

Northland Lakes water quality and ecology

State and trends 2007-2011



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Executive Summary

The Northland region has a large number of lakes, a large proportion of which were formed by dune activity and are classed as dune lakes. Many Northland Lakes are of national importance representing some of the few remaining lakes with intact native flora and containing a number of rare and endangered plant and animal species.

This report is a companion report to the five yearly State of the Environment Report 2012, detailing the state and trends of water quality for 28 lakes in the current Northland lake monitoring network from 2007 to 2011. The report also provides a summary of relevant ecological data from the annual report produced by the National Institute of Water and Atmospherics (NIWA) which updates the ecological status of 86 lakes in the Northland region (Wells & Champion, 2011). Both the water quality and ecological data was used to develop the Northland Lake Monitoring Strategy (Champion, de Winter 2012) which aims to prevent the deterioration of water quality and biodiversity values in Northland's lakes and help to restore these valuable ecosystems.

Water quality state is measured using the nationally recognised indicators Lake Trophic Level Index (TLI) and Lake Submerged Plant Indicator (LakeSPI). Trend analysis was carried out on all variables with more than three years' worth of data. A Biodiversity Assessment gives each lake an overall ranking taking into account many indicators including water quality, endangered species identified, wetland extent, species composition, submerged vegetation abundance and composition (including the Lake SPI), water birds, fish and aquatic invertebrate presence and abundance (Wells and Chapman, 2011).

The water quality state of 64% percent of the tested lakes was found to be eutrophic (high levels of nutrients and algae) or worse in 2010/11. Of these lakes 79% are located in pastoral catchments, 16% in native scrub and 5% in exotic forestry. Ten percent of the lakes were oligotrophic (low levels of nutrients and algae) and are situated in predominately indigenous forest and exotic forestry catchments.

Significant changes in total nitrogen were identified in 12 lakes with four of these being improving trends and 8 being deteriorating trends. Just one lake had a significant change in total phosphorous levels and this was an improving trend. Eight lakes had significant changes in dissolved oxygen levels with 5 improving and 3 deteriorating trends.

Ten lakes recorded a significant trend in water clarity; 7 of which were deteriorating trends. Of the 10 lakes 6 had corresponding trends in algal biomass indicating the changes in water clarity were the result of increases/decreases in chlorophyll a concentrations. However these results should be viewed with caution as a change in sampling methodology in 2005 may have affected the results.

Trends in TLI were analysed for 5 lakes over ten years and 23 lakes over five years. Results indicate that water quality has remained stable in the majority of lakes with 68% showing no significant trends in TLI. However four (14%) had significant improvements in TLI and five (18%) deteriorated. The lakes with significantly improving trends include Lakes Omapere, Waiporohitu, Kahuparere and Wainui. Those with significant declining trends in TLI include

Lakes Ngatu, Waipara, Kai Iwi, Rototuna and Swan. Four of these had corresponding increases in total nitrogen levels and Lakes Ngatu and Kai Iwi have also dropped in ecological condition with reduced LakeSPI scores.

Lake SPI results show that although 21 (71%) of lakes have retained the same LakeSPI over the time period, seven (25%) have a reduced rating and one (4%) has improved. Although this does not necessarily correspond with declining water quality it highlights the extent of the spread of invasive plant species within the region.

Combining both ecological and water quality data the Biodiversity Assessment ranks 22 (78%) of the 28 lakes as moderate to high value or above, with high levels of endemic endangered species. Since rankings began in 2005 23 (82%) of lakes have not changed in ranking, however three have gone down in ranking (Lakes Carrot, Heather and Whananeke) and two have improved in ranking (Lakes Rotokawau (Aupouri)) and Omapere). The lakes which have dropped in ranking have shifted down several grades, Lake Carrot and Lake Heather in particular dropping from 'high' to 'moderate' and 'moderate to low' respectively. This has led to an overall downward shift in rankings from 25 (91%) graded as moderate to high or above in 2005, to 22 (78%) in 2011. Conversely in 2009 just 3 (9%) of lakes were graded as moderate or below. In 2011 this has increased to 6 (22%).

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Introduction

Northland has over 400 freshwater lakes, with many of these of national and international significance. Northland has the greatest number of dune lakes nationally and represents a large proportion of warm, lowland New Zealand lakes 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 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.

Most of Northland's lakes are situated along the west coast, having been formed between stabilised sand dunes. The dune lakes are in four main groups situated on the Aupouri Peninsula, Karikari Peninsula, Kai Iwi lakes and Pouto Peninsula. They generally range in size between one and 35 hectares and are usually less than 15 metres deep.

Lake Taharoa of the Kai Iwi group is one of the largest and deepest dune lakes in the country, covering an area of 237 ha and being 37 metres deep. It has the deepest growing vegetation in the North Island growing at a depth of 24 metres. Dune lakes usually have little or no continuous surface inflows or outflows being fed primarily by direct rainfall or from surrounding wetlands. As a result, water levels fluctuate considerably with climatic patterns. Because most of these lakes are relatively small and shallow they have limited capacity to assimilate any contaminants. They are prone to nutrient enrichment from stock and fertilizer particularly where lakeside vegetation has been grazed or removed and where there is direct stock access to the lake.

There are also several shallow inland lakes which originated through the damming of valleys by lava flows such as Lakes Owhareiti and Omapere near Kaikohe. Lake Omapere appears to have formed some 80,000 years ago. The Lake reformed 600 to 700 years ago which is attributed to siltation following deforestation of the area.

Further to the north are two large man-made lakes associated with the Kerikeri irrigation scheme, which are a major water resource for that area.

The Northland Lake Water Quality Monitoring Network (LWQMN) was established in 2005 to collect water quality data at a selection of Northland's lakes. Further to this NIWA carries out an annual Biodiversity Assessment of 86 Northland lakes on a rotating basis including those within the LWQMN. The data from these two programmes is used to assess the monitored lakes environmental condition, and their response to potential impacts such as surrounding land use change and weed infestations. This information is used to prioritise future surveying and management work in order to maintain/restore these valuable ecosystems.

Lakes are highly complex ecosystems and the assessment of water quality needs to take into account the interactions between the lakes physical environment and biological communities that live within them. These factors need to be carefully considered in the management of lakes to avoid any unintentional adverse consequences.

This report presents water quality results as measured by the Trophic Level Index (TLI) as well as a Biodiversity Assessment for each Lake. Trend analysis on both individual water quality parameters and TLI are also presented. The individual water quality measures used to calculate the TLI are important tools in helping to identify causes of decline in both water quality and native biodiversity.

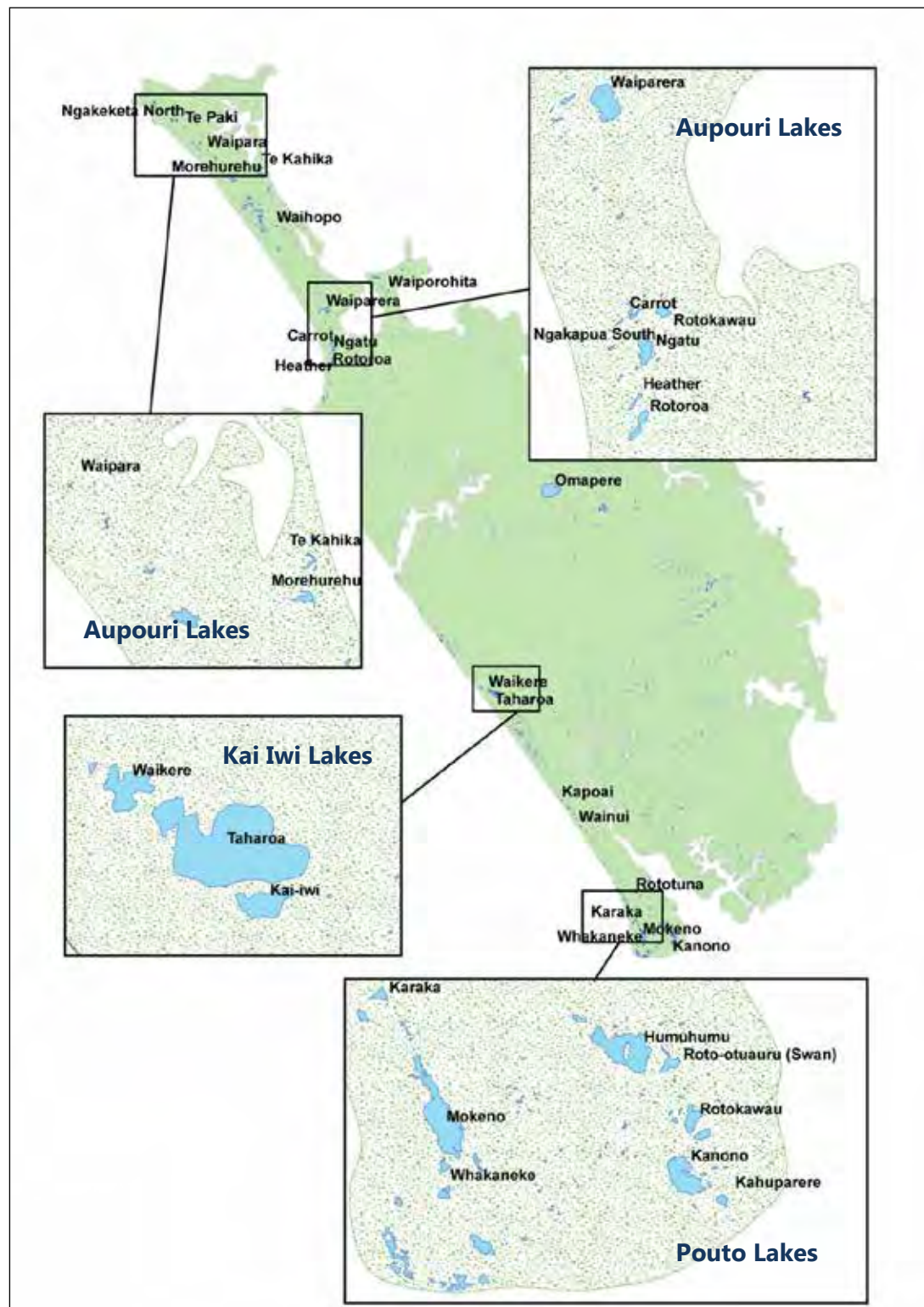


Figure 1 Location of the 28 network lakes in the Northland region.

Methodology

Data collection

In 2005, NRC established the Lakes Water Quality Monitoring Network. Under this programme, water quality samples are taken from 28 of the region's lakes every quarter and analysed for a range of properties. Lakes in this network include those in the Kai Iwi, Aupouri, Central/Karikari and Pouto lakes groups (Figure 1).

Parameters tested include water clarity, chlorophyll *a*, temperature, dissolved oxygen, pH, suspended solids, total phosphorus, total nitrogen, dissolved reactive phosphorus, organic phosphorus, nitrate nitrogen, ammoniacal nitrogen and organic nitrogen. Both temperature and dissolved oxygen are used to test whether or not a lake is stratified.

Stratification occurs when cold water at the bottom and warm water at the top of a lake form layers that act as a barrier to mixing in the water body. This usually happens during summer, when warm water, which is less dense, will sit on top of colder, denser, deeper water with a thermocline separating them. The warm layer is called the epilimnion and the cold layer is called the hypolimnion. Because the warm water is exposed to the sun during the day, a stable system exists and very little mixing of warm water and cold water occurs, particularly in calm weather. With the arrival of winter storms these layers become mixed due to turbulence within the water column created by wind and wave action.

To provide an overview of the overall condition of each lake the biodiversity status is described using the National Institute of Water and Atmospheric Research (NIWA) report 'Northern Lakes Ecological Status 2011' (Wells & Champion, 2011). Monitoring is carried out by NIWA at 86 lakes on a generally 5 year rotational basis. Lakes in this programme are ranked according to their ecological value, i.e., how many native or endangered species they contain, absence of pest species and how close the lake is to its natural state.

Lake water quality state

The state of a lakes water quality is determined using the Trophic Level Index (TLI). The TLI is calculated using four key variables - chlorophyll *a* (an indicator of algal biomass), water clarity (measured by lowering a Secchi disc into water and measuring the depth at which it disappears), total nitrogen and total phosphorus (both a measure of nutrient enrichment). Together, these provide an indication of a lake's overall health. The overall score is categorised into seven trophic states indicating progressively more nutrient enrichment, more algal productivity and reduced water clarity (Table 1). These are:

Ultra-microtrophic lakes are pristine

Microtrophic lakes are very clean

Oligotrophic lakes have low levels of nutrients and algae.

Mesotrophic lakes have moderate levels of nutrients and algae.

Eutrophic lakes are green and murky, with higher amounts of nutrients and algae.

Supertrophic lakes are fertile and saturated in phosphorus and nitrogen, with very high algae growth and blooms during calm sunny periods.

Hypertrophic lakes are highly fertile and supersaturated in phosphorus and nitrogen. They are rarely suitable for recreation and habitat for desirable aquatic species is limited.

Table 1: Values that define the different trophic levels (Burns et al. 2000).

Lake type	Trophic level	Chl α (mg/m ³)	Clarity (m)	TP (mg/m ³)	TN (mg/m ³)
Microtrophic	1.0 - 2.0	0.33 - 0.82	25 - 15	1.8 - 4.1	34 - 73
Oligotrophic	2.0 - 3.0	0.82 - 2.0	15 - 7.0	4.1 - 9.0	73 - 157
Mesotrophic	3.0 - 4.0	2.0 - 5.0	7.0 - 2.8	9.0 - 20	157 - 337
Eutrophic	4.0 - 5.0	5.0 - 12	2.8 - 1.1	20 - 43	337 - 725
Supertrophic	5.0 - 6.0	12 - 31	1.1 - 0.4	43 - 96	725 - 1558
Hypertrophic	6.0 - 7.0	> 31	< 0.4	> 96	> 1558

Trend Data Analysis

Trends are determined by using the seasonality trend test in Time Trends¹ which removes the effects of seasonal variation. The effect of seasonal variation is removed as it enables the confident identification of trends in the data (Burns, et. al, 2000). The seasonality trend test plots observed and residual data against time with no regard for year and fits a straight-line plot using ordinary least square regressions. A p-value is then calculated for the line fitted to the data. P-values less than 0.05 indicate a significant trend with the slope indicating the change per year in the variable. A negative slope value indicates a decreasing trend and a positive slope value indicates an increasing trend

Lake Biodiversity Assessment

The lake Biodiversity Assessment gives an overall ranking for each lake taking into account endangered species identified, wetland extent, species composition, submerged vegetation abundance and composition (Submerged Plant Indicators (SPI)), water bird, fish and aquatic invertebrate presence and abundance as assessed by NIWA (Wells and Chapman, 2011).

¹ Time Trends is a tool that has been developed by NIWA with a particular emphasis on meeting requirements for State of the Environment (SoE) reporting. It provides a series of linked procedures to import data, explore time series patterns and analyse for trends using recognised statistical methods.

The Submerged Plant Indicators (SPI) component is based on the macrophyte community structure and composition (Clayton and Edwards 2006(a) (b)). There are three indices:

- Native Condition Index: a measure of the native vegetation within a lake. A higher score means a healthier, more diverse community of native plants growing to greater depths.
- Invasive Condition Index: a measure of the invasive vegetation within a lake. A higher score means more impact from exotic plants.
- LakeSPI Index: this is a combination of the Native Condition Index and the Invasive Condition Index and gives an overall indication of lake condition. The higher the score the better the condition of the lake.

Lake SPI is presented as a percentage of a lake's maximum scoring potential and corresponds to the depth of each lake.

Lake SPI grades:

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

The biodiversity assessment is based on three components; indigenous biota, endangered species (both plant and animal) and habitat availability and is interrelated with water quality. Each parameters is scored on a scale or 1 -6 and then ranked as either Outstanding; High; Moderate-High; Moderate; Low-Moderate; or Low. Outstanding Lakes are of national importance, high in diversity and contain self-sustaining populations of endangered species. Low ranked lakes are usually de-vegetated with poor water quality or infested with invasive pest species.

Results

Water Quality trends

Table 2: Trends for the 28 monitored lakes from December 2005 to June 2011 based on samples taken at the surface. Note * lakes with trends calculated over a ten year period. A green "arrow" indicates an improving trend and a red "arrow" indicates a degrading trend. A black arrow is neither an improving nor degrading trend. An empty cell indicates no significant trend. ND = no data, BD= below detection, ID= insufficient data. (Refer to Appendix 1 for trend data)

		Temp.	DO	Cond.	Chly. a	pH	Clarity	DRP	NH4	TN	TP	S. Solids	TU
Aupouri lakes	Carrot			↓			↑	BD	↓	↓	↓		
	Heather		↑	↓			↓						
	Morehurehu						↓		↑	↑			
	Ngakapua North								↑	↑		↑	
	Ngakapua South						↓		↑				
	Ngatu		↑		↑	↑	↓		↓			↑	↑
	Rotokawau		↑						↑				
	Rotoroa						↓	BD		↑			
	Te Kahika		↑										
	Waihopo												
	Waipara		↓		↑		↓	BD		↑		↑	↑
	Waiparera							BD					
Karikari/ Central lakes	Omapere (east)*		↓	↑	↓	↓	↑		↓	↓		↓	↓
	Omapere (west)*		↓	↑	↓	↓	↑	ND	ND	↓			↓
	Waiporohita								↓			↓	↓
Kai iwi lakes	Kai Iwi*				↑		↓			↑			↑
	Taharoa*				↑								
	Waikare*												
Pouto lakes	Humuhumu					↑							
	Kahuparere												↓
	Kanono			↑									
	Kapoai												
	Karaka				↑	↑	↓			↑			
	Mokeno		↑										
	Rotokawau			↓									
	Rototuna			↓	↑					↑			↑
	Swan		↓	↑	ID					↑			↑
	Wainui						↑					↓	↓

Aupouri Lakes

Lake Carrot



Description

Lake Carrot is a 1.7 ha dune lake, located near Waipapakauri and is part of the Sweetwater dune lake system. Lake Carrot has a maximum recorded depth of 8.2 m and has no surface water inflows or outflows. The catchment is dominated by pasture and forestry. The lake contains good native charophyte meadows however the invasive oxygen weed (*Egeria densa*) is now present in the lake and both water quality and ecological impacts are likely if eradication is not achieved.

Table 3: 5 year median, minimum and maximum results of 13 water quality parameters for Lake Carrot.

Parameter	Min	Max	Median
Temperature (°C)	12.4	26.6	18.5
Dissolved Oxygen (% sat)	34.8	106.5	84.3
Chlorophyll a (mg/l)	1.9	22.9	13
Water Clarity (m)	1.48	3.5	2.265
Total Nitrogen (mg/m ³)	540	1060	677
Total Phosphorus (mg/m ³)	15	82	31
Ammoniacal Nitrogen (mg/m ³)	2	123	16
Nitrate Nitrogen (mg/m ³)	0.5	66	2
Dissolved Reactive Phosphorus (mg/m ³)	0.5	40	1
Suspended Solids (g/l)	0.25	6.4	2
Conductivity (ms/m ³)	15	21.5	18
pH	5.9	7.5	6.65
Trophic Level Index	3.84	5.09	4.71
Trophic Level Index Grading: Eutrophic			

Water Quality

Lake Carrot is classified as eutrophic with high amounts of nutrients and algae as summarised in the table above. The high nutrient loads are likely to be associated with nutrient run off from pastoral land. Despite this, trend analysis on the five years of data indicates a number of improvements in water quality in Lake Carrot. Significant improving trends have been observed in five parameters; COND, Secchi, NH₄, TN and TP. TN and TP are decreasing at a rate of 0.055 g/m³ and 0.004 g/m³ per year, respectively. Water clarity is increasing at a rate of 0.12 m or 5.02% per year. These results are inconsistent with information in the 2012 NIWA lakes status report which outlines that there has been a reduction in submerged vegetation bottom limits (5.7 m in 2005 to 3.0 m in 2010). Significant improving trends in three of the four principle indicators of trophic status have not affected the overall TLI trend. It is unclear what has influenced positive changes in water quality.

Lake Carrot generally stratifies in October/November each year with deoxygenation of bottom waters and de stratifies in February/March each year. No changes in nutrient levels between top and bottom waters have been observed.

Biodiversity Assessment

Despite a high scoring LakeSPI score of 60% in both 2005 and 2010, Lake Carrot has a biodiversity ranking of 'Moderate' (NIWA, 2011). This is a drop in ranking of two grades since 2005 when it was ranked as 'High' and is due to the much reduced extent of the native plant community. However it still provides habitat for a number of native animal species including freshwater sponges and a number of water birds which are rare/endangered (Table 4).

Table 4 Bird and fish species identified in Lake Carrot (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
bittern (<i>Botaurus poiciloptilus</i>)	
dabchick (<i>Poliocephalus rufopectus</i>)	
Australasian little grebe (<i>T. novaehollandiae</i>)	
brown teal (<i>Anas aucklandica chloritus</i>)	
common bully (<i>G.cotidianus</i>)	

Lake Heather



Description

Lake Heather is a small dune lake approximately 8 ha in size with a maximum depth of 5.6 m. The surrounding land use is predominantly pastoral however the lake is entirely fenced with riparian planting. The lake is surrounded by a dense band of emergent vegetation which is dominated by kuta (*Eleocharis sphacelata*). Unfortunately the submergent vegetation is dominated by the invasive aquatic plants hornwort (*Ceratophyllum demersum*) and oxygen weed (*Egeria densa*). These weeds were first recorded in Lake Heather in 2001 with the introduction probably occurring in the 1990's. In June 2010 grass carp were introduced to eradicate hornwort and oxygen weed. The 2011 survey shows that the grass carp have already heavily grazed the oxygen weed and have removed 20% of the hornwort in Lake Heather. Once eradication is complete the grass carp will be removed to allow for regeneration of native aquatic species.

Table 5: 5 year median, minimum and maximum results of 13 water quality parameters for Lake Heather.

Parameter	Min	Max	Median
Temperature (°C)	12.5	27.5	18.1
Dissolved Oxygen (% sat)	84	122.3	96.2
Chlorophyll a (mg/l)	1.4	9.6	3.8
Water Clarity (m)	1.69	4.4	3.75
Total Nitrogen (mg/m ³)	278	856	316
Total Phosphorus (mg/m ³)	5	29	11
Ammoniacal Nitrogen (mg/m ³)	0.5	13	2
Nitrate Nitrogen (mg/m ³)	0.5	4	0.75
Dissolved Reactive Phosphorus (mg/m ³)	0.5	14	0.5
Suspended Solids	0.6	3.4	1.25
Conductivity	16	21.8	18.55
pH	6.5	8.3	7.35
Trophic Level Index	2.52	4.17	3.63
Trophic Level Index Grading: Mesotrophic			

Water Quality

Lake Heather is classified as mesotrophic with moderate levels of nutrients and algae as summarised in the table above. Despite the surrounding land use being pastoral the lake does not show the elevated nutrient loads normally associated with pastoral land use. This is likely to be associated with nutrient uptake by the dense riparian buffer which is acting as a nutrient sink.

Three significant trends were identified in Lake Heather over the observed period. One increasing trend was observed in DO% which is increasing at a rate of 2.3 % saturation per year and is the likely result of the dense aquatic weed beds. Water clarity is declining at a rate of 0.16 m or 4.1% per year but this is attributed to the Secchi getting stuck on the dense weed growth (the hornwort beds are on average 2 m in height) which is preventing an accurate water clarity measurement. A decreasing trend in Conductivity was also observed and is decreasing at a rate of 0.5 ms/m³ per year.

Summer stratification occurs occasionally in Lake Heather with deoxygenation of bottom waters.

Biodiversity Assessment

This lake has a 'Moderate-Low' ranking and has dropped four grades since 2005 when it was ranked 'high'. The LakeSPI has reduced from moderate (22%) to 'poor' in 2010 (18%). It is highly impacted by pest plants. Despite its low biodiversity ranking the lake still provides an excellent water bird habitat (NIWA, 2011) and has records of 27 invertebrate species dominated by four dragonfly species and the damsel fly *Xnathocnesis* as well as water boatmen (Corixid species) and the whirligig beetle *Gyrinus* which originates from Australia and is only recorded north of Auckland and in the Waikato (Ball *et al* 2009). Lake Heather is an important breeding ground for the paradise shelduck (Table 6).

Table 6: Bird and fish species identified in Lake Heather (green=rare/endangered, red=pest species.

Native Species	Exotic Species
bittern (<i>Botaurus poiciloptilus</i>), dabchick (<i>Poliocephalus rufopectus</i>)	Canada geese (<i>Branta Canadensis</i>) grass carp (<i>Ctenopharyngodon idella</i>)
paradise shelduck (<i>T. variegata</i>) common bully (<i>G. cotidianus</i>) shortfin eel (<i>Anguilla australis</i>)	

Lake Morehurehu



Description

Lake Morehurehu is a large dune lake of 36.3 ha and a depth of 14 m, located near Te Kao on the Aupouri Peninsula. The lake is situated in a catchment dominated by pine forestry which was recently harvested (in 2010) and is fringed with extensive emergent beds. The lake is predominantly fed by rainfall however there are three small streams that flow into the lake. This dune lake is ranked as 'Outstanding' due to its remoteness and diverse native submerged and emergent vegetation (NIWA, 2011).

Table 7: 5 year median, minimum and maximum results of 13 water quality parameter for Lake Morehurehu.

Parameter	Min	Max	Median
Temperature (°C)	14	26.7	19
Dissolved Oxygen (% sat)	75.3	113.5	93.5
Chlorophyll a (mg/l)	1.4	6	2.8
Water Clarity (m)	0.9	5.08	2.72
Total Nitrogen (mg/m ³)	282	521	336.5
Total Phosphorus (mg/m ³)	5	65	9
Ammoniacal Nitrogen (mg/m ³)	1	52	6
Nitrate Nitrogen (mg/m ³)	0.5	22	0.75
Dissolved Reactive Phosphorus (mg/m ³)	0.5	3	0.5
Suspended Solids	0.25	12	1.6
Conductivity	15	39.2	31.9
pH	5.7	7	6.3
Trophic Level Index	3.21	4.19	3.57
Trophic Level Index Grading: Mesotrophic			

Water Quality

Lake Morehurehu is classified as mesotrophic with moderate levels of nutrients and algae as summarised in the table above. Moderate to low nutrient levels are typical of catchments where the dominant land use is native or exotic forest. Some of the key variables indicate that water quality in Lake Morehurehu has declined between 2005 and 2011 which is likely to be

linked to increased sediment and nutrient loads from the harvesting of pine forestry within the catchment. The Lake has become peat stained as a result of run off from disturbed peat soils.

Significant deteriorating trends have been detected in water clarity, NH₄ and TN. Secchi is decreasing at a rate of 0.25 m per year (-8.63% per year). NH₄ and TN are increasing at a rate of 0.003 and 0.013 g/m³ per year, respectively.

Lake Morehurehu stratifies in October/November each year with deoxygenation of the bottom waters occurring and de stratifies in April each year.

Biodiversity Assessment

Lake Morehurehu is ranked as 'Outstanding'. It is a remote lake with diverse submerged and emergent vegetation including a number of endangered native species. It also provides habitat for two endangered bird species (Table 8). A low invertebrate diversity of 18 species has been recorded in this lake with water boatmen being the most abundant species but the damselfly *Xanthocnemis* and the dragonfly *Hemicorduli* are also relatively abundant (Ball *et al* 2009). Freshwater sponges are also found in the lake. Its ranking has not changed since records began in 2005. However, the LakeSPI which is one of the variables included in the biodiversity assessment has reduced from high (57% and 51%) in 2005 and 2006 respectively, to moderate (43%) in 2009 due to the increased spread of the introduced bladderwort *Utricularia gibba* (NIWA, 2011).

Table 8: Bird and fish species identified in Lake Morehurehu (green=rare/endangered, red= pest species)

Native Species	Exotic Species
bittern (<i>Botaurus poiciloptilus</i>) fern bird (<i>B. punctate vealeae</i>)	Canada geese (<i>Branta Canadensis</i>) mallards (<i>Anus platyrhyncus</i>)

Lake Ngakapua North



Description

Lake Ngakapua is divided into two basins (North and South) and is separated by a dense bed of kuta and a small island. Ngakapua North is approximately 2.2 ha with a maximum depth of 9 m. Surrounding land-use is predominantly pasture with some pines on the western edge. The north basin was fenced to exclude stock in 2009.

Table 9: 5 year median, minimum and maximum results of 13 water quality parameters for Lake Ngakapua.

Parameter	Min	Max	Median
Temperature (°C)	12.8	26.5	19.1
Dissolved Oxygen (% sat)	71.8	97.9	85.9
Chlorophyll a (mg/l)	1.7	18.2	5.1
Water Clarity (m)	2.1	6.04	3.66
Total Nitrogen (mg/m ³)	425	704	514
Total Phosphorus (mg/m ³)	6	58	14
Ammoniacal Nitrogen (mg/m ³)	1	56	5
Nitrate Nitrogen (mg/m ³)	0.5	19	0.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	5	0.5
Suspended Solids	0.7	5.4	1.7
Conductivity	14.5	21.1	17.5
pH	5.9	7.34	6.6
Trophic Level Index	3.47	4.78	4.00
Trophic Level Index Grading: Eutrophic			

Water Quality

Lake Ngakapua North is classified as eutrophic with high amounts of nutrients and algae as summarised in the table above. The high nutrient loads are likely to be associated with nutrient run off from pastoral land.

Water quality in Ngakapua North has declined slightly between 2005 and 2011 with three significant deteriorating trends detected. Significant increasing trends were observed in SS, NH₄ and TN. NH₄ is increasing at a rate of 0.003 g/m³ per year and TN is increasing at a rate

of 0.015 g/m³ per year. SS is increasing at a rate of 0.36 g/m³ per year or 16.7% per year which over time will likely reduce water clarity. Increases in nitrogen and suspended solids indicate diffuse runoff as the likely source of pollution. Riparian planting is recommended to further reduce the impacts of diffuse runoff.

Lake Ngakapua North generally stratifies between September and November with deoxygenation of bottom water and no differences in nutrient levels between surface and bottom waters.

Biodiversity Assessment

This lake is ranked as 'Moderate-High' as the aquatic plant community is predominately native with some regionally rare and nationally endangered species however there are some impacts from pest plants. It was surveyed in 2005 and 2010. On both occasions it had a 'moderate' LakeSPI score of 49% and 46% respectively which reflects the limited depth of submerged vegetation and the impacts of *Utricularia gibba* (NIWA, 2011). There are records of a number of both native and exotic animal species including some rare/endangered species and the pest fish gambusia (Table 10). The lake has records of a high invertebrate density of 32 species dominated by water boatmen (Corixids), dragonflies and damselflies (Odonata) and midges (Chironomidae). Five dragonfly species were recorded including *Tamea loewii* (Figure 2) which was first identified in New Zealand in Lake Rotokawau in 2005 and is thought to have self-migrated from Australia (Ball *et al* 2009). The fresh water mussel (*Hyridella menziesi*) and the leech (*Richardsonianus mauianus*) are also present as well as the pest species ramshorn snail (*Planorbarius corneus*). Its ranking has remained the same since records began in 2005.

Table 10: Bird and fish species identified in Lake Ngakapua (green= rare/endangered, red = pest species)

Native Species	Exotic Species
bittern (<i>Botaurus poeciloptilus</i>), dabchick (<i>Poliocephalus rufopectus</i>)	mallards (<i>Anas platyrhynchos</i>) black swan (<i>Cygnus atrelus</i>). goldfish (<i>Carrassius auratus</i>) gambusia (<i>Gambusia affinnis</i>)
common bully (<i>G. cotidianus</i>) paradise shelduck (<i>Tardorna variegata</i>) Australasian little grebe (<i>T. novaehollandiae</i>)	



Figure 2: The dragonfly *Tamea loewii* first recorded in the Aupouri Lakes in 2005 (Photo credit: Tony Ashton).

Lake Ngakapua South



Description

Lake Ngakapua South is 6.7 ha in size with a maximum depth of 5.2 m and is predominately surrounded by pasture with some native scrub on the southern side. In contrast to the northern arm stock have direct access to the lake and have grazed the kuta beds around the shallows.

Table 11: 5 year median, minimum and maximum results of 13 water quality parameters for Lake Ngakapua South

Parameter	Min	Max	Median
Temperature (°C)	12.2	26.2	19.3
Dissolved Oxygen (% sat)	78.3	101.4	87.2
Chlorophyll a (mg/l)	1.9	12.3	5.5
Water Clarity (m)	2	4.8	3.235
Total Nitrogen (mg/m ³)	466	789	554.5
Total Phosphorus (mg/m ³)	7	60	18.5
Ammoniacal Nitrogen (mg/m ³)	2	23	6.5
Nitrate Nitrogen (mg/m ³)	0.5	12	0.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	18	0.5
Suspended Solids	0.25	5.4	2.15
Conductivity	14.3	20.8	18
pH	5.9	9.3	6.5
Trophic Level Index	3.80	4.43	4.13
Trophic Level Index Grading: Eutrophic			

Water Quality

Lake Ngakapua South is classified as eutrophic with high amounts of nutrients and algae as summarised in the table above. The high nutrient loads are likely to be associated with nutrient run off from pastoral land and stock access to the lake.

Water quality in Ngakapua South has been relatively stable over the past five years as no trend in TLI was found. Two significant trends were recorded in Secchi and NH₄. A declining

trend in water clarity was observed and is decreasing at a rate of 0.19 m per year. The reason for this declining trend in water clarity is unknown as no trends were identified in Chla and SS. An increasing trend in NH4 was detected and is increasing at a rate of 0.001 g/m³ per year. Diffuse run off from the surrounding pastoral land is the likely cause of this increasing trend.

Lake Ngakapua South tended not to stratify consistently throughout the observed period.

Biodiversity Assessment

This lake is ranked as 'Moderate-High' as the aquatic plant community is predominately native with some regionally rare and nationally endangered species however there are some impacts from pest plants. Lake Ngakapua South was surveyed in 2005 and 2010. On both occasions it had a 'moderate' LakeSPI score of 46% which reflects the limited depth of submerged vegetation and the impacts of *Utricularia gibba* (NIWA, 2011). There are also records of a number of both native and exotic animal species including some rare/endangered species and the pest fish gambusia (Table 12). The lake has records of a relatively low invertebrate diversity of 22 species dominated by midges (Chironomids), water boatmen (Corixids) and the damselfly *Xanthocnysis* (Ball *et al* 2009). The pest species ramshorn snail (*Planorbis* *corneus*) is also present in the lake as well as the leech (*Richardsonianus mauianus*) and the fresh water mussel (*Hyridella menziesi*). Its ranking has remained the same since records began in 2005.

Table 12: Bird and fish species identified in Lake Ngakapua (green= rare/endangered, red= pest species)

Native Species	Exotic Species
bittern (<i>Botaurus poeciloptilus</i>), dabchick (<i>Poliocephalus rufopectus</i>)	mallard (<i>Anas platyrhynchos</i>) black swan (<i>Cygnus atrelus</i>). goldfish (<i>Carrassius auratus</i>) gambusia (<i>Gambusia affinis</i>).
common bully (<i>G. cotidianus</i>) paradise shelduck (<i>Tardorna variegata</i>) Australasian little grebe (<i>T. novaehollandiae</i>)	

Lake Ngatu



Description

Lake Ngatu is located near Waipapakauri and is part of the Sweetwater dune lake system. Lake Ngatu is 5.3 ha in size with a maximum depth of 6.5 m. The lake is surrounded by native scrub, with some fenced pasture and housing on the northern edge of the lake. It is a popular recreational lake with easy access which makes this lake vulnerable to the spread of pest plants. *Lagarosiphon major* was first recorded in Lake Ngatu in 1988. Its spread in the lake has been limited due to the particular water chemistry found in the lake (NIWA, 2011). However the nutrient status of Lake Ngatu is showing evidence of change and may lead to rapid weed growth impacting on its currently high ecological status. In response the Department of Conservation in collaboration with Ngai Takoto Iwi and the local community are in the process of establishing a management plan for the restoration of Lake Ngatu.

Table 13: 5 year median, minimum and maximum results of 13 water quality parameters for Lake Ngatu.

Parameter	Min	Max	Median
Temperature (°C)	12.6	27.7	18.6
Dissolved Oxygen (% sat)	76	121.6	97
Chlorophyll a (mg/l)	0.8	20.5	2.85
Water Clarity (m)	2	5.6	3.85
Total Nitrogen (mg/m ³)	542	1140	784.5
Total Phosphorus (mg/m ³)	3	61	11
Ammoniacal Nitrogen (mg/m ³)	5	467	68.5
Nitrate Nitrogen (mg/m ³)	0.5	35	6
Dissolved Reactive Phosphorus (mg/m ³)	0.5	5	0.5
Suspended Solids	0.25	4.9	1.6
Conductivity	16.5	22.8	19.55
pH	6.4	8.2	7
Trophic Level Index	3.24	4.61	3.89
Trophic Level Index Grading: Mesotrophic			

Water Quality

Lake Ngatu is classified as mesotrophic with moderate levels of nutrients and algae as summarised in the table above. Moderate to low nutrient levels are typical of catchments where the dominant land use is native.

Trend analysis suggests water quality has declined in Lake Ngatu over the past five years. Significant declining trends have been observed in Chla, pH, Secchi, SS and TLI. Water clarity is decreasing at a rate of 0.31 m per year which is a likely result of an increase in algal biomass. Chla is increasing at a rate of 1.18 mg/m³ per year. SS is increasing at a rate of 0.27 g/m³ and is also a result of increasing algae concentrations.

Degrading trends in two of the four TLI indicators has led to an overall increasing trend in TLI which is increasing at a rate of 0.06 per year or 1.64% per year. The overall TLI mean classes Lake Ngatu as mesotrophic, however with an increasing trend in TLI the 2010/11 median of 4.03 would place this lake in the eutrophic category.

An improving trend has been observed in NH₄ which is decreasing at a very steep rate of 41.8 mg/l or 33.5% per year. It is possible that this decreasing trend is a reflection of the increase in algal biomass in the lake.

Thermal stratification has been observed once in Lake Ngatu over the 2010/11 summer period.

Biodiversity Assessment

Lake Ngatu is ranked as having 'Outstanding' biodiversity due to the large emergent beds surrounding the lake and predominately native submerged plant communities. However, corresponding with a decline in water quality, the Lake SPI has declined from a 'high' score of 65% in 2001 to a 'moderate' one of 46% in 2010 with the increased spread of *Utricularia gibba* in the lake (NIWA, 2011). The lake provides habitat for a number of animal species including a number of rare/endangered birds (Table 14). There are records of an invertebrate diversity of 22 species dominated by midges (Chironimini and Tanyttarsini) (Ball *et al* 2009). The native beetle (*Onychohydrus hookeri*) is also present in the lake as well as the damselfly *Ischnura aurora* (recently self-introduced from Australia). The pest species ramshorn snail (*Planorbis* *corneus*) is also present in the lake. Its ranking has remained the same since records began in 2005 however there are signs this may be at risk with declining water quality and LakeSPI results.

Table 14: Bird and fish species identified in Lake Ngatu (green=rare/endangered, red= pest species)

Native Species	Exotic Species
bittern (<i>Botaurus poeciloptilus</i>),	goldfish (<i>Carrassius auratus</i>)
dabchick (<i>Poliocephalus rufopectus</i>)	rudd (<i>Scardinius erythrophthalmus</i>)
scaup (<i>Arthya novaezeelandiae</i>) <i>cotidianus</i>)	
Caspian tern (<i>Sterna caspia</i>).	
common bully (<i>G. cotidianus</i>)	
inanga (<i>Galaxias maculatus</i>)	

Lake Rotokawau



Description

Lake Rotokawau is a small dune lake approximately 14.2 ha in size with a maximum depth of 3.5 m. Lake Rotokawau is part of the Sweetwater Dune Lakes and is located west of Waipapakauri. The lake is situated in a mainly pastoral dominated catchment and is completely fenced. Riparian planting has been undertaken on the western side of the lake.

Table 15: 5 year median, minimum and maximum results of 13 water quality parameter for Lake Rotokawau.

Parameter	Min	Max	Median
Temperature (°C)	12.1	27.7	18.8
Dissolved Oxygen (% sat)	75.6	110.2	93.1
Chlorophyll a (mg/l)	0.8	12.3	3.6
Water Clarity (m)	1.75	3.6	2.49
Total Nitrogen (mg/m ³)	414	843	558
Total Phosphorus (mg/m ³)	4	75	11.5
Ammoniacal Nitrogen (mg/m ³)	0.5	53	9.5
Nitrate Nitrogen (mg/m ³)	0.5	8	1
Dissolved Reactive Phosphorus (mg/m ³)	0.5	9	0.5
Suspended Solids	0.7	9.8	1.5
Conductivity	12.5	20.6	15.85
pH	6.3	7.3	6.9
Trophic Level Index	3.30	4.97	3.94
Trophic Level Index Grading: Mesotrophic			

Water Quality

Lake Rotokawau is classified as mesotrophic with moderate levels of nutrients and algae as summarised in the table above. Despite the surrounding land use being pastoral the lake does not show the elevated nutrient loads normally associated with pastoral land use. This may be

associated to some degree with nutrient uptake by the riparian planting on the Western side of the lake and the exclusion of stock from the lake.

Water quality in Lake Rotokawau appears stable as no significant trends have been identified in any of the four TLI indicators. Two significant increasing trends have been observed in DO% and NH4 between 2005 and 2011. DO% is increasing at a rate of 2.21 % saturation per year which is deemed as an improving trend. NH4 is increasing at a rate of 0.0035 g/m³. The reason for this increase is unknown.

Biodiversity Assessment

Lake Rotokawau ranks as 'High' as the lake contains good native plant communities including nationally endangered plants. Its ranking improved from a 'moderate-high' score in 2005, following the discovery of the nationally endangered plant *U.australis* in 2009. The LakeSPI score has reduced however, from high (56%) in 2004, to 'moderate' (46%) in 2009, as a result of the increased spread of the pest plant species *Utricularia gibba* (NIWA, 2011). There are records of a number of both native and exotic animal species including a number of rare/endangered species (Table 16) and 20 invertebrate species. The invertebrate fauna is dominated by midges (Chironomini). Water boatmen (Coroxids), the snail Physa and the dragonfly Hemicordulia were also abundant (Ball *et al* 2009). This Lake is also where the dragonfly species *Tramea loewii* was first recorded in New Zealand.

Table 16: Bird and fish species identified in Lake Rotokawau (green=rare/endangered, red= pest species).

Native Species	Exotic Species
bittern (<i>Botaurus poiciloptilus</i>), dabchick (<i>Poliocephalus rufopectus</i>) fernbird (<i>Bowdleria punctata vealeae</i>).	gambusia(<i>Gambusia affinis</i>).
Australasian little grebe (<i>T.novaehollandiae</i>) common bully (<i>G. cotidianus</i>) inanga (<i>Galaxias maculatus</i>)	

Lake Rotoroa



Description

Lake Rotoroa is also part of the Sweetwater dune lake system and is located to the west of Waipapakauri. The lake is relatively large (26.5 ha) with a maximum depth of 8 m. The catchment is predominantly pastoral, with much of the lake fenced and planted.

Table 17: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Rotoroa.

Parameter	Min	Max	Median
Temperature (°C)	12.2	27.9	17.95
Dissolved Oxygen (% sat)	78.5	119.2	96.5
Chlorophyll a (mg/l)	0.9	27.6	8.4
Water Clarity (m)	1.1	5.15	2.09
Total Nitrogen (mg/m ³)	545	932	748.5
Total Phosphorus (mg/m ³)	6	95	13
Ammoniacal Nitrogen (mg/m ³)	1	109	5.5
Nitrate Nitrogen (mg/m ³)	0.5	79	1.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	56	0.5
Suspended Solids	0.5	10.8	2.2
Conductivity	24.3	34.7	29.9
pH	6	8.6	6.9
Trophic Level Index	3.54	5.34	4.34
Trophic Level Index Grading: Eutrophic			

Water Quality

Lake Rotoroa is classified as eutrophic with high amounts of nutrients and algae as summarised in the table above. The high nutrient loads are likely to be associated with nutrient run off from pastoral land.

Some of the key variables indicate the water quality in Lake Rotoroa has deteriorated between 2005 and 2011. A significant declining trend has been observed in water clarity with secchi

decreasing at a rate of 0.33 m or 13.6 % per year. A significant increasing trend has been identified in TN which is increasing at a rate of 0.0384 g/m³ per year.

Lake Rotoroa tended not to stratify consistently throughout the observed period. Deoxygenation of the bottom waters occurred during stratification with a slight increase in TN concentrations in the bottom waters compared to the top waters.

Biodiversity Assessment

Despite its poor water quality Lake Rotoroa rates 'High' in its Biodiversity Assessment due to a large population of the endangered plant *Trithuria inconspicua* and contains good water bird habitat. The submerged vegetation, however, is dominated by the aquatic pest plant *Egeria densa* resulting in a 'moderate' LakeSPI score of 25%. There are records of a number of both native and exotic animal species including a number of rare/endangered species (Table 18) and an invertebrate diversity of around 25 species dominated by the native snail *Potamopyrgus* (Ball *et al* 2009) but also including the pea mussel (*Sphaerium novaezeelandiae*), very large specimens of the native pulmonate snail *Glyptophysa* and the fresh water mussel (*Hyridella menziesi*). Its ranking has remained the same since records began in 2005.

Table 18: Bird and fish species identified in Lake Rotoroa (green= rare/endangered, red=pest species)

Native Species	Exotic Species
bittern (<i>Botaurus poiciloptilus</i>), dabchick (<i>Poliocephalus rufopectus</i>) scaup (<i>Aythya novaezeelandiae</i>)	gambusia(<i>Gambusia affinis</i>)
Australasian little grebe(<i>T.novaehollandiae</i>) common bully (<i>G. cotidianus</i>) inanga (<i>Galaxias maculatus</i>) smelt (<i>Retropina retropina</i>) shortfin eel (<i>Anguilla Australis</i>) paradise shelduck (<i>T. variegata</i>)	black swan (<i>Cygnus atrelus</i>)

Lake Te Kahika



Description

Lake Te Kahika is a unique lake with a pH of about 4 which prevents submerged vegetation from growing in the lake. The lake is approximately 18 ha in size with a maximum depth of 12 m and is located near Te Kao. Lake Te Kahika is situated in a forestry dominated catchment, surrounded by a fringe of manuka scrub. The pines have recently been harvested around the lake. There are two small streams that feed the lake and one outlet that flows towards Great Exhibition Bay.

Table 19: 5 year median, minimum and maximum results of 13 water quality parameters for Lake Te Kahika.

Parameter	Min	Max	Median
Temperature (°C)	13.5	24.9	19.05
Dissolved Oxygen (% sat)	74	105.2	87.25
Chlorophyll a (mg/l)	0.2	7.6	1
Water Clarity (m)	1.06	10.2	5.495
Total Nitrogen (mg/m ³)	70	448	172.5
Total Phosphorus (mg/m ³)	1	93	2.5
Ammoniacal Nitrogen (mg/m ³)	1	92	19
Nitrate Nitrogen (mg/m ³)	0.5	36	5.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	3	0.5
Suspended Solids	0.25	5	1.2
Conductivity	57	76.3	68.35
pH	3.3	4.4	3.9
Trophic Level Index	1.72	4.16	2.36
Trophic Level Index Grading: Oligotrophic			

Water Quality

Lake Te Kahika is classified as oligotrophic with low levels of nutrients and algae.

Trend analysis on the five years of data suggests that water quality in Lake Te Kahika is relatively stable as no trends were detected in the four key variables. Only one significant

increasing trend was observed for DO% which is increasing at a rate of 2.48 % saturation per year. However as a result of recent forestry harvesting the lake has become peat stained as a result of run off from disturbed peat soils.

Thermal stratification generally occurs most years over summer with deoxygenation of bottom water and slightly higher nutrient levels.

Biodiversity Assessment

Lake Te Kahika ranks as 'Outstanding' which is based on its uniqueness and isolation. Although there is little submerged vegetation due to low pH meaning no LakeSPI can be generated, the lake is completely fringed by a native wetland plant community including nationally endangered plants (NIWA 2011). There are also records of a number of both native and exotic animal species including a number of rare/endangered species (Table 20). A low species diversity of 12 invertebrates has been recorded in this lake, reflecting the very low pH. The lake is dominated by chironomid species (midges) but also large numbers of the damselfly *Xanthocnemis*, the dragonfly *Hemicorduli* as well as the whirligig beetle *Gyrinus* which originates from Australia and is only recorded north of Auckland and in the Waikato (Ball *et al* 2009). Its ranking has remained the same since records began in 2005.

Table 20: Bird and fish species identified in Lake Te Kahika (green=rare/endangered, red= pest species)

Native Species	Exotic Species
spotless crane (<i>P. tabuensis plumbea</i>), fernbird (<i>B. punctate vealeae</i>), dabchick (<i>Poliiocephalus rufopectus</i>)	
little black shag (<i>Phalacrocarax silcristis</i>) Caspian tern (<i>Sterna caspia</i>)	

Lake Waihopo



Description

Lake Waihopo is located north of Pukenui on the Aupouri Peninsula. It is a small peat-stained dune lake (3.3. ha) with a maximum depth of 3.5 m. Its catchment is dominated by pasture with areas of grazed manuka/kanuka scrub. There is one outflow which flows east through a wetland then out into the Houhora Harbour. The edges of the lake are fenced but the margins are occasionally grazed.

Table 21: 5 year median, minimum and maximum results of 13 water quality parameters for Lake Waihopo.

Parameter	Min	Max	Median
Temperature (°C)	12.9	26.9	19.4
Dissolved Oxygen (% sat)	70.3	117.7	84.6
Chlorophyll a (mg/l)	0.6	13.1	4
Water Clarity (m)	1.55	3.5	2.48
Total Nitrogen (mg/m ³)	520	789	651
Total Phosphorus (mg/m ³)	7	75	19
Ammoniacal Nitrogen (mg/m ³)	5	50	15
Nitrate Nitrogen (mg/m ³)	0.5	29	0.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	7	1
Suspended Solids	0.7	4.3	1.9
Conductivity	17.7	30.4	23.7
pH	6.2	7.4	6.8
Trophic Level Index	3.59	4.68	4.11
Trophic Level Index Grading: Eutrophic			

Water Quality

Lake Waihopo is classified as eutrophic with high amounts of nutrients and algae as summarised in the table above. The high nutrient loads are likely to be associated with nutrient run off from pastoral land.

Trend analysis indicates water quality is stable in Lake Waihopo as no significant trends were observed in any of the 13 variables

Thermal stratification irregularly occurs during summer in Lake Waihopo with low oxygen concentrations in the bottom waters.

Biodiversity Assessment

This lake ranks as 'Outstanding' due to the well developed submerged and emergent plant communities that support numerous endangered biota. Lake Waihopo has been surveyed twice for Lake SPI. On both occasions it scored 'high' with 54% in 2006 and 59% in 2009 due to the extent of development of the chareophyte meadows and moderate exotic weed impacts (NIWA, 2011). There are records of a number of both native and exotic animal species including a number of rare/endangered species (Table 22). 25 invertebrate species have been recorded in this lake, the dominant species being midges (Chironominae), the backswimmer *Anisops*, Corixidae and the dragonfly *Hemicordulia australiae*. Three other species of dragonfly are also present; *Aeshna brevistylis*, *Diplacodes bipunctata*, and *Tramea loewii* (Ball *et al* 2009) as well as freshwater sponges. Its ranking has remained the same since records began in 2005.

Table 22: Bird and fish species identified in Lake Waihopo (green=rare/endangered, red=pest species)

Native Species	Exotic Species
bittern (<i>Botaurus poiciloptilus</i>)	
spotless crane (<i>P. tabuensis plumbea</i>)	
dabchick (<i>Poliocephalus rufopectus</i>)	
scaup (<i>Aythya novaezeelandiae</i>)	
fernbird (<i>B. punctata vealeae</i>)	
black mudfish (<i>Neochanna diversus</i>)	
chestnut breasted shelduck (<i>T. tardonoides</i>),	

Lake Waipara



Description

Lake Waipara is a small humic stained dune lake of 1.3 ha and is less than 5 m deep. It is situated northwest of Te Kao near Ninety Mile Beach. This lake is located in a forestry dominated catchment and is fringed by manuka scrub. There are no inflowing or outflowing streams. Submerged plant communities are reduced due to the humic stained water.

Table 23: 5 year median, minimum and maximum results of 13 water quality parameters for Lake Waipara.

Parameter	Min	Max	Median
Temperature (°C)	13	26.6	19.5
Dissolved Oxygen (% sat)	62	101.5	83.45
Chlorophyll a (mg/l)	0.4	14.7	2.6
Water Clarity (m)	1.45	4.7	3.32
Total Nitrogen (mg/m ³)	281	658	474
Total Phosphorus (mg/m ³)	4	50	17
Ammoniacal Nitrogen (mg/m ³)	1	47	7
Nitrate Nitrogen (mg/m ³)	0.5	46	1
Dissolved Reactive Phosphorus (mg/m ³)	0.5	15	0.5
Suspended Solids	0.25	2.6	0.8
Conductivity	14.4	41.6	16.5
pH	5.5	6.8	6.2
Trophic Level Index	2.67	4.70	3.86
Trophic Level Index Grading: Mesotrophic			

Water Quality

Lake Waipara is classified as mesotrophic with moderate levels of nutrients and algae as summarised in the table above.

Trend analysis for Lake Waipara indicates water quality has deteriorated over the past five years. Degrading trends have been identified in six variables including DO%, Chla, Secchi, TN, SS and TLI. Water clarity is decreasing at a rate of 0.41 m per year which is a likely result of an

increase in algal biomass and suspended solids in the lake. Chla and SS are increasing at a rate of 0.9 mg/m³ and 0.14 g/m³, respectively.

TN and TLI are increasing at a rate of 0.031 g/m³ (6.6%) and 0.17 units (4.3%) per year, respectively. Median TLI for the observed period is 3.86 which suggest a mesotrophic status however the 2010/11 TLI median was 4.00 which indicates a eutrophic status.

Lake Waipara generally thermally stratifies in spring with anoxia of bottom waters.

Biodiversity Assessment

Although no LakeSPI has been calculated for Lake Waipara the lake ranks as 'High' due to indigenous scrub surroundings and rare and threatened bird species (Table 24). 27 invertebrate species have been recorded in this lake, the most abundant species being the backswimmer *Anisops*, the waterboatmen *Diaprepocoris*, the pea mussel *S. novaezelandiae* and a large population of the dragonfly *Hemicorduli* (Ball *et al* 2009). Freshwater sponges are also present as well as the whirligig beetle *Gyrinus* which originates from Australia and is only recorded north of Auckland and in the Waikato. Its ranking has remained the same since records began in 2005 although deteriorating water quality may put this at risk.

Table 24: Animal species identified in Lake Waipara (green=rare/endangered, red=pest species).

Native Species	Exotic Species
bittern (<i>Botaurus poiciloptilus</i>), fernbird (<i>B. punctate vealeae</i>)	

Lake Waiparera



Description

Lake Waiparera is the largest of the Aupouri lakes at 103 ha in size but is relatively shallow (maximum depth 6 m). Two thirds of its catchment is pasture, with the remainder in native scrub or wetland. There are several small inflows and one outflow that flows south east into the Rangaunu Harbour.

Table 25: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Waiparera.

Parameter	Min	Max	Median
Temperature (°C)	12.4	23	17.3
Dissolved Oxygen (% sat)	89.2	124.9	98
Chlorophyll a (mg/l)	3.3	51	10.25
Water Clarity (m)	1.28	3.21	2.1
Total Nitrogen (mg/m ³)	703	1180	822
Total Phosphorus (mg/m ³)	8	73	26
Ammoniacal Nitrogen (mg/m ³)	1	45	6
Nitrate Nitrogen (mg/m ³)	0.5	227	0.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	38	1
Suspended Solids	1.6	5.4	2.7
Conductivity	0.2	36.5	28.7
pH	6.8	8.4	7.31
Trophic Level Index	4.10	5.28	4.69
Trophic Level Index Grading: Eutrophic			

Water Quality

Lake Waiparera is classified as eutrophic with high amounts of nutrients and algae as summarised in the table above. The high nutrient loads are likely to be associated with nutrient run off from pastoral land.

Trend analysis for Lake Waiparera suggests that water quality has been stable between 2005 and 2011 as no significant trends have been detected.

Biodiversity Assessment

Lake Waiparera biodiversity ranks as 'Moderate-high' as the lake is impacted by invasive oxygen weeds and pest fish species. It has been surveyed twice for Lake SPI. On both occasions it was classified as 'moderate' scoring 48% in 2005 and 37% in 2010. The declining biodiversity value reflects the increasing spread of invasive weed species (*Egeria densa* and *Lagarosiphon major*) (NIWA, 2011) however it still contains good native submerged plant communities and some rare and threatened bird species (Table 26). 20 invertebrate species have been recorded in this lake, the most abundant species being midges (Chironomini) and the damselflies *Xanthocnemis* and *Ischnura aurora* (the latter having recently self-introduced from Australia) (Ball *et al* 2009). Freshwater sponges are also present. Its ranking has remained the same since records began in 2005.

Table 26: Bird and fish species identified in lake Waiparera (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
bittern (<i>Botaurus poiciloptilus</i>), scaup (<i>Aythya novaezeelandiae</i>)	black swan (<i>Cygnus atrelus</i>)
common bully (<i>G. cotidianus</i>)	rudd (<i>Scardinius erythrophthalmus</i>)
inanga (<i>Galaxias maculatus</i>)	gambusia (<i>Gambusia affinis</i>).
smelt (<i>Retropina retropina</i>)	
shortfin eel (<i>Anguilla australis</i>)	
longfin eel (<i>Anguilla dieffenbachii</i>)	
paradise shelduck (<i>T.variegata</i>)	



Figure 3: The damselfly *Ischnura aurora* is present in Lake Waiparera and Lake Ngatu, recently self introduced from Australia (Photo credit: Andre Gunther).

Karikari and Central Lakes

Lake Omapere



Description

Lake Omapere is the largest lake in Northland, being 1197 ha in area but only 2 m at its deepest. The surrounding catchment is mainly pasture with a few areas of native scrub and mature bush. There are a number of small streams flowing into the lake and one large outlet, which feeds the Utakura River. Lake Omapere has undergone a number of changes over the past 30 years. The oxygen weed *Egeria densa* was first recorded in the lake in 1970's and spread rapidly forming dense surface reaching beds. In 1985 the oxygen weed stands collapsed releasing large amounts of nutrients back into the water column which encouraged the growth of algae. The lake became unusable for recreational activities and stock drinking water due to toxic algal blooms and remained devegetated until 1994. *E. densa* re-colonised and spread to its maximum biomass in 2001. The beds then collapsed again causing the lake to flip back to an algal dominated lake.

Associated with the collapse of lake vegetation was a high mortality rate in the lake's mussel population in both 1985 and 2001, most likely as a result of low oxygen levels on the lake bed (LOPMG 2005a). In April 2001, average mussel densities recorded were 4 living mussels/m² (figure 14) and 30 dead mussels/m². However, by April 2004 the mussel population had recovered to the pre-collapse densities and has stayed reasonably stable since at around 19 mussels/m². *Hyridellamenziesi* or torewai are an important part of the lake ecosystem as they filter feed on algae and Lake Omapere has the highest recorded densities of mussels in any New Zealand lake. An estimated density of 35 mussels/m² would be able to filter the entire water column in a day (LOPMG 2005a).

In response to the severe water quality issues affecting Lake Omapere the Lake Omapere Restoration Management Project (LORMP) was set up in 2003. This was as a joint initiative between NRC and the Lake Omapere Trust, funded by the Ministry for the Environment's Sustainable Management Fund, to develop and implement a voluntary lake management

strategy. The project was established and is working towards improving the health of the lake. Currently 8 farms that border the lake have farm management plans in place and a total of 17.5 kilometres of fencing has been erected around the lake margin to exclude stock from the lake, lakeside bush and lakeside wetlands. Approximately 84% of the lake margin is now fenced (Gray, 2012).

Table 27: 10 year median, minimum and maximum results for 13 water quality parameters for site 106461 for Lake Omapere.

Parameter	Min	Max	Median
Temperature (°C)	9.2	24.7	18
Dissolved Oxygen (% sat)	64.5	138.2	95.1
Chlorophyll a (mg/l)	1.5	240	40
Water Clarity (m)	0.14	1.3	0.33
Total Nitrogen (mg/m ³)	390	4700	1400
Total Phosphorus (mg/m ³)	15	639	126
Ammoniacal Nitrogen (mg/m ³)	5	490	21
Nitrate Nitrogen (mg/m ³)	1	392	5
Dissolved Reactive Phosphorus (mg/m ³)	2.0	262.0	5.0
Suspended Solids	4	217	42
Conductivity	4.5	9.7	7.3
pH	5.9	9.6	7.0
Trophic Level Index	4.1	7.5	6.09
Trophic Level Index Grading: Hypertrophic			

Table 28: 10 year median, minimum and maximum results for 13 water quality parameters for site 106463 for Lake Omapere.

Parameter	Min	Max	Median
Temperature (°C)	9.20	23.20	18.10
Dissolved Oxygen (% sat)	46.4	131.1	95.5
Chlorophyll a (mg/l)	1.00	250.00	30.00
Water Clarity (m)	0.11	1.25	0.32
Total Nitrogen (mg/m ³)	350	4800	1400
Total Phosphorus (mg/m ³)	17	430	125
Ammoniacal Nitrogen (mg/m ³)	5	31	15
Nitrate Nitrogen (mg/m ³)	1	114	2
Dissolved Reactive Phosphorus (mg/m ³)	2.0	36.0	4.0
Suspended Solids	5	250	43
Conductivity	2.9	10.2	7.4
pH	5.8	9.2	7.1
Trophic Level Index	3.89	8.40	6.08
Trophic Level Index Grading: Hypertrophic			

Water Quality

Lake Omapere is classified as hypertrophic which means it is highly fertile and supersaturated in phosphorus and nitrogen

Water quality is measured at 2 sites on the lake. Trend analysis on the past ten years of data (2001 to 2011) indicates that water quality is improving in Lake Omapere. Significant improving trends have been recorded in chlorophyll a, clarity, total nitrogen, trophic level index and suspended solids. An increasing trend in secchi was observed at both sites with clarity increasing by 5 cm per year at site 106461 and 3 cm per year at site 106463. Chlorophyll a is decreasing at sites 106461 and 106463 by 9.21 and 8.09 mg/m³ per year, respectively. Total nitrogen is decreasing at site 106461 by 0.274 g/m³ per year and at site 106463 by 0.219 g/m³ per year.

As a result of an increasing trend in clarity and decreasing trends in chlorophyll a and total nitrogen, a significant decreasing trend has been detected in the trophic level index (TLI) at both sites (figure 2). TLI is decreasing by 0.19 units per year at site 106461 and by 0.15 units per year at site 106463.

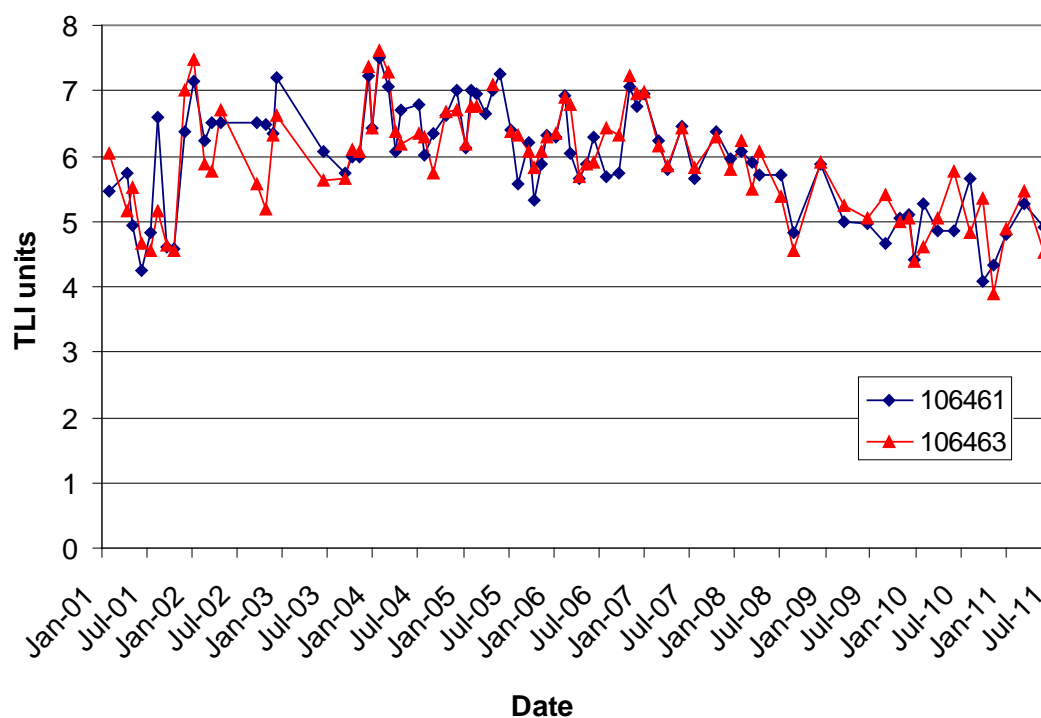


Figure 3: TLI for both Lake Omapere sites from 2001 to 2011.

A significant deteriorating trend has been observed in conductivity at both sites. Conductivity is increasing by 0.13 and 0.16 ms/m per year at sites 106461 and 106463, respectively. The reasons for these increasing trends are unknown at this stage.

A significant trend in pH was also found. pH is decreasing by 0.11 units per year at site 106461 and by 0.12 units per year at site 106463.

Biodiversity Assessment

Lake Omapere ranks as 'High' despite its low water quality issues and lack of submerged vegetation (it has a LakeSPI index of 0 (non-vegetated) with less than 10% submerged plant cover recorded since the collapse of *E.densa* beds in 2001). This is an improvement from 'Low' when first surveyed in 2005 due to the discovery of the regionally significant fernbird (Table 29) and seeds of the rare native aquatic plant *Isoetes kirkii* found in the Lake bed sediments. Other rare and endangered plant and animal species found in its extensive margins include several populations of the rare Northland mudfish (Table 29), the nationally rare bittern and fresh water crayfish (*P.planifrons*). It also has the highest densities of fresh water mussels (*Hyridella menziesi*) recorded in any New Zealand lake (LOPMG 2005a).

Table 29: Bird and fish species identified in Lake Omapere (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
bittern (<i>Botaurus poiciloptilus</i>), fernbird (<i>B. punctate vealeae</i>)	brown bullhead catfish (<i>A. Nebulosus</i>) silver carp (<i>H.molitrix</i>) grass carp (<i>C.idella</i>)
common bully (<i>G. cotidianus</i>) smelt (<i>Retropina retropina</i>) shortfin eel (<i>Anguilla australis</i>) longfin eel (<i>Anguilla dieffenbachii</i>)	gambusia (<i>Gambusia affinis</i>) goldfish (<i>Carrasius auratus</i>) black swan (<i>Cygnus atrelus</i>)
Northland mudfish (<i>Neochanna helios</i>)	

Lake Waiporohita



Description

Lake Waiporohita is a small dune lake (5.6 ha) located near Tokerau Beach on the Karikari Peninsula. This shallow lake (maximum depth of 3.5 m) is located in a pastoral dominated catchment which is completely fenced.

Table 26: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Waiporohita.

Parameter	Min	Max	Median
Temperature (°C)	12.5	25.3	18
Dissolved Oxygen (% sat)	83.5	128.2	94.65
Chlorophyll a (mg/l)	4	99.9	24.55
Water Clarity (m)	0.3	3.1	1.75
Total Nitrogen (mg/m ³)	727	3020	927
Total Phosphorus (mg/m ³)	23	832	45
Ammoniacal Nitrogen (mg/m ³)	3	349	6
Nitrate Nitrogen (mg/m ³)	0.5	70	0.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	28	2
Suspended Solids	0.25	63	5.4
Conductivity	12.7	20.9	17.25
pH	6.4	9	6.95
Trophic Level Index	3.43	7.30	5.13
Trophic Level Index Grading: Supertrophic			

Water Quality

Lake Waiporohita is classified as supertrophic which means it is fertile and saturated in phosphorus and nitrogen, with very high algae growth and blooms during calm sunny periods. High nutrient loads are likely to be associated with nutrient run off from pastoral land as well as high densities of bird life on the lake. However the whole catchment has been fenced and there are signs of improving trends in water quality. A significant decreasing trend in TLI was observed despite no changes in Chla, Secchi, TN and TP being found. TLI is

decreasing at a rate of 0.19 units per year with a five year median of 5.13 places this lake in the supertrophic classification.

Two other positive trends were identified in NH₄ and SS. NH₄ is decreasing at a rate of 0.012 g/m³ per year and SS is decreasing at a rate of 3.35 g/m³ per year. The reduction in NH₄ is a likely result of an increase in plant growth in the lake. *Chara australis* has increased in depth reaching from 1m in 2005 to >3m in 2011. This has also contributed to a reduction in sediment resuspending in the lake and hence a decrease in SS.

Biodiversity Assessment

Despite its low water quality Lake Waiporohita is ranked as 'Outstanding' as the lake contains nationally endangered plants and birds (Table 31) with indigenous submerged plant communities. There are also records of the leech (*Richardsonianus mauianus*). The Lake has been surveyed twice for Lake SPI. On both occasions it was graded as 'excellent', scoring 93% in 2005 and 88% in 2010 reflecting the extent of native vegetation. The slight decline reflects the appearance of small amounts of the invasive species *Utricularia gibba* (NIWA, 2011). Increased spread of pest plants is likely to reduce this ranking which has remained the same since records began in 2005.

Table 27: Bird and fish species identified in lake Waiporohita (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
bittern (<i>Botaurus poiciloptilus</i>)	black swan (<i>Cygnus atrelus</i>).
Caspian tern (<i>Sterna caspia</i>).	mallard (<i>Anas platyrhynchos</i>)
dabchick (<i>Poliocephalus rufopectus</i>)	gambusia (<i>Gambusia affinis</i>).
grey duck (<i>Anas superciliosa</i>)	
common bully (<i>G. cotidianus</i>)	

Kai-Iwi Lakes

Lake Kai-Iwi



Description

Lake Kai Iwi is 22.6 ha in area with a maximum depth of 16 m. It is the smallest of the Kai Iwi lake group. The lake margin is bordered by scrub, with recently felled pine plantation in its upper catchment. There is a small stream that flows into Lake Kai Iwi on the southern side of the lake which drains farmland in the catchment above the lake. There is also a drain that flows from Lake Kai Iwi into Lake Taharoa during higher lake levels.

Table 32: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Kai Iwi.

Parameter	Min	Max	Median
Temperature (°C)	12.5	25	17.75
Dissolved Oxygen (% sat)	68.3	105	96.8
Chlorophyll a (mg/l)	0.44	3.7	1.5
Water Clarity (m)	4.5	10.85	8.2
Total Nitrogen (mg/m ³)	158	425	311
Total Phosphorus (mg/m ³)	3	74	6
Ammoniacal Nitrogen (mg/m ³)	0.5	33	2
Nitrate Nitrogen (mg/m ³)	0.5	37	0.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	65	0.5
Suspended Solids	0.25	2.3	0.9
Conductivity	17.6	30.4	20.25
pH	6.4	7.9	7.05
Trophic Level Index	2.50	3.71	2.99
Trophic Level Index Grading: Oligotrophic			

Water Quality

Lake Kai Iwi classified as oligotrophic with low levels of nutrients and algae.

Trend analysis indicates water quality has declined in Lake Kai Iwi between 2002 and 2011. There has been a slight increase in algal biomass in the lake (Chla increasing at a rate of 0.09 mg/m³ per year) and TN is also increasing in Lake Kai Iwi at a rate of 5.8 mg/m³. The source of the nitrogen could be as a result of diffuse runoff or in the groundwater recharging the lake. A groundwater monitoring programme to try and understand the hydrogeology of the lake and aid in its management is due to begin in 2013.

Declining trends in three of the four key variables have resulted in an increasing trend in TLI (increasing at a rate of 0.03 per year).

Biodiversity Assessment

This lake is ranked as 'Outstanding' as the lake is dominated by native plants, including several key native plant communities and some rare and endangered animal species (Table 33). However, alongside declining water quality, the Lake SPI score has dropped from 'excellent', in 2005 and 2007 (81% and 83%, respectively) to 'high' (69%) in 2011 with the introduction of the invasive species *Utricularia gibba* (NIWA, 2011). This may put the lakes 'Outstanding' ranking, which has remained the same since records began in 2005, at risk.

Table 33: Bird and fish species identified in Lake Kai Iwi (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
bittern (<i>Botaurus poiciloptilus</i>)	gambusia (<i>Gambusia affinis</i>).
dabchick (<i>Poliocephalus rufopectus</i>)	rainbow trout (<i>Oncorhynchus mykiss</i>)
pied shag (<i>Phalacrocorax varius</i>)	
common bully (<i>G. cotidianus</i>)	
dwarf inanga (<i>Galaxias gracilis</i>)	

Lake Taharoa



Description

Lake Taharoa is Northland's deepest lake with a maximum depth of 38 m and is the second largest lake (197 ha). Its catchment is dominated by pine plantation, however the trees were felled in late 2010. This lake is popular for boating, swimming and water skiing.

Table 34: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Taharoa

Parameter	Min	Max	Median
Temperature (°C)	12.7	24.2	17.85
Dissolved Oxygen (% sat)	7.7	115.4	100.2
Chlorophyll a (mg/l)	0.3	2.8	0.75
Water Clarity (m)	6.5	13	10.3
Total Nitrogen (mg/m ³)	102	257	141
Total Phosphorus (mg/m ³)	0.5	50	2
Ammoniacal Nitrogen (mg/m ³)	0.5	32	1
Nitrate Nitrogen (mg/m ³)	0.5	9	0.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	16	0.5
Suspended Solids	0.25	2.1	0.55
Conductivity	17.6	49	19.5
pH	5.8	6.8	6.46
Trophic Level Index	1.71	3.18	2.21
Trophic Level Index Grading: Oligotrophic			

Water Quality

Lake Taharoa is classified as oligotrophic with low levels of nutrients and algae.

Trend analysis indicates that water quality in Lake Taharoa is relatively stable with only one significant trend being observed over the past ten years. An increasing trend in Chla was

detected in Lake Taharoa and is increasing at a rate of 0.07 mg/m³ per year. The reason for this increase is unknown.

Lake Taharoa stratifies annually around spring with moderate deoxygenation of bottom water.

Biodiversity Assessment

Lake Taharoa is ranked as 'Outstanding' as the lake is very clear and has the deepest recorded submerged vegetation in the North Island. It has been sampled three times for LakeSPI and has in all years graded as 'excellent', scoring 81%, 82% and 84% in 2005, 2007, and 2011 respectively. This reflects the depth of vegetation extent and the predominance of the native charophyte community. The lake also contains nationally rare bird and fish species (Table 35) as well as the fresh water crayfish (*P. planifrons*) and fresh water crab (*H. lacustris*). Its ranking has remained the same since records began in 2005.

Table 35: Bird and fish species identified in lake Taharoa (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
dabchick (<i>Poliocephalus rufopectus</i>)	gambusia (<i>Gambusia affinis</i>).
common bully (<i>G. cotidianus</i>)	rainbow trout (<i>Oncorhynchus mykiss</i>)
dwarf inanga (<i>Galaxias gracilis</i>)	
shortfin eel (<i>Anguilla australis</i>)	

Lake Waikere



Description

Lake Waikere is a relatively large lake (26.5 ha) with a maximum depth of 31 m. This lake is easily accessible and is regularly used for water skiing. Its catchment is mainly native scrub, with some pine forestry and pastoral land use.

Table 36: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Waikere.

Parameter	Min	Max	Median
Temperature (°C)	12.6	24.7	17.8
Dissolved Oxygen (% sat)	5	109.8	96.95
Chlorophyll a (mg/l)	0.5	8.3	1.6
Water Clarity (m)	3.55	12.4	9.1
Total Nitrogen (mg/m ³)	105	570	203.5
Total Phosphorus (mg/m ³)	2	83	4.5
Ammoniacal Nitrogen (mg/m ³)	0.5	21	2
Nitrate Nitrogen (mg/m ³)	0.5	8	0.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	67	0.5
Suspended Solids	0.25	4	0.7
Conductivity	17	38	18.4
pH	6	7.7	7.095
Trophic Level Index	1.51	4.11	2.74
Trophic Level Index Grading: Oligotrophic			

Water Quality

Lake Waikere is classified as oligotrophic with low levels of nutrients and algae.

Trend analysis indicates that water quality in Lake Waikere is stable as no significant trends were recorded.

The lake stratifies annually over summer with anoxia of bottom water.

Biodiversity Assessment

Lake Waikere is ranked as 'Outstanding' as the lake is dominated by native plants including some which are nationally rare. This is reflected in the Lake SPI results. It has been surveyed in 2005, 2007 and 2011 with an 'excellent' LakeSPI score of 76%, 79% and 75% respectively due to the large extent of native vegetation and the presence of charophyte meadows (NIWA, 2011). It is also home to a number of native birds and fish (Table 37) as well as the fresh water crayfish (*P.planifrons*) and pea mussel (*S. novaezelandiae*). Its ranking has remained the same since records began in 2005.

Table 37: Bird and fish species identified in Lake Waikere (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
grey heron (<i>Ardea novaehollandiae</i>)	gambusia (<i>Gambusia affinis</i>)
little shag (<i>Phalacrocorax melanoleucos</i>)	rainbow trout (<i>Oncorhynchus mykiss</i>)
common bully (<i>G. cotidianus</i>)	
dwarf inanga (<i>Galaxias gracilis</i>)	
shortfin eel (<i>Anguilla australis</i>)	
longfin eel (<i>Anguilla dieffenbachii</i>)	

Pouto Lakes

Lake Humuhumu



Description

Lake Humuhumu is the deepest Pouto lake, with a maximum depth of 16 m. This large dune lake (139.4 ha) is situated in a catchment dominated by pasture, with pine forestry on the western side of the lake and scattered pockets of kanuka scrub.

Table 38: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Humuhumu.

Parameter	Min	Max	Median
Temperature (°C)	13.2	24.6	19.1
Dissolved Oxygen (% sat)	68.2	111.9	96.55
Chlorophyll a (mg/l)	1.9	6.7	2.6
Water Clarity (m)	2.5	8	5.5
Total Nitrogen (mg/m ³)	257	361	290
Total Phosphorus (mg/m ³)	6	120	12
Ammoniacal Nitrogen (mg/m ³)	0.5	6	2.5
Nitrate Nitrogen (mg/m ³)	0.5	7	0.75
Dissolved Reactive Phosphorus (mg/m ³)	0.5	85	0.5
Suspended Solids	0.5	4.8	1.8
Conductivity	10.4	25.8	21.55
pH	7.35	8.7	8.1
Trophic Level Index	3.16	4.29	3.47
Trophic Level Index Grading: Mesotrophic			

Water Quality

Lake Humuhumu is classified as mesotrophic with moderate levels of nutrients and algae as summarised in the table above.

Water quality in Lake Humuhumu appears to be relatively stable as no significant trends in the key variables were detected. An increasing trend in pH was the only significant trend observed over the data period.

Lake Humuhumu is a monomictic lake, stratifying in December most years with occasional deoxygenation of the bottom waters. The thermocline is generally between 10 and 12 m. The lake destratifies in March/April.

Biodiversity Assessment

Lake Humuhumu has a ranking of 'Outstanding' as it contains nationally rare plants, fish and birds (Table 39) as well as the fresh water crayfish (*P.planifrons*), fresh water mussel (*Hyridella menziesi*), snail (*Glyptophysa variabilis*) and fresh water jellyfish (*C.sowerbyi*), with no major pest species (NIWA, 2011). This is reflected in the 'high' LakeSPI scores of 77% and 81% in 2007 and 2005, respectively. Its ranking has remained the same since records began in 2005.

Table 28: Bird and fish species identified in Lake Humuhumu (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
dabchick (<i>Poliocephalus rufopectus</i>)	
bittern (<i>Botaurus poiciloptilus</i>)	
Caspian tern (<i>Sterna caspia</i>).	
spotless crane (<i>P. tabuensis plumbea</i>)	
scaup (<i>Aythya novaezeelandiae</i>)	
fernbird (<i>B. punctate vealeae</i>)	
common bully (<i>G. cotidianus</i>)	
dwarf inanga (<i>Galaxias gracilis</i>)	

Lake Kahuparere



Description

This small lake 9.4 ha is situated on sand dunes in a pastoral dominated catchment with some forestry and native scrub. The riparian margin is fenced and there is dense emergent vegetation around the lake edge. Lake Kahuparere has a maximum depth of 7.5 m.

Table 40: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Kahuparere.

Parameter	Min	Max	Median
Temperature (°C)	13	25.3	18.75
Dissolved Oxygen (% sat)	81.7	124.2	92.15
Chlorophyll a (mg/l)	4.3	22.1	10.1
Water Clarity (m)	2.25	4	2.665
Total Nitrogen (mg/m ³)	316	517	401
Total Phosphorus (mg/m ³)	11	48	18
Ammoniacal Nitrogen (mg/m ³)	0.5	20	2.5
Nitrate Nitrogen (mg/m ³)	0.5	3	0.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	2	0.5
Suspended Solids	1.8	6.7	3.5
Conductivity	35.4	44.8	38.2
pH	7.8	8.6	8.1
Trophic Level Index	3.82	4.72	4.17
Trophic Level Index Grading: Mesotrophic			

Water Quality

Lake Kahuparere is classified as mesotrophic with moderate levels of nutrients and algae as summarised in the table above.

Data from 2005 to 2011 suggests that there has been a slight improvement in water quality in Lake Kahuparere. A significant improving trend in TLI has been recorded and is decreasing at

a rate of 0.058 units or 1.38% per year however no other significant trends were recorded in the four key indicators.

Lake Kahuparere generally stratifies in October/November with anoxia of the bottom water occurring then destratifies in March/April.

Biodiversity Assessment

A diverse submerged plant community with a number of rare and endangered animal species (Table 41) including the fresh water mussel (*Hyridella menziesi*), fresh water crayfish (*P. planifrons*) and the snail (*Glyptophyoa variabilis*) give this lake a 'High' ranking despite a decline in the LakeSPI scores from 88% (excellent) in 2005 to 71% (high) in 2007 due to the introduction of bladderwort (*Utricularia gibba*) (NIWA, 2011). Its ranking has remained the same since records began in 2005.

Table41: Bird and fish species identified in lake Kahuparere (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
dabchick (<i>Poliiocephalus rufopectus</i>)	eastern little tern (<i>S.albifrons sinensis</i>)
bittern (<i>Botaurus poiciloptilus</i>)	
Caspian tern (<i>Sterna caspia</i>)	
spotless crane (<i>P. tabuensis plumbea</i>)	
scaup (<i>Aythya novaezeelandiae</i>)	
common bully (<i>G. cotidianus</i>)	
dwarf inanga (<i>Galaxias gracilis</i>)	

Lake Kanono



Description

Lake Kanono is a relatively large (74.4 ha) and deep dune lake (15 m) located near Pouto Point. The catchment is predominately pastoral with pine forestry on the western edge and small areas of native scrub. Although approximately two thirds of the lake margin on the pastoral side is fenced with an excellent quality deer fence, the lake margin is frequently grazed by livestock.

Table 42: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Kanono.

Parameter	Min	Max	Median
Temperature (°C)	12.2	24	18.75
Dissolved Oxygen (% sat)	65.8	123.5	99.2
Chlorophyll a (mg/l)	2.3	28.8	7.05
Water Clarity (m)	1.02	3.95	2.55
Total Nitrogen (mg/m ³)	270	675	344.5
Total Phosphorus (mg/m ³)	11	47	21.5
Ammoniacal Nitrogen (mg/m ³)	0.5	11	1
Nitrate Nitrogen (mg/m ³)	0.5	2	0.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	14	1
Suspended Solids	1.4	10	3.65
Conductivity	13.3	32.9	28.95
pH	7.7	9	8.5
Trophic Level Index	3.58	5.01	4.14
Trophic Level Index Grading: Eutrophic			

Water Quality

Lake Kanono is classified as eutrophic with high amounts of nutrients and algae as summarised in the table above. The high nutrient loads are likely to be associated with nutrient run off from pastoral land, and livestock access.

Water quality appears to be relatively stable as no significant trends were detected in the key variables. An increasing trend in COND of 1.1 ms/m or 4% per year was recorded.

Lake Kanono stratifies in October and destratifies in March/April of most years. The thermocline consistently sits around the 10 m mark with anoxia of bottom waters regularly occurring below.

Biodiversity Assessment

Lake Kanono has a ranking of 'Outstanding' due to the diverse native submerged and emergent plant communities, reflected in a 'high' LakeSPI score of 76% in 2005 and 2007. This provides an excellent habitat for fish and birds (NIWA, 2011) including a number of rare and endangered species (Table 43). There are also records of the fresh water mussel (*Hyridella menziesi*), fresh water crayfish (*P.planifrons*) and the snail (*Glyptophysa variabilis*). Its ranking has remained the same since records began in 2005.

Table 43: Bird and fish species identified in Lake Kanono (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
dabchick (<i>Poliocephalus rufopectus</i>)	black swan (<i>Cygnus atrelus</i>)
scaup (<i>Aythya novaezeelandiae</i>)	eastern little tern (<i>S.albifrons sinensis</i>)
bittern (<i>Botaurus poiciloptilus</i>)	
Caspian tern (<i>Sterna caspia</i>)	
spotless crane (<i>P. tabuensis plumbea</i>)	
common bully (<i>G. cotidianus</i>)	
dwarf inanga (<i>Galaxias gracilis</i>)	

Lake Kapoai



Description

Lake Kapoai is located near Te Kopuru, just south of Dargaville, and is 1.6 ha in area with a maximum depth of 9 m. The catchment is entirely pastoral and the majority of the lake is fenced to prevent livestock access.

Table 29 5 year median, minimum and maximum results for 13 water quality parameters for Lake Kapoai.

Parameter	Min	Max	Median
Temperature (°C)	13.3	27.5	19.5
Dissolved Oxygen (% sat)	66.7	132.2	90.1
Chlorophyll a (mg/l)	20	216	64.4
Water Clarity (m)	0.34	0.9	0.65
Total Nitrogen (mg/m ³)	1310	3080	2100
Total Phosphorus (mg/m ³)	27	212	126
Ammoniacal Nitrogen (mg/m ³)	4	1420	17
Nitrate Nitrogen (mg/m ³)	0.5	59	0.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	37	3
Suspended Solids	6.5	27	14.5
Conductivity	31.3	46.2	36.65
pH	7.3	9.5	8.7
Trophic Level Index	5.55	6.90	6.18
Trophic Level Index Grading: Hypertrophic			

Water Quality

Lake Kapoai is classified as hypertrophic which means it is highly fertile and supersaturated in phosphorus and nitrogen. The high nutrient loads are likely to be associated with nutrient run off from pastoral land.

Water quality is stable, showing no significant trends.

Biodiversity Assessment

Lake Kapoai has a 'Low' to 'Moderate' ranking due to the lack of aquatic plant communities and poor water quality. There is an absence of submerged vegetation and there are only a few small areas of emergent vegetation. As a result no Lake SPI can be generated (NIWA, 2011). Never the less it still provides habitat for a number of rare and endangered species (Table 45). Its ranking has remained the same since records began in 2005.

Table 45: Bird and fish species identified in lake Kapoai (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
black shag (<i>Anus platyrhincus</i>)	black swan (<i>Cygnus atrelus</i>)
grey duck (<i>Anas superciliosa</i>)	mallard (<i>Anus platyrhincus</i>)
dabchick (<i>Poliiocephalus rufopectus</i>)	rudd (<i>Scardinius erythrophthalmus</i>)
scaup (<i>Aythya novaezeelandiae</i>)	tench (<i>Tinca tinca</i>)
common bully (<i>G. cotidianus</i>)	goldfish (<i>Carassius auratus</i>)
shortfin eel (<i>Anguilla australis</i>)	

Lake Karaka



Description

Lake Karaka is located near the West Coast on the Pouto Peninsula. Its catchment comprises wetlands, native scrub, pastoral land and forestry. The lake is over 11 ha in size and has a maximum depth of 6 m.

Table 46: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Karaka.

Parameter	Min	Max	Median
Temperature (°C)	12.5	24	18.15
Dissolved Oxygen (% sat)	74.4	139.1	98.15
Chlorophyll a (mg/l)	1.5	203	16.6
Water Clarity (m)	0.35	5.58	2.565
Total Nitrogen (mg/m ³)	174	2580	486
Total Phosphorus (mg/m ³)	12	169	40.5
Ammoniacal Nitrogen (mg/m ³)	1	275	11
Nitrate Nitrogen (mg/m ³)	0.5	75	4
Dissolved Reactive Phosphorus (mg/m ³)	0.5	44	2
Suspended Solids	1	18.4	6
Conductivity	26	36.1	30.6
pH	7.5	9	7.9
Trophic Level Index	3.51	6.90	4.71
Trophic Level Index Grading: Eutrophic			

Water Quality

Lake Karaka is classified as eutrophic with high amounts of nutrients and algae as summarised in the table above. The high nutrient loads are likely to be associated with nutrient run off from pastoral land and forestry activities.

The key variables indicate that water quality in Lake Karaka has declined between 2005 and 2011. The decline appears to be driven by an increase in nitrogen with an upwards trend in TN of 0.12 g/m³ or 18.7% per year. Significant trends in Chla and water clarity were observed with Chla increasing at a rate of 11.78 mg/m³ per year (34.28%) and water clarity decreasing at a rate of 0.27 m per year (11.23%). The increase in algal biomass is the likely cause in the decrease in water clarity. Despite declines in three of the four key variables, no significant trend in TLI was observed.

A significant trend in pH was also observed and is increasing at a rate of 0.1 units or 1.25% per year.

Lake Karaka does not stratify however temporary anoxia of the bottom waters does occasionally occur during summer with oxygen levels recorded down to 2.7 %sat.

Biodiversity Assessment

Lake Karaka has a ranking of 'High' (NIWA, 2011) due to its native vegetation. It scored an 'excellent' LakeSPI score of 83% and 81% in 2005 and 2007 respectively due to the large extent of native vegetation and the presence of charophyte meadows (NIWA, 2011). Much of the lake is surrounded by wetlands and it supports a number of nationally endangered plant, bird and fish species (Table 47). Its ranking has remained the same since records began in 2005.

Table 47: Bird and fish species identified in lake Karaka (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
dabchick (<i>Poliocephalus rufopectus</i>)	
scaup (<i>Aythya novaezeelandiae</i>)	
bittern (<i>Botaurus poiciloptilus</i>)	
spotless crake (<i>P. tabuensis plumbea</i>)	
fernbird (<i>B. punctate vealeae</i>)	
grey duck (<i>Anas superciliosa</i>)	
brown teal (<i>Anus aucklandica chloritus</i>)	
banded rail (<i>G. phillippensis assimilis</i>)	
common bully (<i>G. cotidianus</i>)	
shortfin eel (<i>Anguilla australis</i>)	
longfin eel (<i>Anguilla dieffenbachii</i>)	
giant kokopu (<i>Galaxias argenteus</i>)	

Lake Mokeno



Description

Lake Mokeno is 148 ha in size making it the largest Pouto lake. It has a maximum recorded depth of 6.1 m and is located near the West Coast. It is entirely surrounded by native scrub and wetlands, with pine forestry in its upper catchment. Water from this lake flows south through extensive wetlands until it reaches the Kaipara Harbour.

Table 48: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Mokeno.

Parameter	Min	Max	Median
Temperature (°C)	11.8	24.6	17.2
Dissolved Oxygen (% sat)	77.5	110.2	97
Chlorophyll a (mg/l)	1.1	7.2	2.4
Water Clarity (m)	1.8	5.9	3.5
Total Nitrogen (mg/m ³)	395	1030	548
Total Phosphorus (mg/m ³)	10	179	17
Ammoniacal Nitrogen (mg/m ³)	1	509	16
Nitrate Nitrogen (mg/m ³)	0.5	88	3
Dissolved Reactive Phosphorus (mg/m ³)	0.5	130	2
Suspended Solids	0.7	16	2
Conductivity	24.3	33.3	27.3
pH	7.4	9.28	7.85
Trophic Level Index	3.43	4.88	3.96
Trophic Level Index Grading: Mesotrophic			

Water Quality

Lake Mokeno is classified as mesotrophic with moderate levels of nutrients and algae as summarised in the table above.

Water quality is stable and has not changed between 2005 and 2011. One significant increasing trend in DO% was observed and is increasing at a rate of 1.77 % sat per year

(1.83%). Lake Mokeno remained fully mixed throughout the study period, though oxygen was depleted to the point of anoxia from the bottom 1-2 m during summer.

Biodiversity Assessment

This lake is ranked as 'Outstanding' due to its native flora and fauna, some of which are nationally endangered (Table 49) and including the fresh water mussel (*Hyridella menziesi*) and fresh water jellyfish (*C.sowerby*). This is reflected in "excellent "LakeSPI scores of 83% and 90% respectively in 2005 and 2007 indicative of high quality native submerged vegetation and a lack of invasive species (NIWA, 2011). This provides an excellent habitat for fish and bird species. Its ranking has remained the same since records began in 2005.

Table 49: Bird and fish species identified in lake Mokeno (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
dabchick (<i>Poliiocephalus rufopectus</i>)	
scaup (<i>Aythya novaezeelandiae</i>)	
bittern (<i>Botaurus poiciloptilus</i>)	
spotless crane (<i>P. tabuensis plumbea</i>)	
fernbird (<i>B. punctate vealeae</i>)	
Caspian tern (<i>Sterna caspia</i>)	
brown teal (<i>Anus aucklandica chloritus</i>)	
banded rail (<i>G. phillippensis assimilis</i>)	
common bully (<i>G. cotidianus</i>)	
shortfin eel (<i>Anguilla australis</i>)	
smelt (<i>Retropina retropina</i>)	
inanga (<i>Galaxias maculatus</i>)	

Lake Rotokawau



Description

Lake Rotokawau is set in a pastoral catchment and is 26.4 ha in size with a maximum depth of 12 m. The lake is completely fenced and is bordered by pine forestry.

Table 50: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Rotokawau.

Parameter	Min	Max	Median
Temperature (°C)	12.6	24.3	20.15
Dissolved Oxygen (% sat)	3.5	102.7	95.6
Chlorophyll a (mg/l)	0.9	6.8	2.6
Water Clarity (m)	3.25	8.37	6.14
Total Nitrogen (mg/m ³)	292	507	334
Total Phosphorus (mg/m ³)	5	101	8.5
Ammoniacal Nitrogen (mg/m ³)	0.5	21	3
Nitrate Nitrogen (mg/m ³)	0.5	4	0.5
Dissolved Reactive Phosphorus (mg/m ³)	0.5	59	0.5
Suspended Solids	0.25	6.9	1.35
Conductivity	12.2	14.5	13.8
pH	6.6	8.34	7.2
Trophic Level Index	2.87	3.92	3.29
Trophic Level Index Grading: Mesotrophic			

Water Quality

Lake Rotokawau is classified as mesotrophic with moderate levels of nutrients and algae as summarised in the table above.

Water quality in Lake Rotokawau has been stable over the past five years as no significant trends in the key indicators have been observed.

One significant trend in COND was recorded and is decreasing at a rate of 0.133 mS/m per year (1%).

Stratification in Lake Rotokawau is irregular but generally stratifies in late spring and de-stratifies in early autumn. Anoxia of the bottom water occurs during some summers.

Biodiversity Assessment

Lake Rotokawau contains a good population of the nationally rare dwarf inanga and extensive turf communities which include the nationally endangered *Hydatella inconspicua* giving this lake a 'High' ecological ranking with a LakeSPI score of 56% (NIWA, 2011). It is home to a number of rare and endangered bird species (Table 46) as well as the fresh water mussel (*Hyridella menziesi*), leech (*Richardsonianus mauianus*) and snail (*Potamopyrgus antipodarum*). Its ranking has remained the same since records began in 2005.

Table 51: Bird and fish species identified in Lake Rotokawau (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
dabchick (<i>Poliiocephalus rufopectus</i>)	Cape Barren goose (<i>C. navaehollandiae</i>)
scaup (<i>Aythya novaezeelandiae</i>)	
bittern (<i>Botaurus poiciloptilus</i>)	
dwarf inanga (<i>Galaxias gracilis</i>)	
common bully (<i>G. cotidianus</i>)	
shortfin eel (<i>Anguilla australis</i>)	
paradise shellduck (<i>T.variegata</i>)	

Lake Rototuna



Description

This small 6 ha dune lake is 5.1 m deep and located mid-way down the Pouto Peninsula in a mainly pastoral catchment. It is easily accessible from the main road. The lake is fenced in the area administered by the Department for Conservation and the lake margins have been planted with native wetland species. In the area to the south, livestock have access to the lake.

Table 52: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Rototuna.

Parameter	Min	Max	Median
Temperature (°C)	12.4	25.4	20.1
Dissolved Oxygen (% sat)	66.7	119.4	99.3
Chlorophyll a (mg/l)	5.3	59.7	10.6
Water Clarity (m)	0.88	3.7	2.65
Total Nitrogen (mg/m ³)	456	956	607
Total Phosphorus (mg/m ³)	8	75	28
Ammoniacal Nitrogen (mg/m ³)	1	29	4
Nitrate Nitrogen (mg/m ³)	0.5	3	0.75
Dissolved Reactive Phosphorus (mg/m ³)	0.5	14	1
Suspended Solids	2.2	14.4	4.6
Conductivity	14.7	23.7	17.35
pH	6.9	9.3	7.8
Trophic Level Index	4.03	5.41	4.48
Trophic Level Index Grading: Eutrophic			

Water Quality

Lake Rototuna is classified as eutrophic with high amounts of nutrients and algae as summarised in the table above. The high nutrient loads are likely to be associated with nutrient run off from pastoral land and livestock access to the lake.

Trend analysis indicates water quality has declined in Lake Rototuna. Deteriorating trends were observed in CHLA, TN and TLI. Algal biomass is increasing at a rate of 2.85 mg/m³ and

TN is increasing at a rate of 0.037 g/m³. Increases in two of the four key variables have led to an increase in TLI.

Biodiversity Assessment

Despite its poor water quality, Lake Rototuna has a 'High' ecological ranking with its retired margins and native vegetation. It scored an 'excellent' LakeSPI of 86% reflecting the high quality of native submerged vegetation which has improved from 76% in 2005 with the invasive plant species *P.crispus* no longer recorded. The lake provides habitat for a number of endangered biota (Table 53), although the pest fish species gambusia and rudd have recently become established (NIWA, 2011). Its ranking has remained the same since records began in 2005.

Table 53: Bird and fish species identified in lake Rototuna (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
dabchick (<i>Poliocephalus rufopectus</i>)	black swan (<i>Cygnus atrelus</i>)
scaup (<i>Aythya novaezeelandiae</i>)	rudd (<i>Scardinius erythrophthalmus</i>)
bittern (<i>Botaurus poiciloptilus</i>)	gambusia (<i>Gambusia affinis</i>)
dwarf inanga (<i>Galaxias gracilis</i>)	
common bully (<i>G. cotidianus</i>)	
paradise shellduck (<i>T.variegata</i>)	

Lake Roto-otuauru / Swan



Description

Lake Swan is a small dune lake of 17.4 ha. It is 5.5 m deep and situated in a pastoral dominated catchment with some areas of scrub and pines. The lake perimeter is fenced and can only be accessed through private land.

Table 30: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Swan.

Parameter	Min	Max	Median
Temperature (°C)	12.8	25.9	19.4
Dissolved Oxygen (% sat)	75.4	105	90.45
Chlorophyll a (mg/l)	1.9	25.3	3.7
Water Clarity (m)	1.01	3.8	3.1
Total Nitrogen (mg/m ³)	121	1130	597.5
Total Phosphorus (mg/m ³)	8	609	15
Ammoniacal Nitrogen (mg/m ³)	1	145	4
Nitrate Nitrogen (mg/m ³)	0.5	125	12
Dissolved Reactive Phosphorus (mg/m ³)	0.5	395	1
Suspended Solids	0.25	5.7	0.95
Conductivity	13	19.4	18.35
pH	6.4	7.6	7.3
Trophic Level Index	2.98	6.09	3.86
Trophic Level Index Grading: Mesotrophic			

Water Quality

Lake Swan is classified as mesotrophic with moderate levels of nutrients and algae as summarised in the table above.

Key variables indicate water quality has deteriorated in Lake Swan over the past 5 years with TLI increasing 0.22 units or 5.43 % per year. TN levels have increased significantly with levels increasing 0.091 g/m³ or 14.73 % per year and algae blooms have developed in the warmer

summer months. This is likely to be a consequence of devegetation caused by the introduction of grass carp to control invasive plant species (refer below).

Biodiversity Assessment

Lake Swan has a 'Moderate' ecological ranking. It has been degraded by the presence of invasive plant species *Ceratophyllum demersum* and *Egeria densa* and is now in a "non-vegetated" state with the introduction of grass carp as a control measure. As a result the lake scored a LakeSPI of 14% (poor), compared to 21% (moderate) in 2005. Once invasive plant species have been controlled and grass carp removed it is expected that the SPI will improve rapidly with native submerged plant regeneration (NIWA, 2011). Despite the poor state of the vegetation the dwarf inanga, a rare native fish species, and a number of rare birds are present (Table 55). The lake also contains populations of the fresh water mussel (*Hyridella menziesi*). Its ranking has remained the same since records began in 2005.

Table 55: Bird and fish species identified in Lake Swan (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
dabchick (<i>Poliiocephalus rufopectus</i>)	black swan (<i>Cygnus atrelus</i>).
bittern (<i>Botaurus poiciloptilus</i>)	mallard (<i>Anus platyrhyncus</i>)
fernbird (<i>B. punctate vealeae</i>)	grass carp (<i>Ctenopharyngodon idella</i>)
dwarf inanga (<i>Galaxias gracilis</i>)	
common bully (<i>G. cotidianus</i>)	
shortfin eel (<i>Anguilla australis</i>)	

Lake Wainui



Description

Lake Wainui is a small 4.8 ha dune lake with a maximum depth of 11.8 m that is surrounded by pastoral land. A narrow riparian edge has recently been fenced to exclude livestock which should enable emergent vegetation to establish.

Table 56: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Wainui.

Parameter	Min	Max	Median
Temperature (°C)	12.3	25.6	19.4
Dissolved Oxygen (% sat)	81.8	122.6	97.8
Chlorophyll a (mg/l)	1.3	33.6	11.2
Water Clarity (m)	1	5.5	1.6
Total Nitrogen (mg/m ³)	290	784	558
Total Phosphorus (mg/m ³)	12	259	39
Ammoniacal Nitrogen (mg/m ³)	1	82	3
Nitrate Nitrogen (mg/m ³)	0.5	30	1
Dissolved Reactive Phosphorus (mg/m ³)	0.5	85	1
Suspended Solids	0.6	10	5.5
Conductivity	22.7	56.4	44.2
pH	7.2	8.8	7.9
Trophic Level Index	3.24	5.32	4.73
Trophic Level Index Grading: Eutrophic			

Water Quality

Lake Wainui is classified as eutrophic with high amounts of nutrients and algae as summarised in the table above. The high nutrient loads are likely to be associated with nutrient run off from pastoral land.

Changes in a few key water quality variables indicate an improvement in Lake Wainui. Improving trends in TN (reducing at a rate of 0.039 g/m³ per year) and clarity (increasing at a

rate of 25 cm per year) has led to an improvement in TLI. An improving trend in SS was also observed over the five year period. The fencing to exclude livestock is likely to have contributed to the improving trends in Lake Wainui.

The lake stratified over summer with moderate deoxygenation of bottom water (down to 0.5 g/m³).

Biodiversity Assessment

Lake Wainui has a 'Moderate to High' ecological ranking. It is a small lake which contains totally native vegetation but is prone to nutrient enrichment. It has been surveyed twice for LakeSPI. On both occasions it rated as 'excellent' with a score of 80% in 2005 and 76% in 2007. The totally native vegetation is moderated slightly by poor water quality which is limiting the depth at which submerged plants can grow (NIWA, 2011). It provides habitat for a number of rare and endangered species (Table 57) as well as the leech (*Richardsonianus mauianus*). Its ranking has remained the same since records began in 2005.

Table 57: Animal species identified in lake Wainui (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
dabchick (<i>Poliiocephalus rufopectus</i>)	black swan (<i>Cygnus atrelus</i>).
bittern (<i>Botaurus poiciloptilus</i>)	
scaup (<i>Aythya novaezeelandiae</i>)	
paradise shellduck (<i>T.variegata</i>)	

Lake Whakaneke



Figure 4: *Schoenoplectus tabernaemontani* a dominant emergent native plant species at Lake Whaneke.

Description

Lake Whakaneke is located south of Lake Mokeno at the bottom of the Pouto Peninsula. This shallow 20.5 ha dune lake is about 2.5 m deep and surrounded by manuka scrub and wetlands. The lake can only be accessed through forestry or Māori land.

Table 58: 5 year median, minimum and maximum results for 13 water quality parameters for Lake Whakaneke.

Parameter	Min	Max	Median
Temperature (°C)	12.5	23.9	15.85
Dissolved Oxygen (% sat)	68.9	142.6	86.55
Chlorophyll a (mg/l)	1.5	213	33.55
Water Clarity (m)	0.2	3.1	0.92
Total Nitrogen (mg/m ³)	385	3130	630
Total Phosphorus (mg/m ³)	26	939	70
Ammoniacal Nitrogen (mg/m ³)	0.5	38	6.5
Nitrate Nitrogen (mg/m ³)	0.5	12	0.5
Dissolved Reactive Phosphorus (mg/m ³)	2	698	6
Suspended Solids	1.3	36.8	8.75
Conductivity	25.7	42.1	37.1
pH	7.3	9.6	8
Trophic Level Index	3.91	7.49	5.31
Trophic Level Index Grading: Supertrophic			

Water Quality

Lake Whakaneke is classified as supertrophic which means it is fertile and saturated in phosphorus and nitrogen, with very high algae growth and blooms during calm sunny periods.

Water quality appears to be stable with no significant trends observed over the sampling period.

Biodiversity Assessment

Lake Whakaneke has a 'Moderate' ecological ranking. It is surrounded by native vegetation and has dense emergent wetland vegetation around its margins with excellent water bird habitat supporting a number of rare and endangered species (Table 59) However it has poor water clarity and little or no submerged vegetation. Because of its non-vegetated state it has a LakeSPI score of 0%. Its ranking has reduced since 2005 when it was graded as 'High' with the nationally rare bittern recorded in 2005 but not in 2011.

Table 59: Bird and fish species identified in Lake Wainui (Green = rare/endangered. red=pest species)

Native Species	Exotic Species
dabchick (<i>Poliocephalus rufopectus</i>) scaup (<i>Aythya novaezeelandiae</i>) spotless crake (<i>P. tabuensis plumbea</i>) fernbird (<i>B. punctate vealeae</i>) brown teal (<i>Anas aucklandica chloritus</i>) banded rail (<i>G. phillippensis assimilis</i>) common bully (<i>G. cotidianus</i>)	snail (<i>Physa acuta</i>)

Lake Water Quality Summary

Water quality data for the 28 lakes monitored shows that although none of the Northland lakes monitored are microtrophic (pristine), 50% are mesotrophic or oligotrophic (with low to moderate levels of nutrients). The remaining 50% are graded as eutrophic or below. Lakes graded as eutrophic or less have high nutrient and algal levels and low water clarity. This compares to 65% of lakes being graded as mesotrophic or above nationally and 44% eutrophic or below from the latest Ministry for the Environment (MfE) results (Verburg et al, 2010) (Figure 5). In Northland, eutrophic lakes are generally set in pastoral catchments and lack emergent vegetation. Examples include Lakes Omapere (Central), Rotoroa (Aupouri) and Wainui (Pouto). By comparison, lakes graded as oligotrophic, for example, Lakes Te Kahika (Aupouri), Taharoa and Waikere (Kai Iwi), are set in forested catchments and have emergent vegetation. The lack of microtrophic or 'pristine' lakes is to be expected with local geology precluding Northland lakes from having very low levels of nutrients. Microtrophic lakes are generally restricted to glacial/alpine lakes (of the 8 New Zealand lakes categorised as microtrophic in the latest Ministry for the Environment lake water quality report, 7 were alpine).

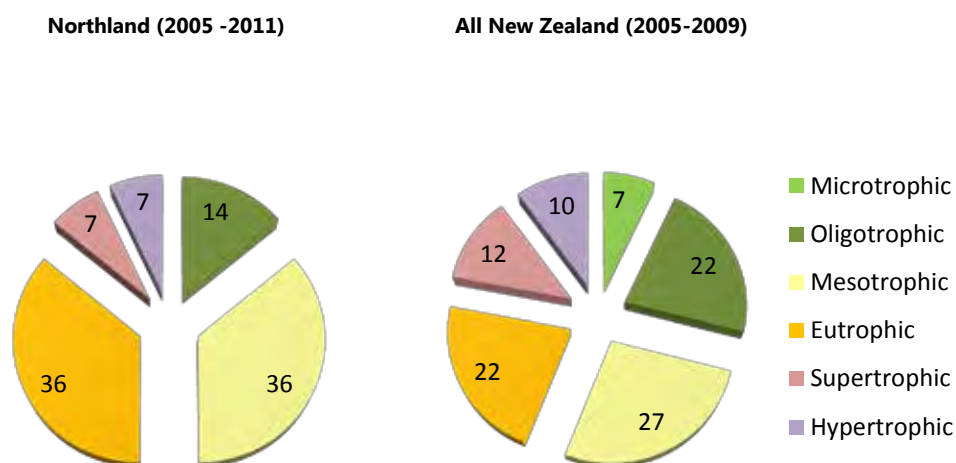


Figure 5. Trophic status (combining- chlorophyll a , water clarity, total nitrogen and total phosphorus for an indication of a lake's overall health) of 27 Northland lakes 2005-2011 left, New Zealand lakes 2005-2009 right (data taken from Verburg et al, 2010)

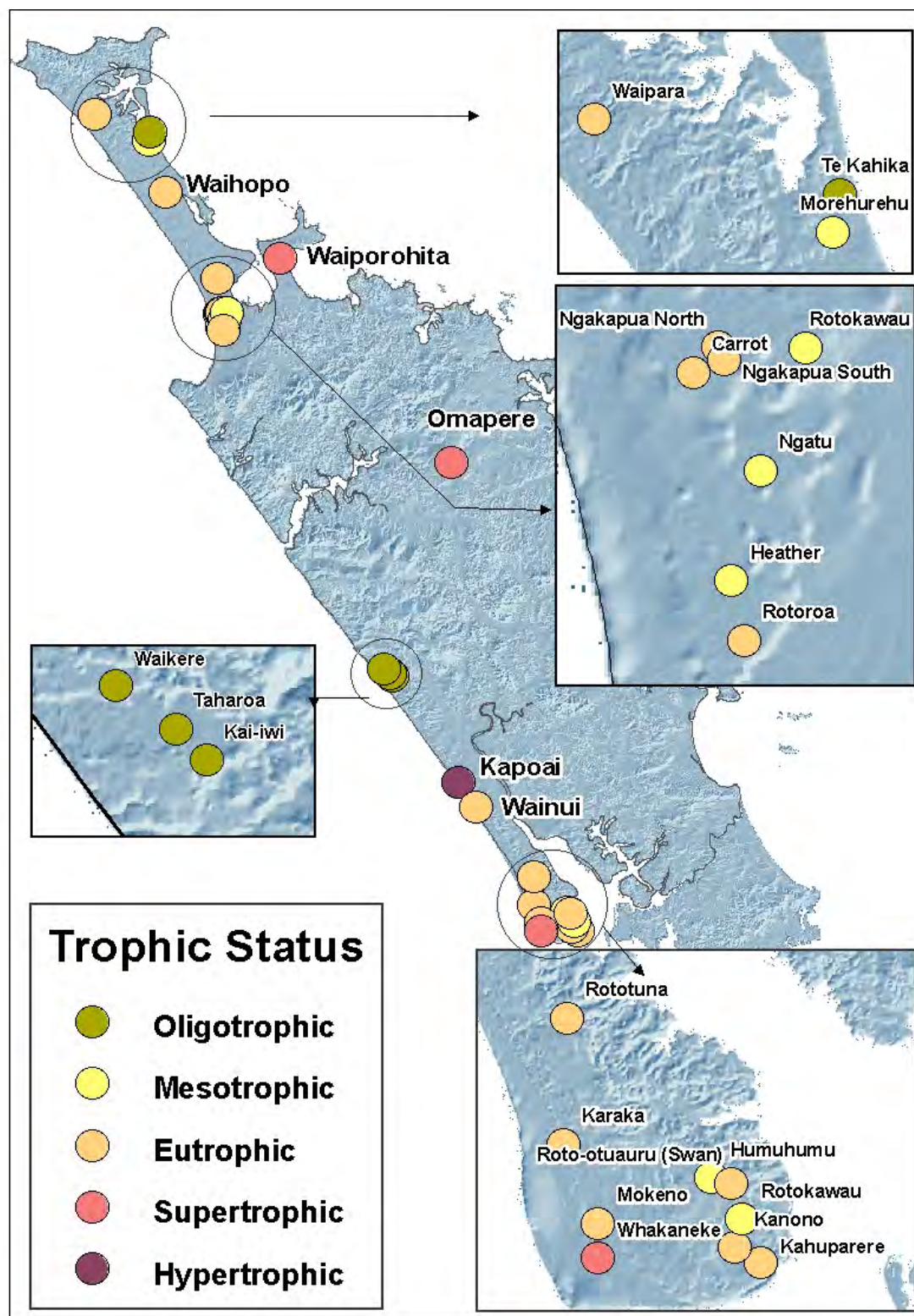


Figure 6 Lake Trophic level Index scores for the period 2007-2011.

Trend data indicates that water quality in the 27 lakes sampled remains relatively stable; 20 lakes recorded no significant change in TLI, 4 recorded improving trends and 5 deteriorating trends (table 2).

Looking at the TLI components individually:

- Significant changes in total nitrogen were identified in 12 lakes with only four of these being improving trends.
- Only one lake had a significant change in total phosphorous levels, Lake Carrot, and this was an improving trend.
- Eight lakes had significant changes in dissolved oxygen levels; 5 improving and 3 declining.
- 10 lakes recorded a significant trend in water clarity; seven of which were deteriorating trends. Of the 10 lakes six had a corresponding trends in algal biomass indicating the changes in water clarity was the result of increases/decreases in chlorophyll a concentrations. However these results need to be viewed with caution as a change in sampling methodology in 2005 may be, at least partly, responsible for some of these trends.

Despite the apparent low water quality of many of the 28 lakes monitored, many Northland Lakes have a very high ecological status (LakeSPI). The Ministry for the Environment Lake State and Trend report, 2010 (Verburg et al, 2010) indicates that over half the lakes categorised as excellent in New Zealand (13 out of 23 lakes) are situated in Northland.

The biodiversity rankings of lakes carried out by NIWA each year (NIWA, 2011), which incorporates the Lake SPI, ranks (67%) of lakes as outstanding/high value with just 22% ranking as moderate and 11% as low-moderate value. None are ranked 'low' value (Figure 7). NRC engaged NIWA to monitor the ecological status of Northland Lakes in recognition of their national importance in 2005. Lakes are monitored on a yearly basis with a ranked inventory of Lakes updated annually as part of the NRC Lake Monitoring Strategy aimed at preventing the deterioration of water quality and biodiversity.

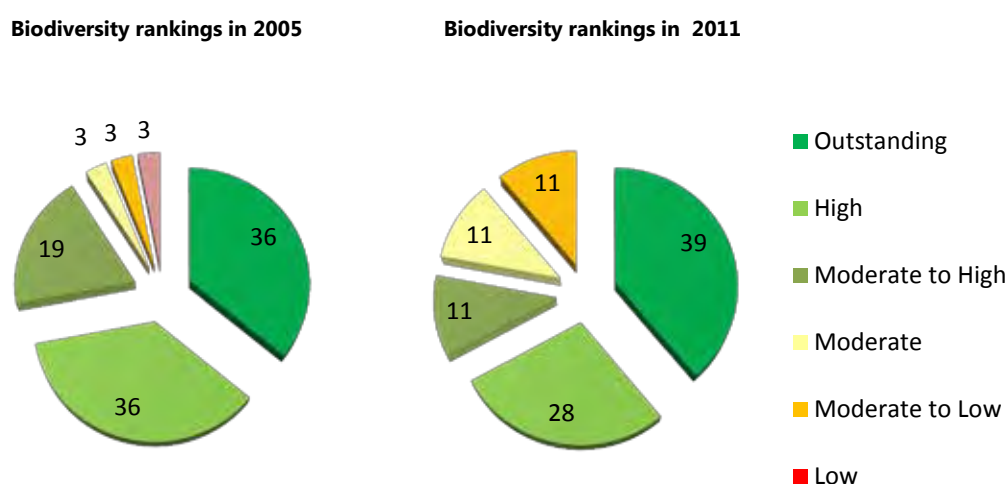


Figure 7: Lake biodiversity rankings in 2005, and in 2011

In general high ranking lakes contain rare/endangered plants or animals and have good water quality. Lake Taharoa falls into this category as it has relatively good water quality, the deepest recorded vegetation in New Zealand and a number of nationally rare plant, bird and fish species. Lower ranking lakes are generally highly impacted by land use activity, have low water quality, and may be heavily impacted by pest plants or have low faunal diversity, for example, Lake Kapoai which has little aquatic vegetation and also contains the pest fish rudd (*Scardinius erythrophthalmus*). However a lake with high biodiversity and with a rich native flora and fauna may also have relatively poor water quality with such factors as a diverse fauna increasing nutrient loads. A good example of this is Lake Waiporohita which despite very poor water quality is ranked as 'Outstanding' as the lake contains a number of nationally endangered plant and animal species. Conversely Lake Heather has relatively good water quality but has a moderate to low biodiversity ranking because of the impact of invasive weed species. This highlights the difficulty of assessing/managing lake systems. They are highly complex and management of them needs to take a holistic view of the ecosystem as a whole to avoid detrimental impacts when planning remediation work.

The biodiversity rankings indicate that although there have been improvements at both ends of the scale with no lakes being graded as poor in 2011 and a greater number graded as outstanding, a number of lakes are slipping into lower categories (Figure 6). In 2005 91% of lakes were graded as moderate to high or above, in 2011 this has reduced to 78%. Conversely in 2009 just 9% of lakes were graded as moderate or below. In 2011 this has increased to 22%. The causes of this are likely to include a number of factors. There are indications of nutrient enrichment from land management practices with an increase in nitrogen levels in 8 lakes and the impact of invasive plant and animal species will also have a detrimental effect on Lake Biodiversity. Details of threats to individual lakes are outlined in the report; Northern Lakes Ecological Status 2011 (NIWA, 2011).

In response to the monitoring programme indicating a decline in condition of some Northland Lakes, NRC recently engaged NIWA to produce the Northland Lake Strategy via a medium Envirolink grant which has recommended a number of additional assessments/monitoring projects as well as management actions (Champion, de Winter 2012) to protect Northlands lakes, many which are of national importance.

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Table 31: Temporal trend results for water quality in Northland lakes 2005 -2011 based on deseasonalised data (bold figures indicate a significant trend).

	Temperature (°C)			Dissolved Oxygen (%sat)			Conductivity (ms/m)			Chlorophyll a (mg/l)			pH			Secchi (m)		
	median	p	slope	median	p	slope	median	p	slope	median	p	slope	median	p	slope	median	p	slope
<i>Aupouri lakes</i>																		
Carrot	18.5	0.1	0.21	84.3	0.402	-1.20	18.00	0.047	-0.39	13.00	0.867	0.12	6.65	0.609	-0.02	2.27	0.019	0.12
Heather	18.1	0.103	0.23	96.2	0.004	2.30	18.55	0.003	-0.50	3.80	0.137	-0.26	7.35	0.086	0.09	3.75	0.04	-0.16
Morehurehu	19	0.147	0.17	93.5	0.094	1.33	31.90	0.754	0.18	2.80	0.186	-0.19	6.30	0.093	-0.07	2.72	0.037	-0.25
Ngakapua North	19.1	0.167	0.17	85.9	0.692	-0.25	17.50	0.958	-0.01	5.10	0.41	0.39	6.60	0.712	-0.01	3.66	0.183	-0.11
Ngakapua South	19.3	0.213	0.18	87.2	0.379	-0.55	18.00	0.502	-0.13	5.50	0.416	0.29	6.50	0.464	0.06	3.24	0.002	-0.19
Ngatu	18.6	0.14	0.22	97	0.023	2.12	19.55	0.209	-0.26	2.85	0.041	1.18	7.00	0.026	0.10	3.85	0.003	-0.31
Rotokawau	18.8	0.182	0.24	93.1	0.013	2.21	15.85	0.083	-0.38	3.60	0.393	-0.27	6.90	0.613	0.01	2.49	0.615	-0.02
Rotoroa	17.95	0.081	0.25	96.5	0.3	0.78	29.90	0.588	-0.15	8.40	0.086	1.60	6.90	0.122	0.09	2.09	0.005	-0.33
Te Kahika	19.05	0.253	0.11	87.25	0.027	2.48	68.35	0.478	0.57	1.00	0.37	0.19	3.90	0.202	-0.04	5.49	0.762	0.09
Waihopo	19.4	0.359	0.16	84.6	0.834	-0.03	23.70	0.601	0.21	4.00	0.515	0.17	6.80	0.132	0.05	2.48	0.148	-0.08
Waipara	19.5	0.382	0.09	83.45	0.013	-2.61	16.50	0.588	0.36	2.60	0.04	0.90	6.20	0.48	-0.03	3.32	0	-0.41
Waiparera	17.3	0.752	0.04	98	0.069	1.78	28.70	0.909	0.11	10.25	0.849	0.24	7.31	0.074	0.07	2.10	0.101	-0.07
<i>Karikari/Central lakes</i>																		
Omapere (eastern site)	18	0.287	0.06	95.1	0.001	-1.50	7.30	0.008	0.13	40.00	0	-9.21	7.00	0	-0.11	0.33	0	0.05
Omapere (western site)	18.1	0.564	0.03	95.5	0.005	-1.45	7.40	0.011	0.16	30.00	0	-8.09	7.10	0	-0.12	0.32	0.001	0.03
Waiporohita	18	0.122	0.19	94.65	0.316	1.04	17.25	0.86	-0.05	24.55	0.302	-3.32	6.95	0.357	0.08	1.75	0.228	0.11
<i>Kai iwi lakes</i>																		
Kai Iwi	17.75	0.882	-0.01	96.8	0.135	1.08	20.25	0.232	-0.15	1.50	0.027	0.09	7.05	0.401	-0.01	8.20	0.049	-0.14
Taharoa	17.85	0.111	0.21	100.2	0.207	2.12	19.50	0.685	-0.11	0.75	0.005	0.07	6.46	0.09	-0.02	10.30	0.869	-0.01
Waikere	17.8	0.625	0.03	96.95	0.349	1.59	18.40	0.457	-0.14	1.60	0.084	-0.13	7.10	0.858	0.00	9.10	0.504	0.06
<i>Pouito lakes</i>																		
Humuhumu	19.1	0.935	0.01	96.55	0.205	1.16	21.55	0.732	0.12	2.60	0.807	-0.02	8.10	0.037	0.06	5.50	0.134	-0.18
Kahuparere	18.75	0.57	-0.07	92.15	0.564	-0.51	38.20	0.794	-0.07	10.10	0.634	-0.22	8.10	0.578	-0.01	2.67	0.483	-0.03
Kanono	18.75	0.438	-0.07	99.2	0.492	0.75	28.95	0.017	1.10	7.05	0.89	-0.10	8.50	0.491	0.02	2.55	0.331	-0.74
Kapoi	19.5	0.204	0.19	90.1	0.879	0.37	36.65	0.786	-0.09	64.40	0.264	-5.48	8.70	0.902	-0.01	0.65	0.826	0
Karaka	18.15	0.493	-0.05	98.15	0.063	2.86	30.60	0.352	-0.22	16.60	0.028	11.78	7.90	0.015	0.10	2.57	0.012	-0.27
Mokeno	17.2	0.825	-0.02	97	0.004	1.77	27.30	0.313	-0.26	2.40	0.869	-0.03	7.85	0.053	0.09	3.50	0.488	-0.08
Rotokawau	20.15	0.56	0.1	95.6	0.37	2.38	13.80	0.036	-0.13	2.60	0.096	-0.17	7.20	0.551	-0.03	6.14	0.712	-0.05
Rototuna	20.1	0.33	-0.07	99.3	0.706	0.37	17.35	0	-0.93	10.60	0.036	2.85	7.80	0.861	-0.01	2.65	0.566	-0.03
Swan	19.4	0.592	0.04	90.45	0.035	-1.60	18.35	0.032	0.55	3.70	ID		7.3	0.823	-0.01	3.10	0.08	-0.21
Wainui	19.4	0.45	0.08	97.8	0.904	0.09	44.20	0.144	-1.00	11.20	0.059	-1.41	7.90	0.66	0.02	1.60	0.015	0.25
Whakaneke	15.85	0.85	-0.02	86.55	0.28	1.47	37.10	0.157	-0.50	33.55	0.981	0.08	8.00	0.776	-0.01	0.92	0.274	-0.06

	Temperature (°C)			Dissolved Oxygen (%sat)			Conductivity (ms/m)			Chlorophyll a (mg/l)			pH			Secchi (m)		
	median	p	slope	median	p	slope	median	p	slope	median	p	slope	median	p	slope	median	p	slope
<i>Aupouri lakes</i>																		
Carrot	18.5	0.1	0.21	84.3	0.402	-1.20	18.00	0.047	-0.39	13.00	0.867	0.12	6.65	0.609	-0.02	2.27	0.019	0.12
Heather	18.1	0.103	0.23	96.2	0.004	2.30	18.55	0.003	-0.50	3.80	0.137	-0.26	7.35	0.086	0.09	3.75	0.04	-0.16
Morehurehu	19	0.147	0.17	93.5	0.094	1.33	31.90	0.754	0.18	2.80	0.186	-0.19	6.30	0.093	-0.07	2.72	0.037	-0.25
Ngakapua North	19.1	0.167	0.17	85.9	0.692	-0.25	17.50	0.958	-0.01	5.10	0.41	0.39	6.60	0.712	-0.01	3.66	0.183	-0.11
Ngakapua South	19.3	0.213	0.18	87.2	0.379	-0.55	18.00	0.502	-0.13	5.50	0.416	0.29	6.50	0.464	0.06	3.24	0.002	-0.19
Ngatu	18.6	0.14	0.22	97	0.023	2.12	19.55	0.209	-0.26	2.85	0.041	1.18	7.00	0.026	0.10	3.85	0.003	-0.31
Rotokawau	18.8	0.182	0.24	93.1	0.013	2.21	15.85	0.083	-0.38	3.60	0.393	-0.27	6.90	0.613	0.01	2.49	0.615	-0.02
Rotoroa	17.95	0.081	0.25	96.5	0.3	0.78	29.90	0.588	-0.15	8.40	0.086	1.60	6.90	0.122	0.09	2.09	0.005	-0.33
Te Kahika	19.05	0.253	0.11	87.25	0.027	2.48	68.35	0.478	0.57	1.00	0.37	0.19	3.90	0.202	-0.04	5.49	0.762	0.09
Waihopo	19.4	0.359	0.16	84.6	0.834	-0.03	23.70	0.601	0.21	4.00	0.515	0.17	6.80	0.132	0.05	2.48	0.148	-0.08
Waipara	19.5	0.382	0.09	83.45	0.013	-2.61	16.50	0.588	0.36	2.60	0.04	0.90	6.20	0.48	-0.03	3.32	0	-0.41
Waiparera	17.3	0.752	0.04	98	0.069	1.78	28.70	0.909	0.11	10.25	0.849	0.24	7.31	0.074	0.07	2.10	0.101	-0.07
<i>Karikari/Central lakes</i>																		
Omapere (eastern site)	18	0.287	0.06	95.1	0.001	-1.50	7.30	0.008	0.13	40.00	0	-9.21	7.00	0	-0.11	0.33	0	0.05
Omapere (western site)	18.1	0.564	0.03	95.5	0.005	-1.45	7.40	0.011	0.16	30.00	0	-8.09	7.10	0	-0.12	0.32	0.001	0.03
Waiporohita	18	0.122	0.19	94.65	0.316	1.04	17.25	0.86	-0.05	24.55	0.302	-3.32	6.95	0.357	0.08	1.75	0.228	0.11
<i>Kai iwi lakes</i>																		
Kai Iwi	17.75	0.882	-0.01	96.8	0.135	1.08	20.25	0.232	-0.15	1.50	0.027	0.09	7.05	0.401	-0.01	8.20	0.049	-0.14
Taharoa	17.85	0.111	0.21	100.2	0.207	2.12	19.50	0.685	-0.11	0.75	0.005	0.07	6.46	0.09	-0.02	10.30	0.869	-0.01
Waikere	17.8	0.625	0.03	96.95	0.349	1.59	18.40	0.457	-0.14	1.60	0.084	-0.13	7.10	0.858	0.00	9.10	0.504	0.06
<i>Pouto lakes</i>																		
Humuhumu	19.1	0.935	0.01	96.55	0.205	1.16	21.55	0.732	0.12	2.60	0.807	-0.02	8.10	0.037	0.06	5.50	0.134	-0.18
Kahuparere	18.75	0.57	-0.07	92.15	0.564	-0.51	38.20	0.794	-0.07	10.10	0.634	-0.22	8.10	0.578	-0.01	2.67	0.483	-0.03
Kanono	18.75	0.438	-0.07	99.2	0.492	0.75	28.95	0.017	1.10	7.05	0.89	-0.10	8.50	0.491	0.02	2.55	0.331	-0.74
Kapoi	19.5	0.204	0.19	90.1	0.879	0.37	36.65	0.786	-0.09	64.40	0.264	-5.48	8.70	0.902	-0.01	0.65	0.826	0
Karaka	18.15	0.493	-0.05	98.15	0.063	2.86	30.60	0.352	-0.22	16.60	0.028	11.78	7.90	0.015	0.10	2.57	0.012	-0.27
Mokeno	17.2	0.825	-0.02	97	0.004	1.77	27.30	0.313	-0.26	2.40	0.869	-0.03	7.85	0.053	0.09	3.50	0.488	-0.08
Rotokawau	20.15	0.56	0.1	95.6	0.37	2.38	13.80	0.036	-0.13	2.60	0.096	-0.17	7.20	0.551	-0.03	6.14	0.712	-0.05
Rototuna	20.1	0.33	-0.07	99.3	0.706	0.37	17.35	0	-0.93	10.60	0.036	2.85	7.80	0.861	-0.01	2.65	0.566	-0.03
Swan	19.4	0.592	0.04	90.45	0.035	-1.60	18.35	0.032	0.55	3.70	ID		7.3	0.823	-0.01	3.10	0.08	-0.21
Wainui	19.4	0.45	0.08	97.8	0.904	0.09	44.20	0.144	-1.00	11.20	0.059	-1.41	7.90	0.66	0.02	1.60	0.015	0.25
Whakaneke	15.85	0.85	-0.02	86.55	0.28	1.47	37.10	0.157	-0.50	33.55	0.981	0.08	8.00	0.776	-0.01	0.92	0.274	-0.06

	Dissolved Reactive Phosphorus (mg/m ³)			Ammoniacal Nitrogen (mg/m ³)			Total Nitrogen (mg/m ³)			Total Phosphorus (mg/m ³)			Suspended Solids (g/l)			Trophic Level Index		
	median	p	slope	median	p	slope	median	p	slope	median	p	slope	median	p	slope	median	p	slope
<i>Aupouri lakes</i>																		
Carrot	1	0.007	1*	16	0.005	-10.7	677	0	-54.6	31	0.005	-4	2	0.215	0.22	4.71	0.054	-0.07
Heather	0.5	0.174	0.4	2	0.714	0.1	316	0.128	-13.3	11	0.068	-0.9	1.25	0.294	-0.09	3.63	0.068	-0.06
Morehurehu	0.5	0.06	0.1	6	0.013	2.8	336.5	0.041	12.9	9	0.119	-2.2	1.6	0.589	-0.13	3.57	0.701	-0.01
Ngakapua North	0.5	0.611	0.1	5	0.012	3	514	0.021	15.4	14	0.636	0.6	1.7	0	0.36	4.00	0.101	0.05
Ngakapua South	0.5	0.902	0	6.5	0.028	1.2	554.5	0.365	-7.4	18.5	0.888	-0.2	2.15	0.245	0.13	4.13	0.243	0.03
Ngatu	0.5	0.072	0.1	68.5	0	-41.8	784.5	0.318	-11	11	0.277	-1.5	1.6	0.037	0.27	3.89	0.02	0.06
Rotokawau	0.5	0.725	0	9.5	0.003	3.5	558	0.176	-14.3	11.5	0.192	-1.3	1.5	0.344	-0.19	3.94	0.573	-0.02
Rotoroa	0.5	0.029	1.1*	5.5	0.103	4	748.5	0	38.4	13	0.25	-2.5	2.2	0.183	0.40	4.34	0.101	0.1
Te Kahika	0.5	0.077	0.1	19	0.363	2.6	172.5	0.573	-6.2	2.5	0.072	-4.5	1.2	0.245	-0.19	2.36	0.173	-0.11
Waihopo	1	0.179	0.1	15	0.173	1.7	651	0.095	12.7	19	0.455	1.1	1.9	0.947	-0.01	4.11	0.687	0.01
Waipara	0.5	0.035	0.4*	7	0.237	1.2	474	0.003	31.1	17	0.909	-0.1	0.8	0.025	0.14	3.86	0.002	0.17
Waiparera	1	0.023	0.9*	6	0.097	1.1	822	0.302	12.8	26	0.764	-0.3	2.7	0.414	0.10	4.69	0.202	0.04
<i>Karikari/Central lakes</i>																		
Omapere (eastern site)	5	0.08	11.5	21	0.021	-16.3	1400	0	-274	126	0.627	-2.5	42	0.003	-4.45	6.09	0	-0.19
Omapere (western site)	4	ND		15	ND		1400	0	-219.3	125	0.984	-0.1	43	0.315	-2.10	6.08	0	-0.15
Waiporohita	2	0.159	0.8	6	0.014	-11.7	927	0.001	-199.9	45	0.098	-28.6	5.4	0.02	-3.35	5.13	0.02	-0.19
<i>Kai iwi lakes</i>																		
Kai Iwi	0.5	BD		2	0.736	-0.2	311	0.016	5.8	6	0.927	0.1	0.9	0.508	0.02	2.99	0.019	0.03
Taharoa	0.5	BD		1	0.839	0	141	0.072	-2.6	2	0.731	-0.2	0.55	0.323	-0.03	2.21	0.578	-0.01
Waikere	0.5	BD		2	0.773	-0.2	203.5	0.511	-2.4	4.5	0.83	-0.2	0.7	0.21	-0.07	2.74	0.127	-0.03
<i>Pouto lakes</i>																		
Humuhumu	0.5	0.334	2.2	2.5	0.103	0.2	290	0.179	3.94	12	0.296	3.04	1.8	0.069	-0.19	3.47	0.423	-0.02
Kahuparere	0.5	0.951	0	2.5	0.398	-0.6	401	0.379	-4.41	18	0.074	-1.88	3.5	0.066	-0.33	4.17	0.032	-0.06
Kanono	1	0.36	-0.4	1	0.064	0.7	344.5	0.527	7.24	21.5	0.854	-0.18	3.65	0.614	-1.50	4.14	0.907	0.01
Kapoi	3	0.71	-0.4	17	0.604	21.1	2100	0.663	21.86	126	0.289	3.65	14.5	0.526	-0.43	6.18	0.807	0.01
Karaka	2	0.835	0.1	11	0.244	-7.7	486	0.029	117.65	40.5	0.094	5.73	6	0.337	0.53	4.71	0.127	0.14
Mokeno	2	0.106	5.4	16	0.363	-12.6	548	0.652	-6.91	17	0.551	2.24	2	0.779	-0.10	3.96	0.915	0
Rotokawau	0.5	0.089	3.8	3	0.976	0	334	0.361	-5.23	8.5	0.464	2.6	1.35	0.122	-0.32	3.29	0.732	0.01
Rototuna	1	0.602	7.6	4	0.279	-0.7	607	0	37.58	28	0.759	0.45	4.6	0.318	0.31	4.48	0	0.11
Swan	1	0.317	19.8	4	0.237	10.5	597.5	0.006	91.1	15	0.071	40.5	0.95	0.767	0.06	3.86	0.038	0.22
Wainui	1	0.17	3	3	0.149	3.1	558	0	-38.59	39	0.21	6.85	5.5	0.004	-0.74	4.73	0.006	-0.14
Whakaneke	6	0.106	-9.6	6.5	0.489	0.6	630	0.387	43.54	70	0.237	-13.15	8.75	0.584	-0.49	5.31	0.68	0.02



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