Pouto Lakes'

Catchment Description

Lake Kanono, Pouto - photo credit - Rod Budd, NIWA

Date: **February 2014**

Version: **1.0 (DRAFT)**

Document information:

	Information
Document ID	A
File name	
Prepared for	
Project Manager	Natalie Glover
Contributors	
Peer Reviewers	
Project Sponsor	Tony Phipps
Sign off	Waiora Northland Water Steering Group

Document history:

Version	Issue date	Notes
1	xxx	Draft for catchment group feedback
2		

Table of contents

Figures

Tables

Executive Summary

Under the Resource Management Act 1991 (RMA) Northland Regional Council is responsible for managing the region's freshwater quality and quantity by controlling discharges, water takes and land use activities that impact on water.

Waiora Northland Water is a programme for improving the management of water quality and quantity across the region. It brings together and coordinates a number of Northland Regional Council's water management responsibilities, including its programme for implementing the National Policy Statement for Freshwater Management 2011 (NPS). Waiora Northland Water will include both catchment specific and region-wide approaches to water management.

Northland Regional Council has identified the Pouto Lakes' catchment as an Area of Outstanding Lakes that is one of the Priority Management Areas. The Pouto Lakes have high cultural, ecological, environmental, recreational and intrinsic values, being important regionally, nationally and even internationally. The lakes vary in their water quality, ecological condition and pressures.

Three of the nine routinely monitored lakes are mesotrophic, with moderate nutrient and algae levels and reasonably clear water; Lakes Humuhumu, Rotokawau and Wainui. The remaining six lakes are eutrophic or worse, with high levels of nutrients and algae and poor water clarity. Four lakes have shown recent declines in their water quality; Lakes Humuhumu, Mokeno, Rotootuauru (Swan) and Rototuna. Declines in water quality in Lakes Humuhumu and Mokeno could be linked to recent forest harvesting in their catchments. Lake Rotootuauru has deteriorated both in terms of water quality and ecological condition but this is due to the use of grass carp to remove invasive weeds from the lake. Once the carp are removed, the lake is expected to improve.

Four lakes have outstanding ecological condition; Lakes Humuhumu, Kanono, Mokeno and Rotokawau and two lakes have high ecological condition; Lakes Kahuparere and Karaka. These six lakes and their surrounding wetlands support a range of endemic endangered plant and fish species, including nationally important populations. They also provide habitat for many threatened and regionally significant birds. However, the habitat quality varies; with some having high quality riparian and emergent wetland vegetation that buffers inputs into the lake, while others have very little emergent vegetation and still have stock access to the lake margins. In general, they have relatively limited impact from invasive weeds and fish.

The major threats to the lakes are nutrient enrichment from surrounding pastoral farming and forestry, and pest plant and fish incursions. There is evidence that suggests that recent forest harvesting in the catchments of several Northland dune lakes has led to significant deterioration in water quality and ecological condition of the lakes. The impacts of forestry and the extent of the groundwater resources are major information gaps that could hinder the ongoing management of the Pouto Lakes.

As catchment description is developed – the executive summary should be fleshed out to include

- *Management unit description [management unit approach; identify which management units are addressed in this document]*
- *Summary of key issues [high level overview of key features identified, ie*

quality/quantity issues. What are the key problems/]

- *Proposals for future management*
    - *Objectives(s) [state desired highest level goal to be achieved through management tools eg "be able to harvest shellfish at most sites by 2050" or "water quality to be assessed as suitable for full contact recreation in 100% of monitoring results by 2030"]*
    - *Limits [explain what limits need to be implemented in order to achieve targets]*
    - *Targets [state metric measure; targets should be progressive/staged where appropriate]*
    - *Management tools [describe methods by which limits will be introduced eg plan change rules, consent conditions, non-regulatory methods etc]*
    - *Implementation costs and timeframes [gantt style chart outlining implementation of management tools and predicted costs]*

1 Introduction

1.1 Background

Waiora Northland Water

Waiora Northland Water is a programme for improving the management of water quality and quantity across the region. It brings together and coordinates a number of Northland Regional Council's water management responsibilities, including its programme for implementing the National Policy Statement for Freshwater Management 2011 (NPS).

The NPS requires Northland Regional Council to establish freshwater objectives and set associated water quality and quantity limits for every stream, river, lake, wetland, and aquifer across the region. It then requires Northland Regional Council to implement regulatory and non-regulatory actions to achieve the freshwater objectives.

Northland Regional Council has committed to an approach that involves setting a combination of specific limits in priority catchments and region-wide interim and/or default limits for other freshwaters. Northland Regional Council is also aware of the strong correlation between freshwater and coastal water in Northland, especially given that all of region's major river systems drain to estuaries and harbours. The proposed Regional Policy Statement for Northland (proposed RPS), notified in October 2012, establishes a framework for the integrated management of fresh and coastal waters, including by identifying a number of regulatory and non-regulatory actions to be implemented by Northland Regional Council.

Actions include policies, regulations, and incentives. Achieving objectives is also dependent on a good deal of landowner and community commitment. Robust information is critical to the limits setting process and very important to assess the on-going achievement of freshwater objectives.

Northland Regional Council has identified the Pouto Lakes' catchment as an Area of Outstanding Lakes that is one of the Priority Management Areas (Figure 1). Priority Management Areas are to receive a specific approach that may include establishing catchment groups to provide local input into implementing the Waiora Northland Water (WNW) programme.

Figure 1 NRC Priority Management Areas

1.2 Purpose of this document

This document has been prepared to provide an up-to-date overview of the Pouto Lakes catchment, describing landuse, water quality and ecological monitoring results, locations of water related consents, and the context for decision making and water management within the Waiora Northland Water Programme.

The catchment description is intended to inform the Pouto Lakes Catchment Group of current NRC knowledge concerning the catchment's freshwater quality and allocation inviting representatives of the group to contribute their local knowledge and identify knowledge gaps.

2 The Pouto Lakes' catchment

2.1 Overview

The Pouto Lakes' catchment is located approximately 50 km south of Dargaville on the Pouto Peninsula, the northern head of the Kaipara Harbour. The boundary of the catchment used for this report is biologically meaningful. It was created by grouping together river and lake catchments of similar ecological characteristics using the Freshwater Ecosystems of New Zealand (FENZ) database.

There are about 50 dune lakes over 1 hectare in size on the Pouto Peninsula. The lakes have mainly formed in basins where newer mobile sand has dammed streams flowing on older, stabilised sand. The majority of the lakes, especially those of higher ecological value, are found near the southern most end of the Peninsula. In general, the Lakes have high cultural, ecological, environmental, recreational and intrinsic values but range in their current water quality and ecological condition. Dune lakes are internationally rare but in addition Northland dune lakes represent a large proportion of New Zealand's warm lowland lakes with reasonably good water quality (Champion & de Winton 2012). They provide habitat for a range of endangered species and in general have minimal impact from invasive plants and fish.

There are several small streams that flow into the dune lakes or flow directly to the Tasman Sea or Kaipara Harbour. There is very little information for these streams. The groundwater is contained in an unconfined shallow sand aquifer and likewise there is very little information on groundwater resources for Pouto Peninsula.

The dominant land uses in the catchment are exotic forestry and pastoral farming, particularly dairy and beef farming. There is a low human population in the Pouto Lakes Catchment and none or very little pressure from subdivision development. The greatest pressures on the lakes are the impacts of farming and forestry and the risk of invasive plants and animals being introduced to the lakes.

3 Surface water

3.1 Waiora Northland Water resources

The fresh water resources in Northland can be found in three broad forms: rivers and streams, lakes and wetlands, and groundwater.

Northland has a dense network of rivers and streams, many of which are relatively short, with small catchments. Most of the major rivers have their outlets into harbours; few discharge directly to the open coast. The Northern Wairoa River is Northland's largest river. It drains a catchment area of some 3650 square kilometres, or 29% of the land area in Northland.

Northland has a large number of small and generally shallow lakes and associated wetlands, most of which have been formed between stabilised sand dunes along the west coast. These dune lakes are grouped on the Aupouri, Karikari and Pouto Peninsulas. They vary in size, with the majority being between 5 and 35 hectares in area and generally 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 hectares and being 37 metres deep.

There are three main types of geological formations associated with groundwater in Northland. These are sands and gravels, volcanic cones and related lava flows and sedimentary rocks such as greywacke and limestone. The main aquifers (rocks which store water) are the Aupouri sands, Kaikohe basalts and Whangarei basalts. There are a number of smaller sand and gravel coastal aquifers such as those at Russell, Matapouri, Taipa and Ruawai. A number of smaller less productive greywacke aquifers are situated throughout the region.

4 Geology

The long dunes and sand terraces of the Pouto Peninsula form the northern barrier of the Kaipara Harbour, which originally was an open embayment (Edbrooke and Brooke 2009). The peninsula was formed by successive layers of sand drifting in over the top of older dunes, some of which have been topped with esturine and marine sand sediments. The Peninsula ranges in width to a maximum of 10km and is mostly up to 150m high, with some elevations of 200m in the south. The barrier contains mobile and fixed dunes on the western sea side and a mixture of dune, lake, fluvial and estuarine sediments on the eastern harbour side (Figure 2). The Peninsula consists of the loose to poorly consolidated sands of the Holocene windblown deposits, the cemented, dune-bedded sandstone of the Neogene sedimentary rocks (Awhitu Group) and early Pleistocene windblown sand deposits.

There are outcrops of three lignite beds associated with the cemented sand layers in the coastal cliffs further north on the peninsula. These beds act as an aquicludes, as can be seen by the water running from above them on the cliffs, and it is possible that they too influenced the formation of the lakes.

The soils that have developed have been influenced by the origin of the sand (its source varies with the age of the dunes), age of the dunes and the vegetation that has historically been present. The soils follow a sequence from west to east becoming progressively older and more poorly drained. The younger sands on the western side of the peninsula overlay layers of the older sands, except for the lower 25 km of the peninsula where sand is continuing to build the coastline seaward.

Most of the dune lakes on Pouto Peninsula have formed in basins in the consolidated Pleistocene dunes, the exceptions being Lakes Humuhumu, Kanono and Kahuparere. These three lakes formed in the depressions created where mobile Holocene dunes moving in from the west coast have pushed up against the older, consolidated Pleistocene dunes that were already present. This has occurred at least three times, with different waves of dunes, and resulted in a distinct difference in the geology and soil types between dune lakes generally, but only once in respect of these lakes, leading to the south-west side of the lakes being different to the north-east side.

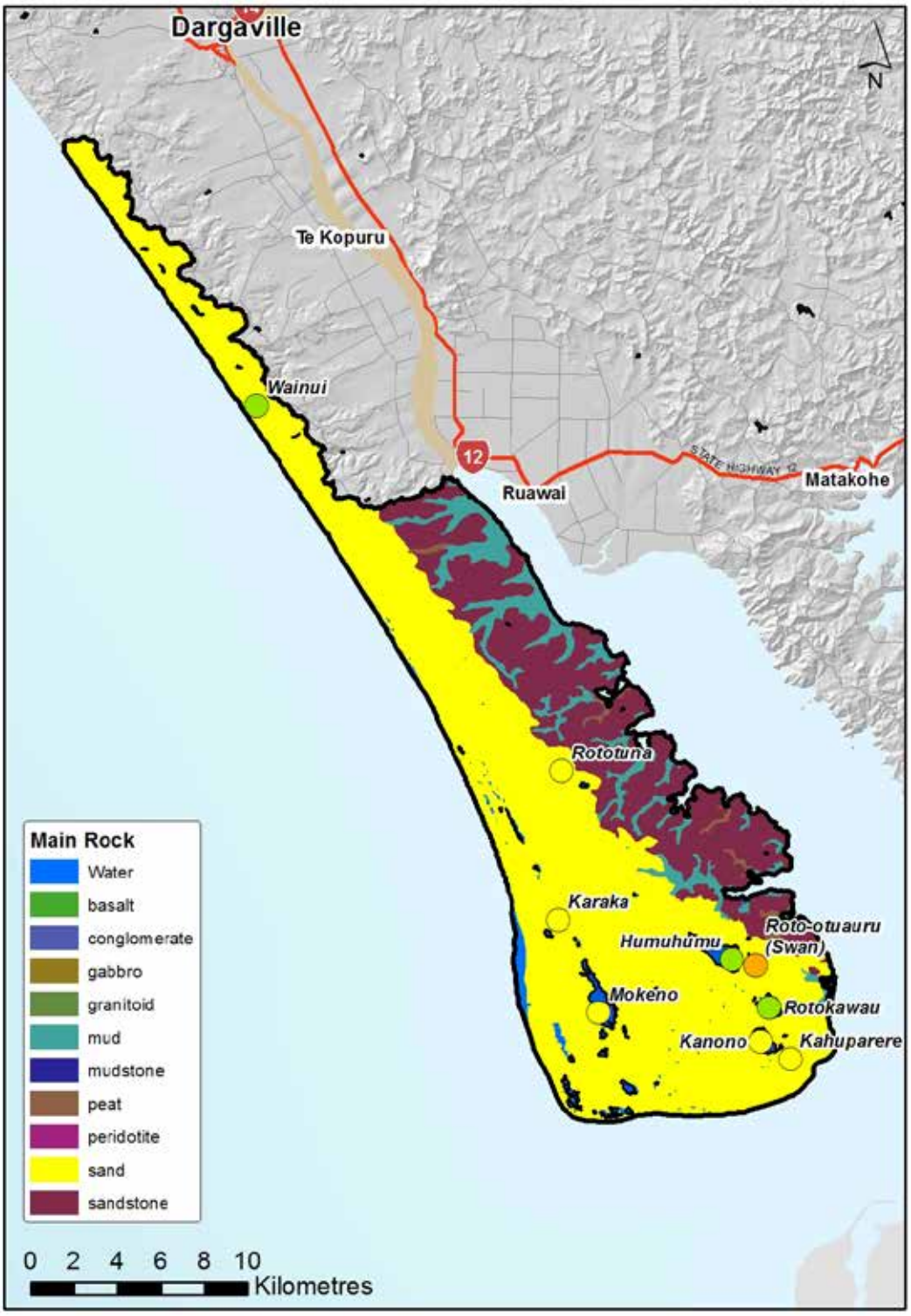

Figure 2 Geology of the Pouto Lakes catchment area

5 Soils

Northland lies outside New Zealand's belt of vigorous geologic activity and has, for millions of years, remained relatively calm. The low relief, the absence of any deposits from recent ash showers, the warm moist climate and the original vegetation have combined to cover much of Northland in strongly leached, mature, heavy clays. Generally, topsoils are thin and subsoils are of low fertility. The main exceptions are the fertile volcanic soils, young alluvial deposits and the young soils developing on unstable steep slopes. The soils formed on more stable but relatively recent dunes and areas of dunes that were still mobile in the 1960s are also an exception.

5.1 Soil types

The soils on the Pouto Peninsula fall into two broad categories: sands on the rolling hills and organic soils in the low-lying basins. The sand is recent and can be divided into four stages of development and drainage (Smale et al. 2009). The youngest and still too early to be considered a 'soil' are the dune sands that were still moving in the 1960s, some of which were 'blow outs' of older Pinaki sands and some 'new' sand dunes. The youngest to be considered a 'soil' is Pinaki sand, which is well drained and, while beginning to accumulate organic matter, is not old enough to have developed soil structure. The oldest are podzolised, poorly drained and acidic Te Kopuru sand on the terrace and ridge tops and mature but not as heavily podzolised Tangitiki sands on the valley sides. Intermediate between Pinaki and the podzolised soils is the Red Hill sand, which is a well drained and mildly acidic soil formed under broadleaf bush. As Red Hill, Te Kopuru and Tangitiki soils on the Pouto Peninsula all, in places, overlay deep loose sands, they are prone to severe gully erosion. The organic Parore peaty sandy loam, which is poorly drained acidic peat, occurs in the intervening shallow basins between the sands and in the deeply entrenched valleys.

5.1.1 Pinaki sands

The dune sands on the south-west side of Lakes Humuhumu and Kanono are unconsolidated well draining and nearly neutral. Prior to the planting of *Pinus radiata* in the 1970's this area was raw, mobile dunes. These dunes would have encroached over the top of existing consolidated material or, in places, had been covered in Pinaki sand from which the surface soil had eroded, exposing old dune sand. Under some of these dunes and at some depth below the surface will be the older, consolidated material, both Pinaki-age and Red Hill-age dunes. Red Hills soils, formed on iron sands weathered to produce allophane clays and often developed and iron sub-soil pan. This combination of clay and iron pans is likely to impact upon groundwater movement, the direction of groundwater flow being influenced by the slope and aspect of these previous dunes and soils formed on them.

As these raw sands and the Pinaki sands they have covered in places are very low in both organic matter and clay minerals, they have very limited ability to retain nutrients applied to the soil. By nature they are free draining with very low water holding capacity. The crop of pines would have increased the soil organic matter content from the roots of the pines, mycorrhizal fungi and needle fall. This fresh organic matter will decompose relatively quickly in these sandy soils. This decomposition of organic matter will result in the nutrients being mineralised into a more soluble and plant available form. Water will quickly drain through this sand until it hits a deeper layer of older sand that has a clay and/or iron pan.

5.1.2 Red Hill sandy loam

To the east and north-east of the Lakes Humuhumu and Kanono the predominant soil type is Red Hill sandy loam. This soil is derived from iron-rich sand but has had sufficient time to develop into a more complex soil under broadleaf forest. The iron-rich sands have weathered to allophane, a form of clay that enhances the soils ability to retain phosphate and stop it from leaching into the groundwater. These soils are well drained and well suited for farming. Use for farming will, however, lead to an increase in nitrogen leaching to the ground water. Care is required to minimise erosion and soil loss, particularly under arable farming or cropping, as sediment washed from the land will be rich in phosphate.

5.1.3 Parore peaty sandy loam

To the north of Lake Humuhumu and between Lake Humuhumu and Lake Rotopouua are areas of Parore peaty sandy loam. This is a soil high in organic matter that has formed in the low lying dune depressions, where a high water table has led to an accumulation of organic matter, but have also received sand-rich runoff. These wetland areas are still largely in native vegetation and play a valuable roll in filtering surface water entering the lakes from the pastoral areas. The organic matter (plants and algae) retains the phosphorus and in the right conditions denitrification can occur converting the nitrates into nitrogen gas. It is likely that there is also organic matter on the lake bed for Lake Humuhumu and nearyby lakes.

5.1.4 Tangitiki and Te Kopuru soils

The old and moderately podzolised Tangitiki soils run along the middle of the peninsula, buried by Red Hill sands, which in turn are buried by Pinaki sands, and the Pinaki sands by more recent dune movement. The Tangitiki soils are usually rolling to steep, with some very steep escarpments. The extent of podsolization is determined by slope and the historical presence or absence of kauri trees (*Agathis australis)*. Generally, Te Kopuru sand is found on the broader ridge and terrace tops and the less podzolised Tangitiki sand on the steeper valley sides.

The oldest of all the soils, the Te Kopuru soils, are found along the harbour side of the Peninsula. Te Kopuru soils are podzolised with a dense, cemented silica sand pan and can also have an iron pan below the silica pan. The Tangitiki soils are progressively more podzolised with less iron remaining in the upper soil horizons and more iron pan formation in the subsoil. Beneath both, however, the sand can be quite loose, as evidenced by the large tomos/tunnel gullies which have developed on the Te Kopuru soils.

5.2 Erosion potential

A large proportion of the Pouto Lakes Catchment is identified as erosion prone land (Figure 3), in the main due to the soil types. Much of the area now in pines was mobile dunes or eroded Pinaki sand before being planted in pines in the 1980s, the dunes first being stabilised with marram grass in the 1970s. These sands are susceptible to erosion and while the potential for erosion has been reduced with the pine forestry, careful management is still required, particularly during harvesting. Some other areas of the catchment, particularly on steeper slopes, are susceptible to sheet and gully erosion, so again careful management is needed, particularly in terms of stocking rates and vehicle tracks.

In the past foreshore erosion on the shores of Lake Humuhumu and Kanono has been a problem, wave-lap of soft edges trampled by cattle, but this has been alleviated where the lake margins have been fenced.

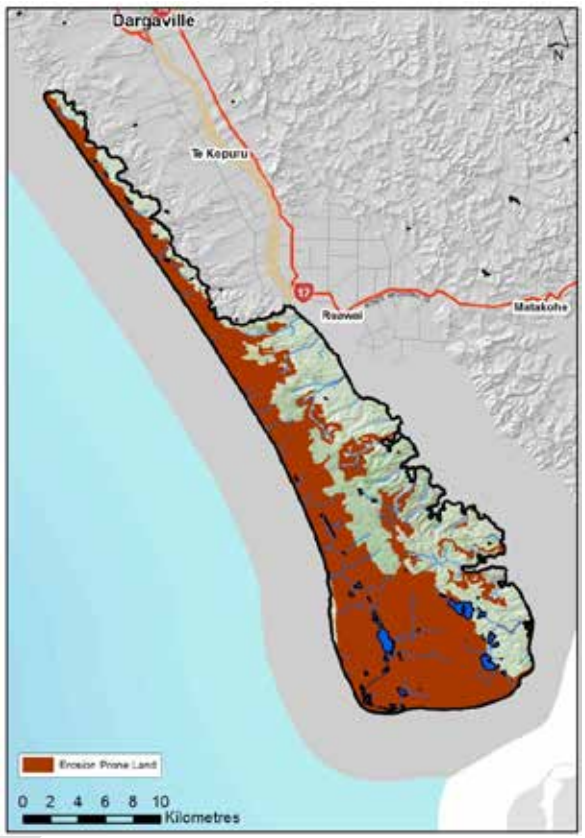

Figure 3 Erosion prone land in the Pouto Lakes' Catchment

6 Land use

Northland has a very complex geology and physical structure which results in a wide variety of landforms, soil types and associated land uses. In Northland, farming, forestry and horticulture collectively contribute 13.7% of the Gross Domestic Product (GDP) of the region.

The future of these industries depends on maintaining the productive capacity of Northland's soils. The consequence of poor soil management is not only the loss of productivity but also an increased environmental impact including the downstream degradation of water quality.

6.1 Land use pressure on water quality and biodiversity

Intensification of land use can impact on water quality and indigenous biodiversity in a number of ways. Although in recent years there has been retirement and regeneration of some areas of marginal land, this has often been negated by the intensification of land use on the more productive areas. Increased fertiliser use and the corresponding increase in stocking rates can lead to higher levels of loss of effluent and nutrients from farms to surrounding areas.

Dune lakes, gumlands, bogs and fens are examples of some of the habitat types in Northland that are particularly at risk. These ecosystems have developed under naturally low fertility conditions and the plant and animal species present are adapted to these conditions. Nutrient enrichment brought about through the intensification of land use within the catchment can lead to rapid invasion by weeds leading to a system dominated by introduced species.

The Pouto Lakes' catchment consists predominantly of *Pinus radiata* forestry (34%) and pastoral farming (38%), with a mixture of sheep, beef and dairy farming (Table 1, Figure 4). The remaining quarter of the catchment area is mainly natural land cover, including large areas of manuka/kanuka scrub and small areas of indigenous forest, coastal sand dunes and wetland vegetation.

Table 1 Landcover in the Pouto Lakes' Catchment (LCDB3 2013)

Land cover description	Area (ha)	Percentage of Pouto Lake catchment
Grassland	13,310	38.3
Exotic forestry	11,823	34.0
Indigenous vegetation	4,750	13.7
Sand & gravel	2,882	8.3
Water & aquatic vegetation	1,682	4.8
Miscellaneous[1]	321	0.9
Total	34,768	

[1] Includes settlements, parklands, crops and other exotic vegetation (other than forestry)

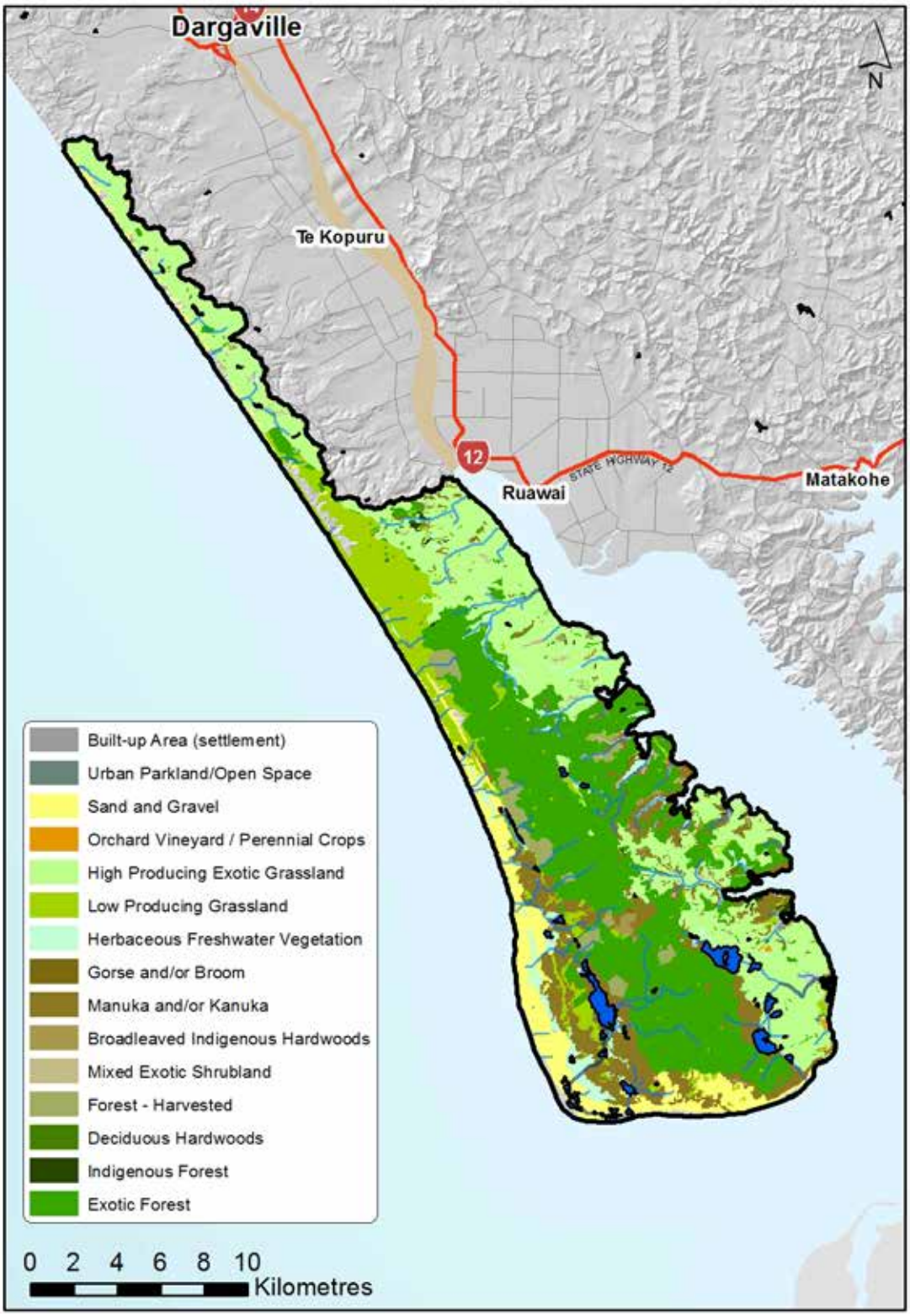

Figure 4 Land cover in the Pouto Lakes' catchment (LCDB3 2013).

Stock access to the lake margins is a major concern for dune lakes, as not only does this input nutrients and bacteria directly into the water, it also degrades surrounding wetland and emergent vegetation on the lake margins; reducing biodiversity values, degrading important littoral habitat for birds, fish and invertebrates and reduces the buffering of groundwater and surface inputs into the lake. While nutrient run-off and/or leaching from surrounding pastoral and forestry land is a significant concern

for the relatively closed and sensitive system of dune lakes, there are many other potential impacts associated with forestry.

In general, potential pressures associated with forestry (Champion and de Winton 2012, Collier 1996) include:

- reduced water inputs causing declining lake levels
- shelter by trees reducing lake mixing
- increased nutrient inputs from fertilizer use and following harvesting
- increased sediment loads following harvesting
- impact of shading and then sudden light exposure following harvesting
- nutrient release and inputs due to the death of mycorrhizae (associated with the pine tree roots) following harvesting.

There are several examples of significant declines in water quality closely following forest harvesting in dune lake catchments, such as in Lakes Te Kahika, Morehurehu, Mokeno, Humuhumu and Kai iwi. Further research into the causes of the water quality declines and what management is required to reduce the impacts on dune lakes should be a priority. This could be studies on lake catchments already undergoing harvesting and declines in water quality e.g., Lakes Humuhumu or Mokeno, or lakes which have catchments due to be harvested in the near future, e.g., Lake Waingata near Waipoua.

7 Current monitoring in the catchment

Northland Regional Council currently undertakes the following monitoring in the Pouto Lakes' catchment:

- **Lake Water Quality Monitoring Network** (LWQMN) established in 2005. Twenty eight lakes throughout Northland are monitored four times a year for a range of parameters including total and dissolved nutrients, chlorophyll α, suspended solids, water clarity, pH, temperature and dissolved oxygen. This monitoring includes one location at the deepest point in each lake. Each lake is sampled at the surface and bottom and temperature/dissolved oxygen profiles are done. Nine Pouto Lakes are currently monitored as part of the LWQMN. Monitoring of Lakes Kapoai and Whakaneke ceased in March 2011. Annual reports are available here: www.nrc.govt.nz/Resource-Library-Summary/Environmental-Monitoring/State-of-the-Environment-Monitoring/

- **Lake Ecological Condition** (LakeSPI) monitoring, started in 2004/05 and is now carried out on 86 lakes throughout Northland, on a rotational basis, including all the lakes in the LWQMN. 17 Pouto Lakes have been assessed. Annual reports are available here: http://www.nrc.govt.nz/lakedata

- **Weed surveillance** began in 2006 and is carried out annually on 8 priority lakes in the LWQMN. This includes Lakes Humuhumu and Rotootuauru on the Pouto Peninsula and includes checking the main access points for weed incursions. Annual reports are available here: http://www.nrc.govt.nz/lakedata

- **Hydrological monitoring.** Water levels are manually measured monthly for Lakes Rototuna, Kahuparere, Kanono, Waingata, Rotokawau, Swan and Humuhumu but less frequently during winter months. Rainfall is recorded at Pouto Point Navigational Beacon at five minute intervals and telemetered to the NRC database every hour. In addition historical rainfall data are available from nine rainfall stations. Eight stations have records varying from 2 to 6 years and one station with 24 years of record. Rainfall distribution throughout the Pouto Peninsula varies from 1,100 mm/year at Pouto Point to 1,250mm at Dargaville.

Together, the information is central to assessing the state of the Pouto Lakes. The data obtained through these programmes and consent monitoring has been used to provide an overview of water quality and ecosystem health in these lakes.

8 The lake ecosystem and water quality

The ecological health, or integrity, of lake ecosystems are related to a number of environmental factors including, but not limited to, the availability of suitable habitat types (e.g. diverse range of emergent and submerged indigenous plants), lack of invasive exotic species, disturbance and high water quality. It is important to note that the relationship between ecosystem health and environmental factors is often very complex and unpredictable.

Lake water quality parameters of concern in terms of ecological health are, in no particular order, temperature and dissolved oxygen, clarity, nutrients, suspended solids and chlorophyll α levels. Faecal pathogens are not known to affect aquatic ecosystems, but do affect the suitability of a water body for swimming and stock drinking water.

8.1 Lake stratification

Lakes can become stratified. Stratification occurs when cold water at the bottom and warm water at the top of a lake form two layers that do not mix. This usually happens during summer, when warmer less dense water, sits on top of colder, denser water with a thermocline separating them. Because the warm water is exposed to the sun during the day, a stable system exists, with very little mixing of warm and cold water, particularly in calm weather. The two layers mix again, either when temperatures in the two layers equalise during autumn/winter or due to turbulence from wind.

This is an important characteristic to monitor in lakes, because while stratified the bottom layer in the lake can become anoxic (low oxygen levels), leading to the release of nutrients from the sediment into the bottom layer. Then when the lake mixes again, these nutrients suddenly become available for algal and plant growth throughout the water column. The temperature/dissolved oxygen profile is used to determine whether or not a lake is stratified.

8.2 Trophic Level Index

The Trophic Level Index (TLI) can be used to determine the state of lakes (Burns et al. 2000). The TLI is calculated using four key variables: chlorophyll α (indicator of algal biomass), water clarity, total nitrogen (TN) and total phosphorus (TP). 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. The states of most relevance for the Pouto Lakes are (Table 2):

- Oligotrophic lakes, which have low levels of nutrients and algae
- Mesotrophic lakes, which have moderate levels of nutrients and algae
- Eutrophic lakes, which 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
- Hypertropic 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 2 Trophic states relevant to Pouto lakes and the water quality ranges that define each trophic level (Burns et al. 2000)

Lake type	Trophic level	Chlorophyll α (mg/m^3)	Clarity (m)	TP (mg/m^3)	TN (mg/m^3)
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

8.3 Water Quality trends

Trends are determined by using the seasonality trend test in TimeTrends which removes the effects of seasonal variation. The trend test calculates a p-value and the slope. P-values less than 0.05 indicate a statistically significant trend, with the slope indicating the change in the variable per year. A negative slope value indicates a decreasing trend and a positive slope value indicates an increasing trend**.**

8.4 Ecological condition

Lake Submerged Plant Indicator (LakeSPI) is a bio-assessment tool that uses submerged plants to assess ecological condition and monitor trends in New Zealand lakes (Wells and Champion 2012). The overall LakeSPI Index provides a measure of how close a lake is to its potential (unimpacted by human) state. It is calculated from two indices, the:

- Native Condition Index, which is a measure of the diversity, quality and abundance of indigenous submerged vegetation. A higher score means a healthier, more diverse community of native plants growing to greater depths.
- Invasive Impact Index, which measures the impact by any of ten invasive exotic plants. A higher score means more impact from exotic plants.

Lakes are assigned to one of five classes of lake ecological condition based on their LakeSPI Index score of either; non-vegetated (0%), poor (>0-20%), moderate (>20-50%, high (>50-75%) or excellent (>75%).

In addition to LakeSPI, 17 Pouto Lakes have been assessed by NIWA since 2004 for their ecological values, initially using the Lake Biodiversity Assessment but more recently using the Lake Ecological Value Assessment (Champion and de Winton 2012, Wells and Champion 2013). The Lake Ecological Value Assessment assigns scores to each lake for the following eight criteria:

- aquatic vegetation diversity (number of indigenous species)
- aquatic vegetation integrity (Native Condition Index component of LakeSPI)
- endangered species (presence of endangered plant and fish species)
- habitat size (lake area and depth)
- buffering (percentage of native vegetation in catchment and extent of wetlands and emergent vegetation in lake area)
- water quality (Trophic Level Index)
- presence of the freshwater mussel *Hyridella menziesii* (important for filtering nutrients and algae from the water)
- connectivity (closeness to other lakes and wetlands).

These scores are totaled to give a total Ecological Value Score out of 20. Based on this total score each lake is given a rating of either; low (<4), low to moderate (4-5), moderate (6-7), moderate to high (8-9), high (10-11) or outstanding (12-20).

Typically outstanding lakes are nationally important, containing a diverse indigenous biota with self-sustaining populations of endangered species. Low ranked lakes are either de-vegetated with poor water quality or severely impacted by exotic pest species. Of the 86 lakes throughout Northland assessed by July 2013, 12 were rated as having outstanding and 17 high ecological value[2].

8.5 Lake Humuhumu

Lake Humuhumu is the deepest Pouto Lake, with a maximum depth of 16 metres. 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. About 41% of the surface water catchment is in native vegetation, 28% is in pastoral land use (beef and dairy) and about 30% is used for pine forestry (FENZ database, Champion and de Winton 2012). The lake is fenced with no stock access.

Lake Humuhumu is classified as having 'outstanding' ecological value in the Northland Lakes Strategy (Champion and de Winton 2012) and is listed as a dune lake in Schedule E of the RWSP and therefore subject to controls on water takes.

8.5.1 Water quality

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 usually mixes in March or April. Based on data from the last five years, Lake Humuhumu is classified as mesotrophic with moderate levels of nutrients and algae (Table 3).

Table 3 Minimum, maximum and median results for surface samples from Lake Humuhumu collected between September 2008 and August 2013

Parameter	Min	Max	Median
Temperature (°C)	12.6	24.6	16.4
Dissolved Oxygen (% sat)	83.3	107.6	97.9
Chlorophyll a (mg/l)	1.7	10.8	3.6
Water Clarity (m)	2.2	6.5	3.8
Total Nitrogen (mg/m^3)	261	355	304.5
Total Phosphorus (mg/m^3)	6	120	11
Ammoniacal Nitrogen (mg/m^3)	<1	17	3
Nitrate Nitrogen (mg/m^3)	0.5	15	1
Dissolved Reactive Phosphorus (mg/m^3)	0.5	85	0.5
Suspended Solids (g/m^3)	0.5	2.5	1.7
Conductivity (mS/m @ 25°C)	21.3	26.2	22.4
pH	7.0	8.7	8.2
Trophic Level Index	3.16	4.07	3.57

[2] Some of these ratings are based on the earlier Lake Biodiversity Assessment method used by NIWA.

Data from 2005 to 2013, suggests that water quality in Lake Humuhumu has deteriorated slightly (Table 4). An increasing trend in ammoniacal nitrogen and total nitrogen was detected of 0.2 mg/m^3 per year (6.7% of median) and 5.7 mg/m^3 per year (1.9% of median) respectively. A decreasing trend in water clarity of 38 cm per year (8.9% of median) was also detected. However, a TLI score of 3.62 for the last two years of data is still indicative of a mesotrophic lake.

Table 4 Trends for December 2005 to August 2013 for the nine Pouto lakes in the LWQMN. A green arrow indicates an improving trend and a red arrow indicates a deteriorating trend. An empty cell indicates no significant trend. See Appendix 2 for all trend results.

Parameter	Humuhumu	Kahuparere	Kanono	Karaka	Mokeno	Rotokawau	Rototuna	Swan	Wainui
Temperature									
Dissolved oxygen				↑	↑				
Conductivity									
Chlorophyll a					↑			↑	↓
pH									
Clarity	↓			↓	↓		↓	↓	↑
Dissolved reactive phosphorus									
Ammoniacal nitrogen	↑						↑		
Total nitrogen	↑				↑	↑	↑	↑	↓
Total phosphorus		↓					↑	↑	↓
Suspended solids						↓		↑	↓
Trophic Level Index					↑		↑	↑	↓

8.5.2 Ecological condition

Lake Humuhumu has a ranking of 'outstanding' due to its size, extent of native vegetation in catchment, buffering from wetlands and emergent plants, water quality and because it contains a diverse range of biota, including nationally rare plants, fish and birds (Table 5) with no major pest species (Wells and Champion 2013). In addition, nine aquatic invertebrates have been recorded, including crayfish (*Paranephrops planifrons*), mussels (*Hyridella menziesii*), the snail (*Glyptophysa variabilis*) and jellyfish *(Craspedacusta sowerbyi).* The introduced Australian golden bell frog (*Litoria aurea*) has also been recorded at Lake Humuhumu (McGlynn and Pingram 2013).

The lake has a very high diversity of indigenous aquatic plants (including emergent, free-floating and submerged) with 26 species recorded to date and emergent vegetation around 70% of the Lake's perimeter. This is evident in the most recent (2012) 'high' LakeSPI score of 72%. The Native Condition Index has remained at 66% since 2005. However, the ecological condition overall has declined slightly from

81% in 2005, due to the presence of the invasive species *Potamogeton crispus* and *Utricularia gibba.*

Table 5 Bird and fish species identified in Lake Humuhumu (Green = rare, endangered or regionally significant (Champion et al. 2012))

Native Species	Exotic Species
dabchick (*Poliocephalus rufopectus*)	
bittern (*Botaurus poiciloptilus*)	
caspian tern (*Sterna caspia*)	
spotless crake (*Porzana tabuensis plumbea*)	
scaup (*Aythya novaezeelandiae*)	
fernbird (*Bowdleria punctata vealeae*)	
common bully (*Gobiomorphus cotidianus*)	
dwarf inanga (*Galaxias gracilis*)	

8.5.3 Threats

The overall threat/pressure score in the Northland Lake Strategy for Lake Humuhumu is moderate (Champion and de Winton 2012). Current threats include introduction of pest fish and plants and nutrient enrichment from surrounding forestry and farming land use. The closest threats being Lake Rototuna in terms of the pest fish, *Gambusia affinis.*

Lake Rotootuauru (commonly known as Lake Swan) is the nearest threat in terms of invasive pest plants. However, the removal of *Ceratophyllum demersum* and *Egeria densa* from Lake Rotootuauru by grass carp has reduced this risk to negligible (Wells and Champion 2013). Annual pest plant surveillance is carried out at the access point on the eastern side of Lake Humuhumu. The 2013 surveillance recorded two pest species; alligator weed (Alternanthera philoxeroides) and the submerged species *U. gibba*, both of which could threaten indigenous vegetation in sheltered margins of the lake. Alligator weed has spread since being first noted in 2005, with it now abundant amongst marginal vegetation. *U. gibba* is growing over submerged indigenous vegetation but is not yet abundant (Wells and Champion 2013).

There is a high risk of nutrient enrichment from pine forestry and pastoral land use in the catchment. There has been recent forestry harvesting in the catchment. It is possible that the declines in water quality are related to this harvesting.

8.6 Lake Kahuparere

Lake Kahuparere is small (9.4 ha) with a maximum depth of 7.5 m. The Lake's catchment is dominated by pasture and forestry with some native scrub. The riparian margin was fenced in 2009 and there is dense emergent vegetation around the lake edge. Lake Kahuparere is classified as having 'high' ecological value in the Northland Lakes Strategy and is listed as a dune lake in Schedule E of the RWSP and therefore subject to particular controls on water extractions.

8.6.1 Water quality

Lake Kahuparere generally stratifies in October/November with anoxia of the bottom water occurring, and then mixes in March/April. Based on the last five years, Lake Kahuparere is classified as mesotrophic to eutrophic with high levels of algae and

moderate nutrient levels (Table 6). The TLI for the last two years of 3.91 is also indicative of a mesotrophic to eutrophic lake.

Table 6 Minimum, maximum and median results for surface samples from Lake Kahuparere collected between September 2008 and August 2013

Parameter	Min	Max	Median
Temperature (°C)	12.6	24.1	17.2
Dissolved Oxygen (% sat)	79.6	105.1	95.2
Chlorophyll a (mg/l)	2.2	17.2	9.7
Water Clarity (m)	2.0	4.8	2.8
Total Nitrogen (mg/m³)	297	475	376
Total Phosphorus (mg/m³)	8	32	14
Ammoniacal Nitrogen (mg/m³)	0.5	64	3
Nitrate Nitrogen (mg/m³)	0.5	14	0.75
Dissolved Reactive Phosphorus (mg/m³)	0.5	1	0.5
Suspended Solids (g/m³)	0.5	7.6	2.7
Conductivity (mS/m @ 25°C)	36.1	46.2	39.4
pH	7.0	8.5	8.1
Trophic Level Index	3.36	4.56	4.05

Data from 2005 to 2013 suggests that water quality in Lake Kahuparere has remained reasonably stable (Table 4). A decreasing trend in total phosphorus of 1.6 mg/m^3 per year (9.4% of median) was detected; however, no other significant trends were recorded.

8.6.2 Ecological condition

Lake Kahuparere has a ranking of 'high' due to the extent of native vegetation in its catchment, buffering from wetlands and emergent plants and because it contains a reasonably diverse range of biota including nationally rare plants, fish and birds (Table 7) (Wells and Champion 2013). The following aquatic invertebrates have also been recorded; crayfish (*Paranephrops planifrons*), mussels (*Hyridella menziesii*), the snail (*Glyptophysa variabilis*) and dragonfly nymph (*Procordulia* sp.).

Table 7 Bird and fish species identified in Lake Kahuparere (Green = rare/endangered species)

Native Species	Exotic Species
dabchick (*P. rufopectus*)	eastern little tern (*Sternula albifrons sinensis*)
bittern (*B. poiciloptilus*)	pukeko (*Porphyrio melanotus*)
caspian tern (*S. caspia*)	
spotless crake (*P. tabuensis plumbea*)	
scaup (*A. novaezeelandiae*)	
common bully (*G. cotidianus*)	
dwarf inanga (*G. gracilis*)	

The lake has a moderate diversity of indigenous aquatic plants (including emergent, free-floating and submerged) with 8 species recorded to date and emergent vegetation around the entire lake margin. The LakeSPI scores have declined from 88% (excellent) in 2005 to 38% (moderate) in 2012 due to the discovery of *U. gibba* in 2007 and one surveyed profile having no submerged vegetation present in 2012. The invasive impact index has increased from 0% in 2005 to 32% in 2012 due to the *U. gibba* but it is not yet displacing native vegetation.

8.6.3 Threats

The only pest species currently present is the *U. gibba.* The overall threat/pressure score in the Northland Lake Strategy for Lake Kahuparere is moderate. The lack of public access reduces the threat of further invasive weed introduction, but if introduced, pest species are likely to grow well, due to the high nutrient levels, and threaten indigenous lake values. While the lake is already nutrient enriched, the risk of more nutrients entering from surrounding pastoral farming and forestry is high but has been reduced with the recent fencing to exclude stock from the lake margins.

8.7 Lake Kanono

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 for weed control purposes.

Lake Kanono is classified as having 'outstanding' ecological value in the Northland Lakes Strategy and is listed as a dune lake in Schedule E of the RWSP and therefore subject to particular controls on water extractions.

8.7.1 Water quality

Lake Kanono stratifies in October and mixes in March/April of most years. The thermocline is at around 9 to 10 metres depth, with anoxia of bottom waters regularly occurring.

Lake Kanono has remained mesotrophic to eutrophic over the last five years with high levels of algae and moderate nutrient levels (Table 8). The nutrient loads are likely to be associated with nutrient run off/leaching from pastoral land, and livestock access.

Table 8 Minimum, maximum and median results for surface samples from Lake Kanono collected between September 2008 and August 2013

Parameter	Min	Max	Median
Temperature (°C)	12.2	23.4	16.4
Dissolved Oxygen (% sat)	80.7	109.0	100.1
Chlorophyll a (mg/l)	2.3	21.7	7.6
Water Clarity (m)	1.9	4.5	2.4
Total Nitrogen (mg/m^3)	281	431	342
Total Phosphorus (mg/m^3)	12	29	16
Ammoniacal Nitrogen (mg/m^3)	0.5	16	2
Nitrate Nitrogen (mg/m^3)	0.5	1	0.5
Dissolved Reactive Phosphorus (mg/m^3)	0.5	6	0.75
Suspended Solids (g/m^3)	1.4	4.1	3.0
Conductivity (mS/m @ 25°C)	26.5	35.1	31
pH	7.7	9.1	8.4
Trophic Level Index	3.58	4.61	4.17

Data from 2005 to 2013 suggests that water quality in Lake Kanono has remained relatively stable (Table 4), with no significant trends detected. A TLI score of 4.05 for the last two years of data is still indicative of a mesotrophic to eutrophic lake.

8.7.2 Ecological condition

Lake Kanono has a ranking of 'outstanding', due to its size and the diverse native submerged and emergent plant communities, reflected in a 'high' LakeSPI score of 74% in 2013. This provides an excellent habitat for fish and birds (Wells and Champion 2013), including a number of rare and endangered species (Table 9). There are also records of the freshwater mussel (*H. menziesi*), crayfish (*P. planifrons*), the snail (*G. variabilis*), leech (*Riachardsonianus mauianus*) and the introduced Australian golden bell frog (*Litoria aurea*). Mosquito fish (*Gambusia affinis*) were recorded in the lake in February 2013 (McGlynn and Pingram 2013).

Table 9 Bird and fish species identified in Lake Kanono (Green = rare/endangered species, red = pest species)

Native Species	Exotic Species
dabchick (*P. rufopectus*)	black swan (*Cygnus atratus*)
scaup (*A. novaezeelandiae*)	eastern little tern (*S. albifrons sinensis*)
bittern (*B. poiciloptilus*)	gambusia (*Gambusia affinis*)
caspian tern (*S. caspia*)	
spotless crake (*P. tabuensis plumbea*)	
common bully (*G. cotidianus*)	
dwarf inanga (*G. gracilis*)	

The lake has a high diversity of indigenous aquatic plants (including emergent, free-floating and submerged) with 15 species recorded to date. The LakeSPI scores have declined slightly from 76% (excellent) in 2005 and 2007 to 74% (high) in 2013, due to the presence of the exotic pondweed *P. crispus* at one site surveyed but it is not yet significantly displacing native vegetation. It is notable that the invasive species, *U. gibba* is not present, although it is common in nearby lakes.

8.7.3 Threats

The overall threat/pressure score in the Northland Lake Strategy for Lake Kanono is moderate. While the risk of invasive tall-growing weeds, such as oxygen weeds, being introduced is low, due to the isolated location and lack of easy access, they would establish easily due to the high nutrients in the lake and would have a significant impact, displacing indigenous vegetation and reducing water quality.

The lake is at risk of increased nutrient enrichment from surrounding forestry and pastoral land use, including stock access to the lake margins. Lake Kanono would benefit from additional fencing and reticulated water supply to exclude livestock. If these were to be done, emergent vegetation could establish reducing nutrient inputs.

8.8 Lake Karaka

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 about 11 hectares in size and has a maximum depth of 6 m. Lake Karaka is classified as having 'high' ecological value in the Northland Lakes Strategy and is listed as a dune

lake in Schedule E of the RWSP and therefore subject to particular controls on water extractions.

8.8.1 Water quality

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% saturation.

Based on data from the last five years, Lake Karaka is classified as eutrophic with high levels of nutrients and algae (Table 10). The high nutrient loads are likely to be associated with nutrient run-off/leaching from pastoral land and forestry activities.

Table 10 Minimum, maximum and median results for surface samples from Lake Karaka collected between September 2008 and August 2013

Parameter	Min	Max	Median
Temperature (°C)	12.6	24.0	16.7
Dissolved Oxygen (% sat)	80.4	139.1	101.0
Chlorophyll a (mg/l)	0.1	203.0	16.9
Water Clarity (m)	0.3	3.8	1.6
Total Nitrogen (mg/m^3)	174	2580	526.5
Total Phosphorus (mg/m^3)	12	169	35.5
Ammoniacal Nitrogen (mg/m^3)	0.5	457	4
Nitrate Nitrogen (mg/m^3)	0.5	94	7.5
Dissolved Reactive Phosphorus (mg/m^3)	0.5	14	2
Suspended Solids (g/m^3)	0.5	23.7	5.9
Conductivity (mS/m @ 25°C)	26	33.4	29.95
pH	7.0	9.3	7.9
Trophic Level Index	3.63	8.08	4.76

While earlier trend analysis suggested that water quality in Lake Karaka had declined (NRC 2012), recent results suggest it has stayed relatively stable (Table 4). The only deteriorating trend detected for data from 2005 to 2013 is a decrease in clarity of 16 cm per year (7.9% of median). An increasing trend in dissolved oxygen of 1.9 % saturation per year was also detected. The TLI score of 4.38 for the last two years of data, suggests that water quality may have improved slightly, offsetting the previous deterioration detected in 2011 but this TLI is still indicative of a eutrophic lake.

8.8.2 Ecological condition

Lake Karaka has an ecological ranking of ‘high’ due to its size, extent of buffering from wetlands and lake emergent vegetation, and diverse native aquatic vegetation. It scored an ‘excellent’ LakeSPI score of 81% in 2013 due to the large extent of native vegetation, the presence of charophyte meadows and lack of invasive species (Wells and Champion 2013). Much of the lake is surrounded by wetlands and it supports a number of nationally endangered plant, bird and fish species (Table 11). The freshwater invertebrates; water boatman (*Sigara argutu)* and the snail (*Potamopyrgus antipodarum)* have also been recorded.

The lake has a high diversity of indigenous aquatic plants (including emergent, free-floating and submerged) with 14 species recorded to date. The LakeSPI scores have remained ‘excellent’ since first surveyed in 2005, with no invasive weeds present.

Table 11 Bird and fish species identified in Lake Karaka (Green = rare/endangered)

Native Species	Exotic Species
dabchick (*P. rufopectus*)	
scaup (*A. novaezeelandiae*)	
bittern (*B. poiciloptilus*)	
spotless crake (*P. tabuensis plumbea*)	
fernbird (*B. punctate vealeae*)	
grey duck (*Anas superciliosa)*	
brown teal (*Anas aucklandica chlorotis*)	
banded rail (*Rallus phillippensis assimilis*)	
common bully (*G. cotidianus*)	
shortfin eel (*Anguilla australis*)	
longfin eel *(Anguilla dieffenbachi*)	
giant kokopu (*Galaxias argenteus*)	

8.8.3 Threats

The overall threat score in the Northland Lake Strategy for Lake Karaka is moderate. The isolated location and difficulty of access makes the risk of introduction of pest fish and plant species low, however, if introduced they would have a very significant impact on indigenous biota.

Further nutrient enrichment from surrounding pastoral farming and forestry, and damage from stock access to the lake, is also threatening the water quality and ecological condition of Lake Karaka. Fencing to exclude stock and reduce nutrient inputs is recommended.

8.9 Lake Mokeno

Lake Mokeno is 148 hectares in size, making it the largest Pouto Lake, and has a maximum depth of 5.5 metres. This lake is located near the West Coast and is entirely surrounded by native scrub and wetlands, with pine forestry in the upper catchment. About 75% of the surface catchment is pine forestry. Water from this lake flows south through extensive wetlands until it reaches the Kaipara Harbour.

Lake Mokeno is classified as having ‘outstanding’ ecological value in the Northland Lakes Strategy and is listed as a dune lake in Schedule E of the RWSP and therefore subject to particular controls on water extractions.

8.9.1 Water quality

Monitoring shows that Lake Mokeno remains mixed throughout the entire year, however, on one occasion bottom anoxia was recorded in March. Based on the last five years data, Lake Mokeno is classified as eutrophic with high levels of nutrients and algae (Table 12).

The water quality in Lake Mokeno has deteriorated substantially in recent years, with a TLI score of 5.93 for the last two years of data, indicative of a supertrophic to hypertrophic lake. Deteriorating trends for total nitrogen, chlorophyll a, water clarity and the TLI were detected for 2005 to 2013 (Table 4). Total nitrogen has increased by 101 mg/m^3 per year (17.2% of median), chlorophyll α has increased by 0.89 mg/l per year (24.8% of median) and clarity has decreased by 48 cm per year (16% of median). This has resulted in an increase in TLI score of 0.19 units per year (4.7% of

median). An increasing trend for dissolved oxygen of 1.9% saturation per year was also recorded.

Table 12 Minimum, maximum and median results for surface samples from Lake Mokeno collected between September 2008 and August 2013

Parameter	Min	Max	Median
Temperature (°C)	12.5	24.6	15.9
Dissolved Oxygen (% sat)	90.4	112.0	99.8
Chlorophyll a (mg/l)	1.2	113.0	4.3
Water Clarity (m)	0.3	4.5	2.4
Total Nitrogen (mg/m³)	437	2070	644
Total Phosphorus (mg/m³)	10	179	27
Ammoniacal Nitrogen (mg/m³)	3	819	17
Nitrate Nitrogen (mg/m³)	0.5	37	3.5
Dissolved Reactive Phosphorus (mg/m³)	0.5	130	2
Suspended Solids (g/m³)	0.9	20.9	4.9
Conductivity (mS/m @ 25°C)	24.5	31.8	27.4
pH	0.0	9.3	8.0
Trophic Level Index	3.62	6.36	4.36

8.9.2 Ecological condition

Lake Mokeno is ranked as 'outstanding' due to its size, extent of buffering from wetlands and emergent vegetation, and diverse native flora and fauna, some of which are nationally endangered (Table 13). The freshwater mussel (*H. menziesi*), water boatman (*S. argutu)* and introduced jellyfish *(C. sowerby)* have also been recorded.

Table 13 Bird and fish species identified in Lake Mokeno (Green = rare/endangered)

Native Species	Exotic Species
dabchick (*P. rufopectus*)	
scaup (*A. novaezeelandiae*)	
bittern (*B. poiciloptilus*)	
spotless crake (*P. tabuensis plumbea*)	
fernbird (*B. punctate vealeae*)	
caspian tern (*S. caspia*)	
brown teal (*A. aucklandica chlorotis*)	
banded rail (*R. phillippensis assimilis*)	
grey duck (*Anas superciliosa)*	
shoveler (*Anas rhynchotis variegata*)	
unidentified shag (*Phalacrocorax* sp.)	
common bully (*G. cotidianus*)	
shortfin eel (*Anguilla australis*)	
smelt (*Retropinna retropinna*)	
inanga (*Galaxias maculatus*)	

Lake Mokeno had 'excellent' LakeSPI scores of 83% and 90% in 2005 and 2007 respectively, indicative of high quality native submerged vegetation and a lack of invasive species (Wells and Champion 2013). However, a LakeSPI score cannot be calculated for 2012, as the lake could not be properly surveyed, due to a severe algal

bloom reducing water clarity to 15 cm. If this bloom continues for too long the submerged vegetation will die, due to low light availability. The decaying vegetation will lead to low oxygen levels, causing more nutrients to be released from the sediments and mussel mortality, exacerbating the algal blooms.

8.9.3 Threats

The overall threat/pressure score in the Northland Lake Strategy for Lake Mokeno is moderate. Like most of the Pouto Lakes, the risk of invasive exotic plants being introduced is low due to the isolated location of Lake Mokeno, however, the impact would be substantial, especially given the recent increase in nutrient levels. Urgent research is needed into the recent and large decline in water quality and how this relates to forest harvesting and/or forestry fertilisation.

8.10 Lake Rotokawau

Lake Rotokawau is set in a pastoral catchment and is 26.4 hectares in size with a maximum depth of 12 m. The lake is completely fenced and is bordered by pine forestry. About 25% of the catchment is in pasture, about 13% is native vegetation and the remaining 60% is pine forestry (FENZ database).

Lake Rotokawau is classified as having 'outstanding' ecological value in the Northland Lakes Strategy and is listed as a dune lake in Schedule E of the RWSP and therefore subject to particular controls on water extractions.

8.10.1 Water quality

Stratification in Lake Rotokawau is irregular but typically stratifies in late spring and de-stratifies in early autumn. Monitoring shows that anoxia of the bottom water does occur.

Based on the last five years, Lake Rotokawau is classified as mesotrophic with low levels of phosphorus and algae but moderate to high nitrogen levels (Table 14).

Table 14 Minimum, maximum and median results for surface samples from Lake Rotokawau collected between September 2008 and August 2013

Parameter	Min	Max	Median
Temperature (°C)	12.6	24.3	17.9
Dissolved Oxygen (% sat)	89.8	102.7	96.7
Chlorophyll a (mg/l)	0.9	6.8	2.0
Water Clarity (m)	3.3	9.0	5.7
Total Nitrogen (mg/m³)	292	447	340
Total Phosphorus (mg/m³)	6	91	8
Ammoniacal Nitrogen (mg/m³)	1	98	6.5
Nitrate Nitrogen (mg/m³)	0.5	20	3
Dissolved Reactive Phosphorus (mg/m³)	0.5	59	0.5
Suspended Solids (g/m³)	0.5	2.2	1.0
Conductivity (mS/m @ 25°C)	11.3	13.4	12.3
pH	6.3	7.4	6.8
Trophic Level Index	2.94	3.83	3.36

Since 2005 water quality in Lake Rotokawau has been reasonably stable, with only one deteriorating trend recorded (Table 4). Total nitrogen has increased by 7.7 mg/m^3 per year (2.3% of median). A decreasing trend in suspended solids of 0.18 g/m^3 per year (16.4% of median) was also detected.

8.10.2 Ecological condition

Lake Rotokawau is ranked as 'outstanding', due to its size, water quality and diverse fauna and flora, including many endangered species. The lake has contained a good population of the nationally rare dwarf inanga, however, very few were recorded in a fish survey in February 2013 (McGlynn and Pingram 2013). The lake also has extensive turf communities, which includes the nationally endangered *Trithuria inconspicua,* giving this lake a 'high' LakeSPI score of 70% in 2013 (Wells and Champion 2013). It is home to a number of rare and endangered bird species (Table 15), as well as the freshwater mussel (*Hyridella menziesii*), leech (*R. mauianus*) and snail *(P. antipodarum*).

Table 15 Bird and fish species identified in Lake Rotokawau (Green = rare/endangered)

Native Species	Exotic Species
dabchick (*P. rufopectus*)	Cape Barren goose *(Cereopsis novaehollandiae)*
scaup (*A. novaezeelandiae*)	
bittern (*B. poiciloptilus*)	
dwarf inanga (*G. gracilis*)	
common bully (*G. cotidianus*)	
shortfin eel (*Anguilla australis*)	
paradise shelduck *(T. variegata*)	

Lake Rotokawau has a high diversity of indigenous aquatic plants (including emergent, free-floating and submerged) with 17 species recorded to date. The LakeSPI scores have improved from 41% in 2005, to 56% in 2007 to 70% in 2012, due to both a reduction in the impact of invasive species and an increase in the native condition. Even though there are three invasive species in the lake; *Egeria densa, Elodea canadensis* and *U. gibba*, they are not yet having a major impact on native vegetation.

8.10.3 Threats

The overall threat score in the Northland Lake Strategy for Lake Rotokawau is moderate. While the exotic *E. densa* is already present, the invasive weed *Ceratophyllum demersum* which grows well in clearer water with low nutrient levels is the greatest risk, with nearby Lake Rotootuauru the closest source. Again the lack of easy access reduces the risk of *C. demersum* and other invasive plants being introduced but the use of eel fishing nets in the lake increases the risk. Also *C. demersum* is close to being eradicated from Lake Rotootuauru.

Water quality has remained good, probably partly due to fencing to exclude stock but nutrient enrichment from pastoral and forestry land use is still a risk.

8.11 Lake Rotootuauru (Swan)

Lake Rotootuauru, also known as Lake Swan, is situated in a catchment dominated by pastoral farming (about 35%) and forestry (about 45%) with some areas of scrub. It is a small shallow dune lake, at 17.4 ha in size and a maximum depth of 5.5 m.

The invasive species *C. demersum* and *E. densa,* which had formed dense mats within the lake, have been reduced significantly since the introduction of grass carp in May 2009. Grass carp were introduced partly due to the close proximity of Lake Rotootuauru to Lake Humuhumu and therefore the risk of the weeds being transferred. As a consequence of the carp feeding on the aquatic plants, water quality has degraded and algal blooms have developed in the warmer summer months. Once eradication of the weeds is achieved, the grass carp numbers will be reduced to allow the regrowth of native aquatic plants.

The ecological rating of this lake is 'moderate to high' in the Northland Lake Strategy. Lake Rotootuauru is also listed as a dune lake in Schedule E of the RWSP and therefore subject to particular controls on water extractions.

8.11.1 Water quality

The limited temperature/dissolved oxygen profile data suggests that Lake Rotootuauru stays mixed throughout the year but oxygen levels can drop at the lake bottom. Based on the last five years data, Lake Rotootuauru is classified as supertrophic, with very high levels of nutrients and algae (Table 16).

Table 16 Minimum, maximum and median results for surface samples from Lake Rotootuauru collected between September 2008 and August 2013

Parameter	Min	Max	Median
Temperature (°C)	12.9	25.9	17.5
Dissolved Oxygen (% sat)	75.4	128.0	89.6
Chlorophyll a (mg/l)	1.9	159.0	14.3
Water Clarity (m)	0.8	3.8	1.7
Total Nitrogen (mg/m³)	415	1530	963.5
Total Phosphorus (mg/m³)	8	609	43.5
Ammoniacal Nitrogen (mg/m³)	1	242	10.5
Nitrate Nitrogen (mg/m³)	0.5	125	17
Dissolved Reactive Phosphorus (mg/m³)	0.5	395	1
Suspended Solids (g/m³)	0.6	15.0	3.5
Conductivity (mS/m @ 25°C)	11.6	19.4	16.95
pH	6.4	9.2	7.1
Trophic Level Index	2.98	6.21	5.13

As highlighted, the eradication of the two invasive weeds; *C. demersum and E. densa*, by the grass carp has led to a substantial decline in water quality in recent years, with a TLI score of 5.64 for the last two years. Deteriorating trends for total nitrogen, total phosphorus, suspended solids, chlorophyll α, water clarity and the TLI were detected for November 2007 to August 2013 (Table 4). Total nitrogen has increased by 188 mg/m^3 per year (20.6% of median), total phosphorus has increased by 16 mg/m^3 per year (45.1% of median), suspended solids has increased by 1.4 mg/l per year (56.8% of median) and chlorophyll α has increased by 6.26 mg/m^3 per year (43.8% of median). Water clarity has decreased by 67 cm per year (35% of

median). These changes have resulted in an increase in the TLI score of 0.52 units per year (10.8% of median).

8.11.2 Ecological condition

Lake Rotootuauru has a 'moderate to high' ecological ranking, due to its size, extent of buffering by wetlands and emergent vegetation and the number of endangered species recorded. It has been degraded by the presence of invasive plant species and due to the introduction of grass carp as a control measure, is now in a 'non-vegetated' state. As a result the LakeSPI has reduced from 21% (moderate) in 2005 to 14% (poor) in 2010, to 0% (non-vegetated) in 2011 and 2012. Despite the poor state of the aquatic vegetation, the rare dwarf inanga, and a number of rare birds are present (Table 17). The lake also contains populations of the freshwater mussel (*H. menziesii*).

Table 17 Bird and fish species identified in Lake Rotootuauru (Green = rare/endangered)

Native Species	Exotic Species
dabchick (*P. rufopectus*)	black swan (*C. atrelus)*
bittern (*B. poiciloptilus*)	mallard (*Anus platyrhyncus*)
fernbird (*B. punctate vealeae*)	grass carp (*Ctenopharyngodon idella)*
dwarf inanga (*G. gracilis*)	
common bully (*G. cotidianus*)	
shortfin eel (*A. australis*)	

There were no signs of *C. demersum* or *E. densa* or other submerged plants other than turf species during the 2012 and 2013 surveys. If no invasive weeds are found in 2014, then grass carp numbers will be reduced and it is expected that the native submerged plant community will regenerate, improving the ecological condition (LakeSPI) of Lake Rotootuauru.

8.11.3 Threats

The overall threat/pressure score in the Northland Lake Strategy for Lake Rotootuauru is high, due to its lack of submerged vegetation, presence of alligator weed (Alternanthera philoxeroides) and high risk of future incursions of pest fish and plants. Vehicle and boat access to Lake Rotootuauru is relatively easy, increasing the risk of future incursions. Alligator weed threatens marginal vegetation in the lake.

8.12 Lake Rototuna

Lake Rototuna is a small dune lake (8.9 ha) with a maximum water depth of 5.5 metres. Located mid-way down the Pouto Peninsula, the lake has a mix of pastoral farming and forestry in its catchment and is easily accessible from the main road. The lake is fenced in the area administered by the Department for Conservation and the community has planted the lake margins with native wetland species. However, livestock still have access to the south side of the lake.

Lake Rototuna is classified as having 'moderate to high' ecological value in the Northland Lakes Strategy and is listed as a dune lake in Schedule E of the RWSP and therefore subject to particular controls on water extractions.

8.12.1 Water quality

Monitoring shows that in general Lake Rototuna remains mixed throughout the entire year, however, anoxia at the lake bottom has been recorded on several sampling occasions.

Based on the last five years of data, Lake Rototuna is classified as eutrophic with high levels of algae and nutrients, particularly nitrogen (Table 18). The high nutrient loads are likely to be associated with nutrient run off from pastoral land and livestock access to the lake.

Table 18 Minimum, maximum and median results for surface samples from Lake Rototuna collected between September 2008 and August 2013

Parameter	Min	Max	Median
Temperature (°C)	12.4	24.6	15.9
Dissolved Oxygen (% sat)	66.7	112.0	99.8
Chlorophyll a (mg/l)	7.0	113.0	4.3
Water Clarity (m)	0.9	4.5	2.4
Total Nitrogen (mg/m³)	520	2070	644
Total Phosphorus (mg/m³)	18	179	27
Ammoniacal Nitrogen (mg/m³)	0.5	819	17
Nitrate Nitrogen (mg/m³)	0.5	37	3.5
Dissolved Reactive Phosphorus (mg/m³)	0.5	130	2
Suspended Solids (g/m³)	2.3	20.9	4.9
Conductivity (mS/m @ 25°C)	11.6	31.8	27.4
pH	6.9	9.3	8.0
Trophic Level Index	4.25	6.36	4.36

The water quality in Lake Rototuna has deteriorated substantially in recent years, with a TLI score of 5.07 for the last two years of data, indicative of a supertrophic lake. Deteriorating trends for ammoniacal nitrogen, total nitrogen, total phosphorus, water clarity and the TLI were detected for 2005 to 2013 (Table 4). Ammoniacal nitrogen has increased by 0.6 mg/m^3 per year (15% of median), total nitrogen has increased by 50 mg/m^3 per year (7.5% of median), total phosphorus has increased by 1.5 mg/l per year (5% of median) and clarity has decreased by 20 cm per year (7.9% of median). This has resulted in an increase in TLI score of 0.11 units per year (2.4% of median).

8.12.2 Ecological condition

Despite its poor water quality, Lake Rototuna has a 'moderate to high' ecological ranking due to the good condition of the indigenous submerged vegetation communities and the presence of a number of endangered fish and plant species. This is consistent with the 'excellent' LakeSPI score of 83% in 2012. The lake provides habitat for a number of endangered biota (Table 19), however, the pest fish species gambusia and rudd have recently been recorded in the lake (Wells and Champion 2013). The introduced snail *Physa acuta* has also been recorded.

The LakeSPI has improved slightly from 76% in 2005 due to the invasive plant species *P. crispus and Juncus bublosus* not being recorded in 2007 or 2012.

Table 19 Bird and fish species identified in Lake Rototuna (Green = rare/endangered, red = pest species)

Native Species	Exotic Species
dabchick (*Poliocephalus rufopectus*)	black swan (*Cygnus atrelus*)
scaup (*Aythya novaezeelandiae*)	rudd *(Scardinius erythrophthalmus)*
bittern (*Botaurus poiciloptilus*)	gambusia (*Gambusia affinnis*)
dwarf inanga (*Galaxias gracilis*)	
common bully (*G. cotidianus*)	
paradise shellduck *(T.variegate*)	

8.12.3 Threats

The overall threat score in the Northland Lake Strategy for Lake Rototuna is high, due to the presence of the emergent pest plant, reed sweet grass (*Glyceria maxima*), the presence of rudd and gambusia and a high risk of future incursions of pest fish and plants, due to proximity to the main road. Further deterioration in water quality is also a threat to the ecological values of the lake. Lake Rototuna would benefit from additional fencing to protect the entire lake margin and reticulated water supply for livestock.

8.13 Lake Wainui

Lake Wainui is a small dune lake (3.8 ha) with a maximum depth of 11 metres. The surface water catchment is dominated by pastoral farming (88% of catchment). A narrow riparian edge was fenced in 2010, to exclude livestock from the lake. In areas of livestock exclusion, emergent vegetation should begin to establish.

Lake Wainui is classified as having 'moderate to high' ecological value in the Northland Lakes Strategy and is listed as a dune lake in Schedule E of the RWSP and therefore subject to particular controls on water extractions.

8.13.1 Water quality

Data suggests that Lake Wainui stratifies in November/December with the thermocline forming at anywhere between 4 and 8 metres depth. Oxygen levels in the bottom water have dropped as low as 1% saturation, with the lake mixing typically around March/April.

Based on the last five years data, Lake Wainui is classified as mesotrophic with high nitrogen levels and moderate levels of phosphorus and algae (Table 20).

The water quality in Lake Wainui has improved in recent years, with a TLI score of 3.51 for the last two years. There is improving trends for total nitrogen, total phosphorus, suspended solids, chlorophyll α, water clarity and the TLI were detected for 2005 to 2013 (Table 4). Total nitrogen has decreased by 41 mg/m^3 per year (8.8% of median), total phosphorus has decreased by 5 mg/m^3 per year (25% of median), suspended solids has decreased by 0.8 mg/l per year (33.7% of median) and chlorophyll α has decreased by 1.76 mg/m^3 per year (32% of median). Water clarity has increased by 34 cm per year (14.2% of median). These changes have resulted in a decrease in TLI score of 0.23 units per year (5.3% of median).

Table 20 Minimum, maximum and median results for surface samples from Lake Wainui collected between September 2008 and August 2013

Parameter	Min	Max	Median
Temperature (°C)	12.3	25.6	18.1
Dissolved Oxygen (% sat)	81.8	109.4	97.9
Chlorophyll a (mg/l)	0.6	22.0	3.0
Water Clarity (m)	1.0	7.5	3.4
Total Nitrogen (mg/m³)	269	682	403.5
Total Phosphorus (mg/m³)	11	259	17.5
Ammoniacal Nitrogen (mg/m³)	1	82	5.5
Nitrate Nitrogen (mg/m³)	0.5	151	3.5
Dissolved Reactive Phosphorus (mg/m³)	0.5	85	1
Suspended Solids (g/m³)	0.6	7.7	1.5
Conductivity (mS/m @ 25°C)	40.8	46.6	43
pH	7.0	8.5	7.8
Trophic Level Index	3.15	5.12	3.91

8.13.2 Ecological condition

Lake Wainui has a 'moderate to high' ecological ranking, due to its depth and entirely native submerged vegetation. It had an 'excellent' LakeSPI score of 76% in 2007. The totally native vegetation is controlled slightly by poor water quality which is limiting the depth at which submerged plants can grow. The lake provides habitat for a number of rare and endangered species (Table 21), as well as the leech (*R. mauianus*), backswimmers (*Sigara arguta*) and the snail (*Physella acuta*).

Table 21 Bird and fish species identified in Lake Wainui (Green = rare/endangered)

Native Species	Exotic Species
dabchick (*P. rufopectus*)	black swan (*Cygnus atrelus)*
bittern (*B. poiciloptilus*)	
scaup (*A. novaezeelandiae*)	
paradise shelduck *(T. variegata*)	

8.13.3 Threats

The overall threat score in the Northland Lake Strategy 2012 for Lake Wainui is low, due to the current lack of invasive species and the risk of pest plants and fish being introduced to the lake in the future is low, given the isolated nature of the lake. The lake is susceptible to nutrient enrichment given the dominance of pastoral land use in the catchment but this risk has been reduced with recent riparian fencing.

8.14 Other lakes

8.14.1 Lake Kapoai

Lake Kapoai is located near Te Kopuru, just south of Dargaville, and is 1.6 hectares 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. Lake Kapoai was sampled as part of the LWQMN from December 2005 to March 2011. This data shows the Lake is hypertrophic with extremely high nutrient and algae levels and poor water clarity. There were no significant changes in water quality during that time.

Lake Kapoai is classified as having 'low' ecological value in the Northland Lake Strategy, due to the lack of aquatic plant communities, the presence of the pest fish, rudd 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 LakeSPI can be generated. Nevertheless it still provides habitat for a number of rare and endangered species (Table 22).

Table 22 Bird and fish species identified in Lake Kapoai (Green = rare/endangered, red = pest species)

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

8.14.2 Lake Rotopouua

Lake Rotopouua is a small dune lake, less than 5 ha in size and about 9 metres deep. The catchment is a mix of native scrub, pastoral farming and pine forestry but is dominated by the latter. The lake is fenced from stock. There is limited water quality data for Lake Rotopouua but it has had ecological assessments carried out by NIWA. NIWA noted poor water quality in 2008 with algal blooms and high mussel mortalities. To identify and manage nutrient inputs to this lake, routine monitoring would be required.

This lake has a 'moderate to high' ecological rating in the 2012 Northland Lake Strategy due to its buffering from native emergent vegetation around the entire lake margin, diverse indigenous submerged plant community and presence of some endangered biota (Table 23). This is consistent with the high LakeSPI scores of 72% and 71% in 2008 and 2012 respectively. The invasive plant *U. gibba* is present in the lake. This lake was identified as having a moderate pressure score in the Lake Strategy, due to its limited access but risk to further nutrient enrichment.

Table 23 Bird and fish species identified in Lake Rotopouua (Green = rare/endangered species)

Native Species	**Exotic Species**
dabchick (*Poliocephalus rufopectus*)	
bittern (*B. poiciloptilus*)	
spotless crake (*P. tabuensis plumbea*)	
dwarf inanga (*Galaxias gracilis*)	
common bully (*G. cotidianus*)	

8.14.3 Lake Whakaneke

Lake Whakaneke is located south of Lake Mokeno at the bottom of the Pouto Peninsula. This 20.5 ha shallow dune lake is surrounded by manuka scrub and wetlands. It appears that it receives water from Lake Mokeno and has an outflow to Kaipara Harbour. Lake Whakaneke was sampled as part of the LWQMN from December 2005 to March 2011. This data shows the Lake is supertrophic with

extremely high levels of algae and poor water clarity, very high phosphorus and high nitrogen levels. There were no significant changes in water quality during that time.

Lake Whakaneke has a 'moderate' ecological ranking in the 2012 Lake Strategy. It is surrounded by native vegetation and has dense emergent wetland vegetation around its margins with excellent bird habitat, supporting a number of rare and endangered species (Table 24). However, due to the poor water clarity, it has almost no submerged vegetation, leading to a LakeSPI score of 0% (non-vegetated). Lake Whakaneke has a reasonably low risk of invasive plant introductions, due to its isolated location and a low risk of plants being established due to the poor water clarity.

Table 24 Bird and fish species identified in Lake Whakaneke (Green = rare/endangered species)

Native Species	Exotic Species
dabchick (*Poliocephalus rufopectus*)	
bittern (*B. poiciloptilus*)	
scaup (*Aythya novaezeelandiae*)	
spotless crake (*P. tabuensis plumbea*)	
fernbird (*B. punctate vealeae*)	
brown teal (*Anus aucklandica chloritus*)	
banded rail (*G. phillippensis assimilis*)	
common bully (*G. cotidianus*)	

8.14.4 Lake Wairere

Lake Wairere is a narrow dune lake, 16.5 ha in size and at least 2 m deep. It has a margin of steep scrub covered cliff to the east and rough pasture, wetland and mobile sand dunes to the west. The catchment is almost entirely pine forestry. There is limited water quality and ecological information for this lake.

Visual observations suggest the lake has poor water quality with algal blooms and poor clarity (Wells and Champion 2013). However, the lake has a 'moderate to high' ecological ranking in the 2012 Lake Strategy, due to the extensive wetlands on the lake margins, intact native emergent and submerged vegetation with no invasive weeds and several endangered bird species recorded (Table 25).

Table 25 Bird and fish species identified in Lake Wairere (Green = rare/endangered)

Native Species	Exotic Species
dabchick (*Poliocephalus rufopectus*)	
bittern (*B. poiciloptilus*)	
scaup (*A. novaezeelandiae*)	
spotless crake (*P. tabuensis plumbea*)	

9 Groundwater

Groundwater is a valuable resource being used mainly for irrigation and drinking water supplies and contributing to the recharge and baseflow/level of rivers and lakes. Reduction in quantity and quality of groundwater by pumping, land use and climatic changes, and inappropriate bore construction are the major pressures on groundwater resources in Northland (NRC 2012).

While very little research has been done on the extent, quality and importance of groundwater on Pouto, given the permeability of most of the sand geology, there is likely to be a substantial groundwater resource (Kokich 1991, McLellan 1985). It is likely to be a shallow unconfined sand aquifer, geologically originating from the Quaternary period. Rainfall is likely to be the main source of recharge to the aquifer, which is generally rapid and intense (NRC 2012).

Given that groundwater is likely to be a significant inflow and outflow for most of the Pouto Lakes, an investigation into the extent of groundwater resources in the Pouto Lakes' catchment area and the influence this has on the lakes should be a priority.

10Managing the catchment

10.1 Management of the catchment

Contaminants can enter waterbodies from direct and diffuse discharges. Direct discharges are sources of contaminants that discharge from discrete points or identifiable localised areas. Direct discharges, including stormwater and wastewater, to streams, rivers, and land are controlled by rules in the Regional Water and Soil Plan (RWSP). Diffuse discharges typically arise from land use activities that are spread across a catchment.

Diffuse contaminants can enter waterbodies by sub-surface drainage (leaching) and surface run-off. Diffuse discharges can include fertilisers, animal faeces and soil from agricultural land, and soil and fertilisers from forestry and horticultural land use. Diffuse discharges also includes stormwater from areas that are not reticulated, including from some roads (without drains) and road banks, which can be a significant source of sediments.

10.2 Consents

Under the Resource Management Act 1991 (RMA) Northland Regional Council is responsible for managing the region's freshwater quality and quantity by controlling discharges, water takes and land use activities that impact on water. Under the Local Government Act 2002, the Kaipara District Council is responsible for the provision and operation of wastewater, stormwater, and potable water infrastructure, as well managing use and development of land generally. Integrating the functions of the two councils for managing the use of land is important for ensuring effective management of water quality.

10.3 Permitted activities

The Regional Water and Soil Plan for Northland (NRC 2004) provides rules for taking and using water without consent.

Contact Susie Osbaldiston at Northland Regional Council for more information on permitted water takes in the Pouto Lakes' Catchment.

10.4 Consented water takes

As of April 2013, there were six water take consents in the Pouto Lakes Catchment (Figure 5). These takes are, from both groundwater and surface water, for irrigation or drinking water supply.

Contact Susie Osbaldiston at Northland Regional Council for more information on consented water takes in the Pouto Lakes' Catchment.

10.5 Other consented activities

As of April 2013, there were a futher 21 resource consents for activities within the Pouto Lakes Catchment (Figure 5), including:

- Discharges to land: treated human effluent (4), stormwater (1) and landfill (1)
- Discharges to water: farm dairy effluent (8), stormwater (3) and herbicide (1)
- Land use: forest harvesting (2) and floodgate (1).

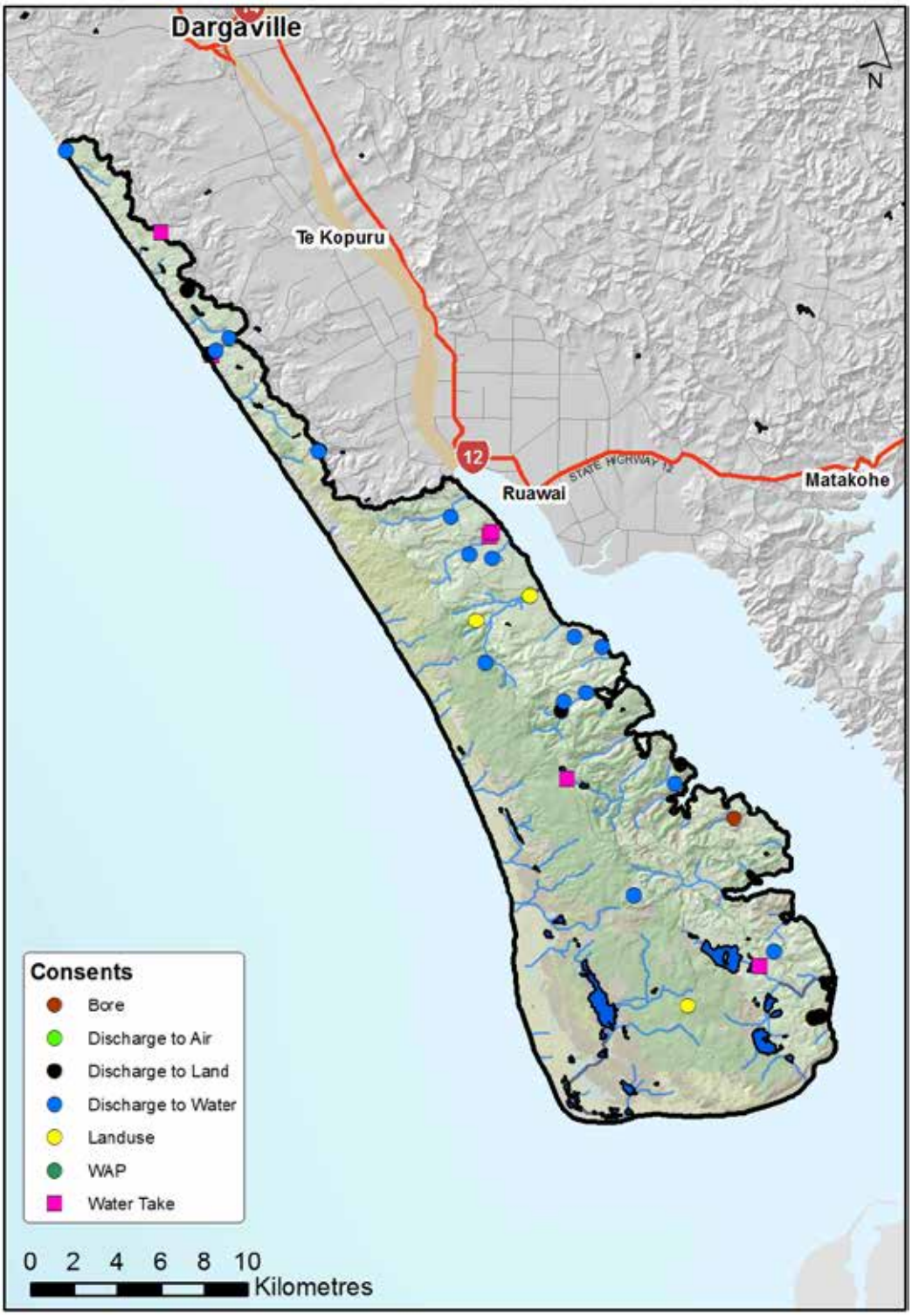

Figure 5 Resource consents in the Pouto Lakes' Catchment

11 Iwi environmental management

Iwi Māori have a living relationship with freshwater that is founded in the respective cosmologies of each iwi and that has spanned, and will continue to span, the full breadth of cultural, environmental, social and commercial interests. The nature of the relationship between iwi and freshwater forms the basis of iwi rights, interests, values and objectives pertaining to freshwater management. Iwi assert foundation rights to freshwater based on the Treaty, customary, and aboriginal rights and that these rights continue to hold relevance in the wider legal framework of water management.

11.1 Te Runanga O Ngāti Whatua[3]

Te Runanga O Ngāti Whātua has interests in five harbours throughout its rohe: Whangārei, Mangawhai, Kaipara, Waitematā and Manukau. The Kaipara Harbour is the largest harbour in the southern hemisphere and is the largest enclosed harbour in Aotearoa.

The Rūnanga provides advice to local and central government agencies regarding Mana Whenua issues across the rohe relating to both marine and land based resource management activities and processes.

11.2 Te Uri O Hau[4]

Te Uri o Hau is a Northland hapu of Ngati Whatua whose area of interest is located in the Northern Kaipara region. Their overarching policies are the Te Uri o Hau' MoU (Memorandum of Understanding) Protocols and Agreements, Te Uri o Hau' Deed of Settlement 2000 and Te Uri o Hau' Claims Settlement Act 2002. Te Uri o Hau Settlement Trust has established business units that cover people health and welfare, tikanga and culture, housing, commercial and economic development and environmental management.

Environs Holdings, the environmental management unit, is heavily tasked to ensure that territorial authorities and government agencies adhere to the Settlement Act and are continually advocating Te Uri o Hau' position in relation to their kaitiakitanga obligation. The guiding aim of Environs Holdings is “To advocate and support Kaitiakitanga throughout the rohe as well as in the education and empowerment of whanau to be proactive in their role as Kaitiaki for Te Uri o Hau”.

[3] www.ngatiwhatua.iwi.nz/kaitiakitanga
[4] www.uriohau.com

12Education and awareness

Northland Regional Council is tasked with monitoring and providing advice, incentives and regulations to protect our environment whilst balancing the economic needs of the community. Ultimately, the state of the environment is determined by the people who live in and use it. Ongoing monitoring helps the council to keep abreast on what's happening to the environment but it's a joint effort, and council looks forward to continuing to work with communities to set and meet environmental expectations.

12.1 Education

The North's Enviroschools Programme is funded by and operated through the Northland Regional Council, with support from The Enviroschools Foundation.

In Northland, 72 schools and three kindergartens are currently on the pathway towards creating sustainable communities. They are all working at their own pace to achieve a range of sustainability actions with some choosing to reflect at different stages along the way. Presently there are 3 Green-Gold, 11 Silver and 22 Bronze Enviroschools.

12.1.1 Pouto School

Pouto School is in the Pouto Lakes Catchment (Figure 6) and along with other Enviroschools in the region has received support through facilitation, resources, professional development and a nationwide network of Enviroschools. In relation to teaching and learning around water, the school has had a long-standing involvement with the inter-agency dune lakes restoration work, especially for Lake Rototuna.

Figure 6 Location of Pouto School

12.2 Awareness

In a new approach, we will be working at a catchment level to enable better integrated management of our freshwater systems. This will be guided by catchment groups, to be formed from locals with an interest in their local water issues, to help determine how each catchment can best be managed.

Regional environmental improvements are also the target of other important Council work programmes that integrate with the WNW programme, including the Priority Rivers Project, the Top Wetlands Project, Community Pest Control Areas, and Farm Management Plans.

In addition to these work programmes, the Regional Council also runs education campaigns to increase awareness about the values of dune lakes and the impacts of pest plants and fish if introduced, including media releases, signage, presentations to community groups and producing brochures. A documentary film and series of posters will be completed in 2014 to further educate the community, lake users and tourists on these values and risks.

12.2.1 Regional State of the Environment Report

The State of the Environment report provides quality environmental information that is accessible and understandable to Northlanders and which can be used to make important resource management decisions in the future. The report is arranged into five chapters: Our people; Our place; Our land, our air; Our freshwater; and Our coast. The chapters provide a broad picture of the core components that make up the state of our environment.

- Each chapter begins with a scene-setting introduction which explains why this part of the environment is significant for Northlanders and what the major pressures on the environment are;
- Describes the current state of each aspect of the environment – core information is presented on the state of the environment and key trends or changes over time;
- Outlines the management responses to environmental conditions now and into the future.
- Information is presented on what is being done now to address issues raised and what might be done in the future; and
- Provides a summary of progress in implementing regional objectives and policies.

12.2.2 Environment Fund

The Northland Regional Council Environment Fund has provided around $4 million to help people enhance and protect Northland's natural environment since 1996.

The Regional Council recognises the effort and commitment that Northlanders are putting into addressing their environmental issues and the continuation of funding reflects this. The fund is provided through five different funding streams with projects funded at up to 50% of their total costs.

Priority Funding Streams have been identified to ensure that recipients of funding are proposing activities aligned with Regional Council Land Management priorities.

12.2.3 Priority Funding Streams

Soil conservation – targeting the maintenance and control of erodible soils, e.g. erodible land soil stabilisation via tree planting, fencing to exclude stock, pest control and other suitable means.

Biodiversity – targeting the restoration and protection of wetlands and lakes, e.g. fencing to keep out stock, riparian planting, pest control.

Coastal – targeting the restoration, protection and maintenance of estuaries, dunes and salt marsh, e.g. the planting of spinifex and pingao for dune stabilisation, pest control, fencing to exclude stock and riparian planting.

Water quality – targeting dairying and clean stream accord targets, dry stock exclusion from waterways and similar projects within recreational bathing site catchments e.g. fencing to exclude stock from waterways, riparian enhancement.

13Conclusion

The Pouto Lakes have high cultural, ecological, environmental, recreational and intrinsic values, being important regionally, nationally and even internationally. The lakes vary in their water quality, ecological condition and pressures (Table 26). Only three of the nine routinely monitored lakes are mesotrophic; Humuhumu, Rotokawau and Wainui (Figure 7). The remaining six lakes are eutrophic or worse with high levels of nutrients and algae and poor water clarity.

Although four lakes have shown recent declines in their water quality, two of these lakes still have outstanding ecological condition (Table 26). Declines in water quality in Lakes Humuhumu and Mokeno could be linked to recent forest harvesting in their catchments. Lake Rotootuauru has deteriorated both in terms of water quality and ecological condition but this was expected with the use of grass carp to remove invasive weeds from the lake. Once the carp are no longer needed and removed, it is expected that the lake will improve. Water quality has also declined in Lake Rototuna. Water quality has improved in only one lake, Wainui.

Table 26 Summary of Trophic Level Index (TLI), water quality trends (2005 to 2013), ecological condition rankings and changes and pressure/threat rankings for nine Pouto Lakes. Red arrow indicates deterioration, green arrow indicates improvement and a dash indicates no significant change.

Lake	TLI	WQ trends	Ecological condition ranking	Ecological condition trends	Threat ranking
Humuhumu	Mesotrophic	↓	Outstanding	-	Moderate
Kahuparere	Meso to eutrophic	-	High	↓	Moderate
Kanono	Meso to eutrophic	-	Outstanding	-	Moderate
Karaka	Eutrophic	-	High	-	Moderate
Mokeno	Eutrophic	↓	Outstanding	-	Moderate
Rotokawau	Mesotrophic	-	Outstanding	↑	Moderate
Rotootuauru	Supertrophic	↓	Moderate to high	↓	High
Rototuna	Eutrophic	↓	Moderate to high	-	High
Wainui	Mesotrophic	↑	Moderate to high	-	Low

Four lakes have outstanding ecological condition; Lakes Humuhumu, Kanono, Mokeno and Rotokawau. A further two lakes have high ecological condition; Kahuparere and Karaka. These six lakes and their surrounding wetlands support a range of endemic endangered species providing habitat for nationally important populations of dwarf inanga, *Trithuria inconspicua* and *Thelypteris confluens*. They also provide important habitat for many threatened and regionally significant birds including the banded rail, brown teal, Australasian bittern, New Zealand dabchick, spotless crake and North Island fernbird. However, even for these six lakes the habitat quality varies; with some having high quality riparian and emergent wetland vegetation that buffers inputs into the lake, while others have very little emergent vegetation and still have stock access to the lake margins. In general, they have relatively limited impact from invasive weeds and fish.

The major threats to the lakes are nutrient enrichment from surrounding pastoral farming and forestry, and pest plant and fish incursions. The impacts of forestry and

the extent of the groundwater resources are major information gaps that could hinder the ongoing management of the Pouto Lakes.

Figure 7 Trophic Level Index for the nine routinely monitored Pouto Lakes, based on median data for September 2008 to August 2013

NB - Future sections of the catchment description document to additionally cover the following:

Implementation -Management and Control Actions
Answer the questions:

- *What interventions will improve quality/quantity issues?*
- *Describe regulatory/current practice reforms necessary*

Research and Monitoring - describe

- *How will the council (or others, e.g. management groups) review and monitor whether improvement plan is working?*

APPENDIX 1 References and further sources of information

References

Burns, N., Bryers, G. & Bowman, E. 2000. *Protocols for monitoring trophic levels of lakes and reservoirs. Report* prepared for the Ministry for the Environment. Wellington; New Zealand.

Champion, P. and de Winton, M. 2012. *Northland Lakes Strategy.* Prepared for Northland Regional council. NIWA: Hamilton, New Zealand.

Champion, P., Rowe, D., Smith, B., Wells, R., Kilroy, C. and de Winton, M. 2012, *Freshwater Pests of New Zealand*. National Institute of Water and Atmospheric Research. www.niwa.co.nz/sites/default/files/pest_guide_lndscp_feb_2013_.pdf

Collier, K. J. 1996. Potential Impacts of Plantation Forestry on Dune Lakes in Northland with Interim Guidelines for Riparian Management. Report prepared by National Institute of Water and Atmospheric Research for Department of Conservation.

Edbrooke, S. W. and Brook, F. J. 2009. *Geology of the Whangarei area*. Institute of Geological and Nuclear Sciences: Lower Hutt.

Kokich, D. C. 1991. *Kai Iwi – Pouto Dune Lakes Water Resources.* Northland Regional Council: Whangarei, New Zealand.

McGlynn, M. and Pingram, M. 2013. *Galaxiid survey Pouto Peninsula and Kai Iwi Lakes.* Department of Conservation.

McLellan, C. H. 1985. *The Kai Iwi – Poutu Dune Lakes. A Water Resources Report.* Northland Catchment Commission. Water Resources Report No. 10.

NRC 2012. State of the Environment Report 2012. Northland Regional Council, Whangarei, New Zealand.

Smale, M. C., Clarkson, B. R., Clarkson, B. D., Floyd, C. G., Cornes, T. S., Clarkson, F. M., Gilmour, D. C., Snell, T. M., and Briggs, C. M. (2009). *Natural areas of Kaipara Ecological District (Northland Conservancy): Reconnaissance survey report for the Protected Natural Areas Programme.* Report prepared by Landcare Research New Zealand and The University of Waikato. Department of Conservation: Whangarei, New Zealand.

Wells, R. and Champion, P. 2013. *Northland Lakes Ecological Status 2013.* Report prepared by National Institute of Water and Atmospheric Research for Northland Regional Council.

Further sources of information

1 Northland Regional Water and Soil Plan
2 Northland State of the Environment Report
3 Northland Lakes Strategy

APPENDIX 2 Trend data

Table 27 Trend analysis results for data from December 2005 to August 2013 for the nine routinely monitored Pouto Lakes. Trends shown in bold a statistically significant ($p < 0.05$). Slope = change per year. Med = median. % = the magnitude of the change relative to the median value as a percentage.

	Ammoniacal Nitrogen (g/m^3)				Total Nitrogen (g/m^3)				Total Phosphorus (g/m^3)				Suspended Solids (g/m^3)				Trophic Level Index			
	p-value	Slope	Med	%	p-value	Slope	Med	%	p-value	Slope	Med	%	p-value	Slope	Med	%	p-value	Slope	Med	%
Humuhumu	**0.0453**	**0.0002**	**0.003**	**6.67**	**0.0438**	**0.0057**	**0.299**	**1.91**	0.1771	-0.0003	0.011		1	0.000	1.80		0.2777	0.057	3.53	
Kahuparere	1	0	0.003		0.1872	-0.008	0.384		**0.006**	**-0.0016**	**0.017**	**-9.41**	0.4801	-0.199	3.00		0.135	-0.050	4.118	
Kanono	0.2993	0	0.001		1	0	0.347		0.738	0	0.018		0.4533	-0.051	2.95		1	0.012	4.135	
Karaka	0.5039	-0.0004	0.0085		0.3742	0.0167	0.433		0.6568	0.0005	0.038		0.6568	0.151	5.55		1	0.002	4.757	
Mokeno	0.6218	0.0014	0.015		**0.0076**	**0.1005**	**0.584**	**17.21**	0.1389	0.0022	0.021		0.105	0.747	4.40		**0.0095**	**0.193**	**4.127**	**4.66**
Rotokawau	0.0595	0.001	0.006		**0.0354**	**0.0077**	**0.338**	**2.28**	0.8	-0.0002	0.008		**0.0187**	**-0.181**	**1.10**	**-16.44**	0.7105	-0.019	3.294	
Rototuna	**0.0444**	**0.0006**	**0.004**	**15.00**	**0**	**0.0496**	**0.665**	**7.46**	**0.0085**	**0.0015**	**0.03**	**5.00**	0.2376	0.328	6.20		**0.0012**	**0.113**	**4.683**	**2.42**
Swan	0.0662	0.0014	0.008		**0.0009**	**0.1876**	**0.912**	**20.58**	**0.0009**	**0.016**	**0.036**	**45.07**	**0.02**	**1.362**	**2.40**	**56.76**	**0.0022**	**0.518**	**4.783**	**10.82**
Wainui	0.5292	0.0006	0.005		**0.0019**	**-0.041**	**0.465**	**-8.82**	**0.003**	**-0.005**	**0.02**	**-25.00**	**0.0001**	**-0.843**	**2.50**	**-33.72**	**0.0002**	**-0.231**	**4.374**	**-5.28**

	Dissolved Oxygen (%sat)				Chloropyhll a (mg/l)				Secchi (m)				pH			Temperature (°C)		
	p-value	Slope	Med	%	p-value	Slope	med	%	p-value	Slope	Med	%	p-value	Slope	Med	p-value	Slope	Med
Humuhumu	0.4147	0.3373	97.45		0.571	0.0729	2.835		**0.0024**	**-0.3808**	**4.3**	**-8.86**	0.6689	0.0092	8.16	0.4614	-0.0851	18.1
Kahuparere	0.7919	0.0915	93.4		0.5802	-0.5268	9.8		0.9299	0.0214	2.75		0.246	-0.0169	8.1	0.1872	-0.1523	18.6
Kanono	0.2525	1.0238	99.65		1	-0.02	7.7		0.8056	-0.0289	2.425		0.5372	0.0097	8.48	0.6215	-0.0567	18.25
Karaka	**0.0313**	**1.897**	**99.9**	**1.90**	0.8768	-0.2034	15.6		**0.0313**	**-0.1631**	**2.075**	**-7.86**	0.5899	0.0187	7.9	0.7104	-0.0977	17.3
Mokeno	**0.0026**	**1.909**	**97.4**	**1.96**	**0.0046**	**0.8922**	**3.6**	**24.78**	**0.0024**	**-0.4785**	**3**	**-15.95**	0.3094	0.0339	7.9	0.9438	-0.0126	17.1
Rotokawau	1	-0.0105	96.6		0.8	-0.0249	2.4		0.2655	-0.0808	6		0.2778	-0.0554	6.89	0.3791	-0.1004	19.9
Rototuna	0.6356	0.7799	99.3		0.1808	1.2589	13.3		**0.0305**	**-0.1972**	**2.5**	**-7.89**	1	0	7.8	0.5792	-0.1377	19
Swan	0.3913	1.6398	90.7		**0.0032**	**6.258**	**14.3**	**43.76**	**0.0019**	**-0.6689**	**1.91**	**-35.02**	1	-0.0154	7.195	0.2703	0.2382	17.49
Wainui	0.6284	0.6556	97.6		**0.0007**	**-1.762**	**5.5**	**-32.04**	**0.0003**	**0.3789**	**2.66**	**14.24**	0.1241	-0.0366	7.9	0.7469	0.0196	18.5

WAIORA NORTHLAND WATER

NORTHLAND REGIONAL COUNCIL

WHĀNGĀREI: 36 Water Street, Private Bag 9021, Whāngārei Mail Centre, Whāngārei 0148; Phone 09 470 1200, Fax 09 470 1202.
DARGAVILLE: 61B Victoria Street, Dargaville; Phone 09 439 3300, Fax 09 439 3301.
KAITĀIA: 192 Commerce Street, Kaitāia; Phone 09 408 6600, Fax 09 408 6601.
ŌPUA: Unit 10, Industrial Marine Park, Ōpua; Phone 09 402 7516, Fax 09 402 7510.

Freephone: 0800 002 004 | **24/7 Environmental Hotline:** 0800 504 639
E-mail: mailroom@nrc.govt.nz | **Website:** www.nrc.govt.nz
LinkedIn: www.linkedin.com/companies/northland-regional-council
Facebook: www.facebook.com/NorthlandRegionalCouncil
Twitter: www.twitter.com/NRCExpress