Lake Rotokawau (Pōuto)

MANAGEMENT PLAN

Northland REGIONAL COUNCIL

CONTENTS

LAKE ROTOKAWAU (PŌUTO) MANAGEMENT PLAN

1. PURPOSE

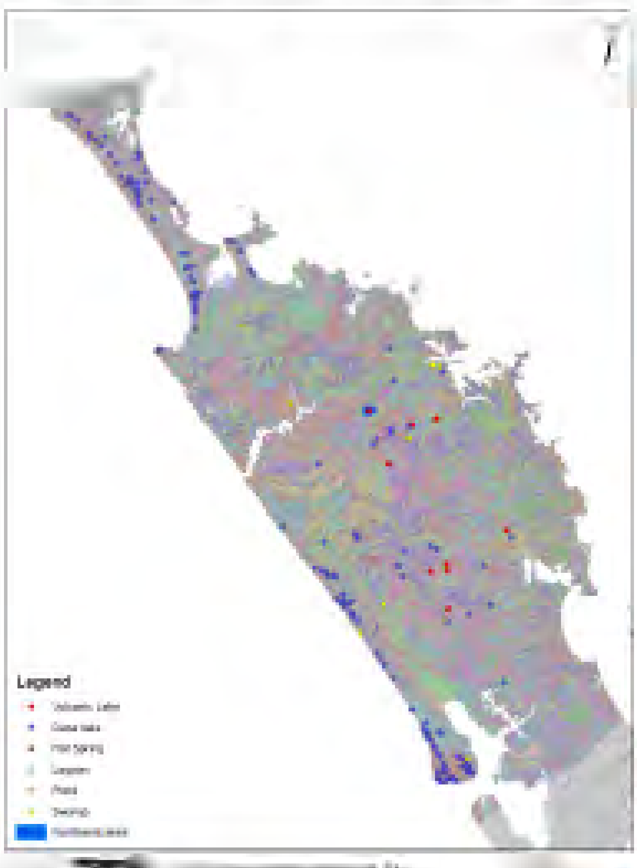
The purpose of the Outstanding Northland Dune Lakes Management Plans is to implement the recommendations of the Northland Lakes Strategy Part II (NIWA 2014) by producing Lakes Management Plans, starting with the 12 'Outstanding' value lakes, and by facilitating actions with mana whenua iwi, landowners and other stakeholders in the lake catchments to deliver priority work which will protect water quality and mitigate current pressures.

2. INTRODUCTION

The following text is taken directly from the Northland Lakes Strategy. Northland dune lakes and their associated wetlands are of national and international significance. These lakes, most of which have been formed between stabilised sand dunes along the west coast, represent a large proportion of warm, lowland lakes in New Zealand which still have relatively good water quality and high ecological values.

The outstanding dune lakes are grouped on the Aupouri, including Sweetwater, Karikari and P uto Peninsulas and the Kai Iwi group North of Dargaville.

The lakes 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 211.07 hectares and being 38.81 metres deep. Lake Taharoa also has the deepest recorded submerged vegetation of any lake in the North Island, to 24 metres.



The dune lakes generally have little or no continuous surface inflows or outflows, being primarily fed by rainfall directly onto their surfaces and surrounding wetlands. As a result, their levels fluctuate considerably with climatic patterns. As most of the lakes are relatively small and shallow, they have limited capacity to assimilate any contaminants. They are prone to nutrient enrichment from stock and fertiliser, particularly where lakeside vegetation has been grazed or removed, and where there is direct stock access to the lake. Further effects on the lakes result from forestry fertilisation, sediment mobilisation during harvest and water budget dynamics.

These lake and wetland ecosystems are important habitats for a wide variety of plant and animal species, some of which are regionally or nationally significant because of their rarity. These include birds such as the pateke/brown teal, banded rail, New Zealand dabchick, marsh crake, fern bird and Australasian bittern, the aquatic plants *Hydatella inconspicua* and *Myriophyllum robustum* and native freshwater fish including the giant kokopu, banded kokopu, short jawed kokopu, inanga, dwarf inanga and dune lakes galaxias.

The most outstanding characteristic of these lakes is the limited impact of invasive species on their biota, which is unparalleled elsewhere on mainland New Zealand. Despite these values, the status of these lakes is not secure and the overall trend has been gradual deterioration.

Northland Regional Council monitors water quality quarterly in 26 dune lakes and undertakes ecological monitoring, along with NIWA, for ~90 dune lakes on an annual rolling basis. Annual weed surveillance is undertaken at high value lakes with public access. Threats and pressures include biosecurity (aquatic weeds, pest fish and the risk of invasion and spread), eutrophication from surrounding land use for farming and forestry, occurrence of algal blooms and water level fluctuations, especially dropping lake levels. Natural events such as summer droughts and high rainfall events place further pressure on these lakes.

Recreational and commercial activities on or around some of the lakes can affect water quality, lake ecology and increases the risk of introduction of pest weeds and fish.

The Northland Lakes Strategy (NIWA 2012) presents a classification and ranking system for Northland lakes including assessment of ecological values and lake pressures and threats. The 12 highest ranked lakes from north to south are:

Outstanding (12)

- Lakes - Wahakari, Morehurehu, Waihopo, Ngatu, Waiporohita, Waikare, Kai iwi, Taharoa, Humuhumu, Kanono, Rotokawau and Mokeno

Northland Lakes Strategy (NIWA 2012, 2014) recommends that individual lake management plans should be developed for each high value lake. This would include:

- Descriptions of each lake and lake catchment
- Outline of lake values and significance (including ecological and social)
- List of agencies and individuals involved in management
- Communications plan
- Monitoring plan
- Identification of gaps in knowledge/research plan
- Current threats and pressures
- Management actions to mitigate or ameliorate threats and pressures
- Work implementation plan

Key principals of lake management are:

- Balance between protection and utilization
- Managing the environmental quality of the catchment, in particular water quality
- Integrated management of habitat and species (including pests)
- Monitoring as a key environmental management tool

The plan takes the approach of presenting robust information on all aspects of the lakes. This includes social and cultural, physical, chemical and biological summaries of information not generally available to the public in a condensed format. This data is the best available at the time of writing and does not represent peer-reviewed science in the sense that errors may be inherent in the raw data and presence and absence of species changes over time. Yet it offers trends for further discussion among partners involved in protection and restoration activities. The plan goes on to scope required work for the mitigation of threats and offers a communication strategy to implement this work.

2.1. Geographic Lake Groupings

The outstanding dune lakes within these plans all sit within two broad ecological districts; Aupouri and Kaipara. Within these two districts there are further geographical associations of lakes, especially relevant to biosecurity species spread.

Within the Aupouri group, there are three lakes situated near Parengarenga and Houhora Harbours on the narrow Aupouri Peninsula (Lakes Wahakari, Morehurehu and Waihopo).

At the base of the Aupouri peninsula, another cluster of lakes form the west coast Sweetwater group and Lake Ngatu is the only outstanding lake in this area. To the east, on the Karikari Peninsula, Lake Waiporohita is found.

Further south within Northland, on the west coast north of Dargaville, are the three Kai Iwi Lakes (Lake Kai Iwi itself, and Lakes Taharoa and Waikare, sometimes referred to as Waikere).

Finally, four outstanding lakes on the Pōuto Peninsula, on the north head of the Kaipara Harbour, round out the final twelves lakes of covered in the Outstanding dune lake plans. These include the west Pōuto Lake Mokeno and the east Pōuto lakes Humuhumu, Kanono and Rotokawau (Pōuto).

Most lake names come from te reo Māori and, therefore, some names refer to several lakes around Northland. Rotokawau is a name given to several lakes, with one in Pōuto, two in Karikari and one in Sweetwater. Additionally, the word "kawau" means the waterbird shag or cormorant and two additional lakes are also called Shag Lake. To avoid confusion, lakes sharing a name are further referred to with their sub-regional area following in parentheses.

LINZ topographic maps do not legally name every freshwater body. Therefore, for the purposes of the lake plans, additional common lake names are used which are the same as those used in the NIWA ecological surveys. These may not be the same as traditional names used by iwi, which are yet to be known by the NRC. NRC will endeavour to consult with mana whenua iwi on their preferred traditional names for each lake.

3. LAKE LOCATION MAP

4. LAKE OVERVIEW

Lake Rotokawau (Pōuto) (NRC Lake Number 364) is a deep, 26.74 ha (12.96 m max and 4.77 m mean depth) lake with a deep basin to the south of the lake and a wide, shallow 7 m basin in the northern half. The lake is located on private farmland to the west of Pōuto Road on the southern end of the Pōuto Peninsula in south-western Northland. The lake is classified as a Class 3 Window dune lake (Timms, 1982), meaning it sits within ground water level, although it receives only around 7% of its water from groundwater, with 59% from rainfall and 34% from surface runoff.

The LiDAR-defined catchment is dominated by high and low producing exotic grassland and herbaceous freshwater vegetation. The FENZ-defined catchment area, including the lake itself, is 1488.7 ha and the surface area of the lake is 26.74 ha. Recent LiDAR has redefined the catchment to be 102.5 ha, including the lake.

The lake does not thermally stratify, which increases nutrient availability in the water column throughout the year. Rotokawau experiences minor periodic algal blooms extending into National Policy Statement for Freshwater Management (NPS) State C for chlorophyll-a, the latest being a peak in February 2015. The water clarity trend, based on Secchi readings, is improving.

Nitrogen trends solely within NPS State B and is the key contributing factor to water quality issues for this lake. Phosphorus levels are likewise stable and low (NPS States A and B) other than one event in February 2011 which pushed into NPS State D. The trophic level steadily remains a low mesotrophic (average water quality).

There is oxygen depletion in water below 6-8 meters between spring and summer. On average, the pH of this lake is near neutral (centred around pH 7).

Lake levels in Rotokawau tend to be steady through time with a marginal decline. Levels vary by .99 metres. The estimated water residence time is just over three years, longer than most Pōuto lakes.

The lake hosts 24 native aquatic plants, including the rare natives *Trithuria inconspicua* and *Myriophyllum votschii*, and the key threat to the lake is the six exotic water weeds. Currently there are two invasive exotic water weeds in the lake; the invasive oxygen weeds Egeria and Elodea. The Lake Submerged Plant Index, Native Condition Index and Invasive Impact Index have each been negatively affected due to the arrival of the invasive exotic water weeds.

The lake has a moderate level of fish diversity and is free of pest fish. However, dwarf inanga is now considered rare in this lake.

The lake has a moderate level of native bird diversity. The paradise shelduck is the only game bird recorded. Dabchicks, Australasian bittern and New Zealand scaup have been recorded in this lake and occur more widely in this sub-region. The only sighting of the Cape Barren goose has been at this lake in 2012.

5. SOCIAL AND CULTURAL DIMENSION

5.1. Mana whenua

Te Uri o Hau (yellow) and Te Runanga o Ngāti Whātua (orange) have rohe whenua Area of Interest in the area of Lake Rotokawau. Te Uri o Hau has reached Deed of Settlement with the Crown and there appears to have been no specific vesting of the lake bed, which remains privately owned.

Rohe whenua is displayed in the diagram below and was sourced from Te Puni Kōkiri’s Te Kahui Mangai web pages (www.tpk.govt.nz).

5.2. Land Tenure

5.2.1 Catchment landowners and Lake bed owners

Five landowners own seven land parcels within the lake catchments. The lake bed is privately owned.

5.3. Community involvement

The Pōuto catchment group was formed in mid-2013 to help determine how the Pōuto Peninsula's freshwater resources should best be managed into the future. The group includes representatives from tangata whenua, forestry, drystock and dairy industries and recreational, community and environmental interests. It also includes representatives from the Department of Conservation, Kaipara District Council and the Northland Fish and Game Council. The chair is an NRC councillor.

A planning initiative called Future Pōuto has recently been undertaken by Te Uri o Hau. The plan assesses social, cultural, economic and environmental needs on the peninsula.

5.4. Public use

5.4.1. Access

Access to the lake is some distance over private farmland by 4WD from Pōuto Road.

5.4.2. Boating

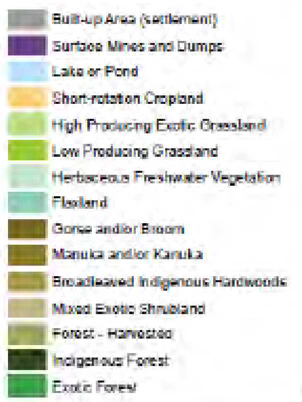
5.4.2.1. Boat access

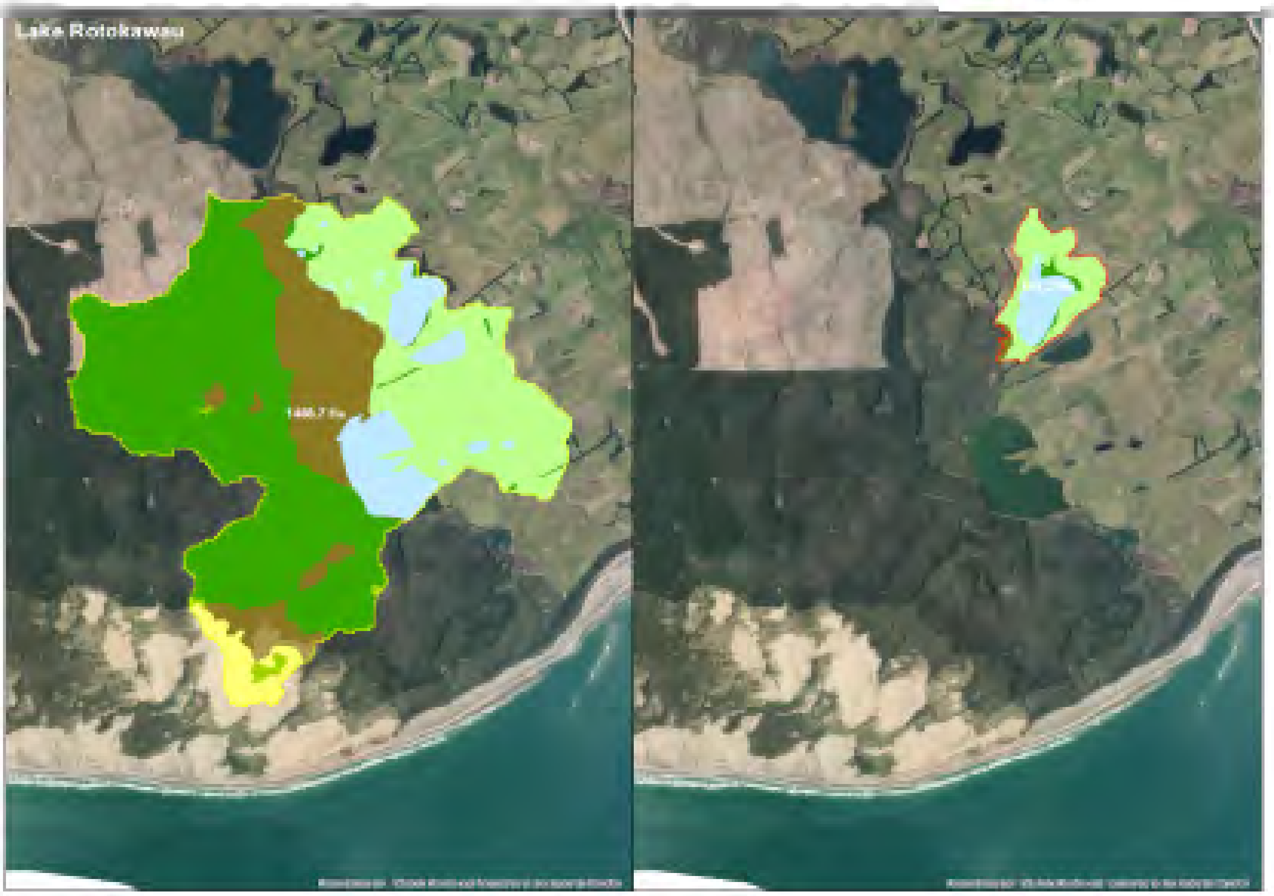
There is relatively easy boat access to the lake but relies on private access. However, it is popular as a summer camping area within the Pōuto community and is utilised the most out of all the private access lakes.

6. PHYSICAL CHARACTERISTICS

6.1. Catchment Area with Map

The following diagram shows the extent of the lake catchment. On the left is the FENZ boundary and the more accurate LiDAR boundary is on the right. The catchment area of the FENZ boundary, including the lake itself, is 1488.7 hectares. The more accurate LiDAR-derived catchment boundary is 102.5 ha, including the lake.





6.2. Catchment Geology and soil types

The following map ((C) GNS Science 2016) of the Pōuto Peninsula and table below it shows the geological history of the lake catchment. Rotokawau has a geology comprised of Early Quaternary dunes (eQd) which formed during higher sea levels 12,000 years ago and earlier. These ancient dunes are now weakly cemented to uncemented. The western catchment extends into late Quaternary dune (lQd).

Lake Name/Plot Symbol	eQd	lQd (Q1d)
Rotokawau	x	x
Name	Early Quaternary dunes	Late Quaternary dunes
Description	Weakly cemented and uncemented dune sand and associated facies. Clay-rich sandy soil. These dunes arose during higher sea level 12,000 years ago and earler.	Loose to poorly consolidated sand in mobile and fixed dunes locally with paleosols and peat. Minor sand, mud and peat in interdune lake and swamp deposits.
Geologic history	Early Quaternary	Late Quaternary
Simple name	Zealandia Megasequence Terrestrial and Shallow Marine Sedimentary Rocks (Neogene)	Zealandia Megasequence Terrestrial and Shallow Marine Sedimentary Rocks (Neogene)
Absolute minimum age (millions of years before present)	0.78	0
Absolute maximum age (millions of years before present)	2.6	0.12
Supergroup equivalent stratigraphic name	Pakihi Supergroup	Pakihi Supergroup
Lithology	sand	sand

Soil types in the catchment are portrayed in the soil map and table below. The lake is dominated by yellow-brown sands of Redhill sandy loam (RL), which forms an iron pan, with patches of organic soils of Parore peaty sandy loam (PZ).

Soil Symbol	Genetic soil group	Geological origin	Suite	Subgroup	Series	Soil name	Description
RL	Yellow-brown sands	Yellow-brown sands	Pinaki	Moderately to strongly leached	Redhill	Redhill sandy loam	**Red Hill series** – recent geomagnetic and radiometric surveys of Northland suggest that soils of the Red Hill series, found along the two barrier arms of the Kaipara Harbour and, to a much lesser extent at Mangawhai and Bream Bay, were formed on a different parent material to most/all other sand soils in Northland. The Red Hill sands have developed on dunes of Taranaki iron sands (and from more local andesite volcanoes?) and have weathered to produce allophane clay. Basins or easier slopes are likely to have an accumulation of iron or even an iron pan in the subsoil. From a pasture management point of view, these are allophanic soils. Because, however, they overlay dune sands, their erosion characteristics are similar to other soil on deep sand deposits – they are prone to severe gully erosion in a similar fashion to the Tangitiki and Te Kopuru soils and also the Pohangina area in the Manawatu. A typical profile of **Red Hill sandy loam** (**RL** & RLH) will include: 80 to 170 mm of very dark brown to very dark greyish brown loamy sand to sandy loam, on 300 to 400mm of yellowish brown to strong brown sandy loam, with clay nodules and iron enrichment, on reddish yellow to yellowish red sandy loam to loamy sand with iron enriched surface layers on clay nodules. This all overlies brownish yellow to light yellowish brown very compact, massive or cemented layer of loamy sand to sand.
PZ	Organic soils		Ruakaka		Parore	Parore peaty sandy loam	**Parore peaty sandy loam** (**PZ**) has developed in narrow valleys draining the sand terrace and dune areas of the west coast of Northland south of the Hokianga Harbour. Alluvial sand from erosion of Tangitiki and Te Kopuru soils on the old dunes and terraces has been spread over the sand in layers of varying thickness, along with fine wind–blown sand. The downstream ends of many of these valley systems have been blocked off by either dune sand, where draining to the coast, river alluvium when draining to inland river valleys (such as the Kaihu) or estuarine sediment deposits where draining to the Kaipara Harbour. This damming has enhanced the development of swamps and peat. The proportions of sand and peat, the presence or absence of layers of sand in the peat and the grade of the valleys varies considerably. The upper reaches of the valleys are prone to gully erosion, which can be controlled by paired willow planting. Shrubby pussy willows appear to tolerate the salt spray and acid soil conditions experienced where this soil is located.

6.3. Catchment Hydrogeology

Only a conceptual understanding of the hydrogeology of Pōuto Peninsula is available as no specific investigations have and bore-logs offer little information. The geology of the dune lakes likely relies on strata of cemented and uncemented dune sands.

Paleo-channels and iron pans likely allow water flow collecting in cemented areas to provide water to the non-perched lakes occurring at lower elevations.

The Jacobs report (2017) models this lake as most heavily influenced by rainwater, followed by surface runoff and a minor groundwater influence, despite being a Window (spring fed) lake.

Lake	Lake class	% rainfall	% surface runoff	% rain + runoff	% groundwater
Humuhumu	dune contact	49	12	61	40
Kanono	dune contact	57	42	99	2
Kahuparere	dune contact	37	60	97	3
Rototuna	window	45	55	100	0
Roto-otuaruru	window	42	28	70	30
Rotokawau (Pōuto)	window	59	34	93	7

6.4. Catchment drainage and sedimentation rates

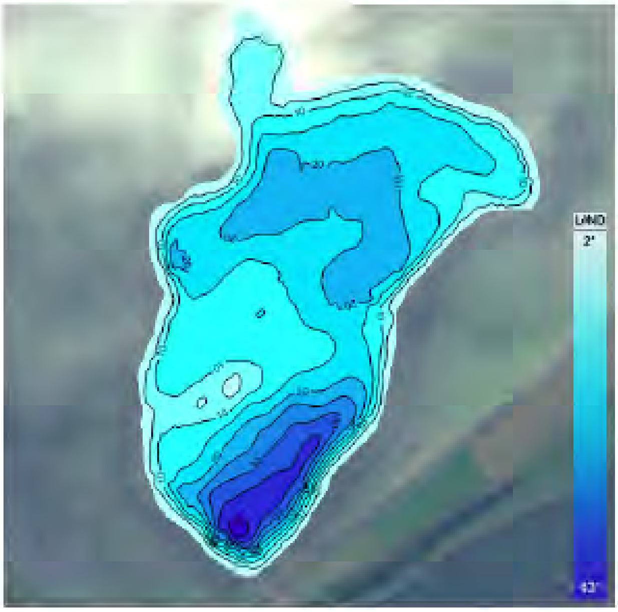
The FENZ-derived catchment area, including the lake itself, is 1488.7 hectares and produces a mean annual flow, based on hydrological models, of 188,217.7 m^3/year. The lake has an estimated lake residence time of 3.220 years, meaning any water entering the lake will remain for just over three years. The average particle size of surface rock in the catchment is 2 on a scale of 5, a value of 1 being sand (FENZ database). However, LiDAR has redefined the catchment area as being only 102.5 ha, including the lake, so the above modelling is now outdated.

6.5. Geomorphology - Lake type and origin, area, depth and volume

In common with other dune lakes on the Peninsula (Rototuna, Phoebe's, Rotopouua, Roto-otuauru/Swan, Waingata), Rotokawau is a Class 3 Window lake originating as interdune basins. The lake has a maximum depth of 12.96 m with a mean overall depth of 4.77 m. The surface area of the lake is 26.74 hectares with a volume of 1,301,369.50 m^3 (NIWA bathymetric survey). The catchment area, including the lake itself is 102.5 ha (LiDAR).

6.6. Bathymetry map

The following bathymetric depth map comes from a survey done by NIWA for the NRC. The deepest point is the single 13 m basin to the south of the lake with a wide shallow 7 m basin in the northern half. Please note that the scale of this map is in feet, not meters.



Bathymetry map

6.7. Natural inlets and outlets

The lake has no natural inlets or outlets.

6.8. Wetland associations

A small wetland extends outside the catchment boundary to the north-western end of the lake.

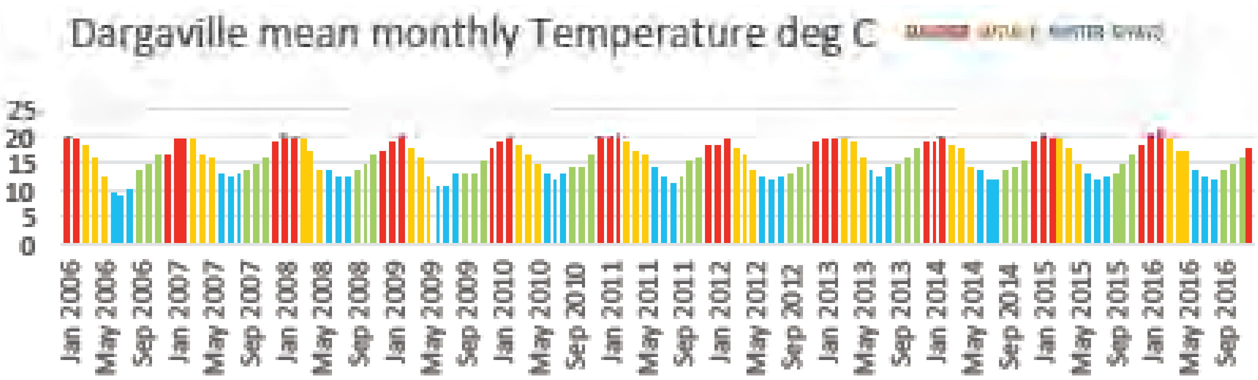
Wetland associations map

6.9. Connectivity

The lake is not connected to any other waterbody.

6.10. Air Temperature

Measurements of Dargaville air temperature data are used as a proxy for Pōuto.

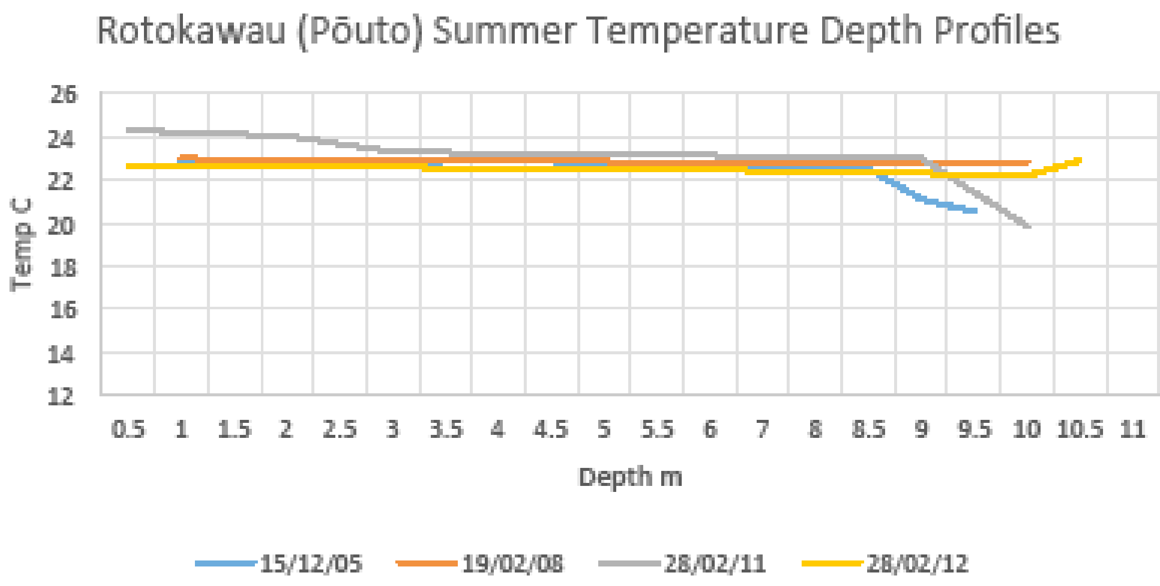


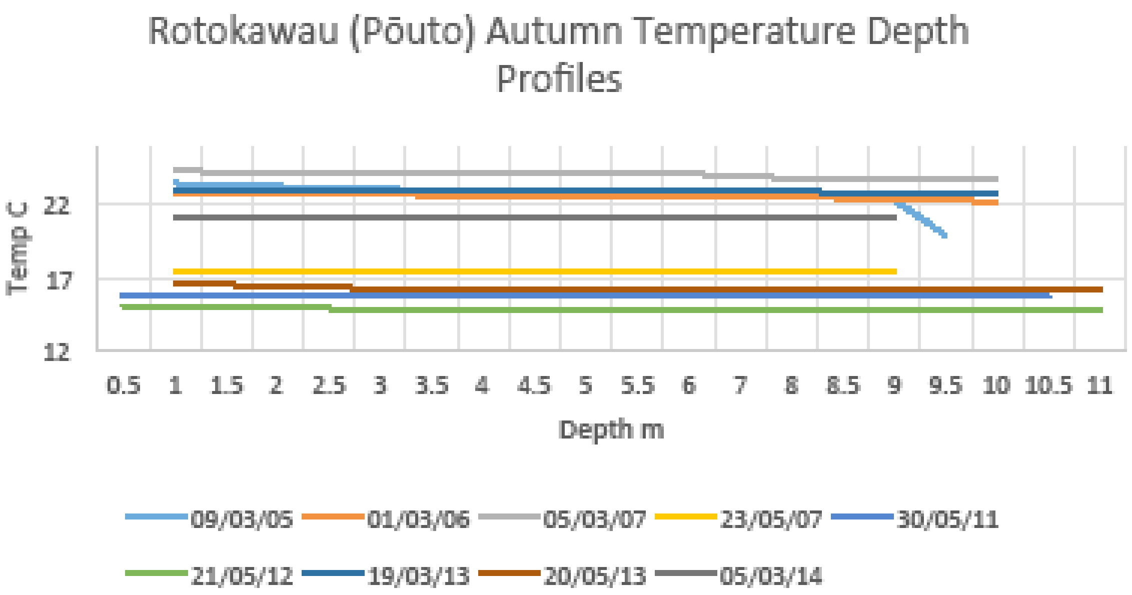
6.11. Thermal stratification

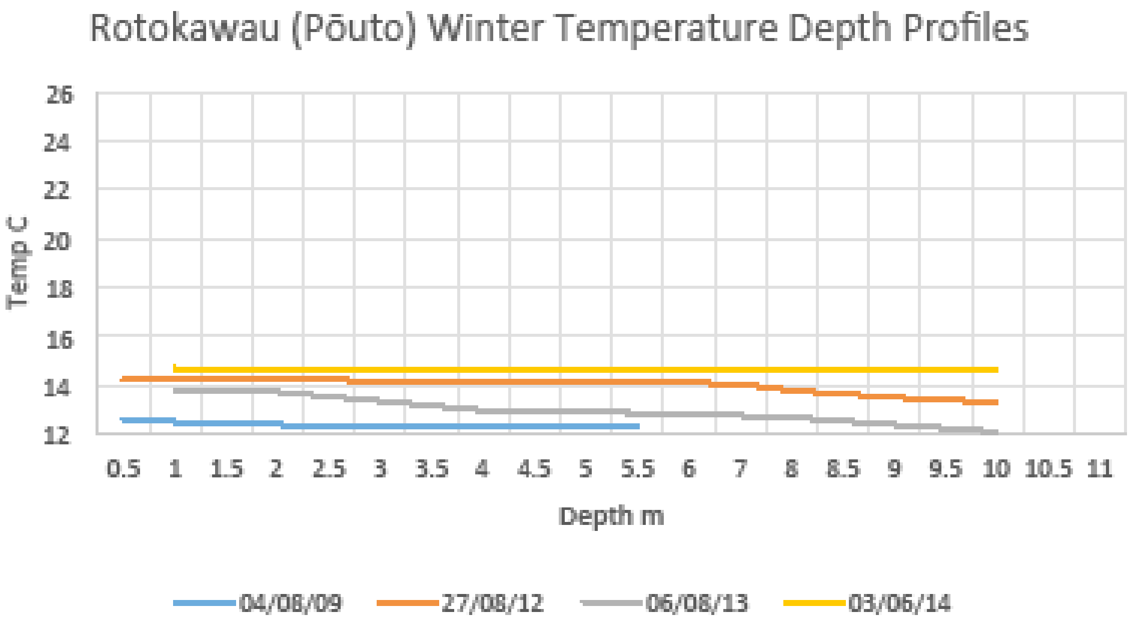
The graphs below show temperature at depth throughout the water column, by season. Each coloured line represents one sample. Water temperatures throughout the year range from 12.3 degrees C to 24.2 degrees C.

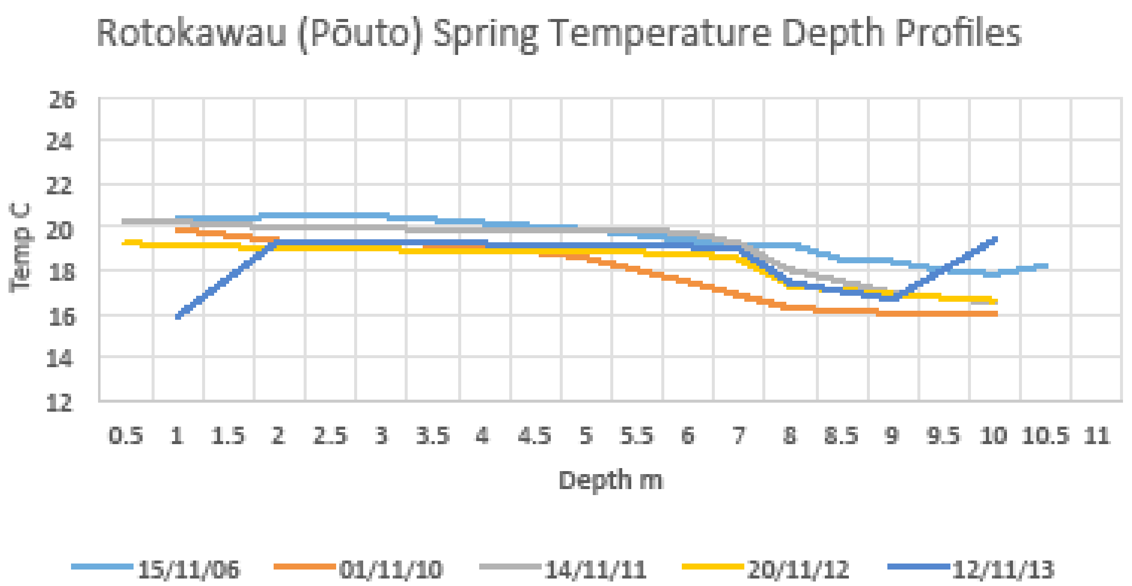
The lake, being on the shallow end of definition for a "deep lake (>10 m), does not thermally stratify in summer and temperature is fairly uniform at all depths year round.

Due to lack of stratification, nutrients are available throughout the water column throughout the year due to wind mixing.



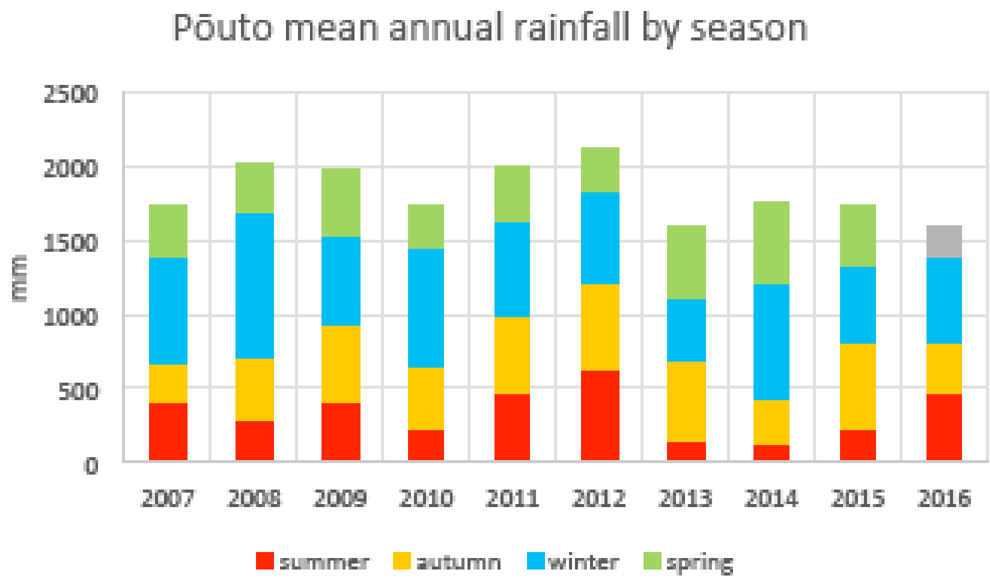

Rotokawau (Pōuto) Autumn Temperature Depth Profiles
Temp C
22
17
12
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 8.5 9 9.5 10 10.5 11
Depth m
09/03/05
01/03/06
05/03/07
23/05/07
30/05/11
21/05/12
19/03/13
20/05/13
05/03/14


Rotokawau (Pōuto) Winter Temperature Depth Profiles
Temp C
26
24
22
20
18
16
14
12
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 8.5 9 9.5 10 10.5 11
Depth m
04/08/09
27/08/12
06/08/13
03/06/14


Rotokawau (Pōuto) Spring Temperature Depth Profiles
Temp C
26
24
22
20
18
16
14
12
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 8.5 9 9.5 10 10.5 11
Depth m
15/11/06
01/11/10
14/11/11
20/11/12
12/11/13

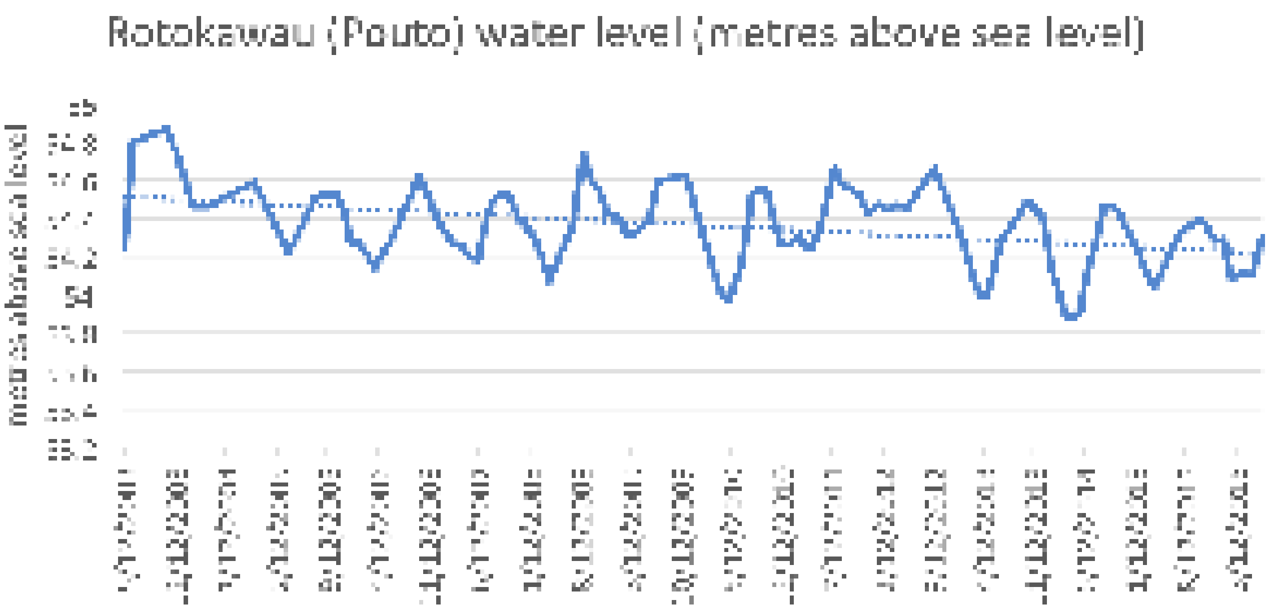
6.12. Rainfall and drought

The graph below shows cumulative rainfall by year displayed as seasons within each bar. Note that summer includes December from the year prior along with January and February of the year shown on the X axis. The greyed season indicates that one month of the three months for that season has no data available so this portion of the bar in underestimated.

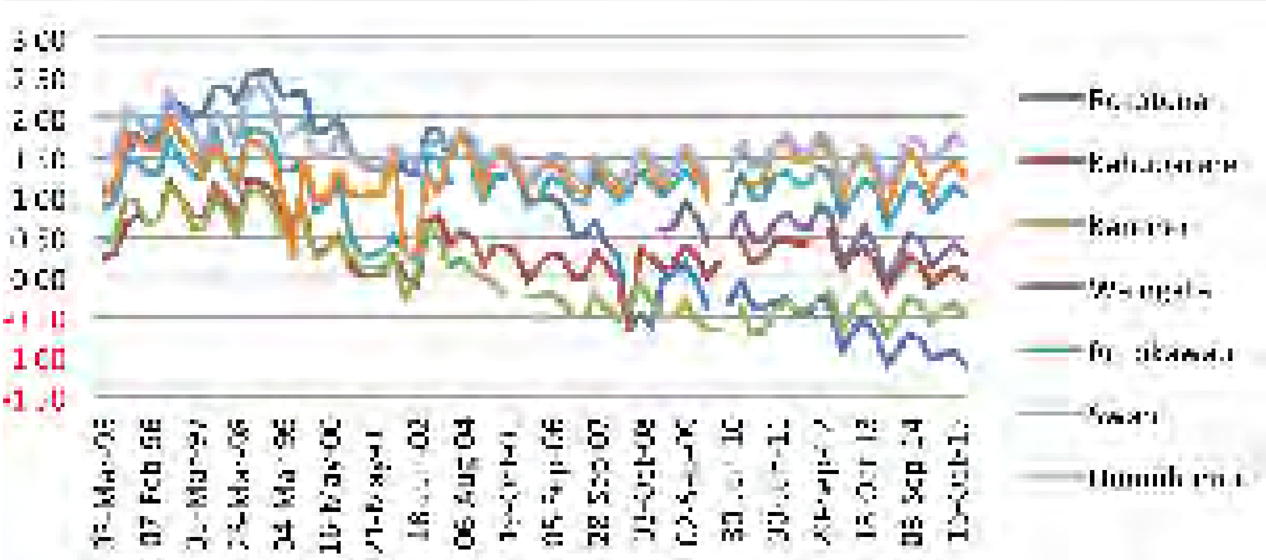


6.13. Lake level

Lake levels in Rotokawau tend to be steady through time with a marginal decline. Levels vary by .99 metres.



A longer time series comparing lake levels between Pōuto dune lakes shows that Rotokawau, like Humuhumu and Swan, is stable. The Y axis represents variation in mm from a fixed altitude mark on the staff gauge.

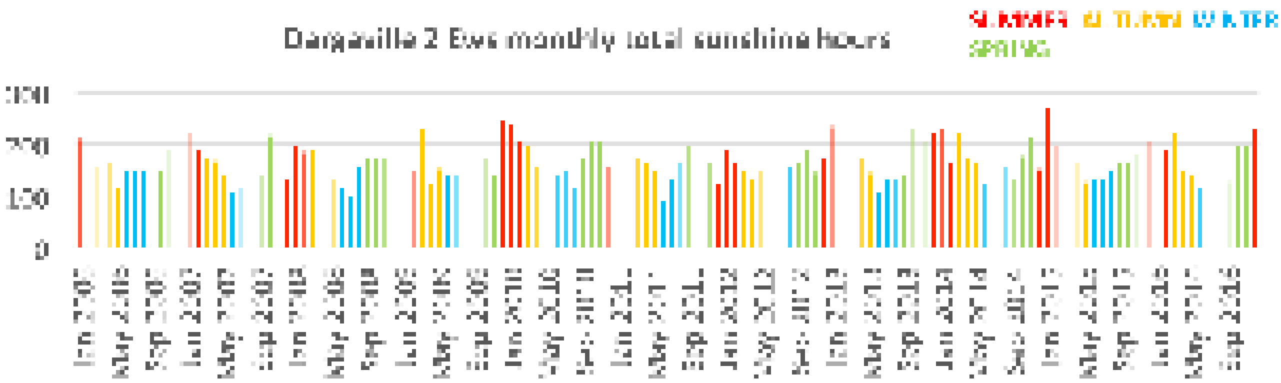


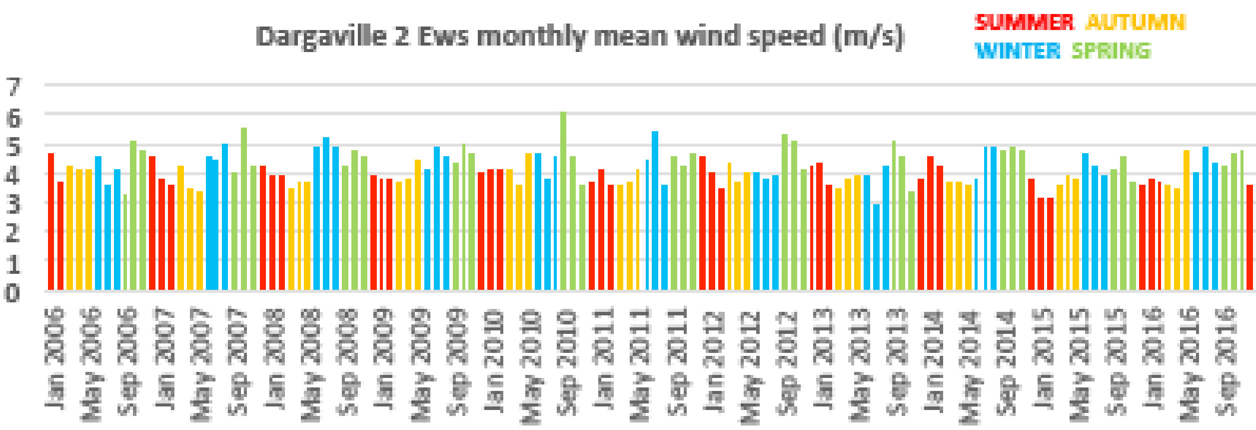
6.14. Sunshine

Dargaville sunshine measurements are used as a proxy. Peak summer sun seasons likely increase the evaporation rates of the lake.

6.15. Wind Speed

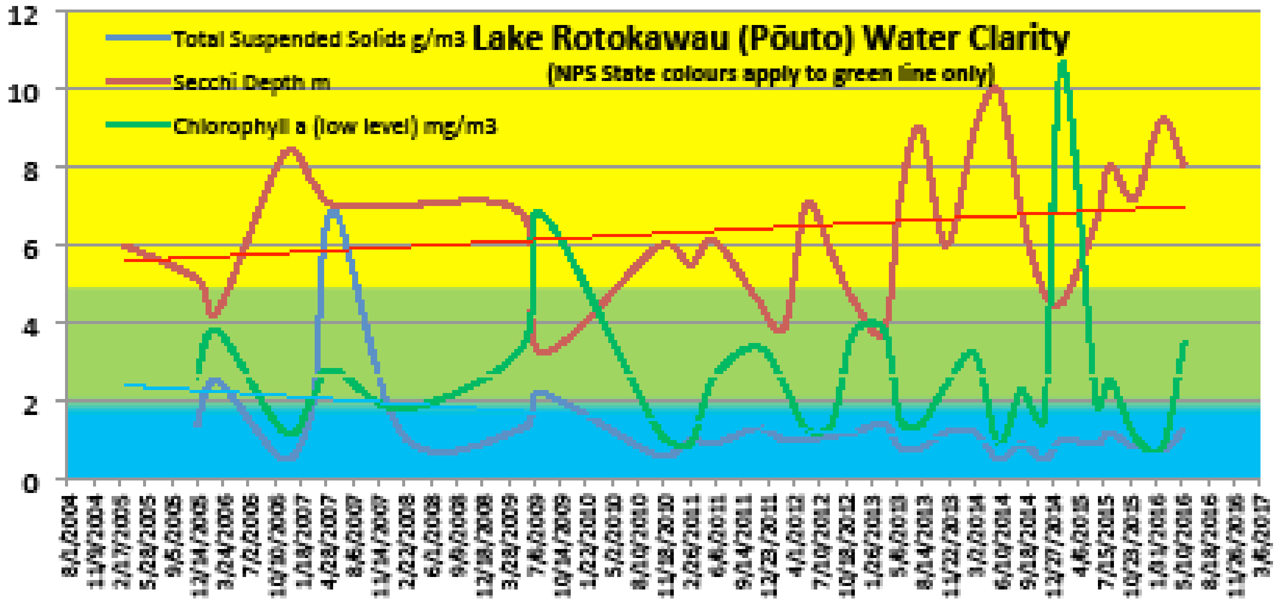
Dargaville wind measurements are used as a proxy.





6.16. Light incidence (Secchi, Total Suspended Solids, Chlorophyll-a)

Three measures which are indicators of water clarity include chlorophyll-a (presence of micro-algal growth in the water column), total suspended solids and the direct measure of visibility at depth by lowering a black and white Secchi disk until it is no longer visible. As seen from the graph below, Rotokawau experiences minor periodic algal blooms (green line), the latest being a peak in February 2015. Water clarity, based on Secchi readings, is improving. The table below the graph shows the National Policy Statement for Freshwater Management states for phytoplankton (chlorophyll-a).



Attribute	Unit	Lake Type	State	Annual Median	Annual Maximum	Narrative State
Phytoplankton	mg Chlorophyll-a/m³	All	A	≤2	≤10	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
Phytoplankton	mg Chlorophyll-a/m³	All	B	>2 and ≤5	>10 and ≤25	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrients levels that are elevated above natural reference conditions.
Phytoplankton	mg Chlorophyll-a/m³	All	C	>5 and ≤12	>25 and ≤60	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes.
Phytoplankton	mg Chlorophyll-a/m³	All	National Bottom Line	12	60	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes.
Phytoplankton	mg Chlorophyll-a/m³	All	D	>12	>60	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

7. CHEMICAL CHARACTERISTICS

7.1. Water Quality

7.1.1. Nutrients

7.1.1.1. Limiting nutrient assay

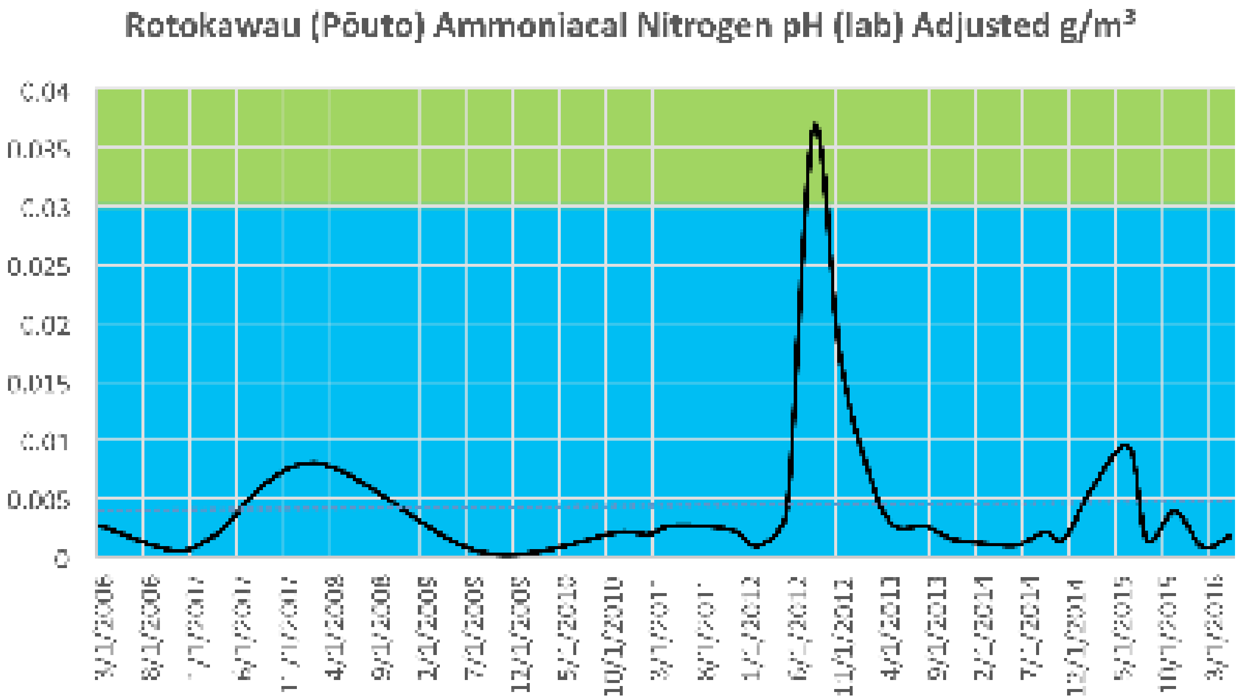
Max Gibbs (pers. comm.) from NIWA conducted limiting nutrient assays on several lakes, including Rotokawau. Significant results are highlighted.

For the years and seasons assayed, nitrogen plus phosphorus is the limiting nutrient combination in autumn and, in summer, both nitrogen and phosphorus and nitrogen and phosphorus combined are limiting. Lack of these nutrients regulate the ability of plants to optimally grow.

	Autumn 2014	Summer 2015	Autumn 2014	Summer 2015	Autumn 2014				Summer 2015		
Lake	Initial Chla	Initial Chla	Change in	Change in	Proportional change over control				Proportional change over control		
	(mg m^{-3})	(mg m^{-3})	Control	Control	+N	+P	+N+P	NP-P	+N	+P	+N+P
Rotokawau (Pouto)	1.1	2.7	0.64	0.81	0.91	0.94	1.10	0.16	1.14	1.23	1.32

7.1.1.2. Ammoniacal Nitrogen (Toxicity)

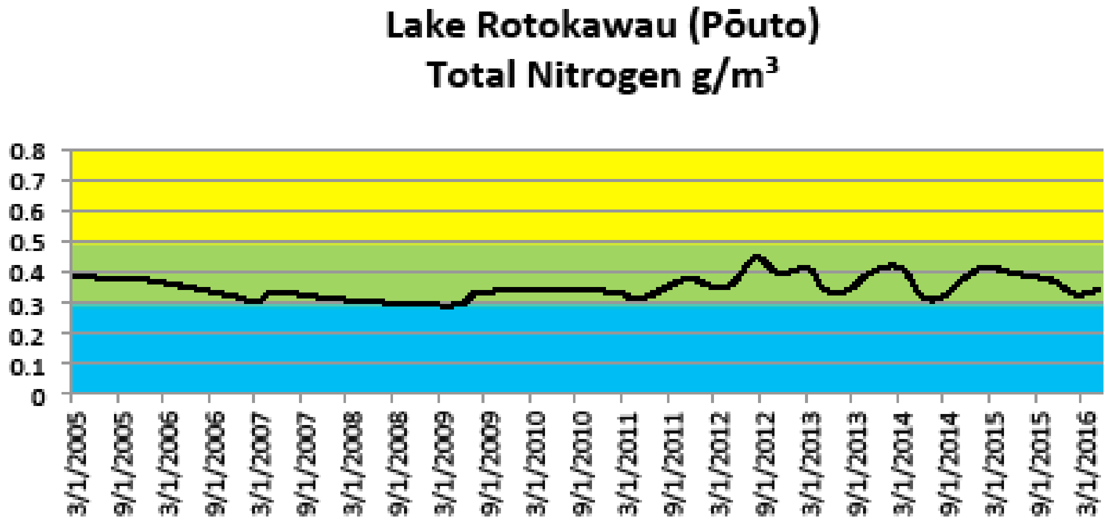
Ammoniacal nitrogen (NH_4-N), also often called 'ammonium', covers two forms of nitrogen; ammonia (NH_3) and ammonium (NH_4). It enters waterways primarily through point source discharges, such as raw sewage or livestock effluent. It is toxic to aquatic life at high concentrations. The table following the graph shows the National Policy Statement Freshwater Management limits for lake state. Rotokawau has remained in State A or low toxicity levels, except during a peak event in August 2008 when it entered State B.



Attribute	Unit	Lake Type	State	Annual Median	Annual Maximum	Narrative State
Ammonia (Toxicity)	mg NH_4-N/L (mg ammoniacal-nitrogen per litre)	All	A	≤0.03	≤0.05	99% species protection level: No observed effect on any species tested
Ammonia (Toxicity)	mg NH_4-N/L (mg ammoniacal-nitrogen per litre)	All	B	>0.03 and ≤0.24	>0.05 and ≤0.40	95% species protection level: Starts impacting occasionally on the 5% most sensitive species
Ammonia (Toxicity)	mg NH_4-N/L (mg ammoniacal-nitrogen per litre)	All	C	>0.24 and ≤1.30	>0.40 and ≤2.20	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
Ammonia (Toxicity)	mg NH_4-N/L (mg ammoniacal-nitrogen per litre)	All	National Bottom Line	1.3	2.2	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
Ammonia (Toxicity)	mg NH_4-N/L (mg ammoniacal-nitrogen per litre)	All	D	>1.30	>2.20	Starts approaching acute impact level (ie risk of death) for sensitive species

7.1.1.3. Nitrogen

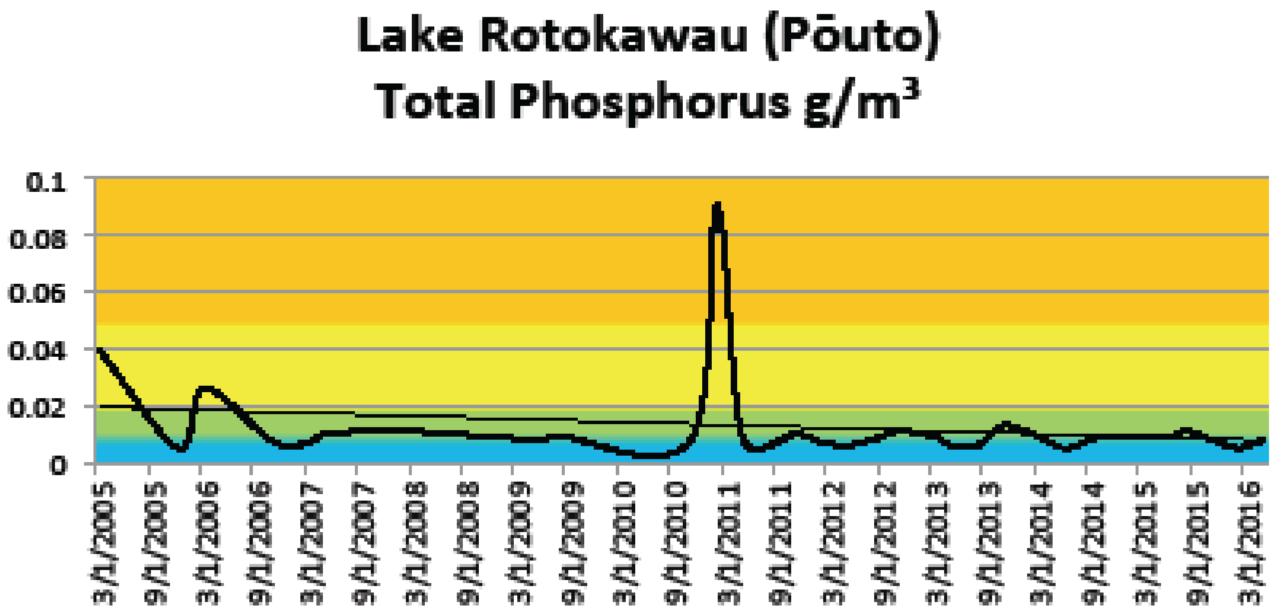
The following graph shows a total nitrogen timeline for the lake from 2005-2016. The trendline is fairly stable and nitrogen is consistently low-moderate. The table following the chart shows the National Policy Statement for Freshwater Management limits for lake state. The trend sits within State B. Although this lake exceeds 10 m depth, it is considered here as polymictic, meaning it does not readily thermally stratify.



Attribute	Unit	Lake Type	State	Annual Median	Narrative State
Total Nitrogen (Trophic state)	g/m3	Polymictic	A	≤.3	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
Total Nitrogen (Trophic state)	g/m3	Polymictic	B	>.3 and ≤.5	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrients levels that are elevated above natural reference conditions.
Total Nitrogen (Trophic state)	g/m3	Polymictic	C	>.5 and ≤.8	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.
Total Nitrogen (Trophic state)	g/m3	Polymictic	National Bottom Line	0.8	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions
Total Nitrogen (Trophic state)	g/m3	Polymictic	D	>.8	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

7.1.1.4. Phosphorus

Total phosphorus levels are, like nitrogen, stable and low other than one event in February 2011 where the it peaked. The chlorophyll-a response to this phosphorus peak did not result in an algal bloom. The table following the chart shows the National Policy Statement for Freshwater Management limits for lake state. Pulse samples are in State D with the trend line otherwise following the boundary of States A and B.



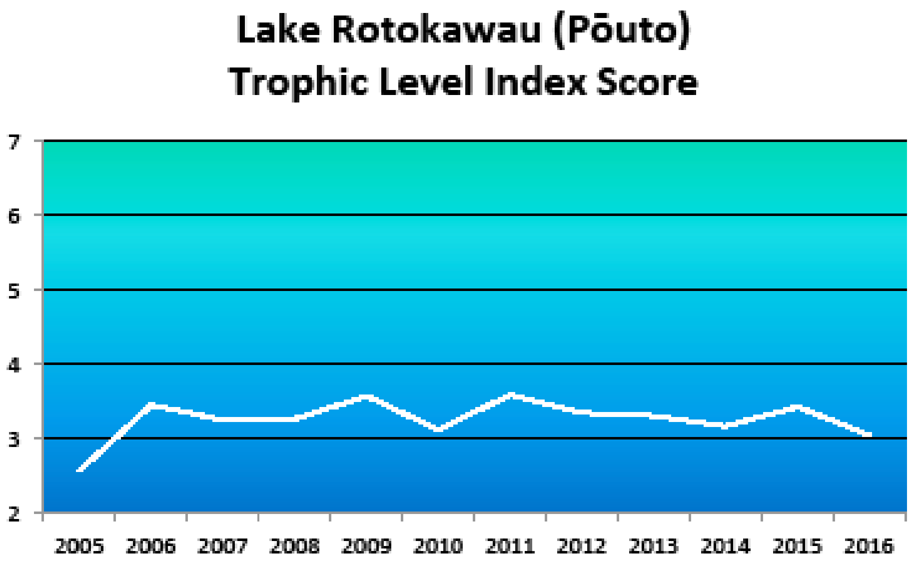
Attribute	Unit	Lake Type	State	Annual Median	Narrative State
Total Phosphorus (Trophic state)	g/m3	All	A	≤.01	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
Total Phosphorus (Trophic state)	g/m3	All	B	>.01 and ≤.02	Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrients levels that are elevated above natural reference conditions.
Total Phosphorus (Trophic state)	g/m3	All	C	>.02 and ≤.05	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.
Total Phosphorus (Trophic state)	g/m3	All	National Bottom Line	0.05	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.
Total Phosphorus (Trophic state)	g/m3	All	D	>.05	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

7.1.1.5. Trophic Level Index

The trophic level index (TLI) is used in New Zealand as a measure of the nutrient status of lakes. The index combines four variables; phosphorus, nitrogen, visual clarity (Secchi disk depth) and algal biomass, each weighted equally.

A low TLI score indicates a healthy lake with clear water and few algal blooms. A high TLI shows an overly nutrient-rich lake prone to algal blooms and poor light incidence, this shading affecting the health of submerged native plant communities.

The 2005-1016 TLI trend, shown below, indicates a stable TLI with the water quality of the lake being low mesotrophic (average water quality).



Water Quality	Trophic Level	TLI Score
Very Good	Microtrophic	<2
Good	Oligotrophic	2-3
Average	Mesotrophic	3-4
Poor	Eutrophic	4-5
Very Poor	Supertrophic	>5
No Data	No data available	

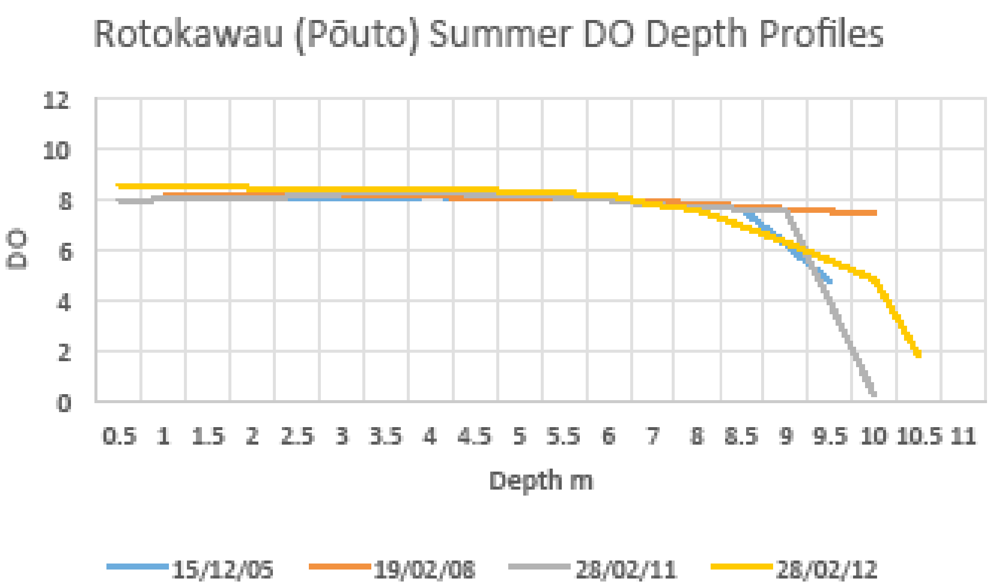
The graph below is display of TLI scores. This allows interpretation of the four contributing variables which are combined into an overall TLI score. From this chart, nitrogen is the key contributing variable to overall TLI for this lake.

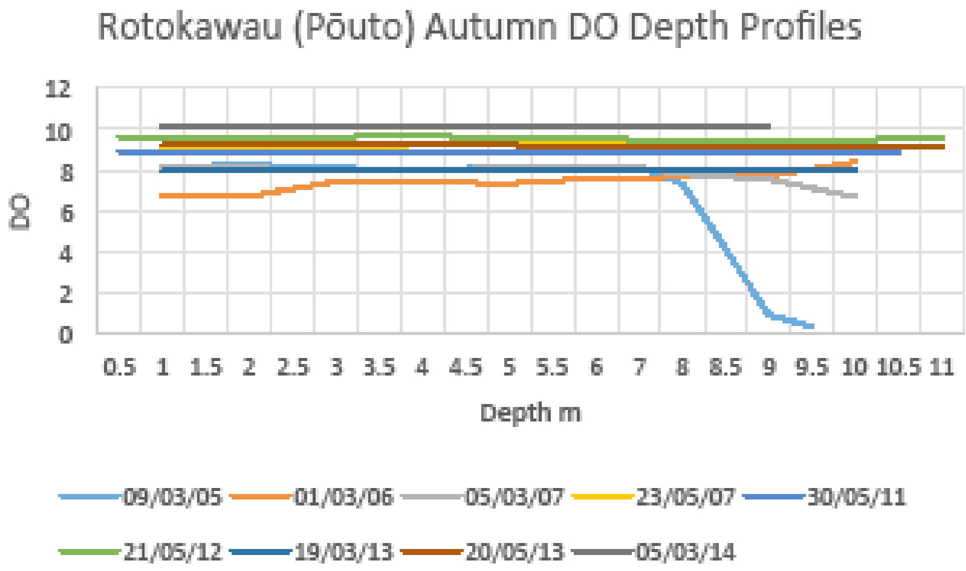
7.1.2. Dissolved Oxygen g/m³

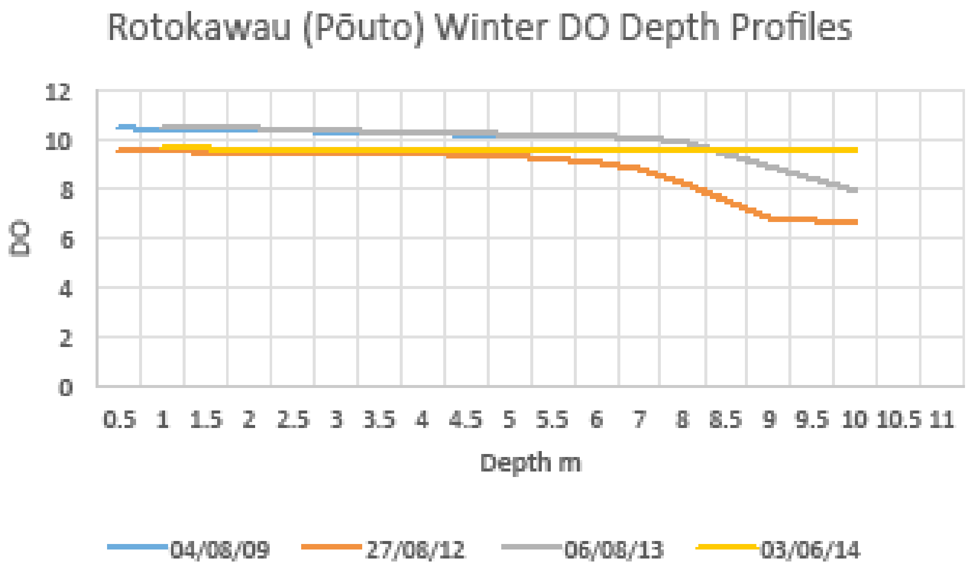
Although the lake does not thermally stratify due to its moderate shallowness, there is an oxygen depletion in water below 6-8 meters between spring and summer, as seen in the graphs below.

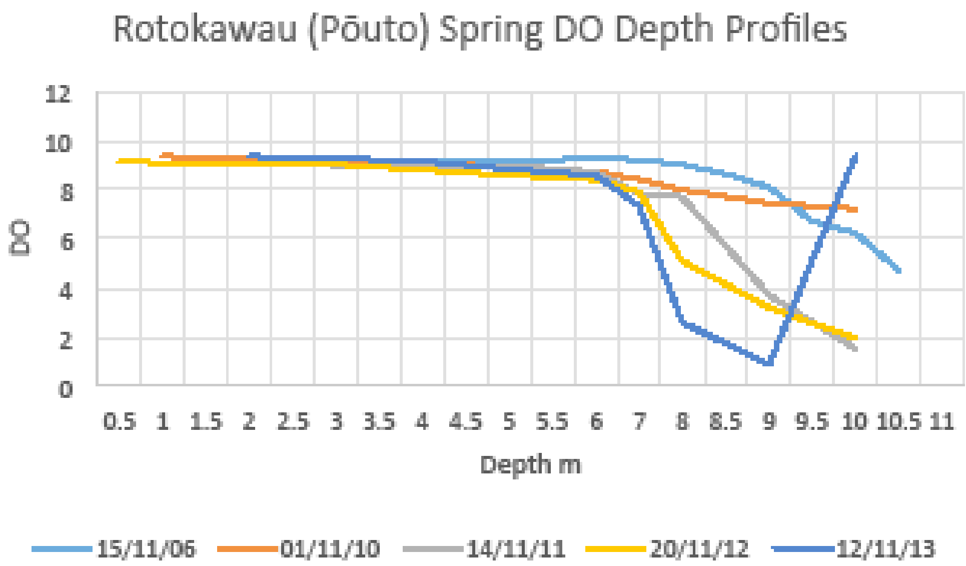
The table below shows the dissolved oxygen (at 15 degrees C) limits for New Zealand freshwater fish from https://www.niwa.co.nz/freshwater-and-estuaries/research-projects/dissolved-oxygen-criteria-for-fish. These guidelines help interpret the depth profiles as to the depth of the water column usable by fish species during the different seasons displayed in the graphs.

Dissolved Oxygen		Early life stages	Adults
30-day mean (mg L^{-1})	Guideline	9.0	8.0
	Imperative	6.5	6.0
7-day mean (mg L^{-1})	Guideline	7.5	6.5
	Imperative	5.5	5.0
7-day mean minimum (mg L^{-1})	Guideline	6.0	5.0
	Imperative	5.0	4.0
1-day minimum (mg L^{-1})	Guideline	5.0	4.0
	Imperative	4.0	3.0



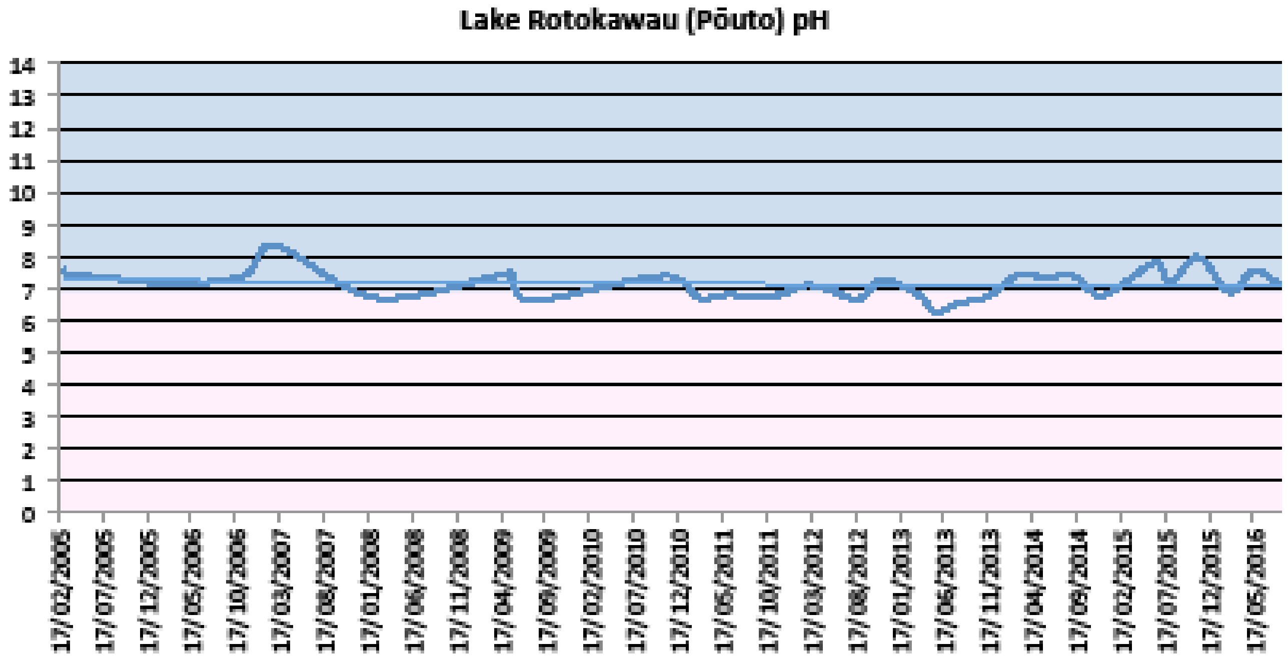

Rotokawau (Pōuto) Autumn DO Depth Profiles
DO
12
10
8
6
4
2
0
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 8.5 9 9.5 10 10.5 11
Depth m
09/03/05
01/03/06
05/03/07
23/05/07
30/05/11
21/05/12
19/03/13
20/05/13
05/03/14


Rotokawau (Pōuto) Winter DO Depth Profiles
DO
12
10
8
6
4
2
0
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 8.5 9 9.5 10 10.5 11
Depth m
04/08/09
27/08/12
06/08/13
03/06/14


Rotokawau (Pōuto) Spring DO Depth Profiles
DO
12
10
8
6
4
2
0
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 8.5 9 9.5 10 10.5 11
Depth m
15/11/06
01/11/10
14/11/11
20/11/12
12/11/13

7.1.3. pH

On average, the pH of this lake is near neutral (pH centred around 7).



8. BIOLOGICAL CHARACTERISTICS

8.1. Lake Biodiversity and Biosecurity species

8.1.1. Plants

Rotokawau is second only, in Pōuto, to Humuhumu in its aquatic plant diversity at 24 native aquatic plant species, as shown in the table below. The table is organised as a depth gradient, from emergent plants to those which are submerged, for each of the invasives and natives. Rare natives are presented last. Rotokawau contains two of these; *Trithuria inconspicua* and *Myriophylum votschii*.

In addition to the natives, there are six exotic species in Rotokawau, three being invasive, including royal fern and the two oxygen weeds; *Egeria* and *Elodea*. These last two, especially *Egeria*, are serious invasive species and likely represent the greatest risk to the lake if they increase their dominance. When the lake was last surveyed in 2015, both species' abundance had declined from levels found in prior surveys.

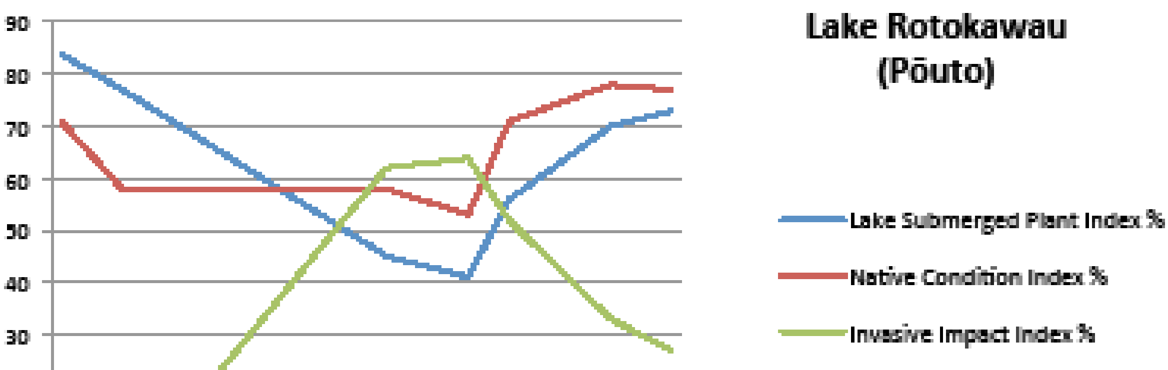
Lakes Roto-otuauru/Swan and Waingata (Pōuto) have introduced grass carp (green column colouration on the table below) as a management tool to rid these lakes of *Egeria densa* (from Swan) and *Elodea* (from Waingata). These operations were successful, with grass carp due for removal. Other species of plants in these lakes have been largely de-vegetated, but will likely return once the carp are removed.

Phoebe's Lake has been successfully treated with endothall for the eradication of *Lagarosiphon* major (purple absence on the chart).

8.1.1.1.1. Lake Submerged Plant Index (LakeSPI), Native Condition Index and Invasive Impact Index

Three indices are valuable for considering the health of a lake's plant community; Lake Submerged Plant Index, Native condition Index and Invasive Plant Index.

From the timeline below, we see that this lake has suffered for each measure due to the arrival of invasive exotic water weeds. This is likely to worsen, as the most recent ecological survey has found *Lagarosiphon* and *Ceratophyllum* present as well.



Ecological Health	Submerged Plant Index Score
Excellent	75-100%
High	50-75%
Moderate	20-50%
Poor	1-20%
Non-Vegetated	0%

8.1.2. Fish

The table below displays the fish of the Pōuto Peninsula. Pest fish are shown in green and conservation species in pink. Lake Rotokawau (Pōuto) appears in yellow. The lake has a moderate level of fish diversity and is free of pest fish.

Gambusia are found at Lake Rototuna to the north and pose a threat to the lakes of the rest of the peninsula to the south.

Common bully, dwarf inanga and short-finned eel are found in the Pōuto lakes, including Lake Rotokawau. Although removed from Lake Karaka but their east/west divide, the common bully of Lake Karaka has parasites also found in Lake Te Riu to the north in Waipoua and may pose a threat to common bully in Lake Rotokawau. Dwarf inanga are now rare in Rotokawau and are generally in need of attention throughout the Peninsula.

common name	species	Conservation status	Degree of loss	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
golden bell frog	Utoria Aurea								x											1
grass carp	Ctenopharyngodon Idella											x		x						[illegible]
goldfish	Carassius auratus			x																1
koi carp	Cyprinus carpio				x															1
Gambusia	Gambusia affinis						x													1
orfe	Leuciscus idus				x															1
rudd	Scardinius erythrophthalmus			x	x		x													[illegible]
tench	Tinca tinca			x																1
shortfinned eel	Anguilla australis			x	x			x	x			x	x				x	x		[illegible]
longfinned eel	Anguilla dieffenbachii	at risk	declining					x									x			[illegible]
giant kokopu	Galaxias argenteus	at risk	declining														x			1
dwarf inanga	Galaxias gracilis	at risk	naturally uncommon				rare			x	x	rare	rare	extinct	x	x				[illegible]
inanga	Galaxias maculatus	at risk	declining															x		1
common bully	Gobiomorphus cotidianus			x	x		x			x	x	x	x	x	x	x	x parasites	x	x	[illegible]
grey mullet	Mugil cephalus																	x		1
smelt	Retropinna retropinna																	x		1
	diversity pest fish			3	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	
	diversity native			2	2	0	2	2	1	2	2	3	3	2	2	2	4	5	1	

8.1.3. Waterbirds

The table below displays the waterbirds of the P uto Peninsula. Game birds are shown in green and non-game bird species in pink. Lake Rotokawau (Pōuto) appears in yellow. The lake has a moderate level of bird diversity and has the paradise shelduck is present as a game species. Dabchicks, Australasian bittern and New Zealand scaup occur widely in this sub-region. The only known sighting of the Cape Barren goose has been at this lake and is shown as an introduced and naturalised species in blue in the table.

common name	species	Conservation status [illegible]	[illegible] / Degree of loss	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Rotokawau (P)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Australasian (NZ) shoveler	Anas rhynchotis (resident native (not introduced) on game bird list)	Not threatened (resident native)																	x		1
grey duck	Anas superciliosa (resident native (not introduced) on game bird list)	threatened	nationally critical		x														x		2
grey duck - mallard hybrid	Anas superciliosa x platyrhynchus (resident native (not introduced) on game bird list)	Not threatened																x			1
black swan	Cygnus atratus (resident native (not introduced) on game bird list)	Not threatened			x		x	x					x			x					5
pukeko	Porphyrio m. melanotus (resident native (not introduced) on game bird list)	not threatened															x				1
paradise shelduck	Tardorna variegata (resident native (not introduced) on game bird list)	Not threatened					x	x		x				x							4
Cape Barren goose	Cereopsis novaehollandiae (introduced & naturalised)	introduced & naturalised												x							1
brown teal	Anas chlorotis	at risk	recovering															x		x	2
New Zealand scaup	Aythya novaeseelandiae	not threatened			x		x	x	x			x		x	x	x	x	x	x	x	12
Australasian bittern	Botaurus poiciloptilus	threatened	nationally critical	x			x	x	x		x	x	x	x		x	x	x	x	x	13
North Island fernbird	Bowdleria punctata vealeae	at risk	declining									x	x					x	x	x	5
banded rail	Gallirallus philippensis assimilis	at risk	declining															x	x	x	3
Caspian tern	Hydroprogne caspia	threatened	nationally vulnerable									x				x	x		x		4
black shag	Phalacrocorax carbo novaehollandiae	at risk	naturally uncommon		x																1
shag spp.	Phalacrocorax spp.																		x		1
New Zealand dabchick	Poliocephalus rufopectus	at risk	recovering	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	17
marsh crake	Porzana pusilla affinis	at risk	declining															x			1
spotless crake	Porzana t. tabuensis	at risk	declining						x		x	x				x	x		x	x	7
Eastern little tern	Sternula albifrons sinensis		migrant													x	x				2
diversity resident native (not introduced) on game bird list				0	2	0	2	2	0	1	0	0	1	1	0	1	1	1	2	0	
diversity introduced & naturalised				0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	
diversity native				2	3	1	3	3	4	1	3	6	3	3	2	6	6	7	8	7	

8.1.4. Invertebrates

Invertebrates are of interest in lake systems as indicators of lake health. They are generally very sensitive to poor water quality. In the case of Rotokawau, the presence of the Ceratopogonidae biting midge which cannot tolerate more than clean water and the three Acarna mites and the mayfly, not tolerant of worse than mild pollution is encouraging. Koura, however, are absent.

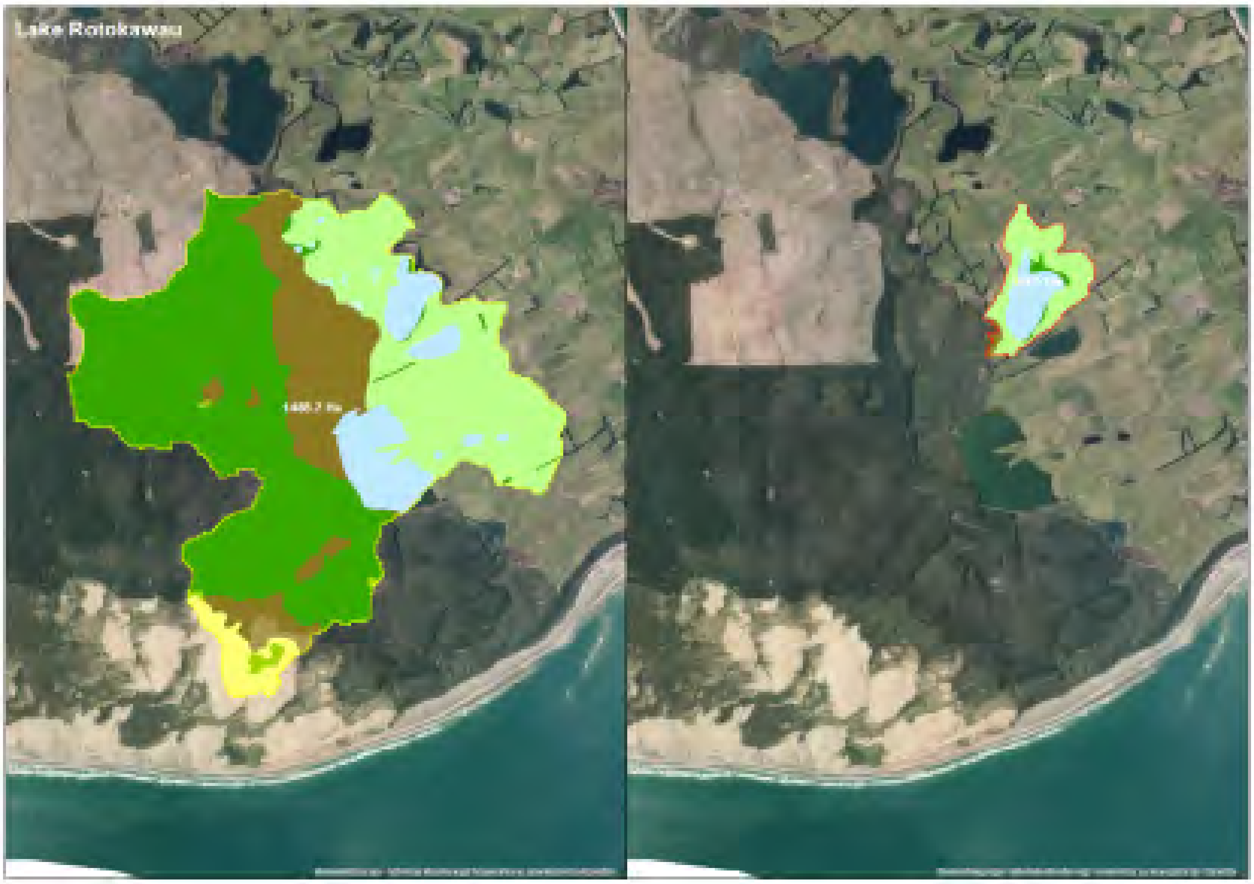
Order or phylum and common name	Family or species	Pollution [illegible] tolerance - Clean Water ([illegible]) Mild Pollution ([illegible]) Moderate Pollution ([illegible]) Severe Pollution ([illegible])	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Rotokawau (P)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hydrozoa, freshwater jellyfish medusae	*Craspedacusta sowerbyi*						x						x		3
Mollusc, snail	*Physa (Physella) acuta*	0.1			x										1
Mollusc, snail	*Physa (Physella) sp*	0.1		x							x			x	3
Acarna, mite	Hydrachnidae	5.2							x		x		x		3
Acarna, mite	Oribatida	5.2		x					x	x	x		x		4
Acarna, mite	Oxidae	5.2							x		x				3
Amphipoda, hopper	Paracalliope sp			x											1
Crustacea, Cladocera	sp	[illegible]		x					x		x		x		4
Crustacea, Copepoda	sp	[illegible]		x					x		x		x		4
Crustacea, Ostracoda, koura	*Paranephrops planifrons*	8.4					x			x	x				3
Crusteacea, Ostracoda	*Herpetocypris*	[illegible]		x					x	x	x				4
Diptera, house fly	Muscidae	[illegible]							x						1
Diptera, midge, biting	Ceratopogonidae	6.2							x	x	x		x		4
Diptera, midge, non-biting, Chironomid	Tanytarsini	4.5		x					x		x		x		4
Diptera, midge, non-biting, Chironomid	*Chironomus sp*	[illegible]		x					x	x	x		x	x	4
Diptera, midge, non-biting, Chironomid	Orthocladiinae	[illegible]		x					x	x	x		x		4
Diptera, midge, non-biting, Chironomid	Tanypodinae	6.5									x		x		3
Ephemeroptera, mayfly	*Deleatidium*	5.6							x						1
Hemiptera, bug	*Microvelia macgregori*	4.6											x		1
Hemiptera, bug, backswimmer	*Sigara arguta*	[illegible]		x							x			x	3
Hemiptera, bug, waterboatman	*Diaprepocoris sp*	4.7									x				1
Hirudinea, leech	Hirudinea			x							x		x		3
Hirudinea, leech	*Richardsonianus mauianus*			x					x						3
Hydrozoa, hydra	*Hydra* sp					x							x		3
Lepidoptera, aquatic moth	*Hygraula nitens*	[illegible]									x		x		3
Mollusca, bivalve	Sphaeriidae			x					x						3
Mollusca, freshwater mussel	*Echyridella menziesi*					shells	x	x	x				x		4
Mollusca, freshwater mussel	*Hyridella menziesi*	6.7	x							x	last 2000				3
Mollusca, snail	*Gyraulus corinna*	[illegible]		x											1
Mollusca, snail	Lymnaea sp			x											1
Mollusca, snail, native	*Glyptophysa variabilis*	[illegible]					x			x	x				3
Mollusca, snail, native	*Potamopyrgus antipodarum*	[illegible]				x			x			x		x	4
Nematoda, roundworm	sp	[illegible]		x					x	x			x		4
Nemertea, proboscis worm	sp	[illegible]		x							x				3
Odonata, damselfly	*Xanthocnemis sp*	[illegible]		x							x				3
Odonata, dragonfly	*Aeshna brevistyla*	[illegible]		x					x						3
Odonata, dragonfly	*Hemianax papuensis*	[illegible]		x							x				3
Odonata, dragonfly	*Hemicordulia australiae*	[illegible]		x					x	x	x				4
Oligochaete worm	Oligochaeta sp	[illegible]							x	x	x		x		4
Ostracod crusteacean	*Cypretta*										x				1
Ostracod crusteacean	*Cypridopsis*								x	x					3
Ostracod crusteacean	*Ilyodromus*								x	x	x		x		4
Platyhelminthes, flatworm	sp	[illegible]		x					x	x	x				4
Porifera, freshwater sponge	sp					x									1

9. LAND USE

9.1. Catchment land cover (ha) and map

The LiDAR-defined catchment is dominated by high and low producing exotic grassland and herbaceous freshwater vegetation.

Lake	Cover Type	Total FENZ (ha)	Total LiDAR (ha)
Lake Rotokawau	Broadleaved Indigenous Hardwoods	11.58	0.00
Lake Rotokawau	Exotic Forest	699.41	6.44
Lake Rotokawau	Herbaceous Freshwater Vegetation	17.82	13.09
Lake Rotokawau	High Producing Exotic Grassland	373.55	81.21
Lake Rotokawau	Lake or Pond	128.97	38.98
Lake Rotokawau	Low Producing Grassland	23.86	13.67
Lake Rotokawau	Manuka and/or Kanuka	242.83	2.76
Lake Rotokawau	Sand or Gravel	43.01	0.00
Lake Rotokawau Total		1535.04	156.14

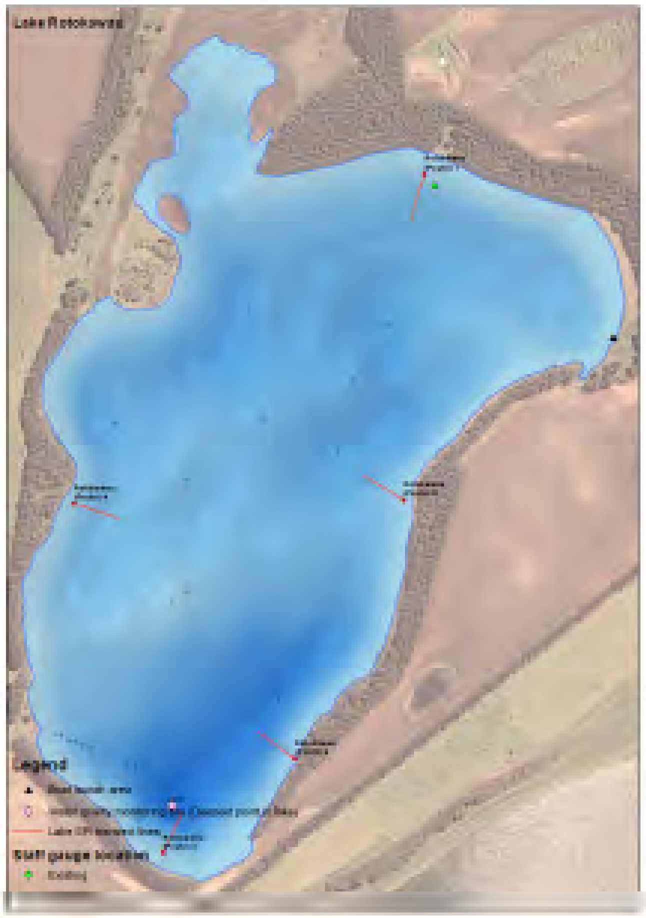


9.2. Fire-fighting mitigations

Rotokawau, due to its invasive water weeds, has been identified as a high-risk water take for fire-fighting, indicated by the red marker at this lake in the map below. Neighbouring lake Waingata is a safe alternative.

10. MONITORING PLAN

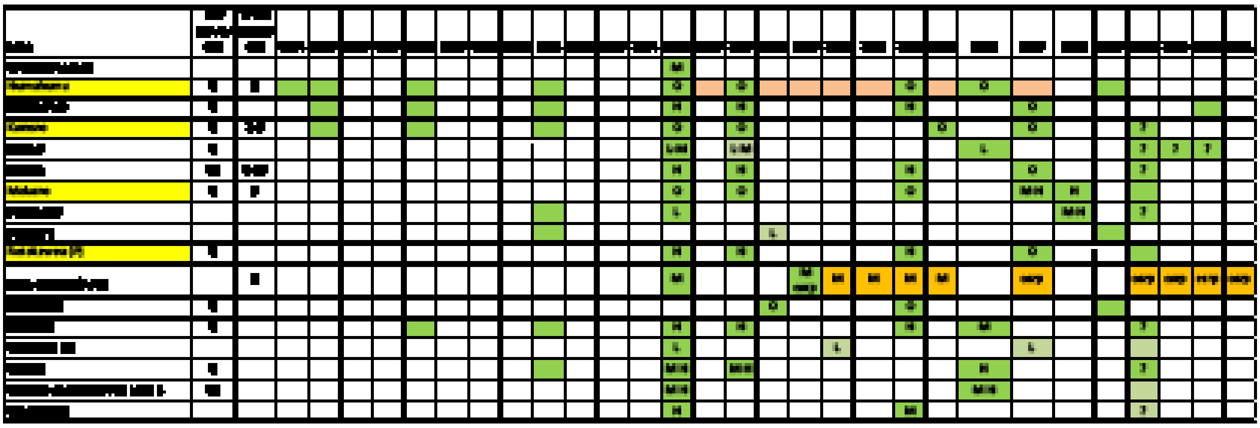
The diagram adjacent shows the five transect lines surveyed during ecological surveys. The dark triangl in the east is the access point for the NRC vessel for water quality sampling. The pink point in the south of the lake is the water quality sampling poin corresponding to the deepest part of the basin.



10.1. NIWA ecological monitoring

The lake is scheduled to be fully ecologically monitored every five years. There have been four full surveys since 2005. The value class of the lake began at High and progressed to Outstanding in 2015. The next full survey is likely to be done in 2018.

KEY
O = Outstanding
H = High
M = Medium
L= Low
Ecological Survey
Reconnaissance or Visit
Weed Surveillance
Grass Carp Assessment
Endothall Assessment
SPI = Submerged Plant Index
Surveillance



10.2. NRC Ecological monitoring

10.2.1. Water quality and quantity monitoring

Water quality sampling occurs quarterly in February, May, August and November. Number of samples taken by year are shown below.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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11. WORK IMPLEMENTATION PLAN

Ongoing work includes:

- The NRC/NIWA ecological surveys will continue every five years. The next full survey will be in 2018. Quarterly NRC water quality monitoring will continue.
- Installation of a continuous electronic water-level recorder is planned by NRC.
- The NRC Dune Lakes Freshwater Improvement Fund project includes several work-streams at Rotokawau, including weed eradication of Elodea and Egeria ($23,232) and modelling of nutrients entering the lake with $10,000 available for mitigation by sediment detention.

Further mitigation work to consider includes:

- Fencing to exclude stock and to protect the wetland to the northeast side of the lake.
- Rotokawau, due to its invasive water weeds, has been identified as a high-risk water take for fire-fighting. Neighbouring lake Waingata is a safe alternative.
- Understanding the drivers for the improved water clarity noted in this lake could have generic benefits for this and other lakes.
- Assessment of why dwarf inanga have declined.
- Biosecurity controls for aquatic weeds will require an understanding of why these species have appeared to take hold only to decline a few years afterwards.

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13. APPENDIX 1. GLOSSARY

Largely adapted from https://www.lawa.org.nz/Learn

Aquatic - Refers to anything that is related to water. For example, aquatic organisms are plants or animals that live in or near water.

Algal or phytoplankton bloom - A rapid increase in the population of algae in an aquatic system. Blooms can reduce the amount of light and oxygen available to other aquatic life.

Bathymetry – The measurement of depth of water.

Biodiversity - The variety of lifeforms at a given time in a given place.

Biosecurity - The precautions taken to protect against the spread harmful organisms and diseases.

Catchment (area) - The total area of land draining into a lake, expressed in hectares (ha).

Chlorophyll a – Chlorophyll a is a green pigment in all plants, including algal phytoplankton, that is used for photosynthesis and is a good indicator of the total quantity of algae present. It can be measured in micrograms per litre (ug/l) or reflective florescence units (RFU). Large amounts of algae in a lake can decrease the clarity of the water, make the water green, form surface scum, reduce dissolved oxygen and alter the pH of the water.

Clarity (of water) - Refers to light transmission through water and has two important aspects: visual clarity and light penetration. Visual clarity indicates how much sediment or runoff is in the water. Light penetration is also important as it controls light availability for growth of aquatic plants.

Classification of dune lakes (Timms, 1982)

Dune lake class (Timms, 1982)	Description
1. Perched lakes in deflation hollows	Perched in leached dunes, in deflation hollows in elevated leached dunes where organic material has sealed the basin floor and provided humic (tea-stained) water.
2. Swamp-associated perched lakes	Similar to Class 1 but close to the sea, associated with extensive swamps.
3. Window lakes	Water table window lakes in a drowned valley or interdune basin, fed by springs with clear water character.
4. Dune contact lakes	Waterbodies where at least one shore is in contact with a coastal dune, often but not exclusively humic.
5. Marine contact lakes	Freshwater lakes with marine contact, where there may be intermittent connection with the sea.
6. Ponds in frontal sand dunes	Ponds where wind erodes sand to form deflation hollows.

Deoxygenation – Also called hypoxia. Air is 20.9% oxygen, whereas water contains around 1% oxygen and this fluctuates depending on the presence of photosynthetic organisms (higher submerged plants and microalgae) and the distance to the surface, as air diffuses oxygen into surface waters. Hypoxia can occur throughout the water column as well as near sediments on the bottom. It usually extends throughout 20-50% of the water column, but depending on the water depth, it can occur in 10-80% of the water column. For example, in a 10-meter water column, it can reach up to 2 meters below the surface. In a 20-meter water column, it can extend up to 8 meters below the surface. Oxygen depletion can result from a number of natural factors, but is most often a concern as a consequence of pollution and eutrophication in which plant nutrients enter a lake, and phytoplankton blooms are encouraged. While phytoplankton, through photosynthesis, will raise Dissolved Oxygen (DO) saturation during daylight hours, the dense population of a bloom reduces DO saturation during the night by respiration. When phytoplankton cells die, they sink towards the bottom and are decomposed by bacteria, a process that further reduces DO in the water column. If oxygen depletion progresses to hypoxia, fish kills can occur and invertebrates like freshwater mussels on the bottom may be killed as well.

Dissolved oxygen (DO) - The oxygen content of water. Dissolved oxygen is important for fish and other aquatic life to breathe. For example, water quality guidelines recommend that water should be more than 80 percent saturated with DO for aquatic plants and animals to be able to live in it.

Eutrophic – A trophic level referring to a lake having an abundant accumulation of nutrients that support a dense growth of algae and other organisms, the decay of which may deplete the shallow waters of oxygen in summer resulting in potential death of animal life. In the Trophic Level Index (TLI), a trophic level of 4-5, meaning the water quality is poor.

Exotic species (also called introduced, alien, non-indigenous or non-native) - A species living outside its native distributional range, which has arrived by human activity, either deliberate or accidental. Exotic species can have various effects on the local ecosystem. Exotic species that become established and spread beyond the place of introduction are called invasive species.

Hapū - Te reo Māori for a sub-tribe or a clan. Each iwi can have a number of hapū. For example, the Ngāti Whātua iwi has hapū including Te Uri-o-Hau, Te Roroa, Te Taou, and Ngāti Whātua ki ōrākei.

Humic - Of, relating to, or derived from humus, which is a dark brown or black mass of partially decomposed organic matter in the soil. Humic acids are present in peats. Humic acids are produced by the bacterial decomposition of dead plant residues and by the prolonged action of atmospheric oxygen or water on organic matter. Run-off from land of this soil type can stain lake-water a dark brown (known as humic or tanin staining), limiting light for plant growth. Forestry harvest has been shown to disturb this soil type, leading to lake water quality decline.

Invasive exotic plant – An exotic species that becomes established and spreads beyond the place of introduction, posing a risk to native ecology.

Invasive Impact Index - The percentage of invasive weeds within a lake. A high Invasive Impact is undesirable.

Invertebrate - An animal that has no backbone or spinal column, such as insects, worms, snails and freshwater mussels.

Lake Submerged Plant Index (SPI) - A method of characterizing the ecological health of lakes based on the amount of native and invasive plants growing in them. Higher Lake SPI scores are associated with the better ecological health.

Limiting nutrient assay – An analytic procedure to determine what nutrient is limiting algal growth in a lake. If the limiting nutrient becomes available, increased growth of algal phytoplankton will occur.

Macrophyte - Large water plants and algae that live in freshwater and are visible to the naked eye, as opposed to the microscopic periphyton and phytoplankton. Macrophytes can be either submerged, floating or emergent. Most macrophytes in Northland are rooted to the bottom.

Mana whenua – Te reo Māori for territorial rights, power from the land, authority over land or territory, jurisdiction over land or territory - power associated with possession and occupation of tribal land. The tribe's history and legends are based in the lands they have occupied over generations and the land provides the sustenance for the people and to provide hospitality for guests.

Mesotrophic - A trophic level of 3-4 meaning the water quality is average. The lake has moderate levels of nutrients and algae.

Native Condition Index - The percentage of native vegetation within a lake. A high native condition is desirable. It is one of the measures used to determine the Lake Submerged Plant Index.

Native species (also indigenous species) - A species found naturally in an ecosystem, including naturally-arriving migrant species which may be found in other countries as well. Endemic natives are found only in one place or country.

Non-invasive exotic plant - Exotic species of plants that become established and do not readily spread beyond the place of introduction, posing little threat to native species.

Oligotrophic - A trophic level of 2-3 meaning the water quality is good. The lake has low levels of nutrients and algae, high oxygen levels due to a lack or decaying organic material. The lake is clear and blue, with very low levels of nutrients and algae.

pH - The degree of acidity or alkalinity as measured on a scale of 0 to 14 where 7 is neutral, less than 7 is more acidic, and greater than 7 is more alkaline. Most natural waters fall within the range between pH 6.5 to 8.0 and in the absence of contaminants most waters maintain a pH value that varies only a few tenths of a pH unit.

Phytoplankton - Microscopic algae and cyanobacteria that drift or float in the water column and are able to produce oxygen through photosynthesis. When overgrowth or algal bloom occurs, it is an indication that excess nutrients are a problem. Algal blooms can shade light from reaching submerged plants and if a bloom collapses, deoxygenation of the water may occur.

Quaternary dunes – We are currently still living in the Quaternary period of geological time. The Quaternary period is subdivided into the Pleistocene epoch (2.6 million years ago to 11,700 years ago), the Holocene epoch (11,700 years ago to 1950) and the Anthropocene epoch (1950-present or the period when the Industrial Revolution began to alter climate). When we refer to dune sand types, they are informally divided into Early/Lower Quaternary (dunes formed 2.6 million-78,000 years ago) and Late/Upper Quaternary (dunes formed 12,000 years ago to the present, basically during the Holocene epoch).

The material in present-day river valleys and beaches has been mainly deposited since the last glacial stage ended, about 14 000 years ago. From then, until about 6000 years ago, there was a substantial warming of climate which caused a rise in sea level; some dune deposits are recognised as having formed at the time that sea level rise ended.

Sea level has dropped again slightly since that time.

Lakes are collecting mud and sand and will eventually fill. Sand dunes naturally advance, blown by the wind until stabilised by vegetation.

Periods of cold climate occurred throughout the Quaternary, not only in New Zealand but globally. The worldwide glaciations caused sea level to drop, as much water was bound up in ice and snow. During warmer interglacial periods, the ice melted and sea level rose. The effect of these oscillating sea levels is clearly seen in uplifted coastal terraces, each flat surface marking the position of an earlier high sea level. Periods of low sea level and cold climate created expanses of bare earth and sand with little vegetation. Winds blew the coastal sand into dunes. In the North Island, there was little active glaciation except in the very highest mountain areas. The build-up of sand dunes was a result of low sea levels and cold climate.

Rare native plant - A rare plant is one that is not commonly found in the wild. It may be naturally rare or sparse or may have a restricted range. Rare plants may or may not be of conservation concern. A threatened plant is a rare plant which is at risk of extinction in the wild. An endangered plant is a category of threatened plant. It is a technical term for describing the degree of risk of extinction a plant is under. Some technical terms, such as endangered, are commonly and inaccurately used to refer to all threatened plants.

Residence time (also retention time, water age or flushing rate) – A calculated quantity expressing the mean time that water spends in a particular lake.

Riparian zone - A strip of land, usually of varying width, that is directly adjacent to a waterway and which contributes to maintaining and enhancing the natural functioning, quality, and character of the waterbody. This area is commonly planted in native species to reduce sediment and nutrient inflows.

Sp. aff. or aff. (short for "species affinis") indicates a potentially new and undescribed species has an affinity to, but is not identical to, the named species. ... spp.; short for "species") indicates potentially new species without remarking on its possible affinity.

Secchi disk - Lake clarity is measured using a Secchi disc attached to a measured line. The disc is lowered into the water until it disappears and this depth is noted. The disc is lowered a little further and then slowly raised until it reappears, this depth is noted. The average of the two readings is the final Secchi depth visibility depth.

Supertrophic - A trophic level greater than 5 meaning the water quality is very poor. The lake is fertile and saturated in phosphorus and nitrogen, often associated with poor water clarity.

Thermal stratification - Refers to a change in the lake water temperature at different depths in the lake, and is due to the change in water's density with temperature. Cold water is denser than warm water and the epilimnion, or shallower waters, generally consists of water that is not as dense as the water in the hypolimnion, or deeper waters. When stratification occurs, the two water masses are not mixing, leading to nutrients and lower oxygen levels being captured in deeper, colder water. This generally occurs in warmer months. When the upper water cools in colder months, mixing will occur, providing nutrients throughout the lake, which can lead to algal bloom conditions.

Total Phosphorus (TP) - Total phosphorus is a measure of all forms of phosphorus that are found in a sample, including dissolved and particulate, organic and inorganic. High levels of total phosphorus in water can come from either wastewater or run-off from agricultural land. Too much phosphorus can encourage the growth of nuisance plants such as algal blooms.

Total Nitrogen (TN) - Total Nitrogen is a measure of all organic and inorganic forms of nitrogen that are found in a sample. High total nitrogen, like total phosphorus can be a cause of eutrophication in lakes, estuaries and coastal waters and can cause algal blooms.

Total Suspended Solids (TSS) - Solids in water that can be trapped by a filter for measurement. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can adversely affect aquatic life.

Trophic Level Index (TLI) - Used in New Zealand as a measure of nutrient status of lakes. The TLI is calculated from data from 4 parameters: water clarity (Secchi), chlorophyll a content, total phosphorus and total nitrogen.

Volumetric flow rate (as a mean annual total) - The amount of water entering a lake in a year, expressed in m3/s or cubic meters per second.

Acknowledgements

Sincere thanks to those who have generously provided their time to the twelve outstanding dune lake plans project, including:

- Lisa Forester for the guidance, support, knowledge and editing.
- Andrew Macdonald for countless analyses, data presentation and editing.
- Bruce Howse for guidance and support along the way.
- Katrina Hansen and Bruce Griffin in Biodiversity for their editing.
- Ngā Kaitiaki o ngā roto tāhuna – Each iwi/hapu/whanau and marae who have engaged in this process and in the korero and mahi to come.
- The NRC teams: Biodiversity, GIS, Biosecurity, Hydrology, State of the Environment, Area Offices in Dargaville and Kaitaia, Land Management, Consents, IS&T, Planning and Policy, Communications, Finance and our Kaiarahi who all made valuable contributions of time, information and thought.
- The Northland Regional Council councillors and our CEO Malcolm Nicolson who are passionate about our region and our lakes.
- Paul Champion and the team at NIWA for data provision and insight.
- Kevin Matthews of the Bushland Trust for local knowledge of the Aupouri and Karikari Peninsulas ecology.
- Graeme Doole at the Ministry for the Environment and Chris Tanner at the Cawthron Institute for the modelling approach to nutrient mitigation presented in the Humuhumu and Kanono plans.
- Our friends at DOC, Taharoa Domain Committee at Kaipara District Council and Lake Ngatu Action Group for collaborations.
- The Catchment Groups, especially Pōuto and Doubtless Bay, for their lakes-related planning.
- The forestry industry for their open engagement and the farmers who are taking steps to protect these lakes.
- The Ministry for the Environment and ratepayers of Northland for the Dune Lakes Freshwater Improvement Fund project which will address many of the actions in these plans over the next five years.