareiti	177	24039
Jacks/Owaheiti Lagoon	180	24024
Kaiwai	193	24015
Tauanui	198	24001
Horahora Dune	199A	n
Waro	410	23994
Ora	205	23863
Kai Iwi lakes & north Dargaville		
Waingata	200A	23314
Te Riu	201	23306
Shag	221	21912
Waikere	227	21926
Taharoa	229	21917
Kai-Iwi	236	21918
Midgeley	257	21814
McEvoy	277	n

Freidrich's	282	21455
Pouto Peninsula		
Grevilles Lagoon	295	21773
Kapoai	296	21759
Parawanui	297	21760
Wainui	305	17761
Rototuna	328	50345
Wairere	339	50336
Phoebe's	346	50326
Karaka	347	50320
Rotopouua	348	50405
Humuhumu	350	50401
Roto-otuauru/Swan	355	50403
Mokeno	356	50314
Rotokawau	364	50413
Waingata	371	50377
Kanono	377	50373
Kahuparere	384	50371
Whakaneke	390	50309

There are 38 lakes on the Aupouri Peninsula, 12 in the eastern and central group, nine in the western area between Dargaville and the Hokianga Harbour and 17 on the Pouto Peninsula.

In order to classify the lakes into various groups a spread sheet was created covering a range of variables including lake area, catchment area, lake depth, whether there were inflows or outflows, soils and the way the lake was formed.

Eastings and Northings, lake area and catchment area were primarily sourced from FENZ. Additional data was sourced from the NRC spread sheet, and lake depth sourced from reports (Cunningham et al. 1953; Tanner et al. 1986; Kokich 1991), bathymetric maps (Irwin 1971; 1973; 1976; 1978; 1982 a & b) and field measurements made during NIWA surveys (Champion et al. 2002; 2005; Wells et al. 2006; 2007; Wells & Champion 2008; 2009; 2010; 2011; 2012). Soil types were discerned from New Zealand Land Inventory maps (Department of Lands and Survey NZMS 290 Series 1988).

Irwin (1975) defines lakes as a body of standing water occupying a basin and lacking continuity with the sea. Processes forming lakes can be classed as constructive (e.g., oxbow lake), destructive (e.g., volcanic crater) or obstructive (e.g., dammed by mobile sand dune). Northland lake types include those formed by volcanic activity, formed by landslides, formed by wind (e.g., sand dune lakes), formed by rivers and man-made dams.

Of the 76 lakes, all but seven are dune lakes, with the remainder being either:

- volcanic (formed initially in basins dammed by volcanic activity) including Lakes Omapere, Owhareiti, Tauanui and Ora (all in eastern and central group)

- alluvial (formed by damming of a stream by alluvium) including Lake Kaiwai (eastern and central group)
- man-made dams including Lake Ngatuwhete (Aupouri), Jacks and Waro (both eastern and central group).

Lake Omapere appears to have formed some 80,000 years ago but became a wetland 55,000 years ago (Newnham et al. 2004). The lake reformed 600 to 700 years ago, attributed to siltation following deforestation of the area.

Lowe & Green (1987) classified dune lakes as either basin or valley lakes, with basin lakes occurring in depressions in consolidated dunes (e.g., Lake Waingata) or between consolidated dunes and shifting dunes (e.g., Lake Humuhumu), whereas valley lakes are essentially stream or river valleys blocked by younger sand dunes (e.g., Lake Ngakeketa). Most dune lakes are thought to be relatively recent in formation being less than 6,500 years old (Lowe & Green 1987), but Lake Taharoa is at least 50,000 years old (Mosley 2004).

Timms (1982) divides dune lakes further into 6 classes:

1. Perched in leached dunes, in deflation hollows in elevated leached dunes where organic material has sealed the basin floor and provides humic (tea-stained) water. Twenty-two lakes are tentatively assigned to this class.
2. Similar to Class 1 but close to the sea, not perched, associated with extensive swamps. Seven lakes are assigned to this class.
3. Water-table window lakes in a drowned valley or interdune basin, fed by springs with clear water character. Nineteen lakes are tentatively assigned to this class.
4. Dune contact waterbodies, where at least one shore is in contact with a coastal dune, often but not exclusively humic. Seventeen lakes are assigned to this class.
5. Freshwater lakes with marine contact, where there may be intermittent connection with the sea. Waitahora Lagoon is the only example of this lake class.
6. Ponds in frontal sand dunes, where wind erodes sand to form deflation hollows. Although common on the west coast, but only one, Te Arai, is included in this strategy. They are shallow, small and often ephemeral, and should be considered in any wetland resource assessment for Northland. Horahora Dune Lake (on the east coast) also would fit within this class.

Timms (1982) also based these lake classifications on relative quantities of six major ions; sodium, potassium, calcium, magnesium, chloride and bicarbonate, Secchi disc, optical density of water at 385 nm, pH, total dissolved solids and species of zooplankton present. It would be advisable to undertake similar assessment of representative Northland lakes.

Class 1 lakes are the most abundant group found in all west coast areas and Karikari Peninsula. They have a median depth of 3 m (maximum Dead/Waipara Lake 10 m), with the

largest of these lakes being Lake Rotokawau West (66.3 ha). Median elevation for these lakes is 37 m a.s.l.

Class 2 lakes include the smaller tea-stained lakes near Lakes Morehurehu and Te Kahika and the Te Arai group in Aupouri as well as the west coast Pouto lakes that occur in recently mobile dunes. They have a median depth of 5 m (maximum Lake Whakaneke 7 m), with the largest of these lakes being Lake Mokeno (159.2 ha). Median elevation for these lakes is 11 m a.s.l.

Class 3 lakes are the deep and clear lakes situated on podzolised/leached soils and include the northern Aupouri lakes near Te Kao, the Kai Iwi lake group and also the moderately to highly leached Sweetwater lakes and some Pouto lakes. They have a median depth of 9 m (maximum Lake Taharoa 37 m), with the largest of these lakes being Lake Taharoa (204.2 ha). Median elevation for these lakes is 53 m a.s.l.

Group 4 lakes include the northern-most Aupouri lakes, either on dammed upland areas or Lower Quaternary sands, also including Lake Te Riu at Waipoua. Lakes on younger soils obstructed by mobile or recently mobile dunes include the southernmost Aupouri lakes and also Lake Kihona and the Pouto lakes, Humuhumu, Kanono and Kahuparere, which until recently were bordered on their western edges by mobile dune faces. They have a median depth of 4 m (maximum Lake Humuhumu 16 m), with the largest of these lakes being Lake Humuhumu (139.6 ha). Median elevation for these lakes is 51 m a.s.l.

Much of the western side of Northland and Aupouri Peninsula are comprised of deposits of sand, with Holocene and older Pleistocene (Quaternary) deposits.

The dominant soil types in which each dune lake is formed can be divided into three ages:

- Holocene (Pinaki sand series).
- Upper Quaternary (Redhill and Houhora series).
- Lower Quaternary (Te Kopuru and Tangitiki series).

The older sand derived soils are the most leached and, in the case of Lower Quaternary sediments, often podzolised. These soil ages reflect different origins and character of the material (Bob Cathcart, NRC pers. comm.). For example, the upper Quaternary Redhill formation is high in the clay mineral allophane (Bob Cathcart, NRC pers. comm.) and although very low in available phosphate, they retain moisture better than Pinaki soils (Gibbs 1964). Thus sand-derived soil character is likely affect lake water chemistry directly or through land use practices in the catchment.

By dividing the lakes between the four areas, lake types and soil age a total of 27 lake groups are discerned (Table 3-2). This classification allows for comparison of lake ecological values and pressures/threats of lakes with similar lake type and geographic range to ensure their representation in the Northland Lake Strategy.

Table 3-2: Classification of Northland lakes into 27 groups based on location, lake type and soil age.

Dune - Class 1, Lower Quaternary soils	Dune - Class 1, Upper Quaternary soils	Dune - Class 1, Holocene soils	
Aupouri	**Aupouri**	**Aupouri**	
Te Kahika South	Waihopo	Te Arai Lake	
Morehurehu South 1	Katavich	**Karikari**	
Taeore	Forest Lake/Deans Swamp	Waiporohita	
Waipara/Dead	Rotokawau		
Salt	Carrot/Ngakapua West		
Yelavich	Little Gem	**Dune - Class 2, Holocene soils**	
Karikari	Heather	**Pouto**	
Rotokawau East	West Coast Rd	Wairere	
Rotokawau West	**Dargaville**	Karaka	
Rotopokaka	Midgeley	Mokeno	
Dargaville	McEvoy	Whakaneke	
Waingaro	Freidrich's		
	Pouto		
	Grevilles Lagoon		
Dune - Class 3, Lower Quaternary soils	**Dune - Class 3, Upper Quaternary soils**	**Dune - Class 3, Holocene soils**	
Aupouri	**Aupouri**	**Pouto**	
Te Kahika	Rotoroa	Kapoai	
Morehurehu	Ngatu	Parawanui	
Wahakari	Waiparera		
Dargaville	Ngakapua		
Shag	**Pouto**		
Waikere	Wainui		
Taharoa	Rototuna		
Kai-Iwi	Phoebe's		
	Rotopouua		
	Roto-otuauru/Swan		
	Rotokawau		
	Waingata		
Dune - Class 4, Lower Quaternary soils	**Dune - Class 4, Upper Quaternary soils**	**Dune - Class 4, Holocene soils**	**Dune - Class 4, Upland soils**
Aupouri	**Aupouri**	**Aupouri**	**Aupouri**
Te Paki dune	Kihona	Bulrush	Waitahora Lake
Austria	Mini/Split		Te Werahi Lagoon
Pretty	Waimimiha North		Ngakaketa North /Te Paki
Morehurehu South 2	Waimimiha South		Ngakeketa
Dargaville	**Pouto**		
Te Riu	Humuhumu		
	Kanono		

Dune - Class 1, Lower Quaternary soils	Dune - Class 1, Upper Quaternary soils	Dune - Class 1, Holocene soils	
	Kahuparere		
		Dune - Class 6, Holocene soils	**Dune - Class 5, Upland soils**
		Aupouri	**Aupouri**
		Te Arai Ephemeral Wetland	Waitahora lagoon
		East Coast	
		Horahora Dune	
Volcanic	**Alluvial**	**Dam**	
Central and east Northland	**Central and east Northland**	**Aupouri**	
Omapere	Kaiwai	Ngatuwhete	
Owhareiti		**Central and east Northland**	
Tauanui		Jacks/Owhareiti Lagoon	
Ora		Waro	

4 Lake ecological values and ranking

The following lake ecological values were assessed and scores assigned to each of the 76 lakes. In all cases the maximum score reflects the highest value:

- Habitat size.
- Buffering.
- Water quality.
- Aquatic vegetation diversity.
- Aquatic vegetation integrity.
- Endangered species.
- Presence of key species.
- Connectivity.

4.1 Habitat size

The largest and deepest lakes are likely to be the most stable in terms of water quality and resilience and support the greatest diversity of habitat and biota. Lake area and depth data were ranked as shown in Table 4-1.

Table 4-1: Lake area and depth ranking.

Lake area (ha)	Rank	Lake depth (m)	Rank
>100	3	>25	3
10-100	2	10-25	2
10>1	1	<10 >2	1
≤1	0	≤ 2	0

The two rankings were averaged to produce an overall habitat size rank (maximum score 3 – minimum score 0).

4.2 Buffering

Lakes are likely to be the most stable when their catchments are predominantly in indigenous vegetation, connected to large wetland systems and are surrounded by extensive beds of emergent vegetation. Percentage native vegetation from the FENZ database, extent of wetland (percentage Freshwater Sedgeland / Rushland and Flaxland * Catchment area) relative to lake area and extent of emergent vegetation were ranked as shown in Table 4-2.

Table 4-2: Percentage native vegetation, extent of wetland and extent of emergent vegetation ranking. To score a maximum (3) emergent beds must >20 m.

% native vegetation catchment cover	Rank	Wetland extent (% of lake area)	Rank	Emergent extent (% of lake perimeter)	Rank
>50	3	>100	3	100	3
25-50	2	10-100	2	<100 >50	2
10-24	1	<10 >0	1	25-50	1
<10	0	0	0	<25	0

The three rankings were averaged to produce an overall buffering rank (maximum score 3 – minimum score 0).

4.3 Water quality

Unimpacted lakes are likely to have water quality of TLI (Trophic Level Index) of 3 or less (Oligotrophic). NRC TLI scores for 28 lakes (Emma Simpson, NRC unpublished data) were ranked as shown in Table 4-3. Lakes where water quality data were not available were assumed to be supertrophic or worse (TLI >5) (maximum score 3 – minimum score 0).

Table 4-3: Water quality ranking.

TLI Score	Trophic level	Rank
<3	Oligotrophic, microtrophic or ultra-microtrophic	3
3-4	Mesotrophic	2
4-5	Eutrophic	1
>5	Supertrophic or hypereutrophic	0

4.4 Aquatic vegetation diversity

Lakes are likely to be the best ecological condition when diverse aquatic vegetation is present.

Data on vegetation composition was analysed from the most recent ecological lake surveys (Wells & Champion 2012 and unpublished data from field sheets).

Total number of indigenous emergent, free-floating and submerged species is scored as follows: >20 species – 3; 15-20 species – 2; 5-14 species – 1; <5 species – 0.

Exceptions to this assumption are lakes where water chemistry restricts the development of diverse vegetation (e.g., Lake Taharoa has low bicarbonate concentration likely to prohibit the growth of submerged vascular plants (Wells et al. 1988) and Lake Te Kahika where acid water (pH <4) prohibit the growth of all but two submerged species (Wells & Champion 2012)). However, these lakes are likely to score highly for other ecological values.

4.5 Aquatic vegetation integrity

In addition to high diversity of aquatic plant species, the higher the percentage cover of littoral habitat occupied and the deeper the maximum depth that native aquatic plants grow to (relative to lake depth) the better the lake ecological condition.

LakeSPI is a bio-assessment tool that uses Submerged Plant Indicators (SPI) for assessing the ecological condition of New Zealand lakes and for monitoring trends (Clayton & Edwards 2006a; Clayton & Edwards 2006b, de Winton et al. 2012). Part of this Index is the Native Condition Index (NCI) that scores the integrity of submerged vegetation as a percentage of the predicted pre-European (unimpacted reference) state.

Data was analysed from the most recent ecological lake surveys (Wells & Champion 2012). NCI scores for lakes were classed as >75% – Rank 3; >50-75% – Rank 2; >20-50% or 1-20%– Rank 1; 0%– Rank 0.

4.6 Endangered species

New Zealand's endangered biota has been most recently assessed by de Lange et al. (2009) – vascular plants; Allibone et al. (2010) – freshwater fish and Hitchmough et al. (2007) – all other biota. Species are assessed using the protocols of Townsend et al. (2008) as Nationally Threatened (Nationally Critical, Nationally Endangered & Nationally Vulnerable), At-Risk (Declining, Relictual and Naturally Uncommon), also recognising new species that have naturally colonised New Zealand (Vagrant or Coloniser). Where there is insufficient information, the taxon is recorded as Data Deficient.

Only plants and fish have been used in this ranking, as most endangered birds are mobile and may utilise a range of degraded lakes as well as those with high ecological integrity. This is further considered in Section 4.8.

Data was analysed from the most recent ecological lake surveys (Wells & Champion 2012 and unpublished data from field sheets). Each Nationally Threatened taxa was given a score of 5, declining species a score of 2 and other At-Risk and new to New Zealand species a score of 1. These were summed and lakes with an endangered species score >15 was ranked 3; 5-15 was ranked 2; <5 >0 was ranked 1 and 0 when no endangered taxa were recorded.

Regionally uncommon species were not assessed. Endangered species were not scored when they were formerly recorded, but not found during the latest assessment.

4.7 Presence of key species

Freshwater mussels, also known as kakahi or torewai (*Echyridella menziesii*), are very important species in shallow water bodies as their ability to filter feed and remove planktonic algae provide significant in-lake buffering to nutrient enrichment (Champion 2002). Presence of living mussels adds an additional point to the ranking.

4.8 Connectivity

Conning & Holland (2003) noted that the abundance of dune lakes and associated wetlands, although discontinuous, collectively provide important habitat for a number of threatened and regionally significant birds. An additional point was added to the ranking of lakes associated with high concentrations of other lakes/wetlands (e.g., Pouto and Aupouri lakes).

4.9 Total Ecological Value Score

Based on these criteria a maximum total Ecological Value Score of 20 could be attained. Lakes were rated as shown in Table 4-4.

Table 4-4: Lake Ecological Score and Rating.

Ecological Value Score	Rating	Number of lakes with rating
12-20	Outstanding	12
10-11	High	8
8-9	High-Moderate	14
6-7	Moderate	18
4-5	Moderate-Low	16
<4	Low	8

These scores were compared with the NIWA 'Lake Biodiversity Assessment' rating (Wells & Champion 2012) as shown in Figure 4-1. There was a reasonable correlation between these scores ($R^2 = 0.4795$). This correlation was expected, although the 'Lake Biodiversity Assessment' was based on three components: indigenous biota, endangered species and habitat availability and did not include assessment of habitat size, buffering, water quality, key biota and connectivity.

The 20 highest ranked lakes are:

Outstanding

- Lakes Taharoa, Humuhumu, Waikere, Rotokawau (Pouto), Mokeno, Kai-Iwi, Ngatu, Wahakari, Kanono, Waiporohita, Waihopo and Morehurehu.

High

- Lakes Kahuparere, Te Kahika, Te Werahi Lagoon, Karaka, Ngakapua, Te Paki Dune, Waiparera and Rotoroa.

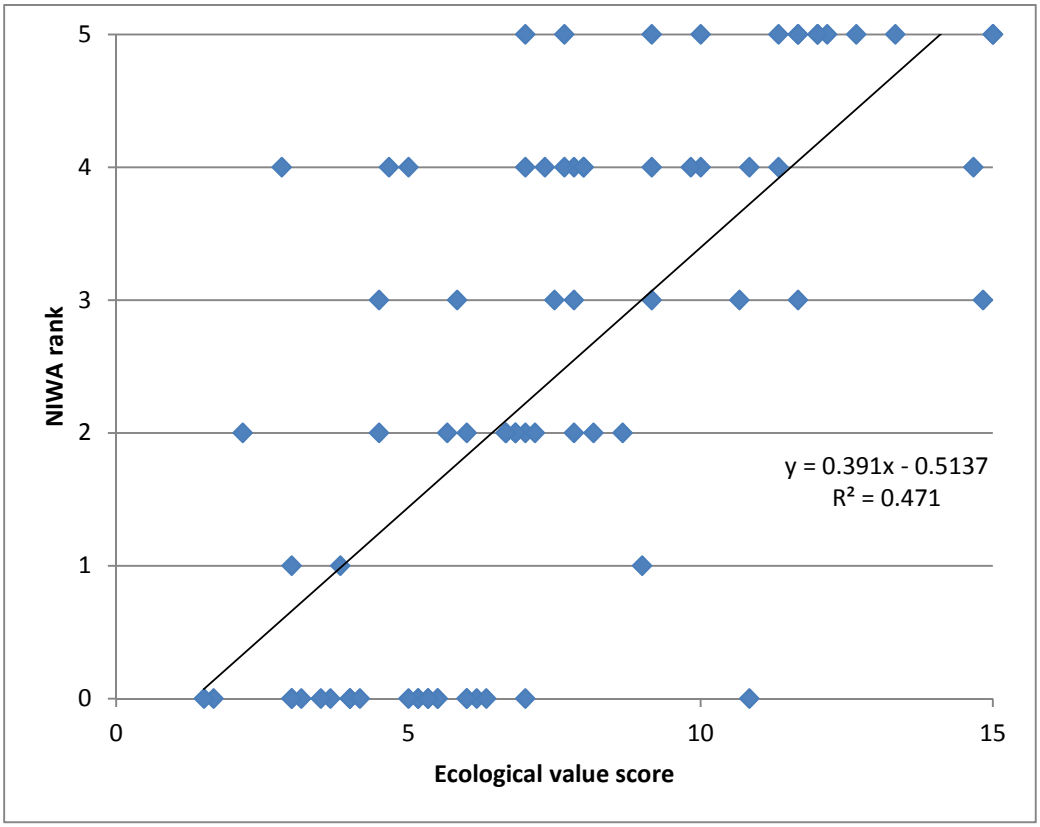


Figure 4-1: Comparison of Ecological Value score and previous NIWA ranking (Wells & Champion 2012).

5 Lake pressures/threats

Many of the Northland dune lakes are still in very good ecological condition but the overall trend is one of deterioration of these values. Lakes are dynamic systems and are naturally subject to change.

We do not tend to think of New Zealand's biota as a dynamically changing one, but many new species have arrived naturally (mostly through prevailing winds and migratory birds) predominantly from Australia (e.g., *Gratiola pedunculata, Alternanthera denticulata* and *Juncus polyanthemus* at Lake Waiporohita - Wells & Champion 2012). However, human induced species introductions have occurred at a much greater rate and have introduced species that could not naturally arrive (e.g., freshwater fish and asexually reproducing weeds).

Similarly, in the natural state the nutrient status of lakes tends to increase over time as influenced by catchment inputs and in the case of shallow lakes, these may eventually become wetlands (e.g., Lake Omapere – Newnham et al. 2004). Human mediated eutrophication from deforestation, agriculture and the use of fertilisers have all contributed to a greatly accelerated rate of eutrophication.

Mobile sand dunes have had a major impact on the genesis and character of many dune lakes, although recent stabilisation of many dunes has interrupted this dynamic process. Changes in water level, now associated with human activities, would have occurred as part of this natural process.

This section seeks to assess and score human mediated pressure and threat values for each of the 76 lakes including:

- Biosecurity
  - Submerged weeds
  - Emergent weeds
  - Pest fish
  - Risk of spread
- Eutrophication
  - % pasture in catchment
  - % pine forest in catchment
  - In-lake enrichment
- Water level change

Each value is assigned so that maximum pressure/threat would result with a score of zero, apart from pine forestry (Section 5.6) where a minimum score of 1 was allotted.

5.1 Biosecurity- Submerged weeds

Invasive submerged weeds have impacted on the majority of New Zealand lakes, with most problem species solely spread by human activity (contaminated boats and trailers, fishing nets, diggers and deliberate introduction). In addition to the NCI (Section 4.5) the other component of LakeSPI is the Invasive Impact Index (III) which captures the degree of impact

from invasive weed species, including assessment of species 'weediness', the proportional occupation by invasive vegetation and invasive depth impact (Clayton & Edwards 2006a; Clayton & Edwards 2006b, de Winton et al. 2012).

Invasive submerged weed pressure was scored as follows: III<10% - 3; III>10 <50% - 2; III >50% -1; no vegetation - 0.

5.2 Biosecurity- Emergent weeds

III only scores submerged species. Absence of the following emergent weeds that could adversely impact on lake ecology was scored an additional 1:

Alligator weed	*Alternanthera philoxeroides*
Manchurian wild rice	*Zizania latifolia*
Primrose willow	*Ludwigia peploides* subsp. *montevidensis*
Reed sweet grass	*Glyceria maxima*

5.3 Biosecurity- Pest fish

Invasive pest fish also have a detrimental impact on lake ecology that can lead to predation of other animals (e.g., the extinction of dune lakes galaxias (*Galaxias* sp.) in Lake Kai-Iwi has been attributed to gambusia (*Gambusia affinis* - Rowe (1998), loss of submerged vegetation and reduction in water clarity. Rowe & Wilding (2012) have developed a Fish Risk Assessment model (FRAM) to quantify the potential impact of invasive freshwater fish.

Invasive fish pressure was scored as follows based on the presence of the highest impact species: no pest fish – 3; FRAM <20 – 2; FRAM 20-25 – 1; FRAM >25 – 0.

5.4 Biosecurity- Risk of spread

Sections 5.1 to 5.3 have quantified the presence of environmentally damaging pest plants and fish but do not estimate the likelihood of future incursions of future pests. A range of variables including proximity to population centres, roading network and lake access to the public, and lake area were modelled by Compton et al. (2012) (wtabs model) to estimate the risk of new introduction to each lake from other lakes. Northland lakes scored from 0.11 (low risk) to 0.88 (high risk) based on the average risk of introduction of hornwort (*Ceratophyllum demersum*) or egeria (*Egeria densa*) (NIWA unpublished data).

Risk of spread was scored as follows wtabs <0.25 – 3; wtabs 0.25-0.49 - 2; wtabs 0.50-0.75 - 1; wtabs >0.75 – 0.

5.5 Eutrophication- Percentage pasture in catchment

Verburg et al. (2010) noted that eutrophication of New Zealand lakes (TLI) increased with increasing percentage of pastoral land coverage. Total percentage pasture cover in the catchment was obtained from the FENZ database.

Pasture nutrient pressure was scored as follows: <1% - 3; 1-25% - 2; >25-50% -1; >50% - 0.

5.6 Eutrophication- Percentage pine forest in catchment

Pine plantation forestry is common in Northland and it is apparent that this is associated with eutrophication of some lakes especially on the western Pouto. Total percentage pine forest cover in the catchment was obtained from the FENZ database.

Pine forest nutrient pressure was scored as follows: <10% - 3; 10-50% - 2; >50% - 1. Impact of pine forest on lake eutrophication was judged to be lower than pasture impact so a maximum impact score of 1 was used.

5.7 Eutrophication- In-lake enrichment

Production of prolonged planktonic algal blooms are indicative of nutrient enrichment. NRC measurements of Chlorophyll a (indicating concentration of planktonic algae) were obtained for 28 lakes (Emma Simpson, NRC unpublished data).

In-lake enrichment pressure was scored as follows: Chl a < 2 mg/m^3 – 3; Chl a 2-5 mg/m^3 – 2; Chl a >5-12 mg/m^3 – 1; Chl a >12 mg/m^3 – 0.

5.8 Water level change

An additional pressure noted by Wells & Champion (2012) was the decline in water level apparent in some dune lakes adjacent to pine plantation forestry. In other cases water level is increasing due to adjacent land use. In both cases these changes appear to be impacting the ecological health of the lake.

Where water level changes were not apparent, an additional score of 1 was added.

5.9 Total Pressure/Threat Score

Using these criteria a maximum total Pressure/Threat Score of 20 could be attained. Lakes were rated as shown in Table 5-1.

Table 5-1: Lake Pressure/Threat Score and Rating.

Pressure/Threat Score	Rating	Number of lakes with rating
15-20	Low	7
9-<15	Moderate	42
<9	High	27

Ecological Value and Pressure/Threat Ratings for each of the 76 lakes are shown in Table 5-2.

Table 5-2: Ecological Value and Pressure/Threat Ratings for 76 Northland lakes. O - Outstanding; H - High; H-M - High to Moderate; M - Moderate; M-L - Moderate.

Lake Name	Value	Pressure
Aupouri Peninsula		
Waitahora Lagoon	H-M	L
Waitahora Lake	M	M
Te Werahi Lagoon	H	H
Ngakaketa North (Te Paki)	M	M
Ngakaketa	M	H
Te Paki dune	H	L
Austria	H-M	M
Ngatuwhete	M-L	H
Pretty	M	M
Waipara/Dead	M	L
Te Kahika	H	L
Te Kahika South	H-M	L
Kihona	M	H
Morehurehu	O	M
Morehurehu South 1	M-L	M
Wahakari	O	H
Morehurehu South 2	H-M	M
Taeore	M-L	H
Te Arai Ephemeral Wetland/Pond	M-L	M
Te Arai Lake	M-L	M
Salt	L	M
Bulrush	M-L	H
Waihopo	O	L
Waiparera	H	M
Katavich	M-L	H
Yelavich	M	M
Forest Lake/Deans Swamp	M	M
Ngakapua	H	M
Rotokawau	H-M	M
Carrot/Ngakapua West	M	M
Ngatu	O	H
West Coast Rd	M	M
Little Gem	M-L	H
Heather	H-M	M
Rotoroa	H	H
Mini/Split	M	H
Waimimiha North	L	H
Waimimiha South	M-L	H

Karikari Peninsula, central and east Northland		
Rotokawau West	M	H
Rotokawau East	M	H
Waiporohita	O	H
Rotopokaka	M	H
Omapere	H-M	H
Owhareiti	M-L	H
Jacks/Owaheiti Lagoon	M-L	H
Kaiwai	M-L	M
Tauanui	M-L	M
Horahora Dune	L	M
Waro	H-M	M
Ora	L	M
Kai Iwi lakes & north Dargaville		
Waingata	L	M
Te Riu	M	M
Shag	M	M
Waikere	O	M
Taharoa	O	M
Kai-Iwi	O	M
Midgeley	L	M
McEvoy	L	M
Freidrich's	M	M
Pouto Peninsula		
Grevilles Lagoon	M	M
Kapoai	L	M
Parawanui	M-L	H
Wainui	H-M	L
Rototuna	H-M	H
Wairere	H-M	M
Phoebe's	M-L	M
Karaka	H	M
Rotopouua	H-M	M
Humuhumu	O	M
Roto-otuauru/Swan	H-M	H
Mokeno	O	M
Rotokawau	O	M
Waingata	M-L	H
Kanono	O	M
Kahuparere	H	M
Whakaneke	M	H

It is recommended that all lakes ranked in the top three Ecological Value classes and best representative lakes of each remaining class be monitored as part of the Northland Lake Strategy. This equates to a total of 47 lakes, or 43 if artificial dams and ephemeral pools are excluded. Pressures/threats are a measure of current condition and even if this is assessed as Low for a lake, monitoring is still required to ensure no additional deterioration of these water bodies in the future. Monitoring requirements are discussed in Section 6.

5.10 Unquantified pressures/threats

The proposed Pressure/Threat Score only takes currently quantifiable impacts/potential into account. Additional to these and requiring evaluation are the following:

- Potential biosecurity impact of lakes from eel fishing/diggers/drainage networks/sources of pests from water bodies other than lakes.
- Impact of shading from pine forest and potentially other vegetation on lake ecological condition.
- Impact of nitrogen fixing plants (especially legumes such as Sydney golden wattle (*Acacia longifolia*), tree lupin (*Lupinus arboreus*)) in the catchment on nitrogen loading to lakes (especially the Kai-Iwi lakes).
- Impact of harvesting pine plantations in the catchment on the release of nutrients through death of mycorrhizae and erosional and aeolian mobilisation of nutrients to lakes.
- Impact of drought cycles on mobilisation of nutrients.
- Specific impact of land use practices on lake ecological condition, including:
  - Subdivisions and effluent treatment (e.g., septic tanks).
  - Harvesting of buried kauri logs and impact on water level.
  - Comparative nutrient run-off from cropping, e.g., avocado, maize, kumara, squash etc., and pastoral land use e.g., dairying, intensive beef, low density dry stock etc.
- Although catchment size is estimated by FENZ based on a topographical model, catchments within sandy soils may well be much larger due to more extensive occluded aquifers. Quantification of land-use impacts on each lake requires an accurate assessment of catchment extent.

6 Measuring impact of pressures on lake values

Section 5 deals with measurement of current impacts affecting the ecological value of lakes in Northland. Much of this information comes from on-going monitoring programmes:

- Undertaken by NRC (e.g., water quality monitoring) Annual reports on Water Quality are presented to NRC (e.g., Simpson 2012).
- Commissioned and funded by NRC (e.g., NIWA Northland Lake Monitoring).
  - Currently covers annual aquatic weed surveillance of six lakes.
  - Assessment of two grass carp projects.
  - Lake Biodiversity Assessment of all lakes ranked as “Outstanding”, “High” or “High to Moderate” (Wells & Champion 2012) on a five year rotation.

From this on-going monitoring, trends in the ecological condition and impact of pressures can be ascertained and also the rate at which these changes are occurring.

A summary of LakeSPI monitoring results and comparison nationally is presented in Section 6.1 and Section 6.2 reports on the loss of species from Northland lakes since monitoring commenced in the mid 1980’s.

6.1 LakeSPI

Figure 6-1 and Figure 6-2 show the current LakeSPI results for Northland and where these values fit on a national scale. These values are expressed as percentage of the assessed pre-European condition (Clayton & Edwards 2006a; Clayton & Edwards 2006b). Northland has a greater proportion of lakes in the excellent category compared to the national proportion, and constitutes nearly half of the excellent category lakes. This graphically shows the good condition that Northland lakes are in on a national scale.

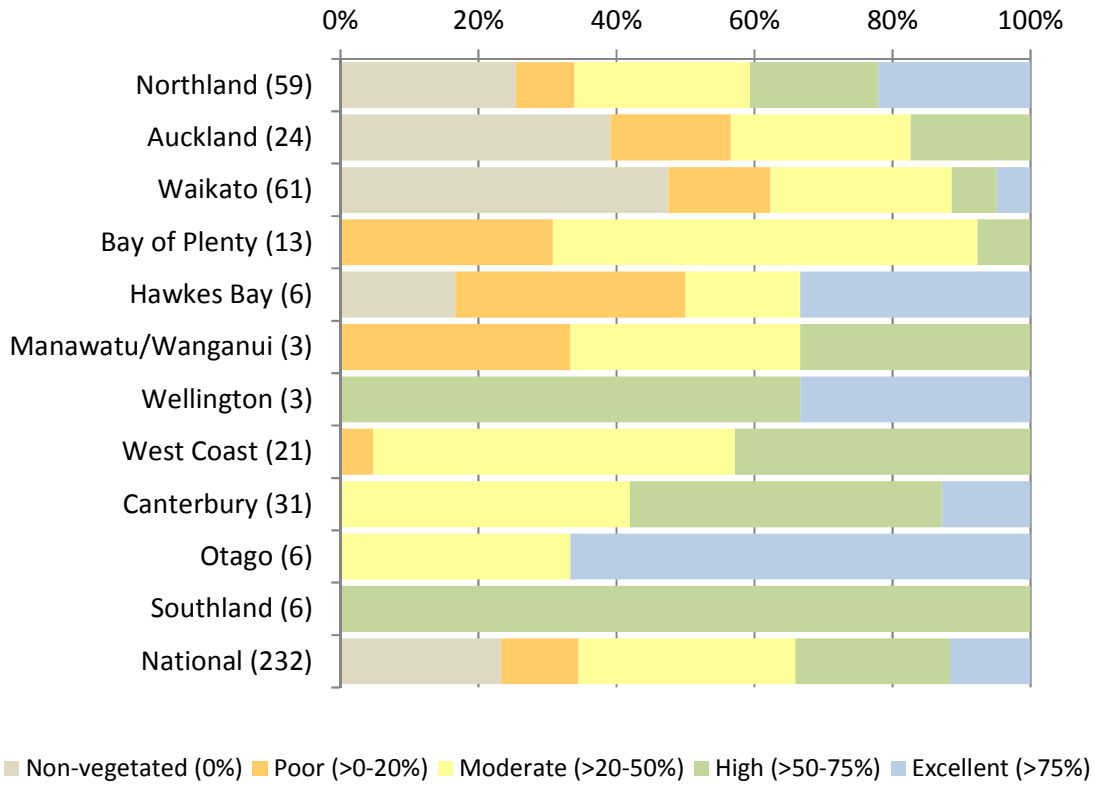
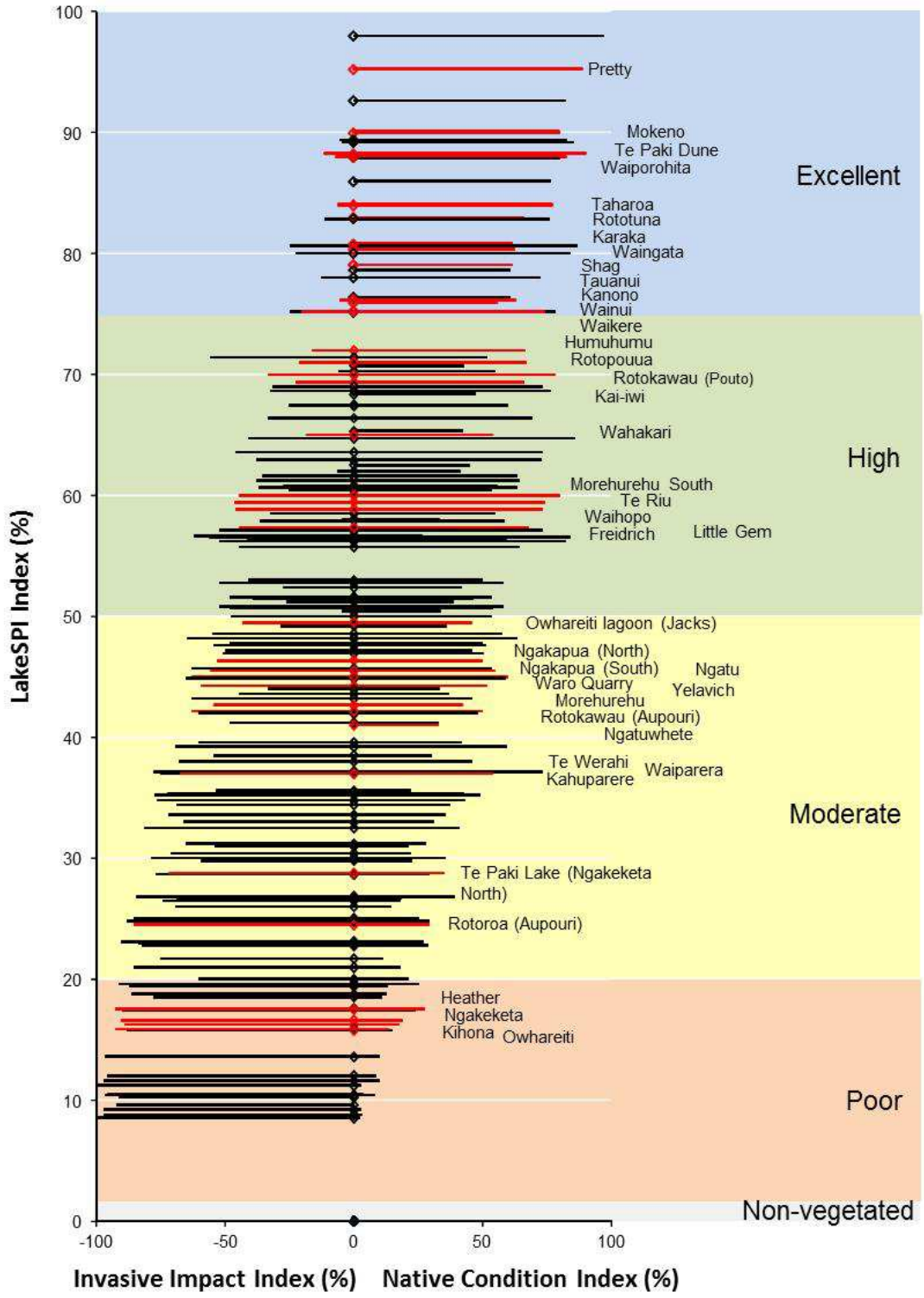


Figure 6-1: LakeSPI results for lakes regionally and nationally (number of lakes in brackets). LakeSPI scores grouped into 5 colour coded categories.



0% =Bulrush, Kaiwai, Kapoai, Katavich, McEvoy's, Ora, Parawanui, Rotokawau East, Rotokawau West, Rotopokaka, Salt (Aupouri), Te Kahika, Te Kahika South, Waitahora Lagoon, Whakaneke.

Figure 6-2: National ranking of LakeSPI score. Northland Lakes shown in red with LakeSPI Index on the y-axis, Native Condition Index on the right of the x-axis, and Invasive Impact Index on the left.

6.2 Loss of species

Table 6-1 outlines the loss of species from individual lakes and the last date these species were recorded.

Table 6-1: Species apparently extinct in some Northland lakes and their last reported occurrence. From Wells & Champion (2012) unless referenced otherwise.

Species	Lake	Date last recorded
Galaxias sp. (dune lake galaxias)	Kai-Iwi	1997 (Rowe & Chisnall 1997)
	Shag	anecdotal (Rowe & Chisnall 1997)
Chara fibrosa	Waiparera	1986 (Tanner et al. 1986)
	Forest/Deans	2001
	Rotoroa	1986 (Tanner et al. 1986)
	Shag	1986 (Tanner et al. 1986)
	Rototuna	1986 (Tanner et al. 1986)
	Kahuparere	1986 (Tanner et al. 1986)
Nitella leonhardii	Waiparera	1986 (Tanner et al. 1986)
	Ngakapua	1986 (Tanner et al. 1986)
Isoetes sp. aff. *kirkii*	Omapere	1998 (Champion & Burns 2001)
Stuckenia pectinata	Rototuna	2005
Trithuria inconspicua	Waiparera	1993 (Champion et al. 1993)
	Ngakapua	1988 (Tanner et al. 1988)
	Rotokawau (Aupouri)	1991 (Champion et al. 1993)
	Shag	1993 (Champion et al. 1993)
	Humuhumu?	2011
	Roto-otuauru/Swan	1988 (Tanner et al. 1988)
	Waingata	1999 (Rowe et al. 1999)
Utricularia australis	Waitahora Lake	2007
	Morehurehu	2006
	Waihopo	2006
	Forest/Deans	2001
	Carrot/Ngakapua West	2005

Species	Lake	Date last recorded
	Ngatu	2007
	West Coast Road	2001
	Heather	2005
	Midgeley	2005

Species loss is also an important indicator of lake pressure. Apparent causes of extinction may include predation by gambusia (e.g., dune lake galaxias in Lake Kai-Iwi) or grass carp (e.g., Lakes Heather, Midgeley and Roto-otuauru/Swan), competition with invasive species (e.g., *Utricularia gibba* displacing many *U. australis* populations), eutrophication or change in hydrology. Declines in abundance of these species and other species would also provide useful indicators of change in lake ecological value additional to TLI and LakeSPI.

The loss of some nationally endangered taxa from these lakes has major implications on their continued survival. For example, the un-named *Isoetes* sp. aff. *kirkii* is now apparently extinct in the wild, surviving only as plants collected in 1996 and cultivated at NIWA Ruakura campus. Loss of *Utricularia australis* from many of the lakes comprising the national stronghold of this plant over the past decade is likely to increase its threat status to Nationally Critical. A survey of all lakes where this species has been recorded is advocated, possibly as a Department of Conservation (DOC) funded project.

6.3 Recommended monitoring

Both TLI and LakeSPI monitoring are essential tools to detect changes in water quality and the status of invasive species, in the case of LakeSPI. The current annual monitoring of 28 lakes for TLI and 10-12 lakes for LakeSPI and other ecological condition is recommended to be continued at a minimum (i.e., x lakes on a 5-year rotation), or preferably expanded to include all lakes ranked in the top three Ecological Value classes and best representative lakes of each remaining class. This equates to a total of 47 lakes, or 43 if artificial dams and ephemeral pools are excluded.

Early detection of pest plant incursions with weed surveillance of high risk lakes is also recommended as outlined in Wells & Champion (2012). The current six lakes: Ngatu, Waiporohita, Waikere, Taharoa, Kai-Iwi and Humuhumu are all at high risk of aquatic weed incursion due to their easy accessibility and should continue to be checked annually. The use of weed cordons to assist with weed surveillance should be investigated.

Additional monitoring of relevance to lake ecological health assessment could include:

- On-going assessment of land use practices (see Section 5.10) to produce a risk profile of each land use type and identify nutrient enrichment hot-spots.
- Establishment of water level gauges in lakes where water level decline/increase is suspected.
- Explore alternative means to assess pressures e.g., identification of nutrient enrichment of lakes by remote sensing.

7 Management/mitigation/amelioration

Decline in condition indicated by the monitoring programme for Northland lakes needs to be followed-up by further investigations into the causes of these changes and exploration of potential management to mitigate or ameliorate these.

NIWA reports (Champion et al. 2002; 2005; Wells et al. 2006; 2007; Wells & Champion 2008; 2009; 2010; 2011; 2012) have recommended a series of management actions for each of the high value water bodies, but to date NRC management in response to these recommendations has been on an ad hoc basis. Even so, some major biosecurity management initiatives such as the eradication programmes for hornwort from outlier lakes in Sweetwater (Lake Heather) and Pouto (Lake Roto-otuauru/Swan) using grass carp and the endothall-based eradication programme for lagarosiphon in Phoebes Lake have been undertaken and appear to be progressing towards their goals.

Management actions can include:

- Identify land tenure in the catchment of high value lakes and maintain a register of ownership.
- Identify if protection of the lake is effective where the catchment is within DOC or District Council reserves. Protected Natural Areas Programme surveys have been completed for DOC Ecological Districts (e.g., Te Paki – Lux et al. 2009; Aupouri – Conning & Holland 2003; Kaikohe – Conning & Miller 2000 and Kaipara – Smale et al. 2009) and care standards for DOC and other reserves has been undertaken by van Meeuwen-Dijkgraaf (2008).
- Install weed cordons at high risk boat entry sites to reduce the risk of weed fragments establishing from boat trailers (contact Hamish Lass, Bay of Plenty Regional Council, Rotorua).
- Undertake strategic eradication of pest species (e.g., alligator weed, reed sweet grass etc.).
- Carry out eradication of new incursions detected through the surveillance programme.
- Carry out publicity about the spread of aquatic weeds and pests (e.g., Check Clean Dry) and also educate the public on preventing impacts of nutrient enrichment (e.g., constructed wetlands, riparian retirement etc.).
- Restrict high-impact land uses in sensitive parts of the catchments of high-risk lakes (especially oligotrophic and mesotrophic lakes that are most likely to deteriorate as a result of nutrient enrichment).
- Encourage the development of Farm Environmental Management Plans and Best Practise for landowners farming in high value lake catchments.
- Encourage and possibly assist in finance of community initiatives such as riparian fencing, restoration planting, riparian management and pest control.
- Attempt to restore and enhance populations of endangered lake biota.

Individual management plans should be developed for each high value lake outlining:

- Tenure of lake and catchment.
- International/national/regional significance of the lake.
- Lake classification.
- Ecological Value Score and important components of this.
- Current threats and pressures.
- Agencies and individuals involved in management.

A framework for the Northland Lake Strategy is presented in Figure 7-1. This identifies components of the strategy described in this report and also future actions to be undertaken by NRC.

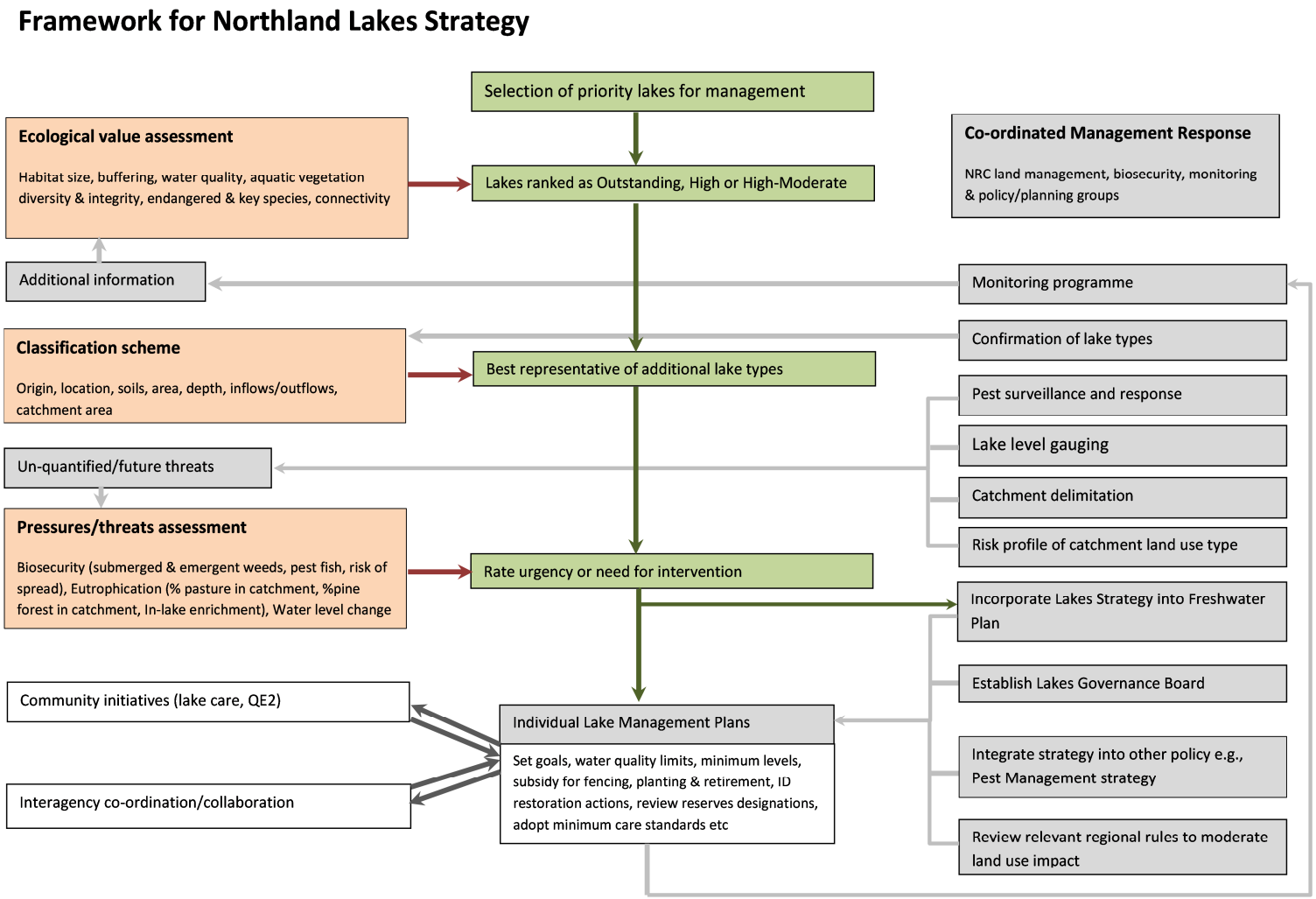


Figure 7-1: Flow diagram showing the proposed Northland Lake Strategy. Sections in orange and green are described in this report, sections in grey require action by NRC.

It is advocated that this strategy should be adopted by NRC. It will integrate activities carried out by four separate groups within NRC (land management, biosecurity, monitoring and policy/planning). As such, the benefits of a coordinated response will lead to both increased effectiveness and efficiency of NRC activities, and allow better reasoning of lake protection measures and clarify the potential impacts of land management practices and also assist in applications for central government assistance to protect these internationally important assets. This strategy is likely to lead to more co-ordinated management actions, and better environmental outcomes. A Northland Lakes Strategy will also influence actions and policy/plans of other stakeholders including DOC, Northland Fish & Game, iwi and territorial authorities. NRC will use the strategy to advise landowners and stakeholders about the special status of water bodies on their property, through direct advice and/or farm/forestry management plans, leading to community support and additional protection of these lakes.

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