Lake Kanono

MANAGEMENT PLAN

Northland
REGIONAL COUNCIL

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LAKE KANONO MANAGEMENT PLAN

1. PURPOSE

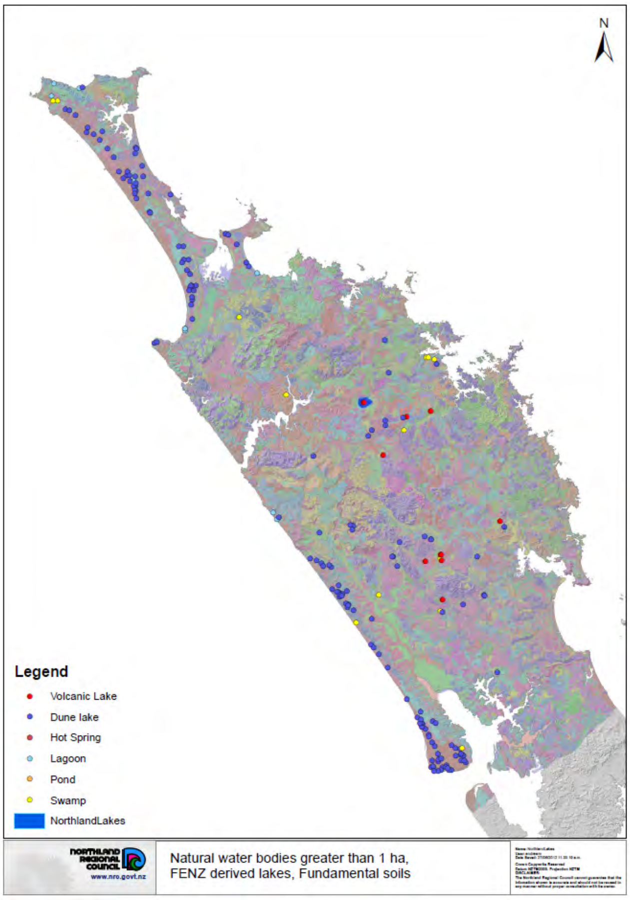
The purpose of the Outstanding Northland Dune Lakes Management Plans is to implement the recommendations of the Northland Lakes Strategy Part II (NIWA 2014) by producing Lakes Management Plans, starting with the 12 'Outstanding' value lakes, and by facilitating actions with mana whenua iwi, landowners 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 Pōuto 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 Kanono (NRC Lake Number 377) is a deep (15.59 m max and 7.21 m mean depth) 80.42 ha dune lake, with a south-eastern basin separated from the northern basin by a shallow area extending from the eastern peninsulas in the centre of the lake. The lake is located on private farmland to the west of Pōuto Road on the far southern end of the Pōuto Peninsula in south-western Northland. The lake is classified as a Class 4 Dune Contact dune lake (Timms, 1982), as its western shore sits in contact with more geologically recent uncemented to loosely-cemented dune with its eastern shore sitting on older cemented dune geology.

The catchment is dominated by high producing exotic grassland, manuka/kanuka scrub and closed canopy exotic pine forest. Cropping has occurred close to the lake at various times. The catchment area as defined by LiDAR, including the lake, is 354.5 hectares. The surface area of the lake is 80.42 ha. Catchment boundaries have recently been redefined but the data is not yet available.

The lake stratifies in summer at 10 m only to a very minor degree due to its shallow mean depth. An extreme algal bloom occurred in February 2015 into National Policy Statement for Freshwater Management (NPS) chlorophyll-a State D with a loss of water clarity (Secchi). The chlorophyll-a trend is likely due an event which spiked both nitrogen and phosphorus levels. Several smaller peaks into State D had preceded this event. These are a concern as they suggest a permanent plant regime shift from macrophytes to phytoplankton. By June 2015, toxic ammonia had spiked into NPS State C.

The nitrogen trend generally remains in State B, other than events where it has pushed into NPS State C in November 2007 and, more recently, into State D in June 2015. The phosphorus trendline wavers between NPS States B and C.

The 2005-1016 Trophic Level Index trend indicates poor water quality (low level eutrophic) with two years of spikes in even poorer water quality (2007 and 2015) with recovery from each of these events. Both total nitrogen and total phosphorus spiked at the same period and were followed by a response in Chlorophyll-a spikes (algal blooms). Oxygen depletion occurs between November and March in water below 6-8 m, respectively. On average, the pH varies consistently between 8 and 9 (alkaline).

Lake levels in Kanono have varied by 1.87 metres and have declined through time. However, a comparison of lake level time series of the Pōuto dune lakes shows that Kanono, along with Rototuna, has seen relative long-term reduction of water level. Estimated lake water residence time is just under 16 months. Water sources are 57% rainfall, 42% surface runoff and only 2% groundwater.

Kanono has a native aquatic plant diversity of 19 species with only one exotic species, the non-invasive *Potamogeton crispus*. No rare species are present. Despite issues with water quality and algal blooms, this lake is in good ecological health, due to its relative high native plant diversity compared to the low number of exotic plant species present.

There are no pest fish present. Common bully and dwarf inanga are present but the lake has an absence of the short-finned eels found in other Pōuto Lakes.

The lake has a high level of non-game native bird diversity and black swan, a game species, is present. Dabchicks, Australasian bittern and New Zealand scaup occur. The only sightings of the eastern little tern have been at this lake and neighbouring Lake Kahuparere.

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 Kanono. The lakebed is currently managed by the Department of Conservation.

A planning initiative called Future Pōuto has recently been undertaken by Te Uri o Hau and an Iwi Environmental Management Plan has been written.

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

Eight landowners own eight land parcels in the lake catchment. The lake bed is managed by the Department of Conservation.

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 a councillor from Northland Regional Council.

5.4. Public use

5.4.1. Access

Access to the lake is over 3 km of private farmland. The lake margin is fully fenced.

5.4.2. Boating

5.4.2.1. Boat access

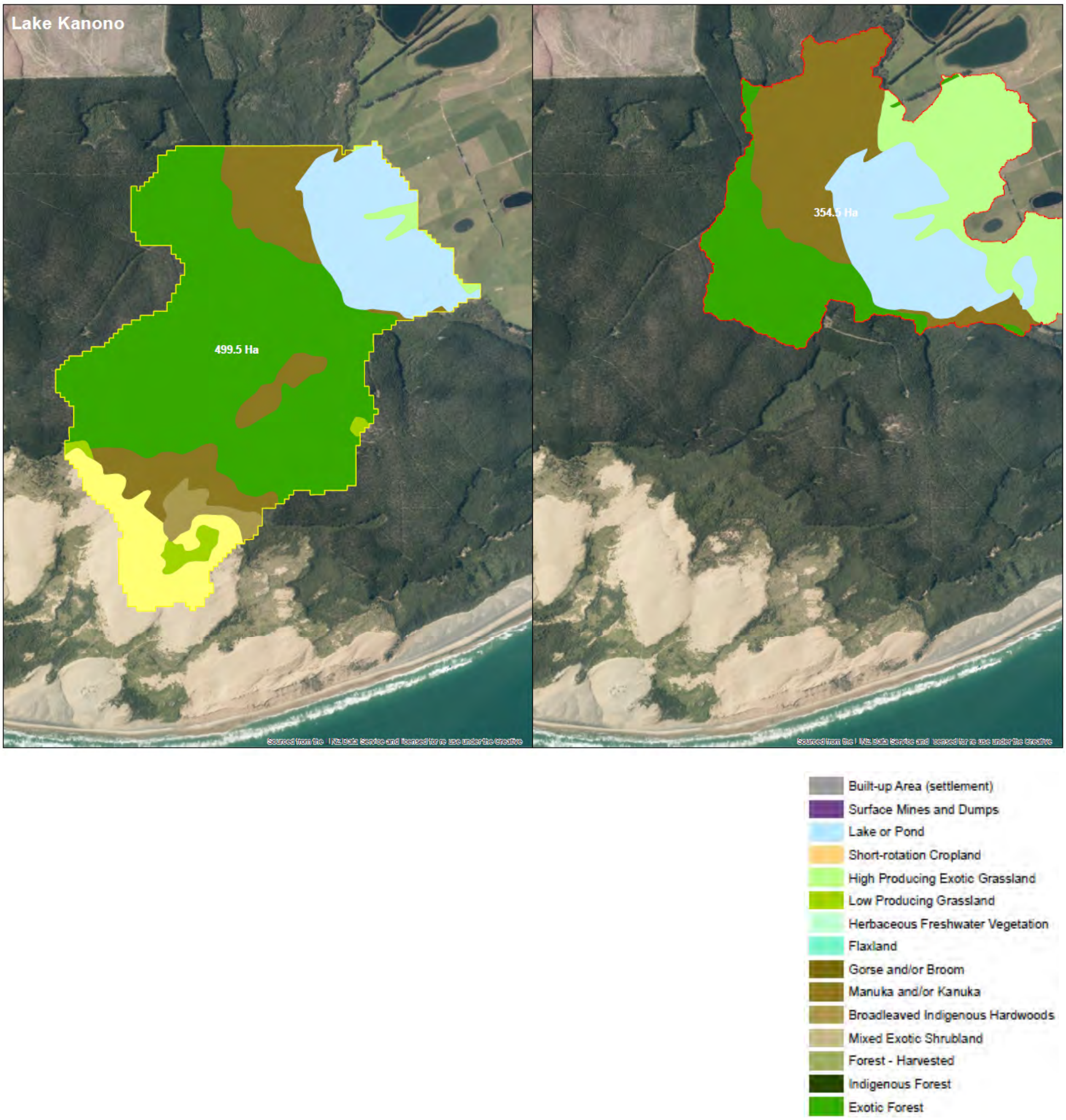
Boat access is through a locked gate by 4WD and off a firm sloping beach.

6. PHYSICAL CHARACTERISTICS

6.1. Catchment Area with Map

The catchment area, defined by LiDAR, including the lake itself, is 354.5 hectares.

Recent LiDAR survey has redefined the catchment and sub-catchments with significant changes to the boundaries. This has implications for benefit-cost modelling of mitigations required to limit nutrient inflows into the lake. The old catchment boundary appears on the left in the map below, with the LiDAR-redefined catchment boundary on the right.



6.2. Catchment Geology and soil types

The following maps and tables display the geology and soil type of the lake catchment. The lake sits between an edge between a geological substrate of weakly cemented to uncemented early Quaternary dune (eQd) and more cemented late Quaternary dune (lQd) which dates to higher sea levels 12,000 or more years ago.

Lake Name/Plot Symbol	eQd	lQd (Q1d)
Kanono	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
Terrane equivalent name		
Lithology	sand	sand

The following soil map and table shows the division of influence of catchment soils on the lake. The catchment features Redhill sandy loam (RL) to the east, which forms an iron pan, and Parore peaty sandy loam (PZ) to the north-west.

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.

6.2.1. Catchment Hydrogeology

Only a conceptual understanding of the hydrogeology of Pōuto Peninsula is available as no specific investigations have been undertaken 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. Lake Kanono is a Class 4 Dune Contact lake of this type.

The Jacobs report (2017) models this lake as most heavily influenced by rainfall, followed by surface run-off and a negligible groundwater influence.

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

6.3. Catchment drainage and sedimentation rates

The LiDAR-defined catchment area, including the lake itself, is 354.5 hectares and produces a mean annual flow, based on hydrological models, of 2,654,270.2 m³/year. The lake has an estimated lake residence time of 1.355 years, meaning any water entering the lake will remain for just under 16 months. The average particle size of surface rock in the catchment is 1.99 on a scale of 5, a value of 1 being sand (FENZ database).

6.4. Bathymetry map

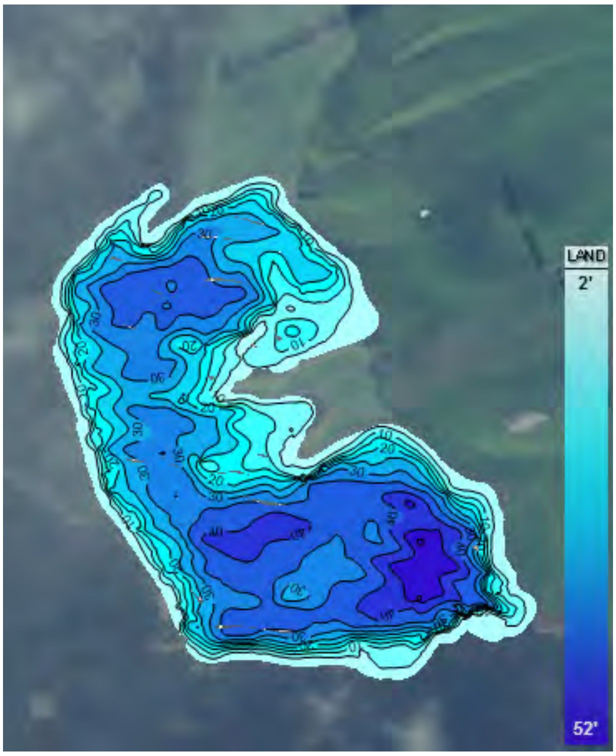
The following bathymetric depth map comes from a survey done by NIWA for the NRC. The deepest point is the south-eastern 15.59 m basin separated from the northern basin by a shallow area extending from two eastern peninsulas in the centre of the lake. Mean lake depth is 7.21 m. Please note that the scale of this map is in feet, not meters.

6.5. Natural inlets and outlets

The lake has no natural inlets or outlets.

6.6. Wetland associations

The lake is fringed by a narrow "Top 150 wetland", in green.



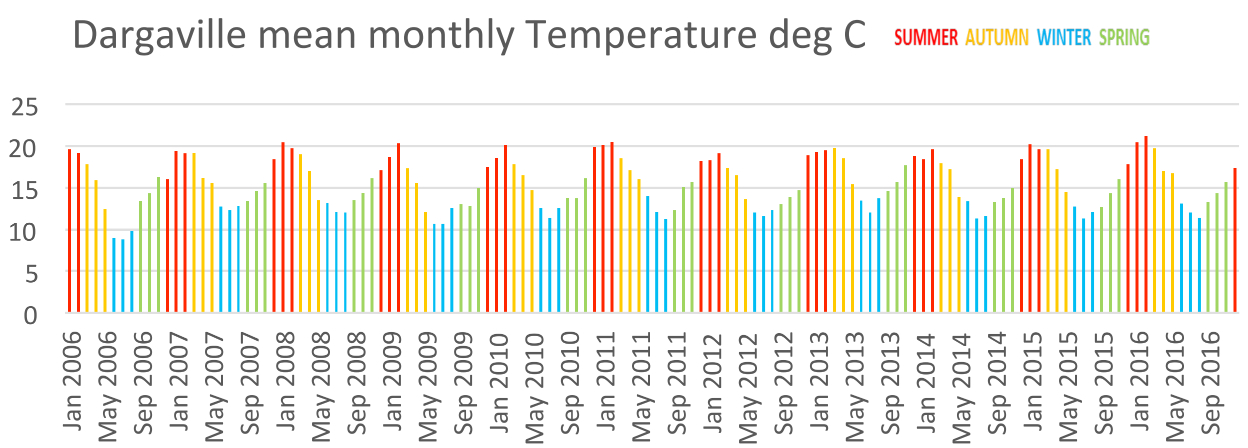
Bathemetry map

6.7. Connectivity

The lake is not connected to any other waterbody.

6.8 Air Temperature

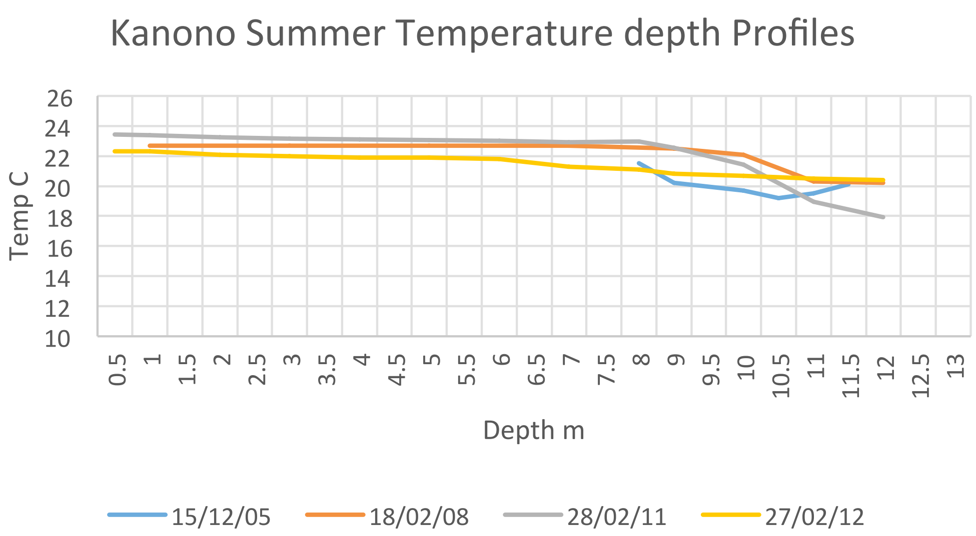
Dargaville air temperature data is used as a proxy for Pōuto.

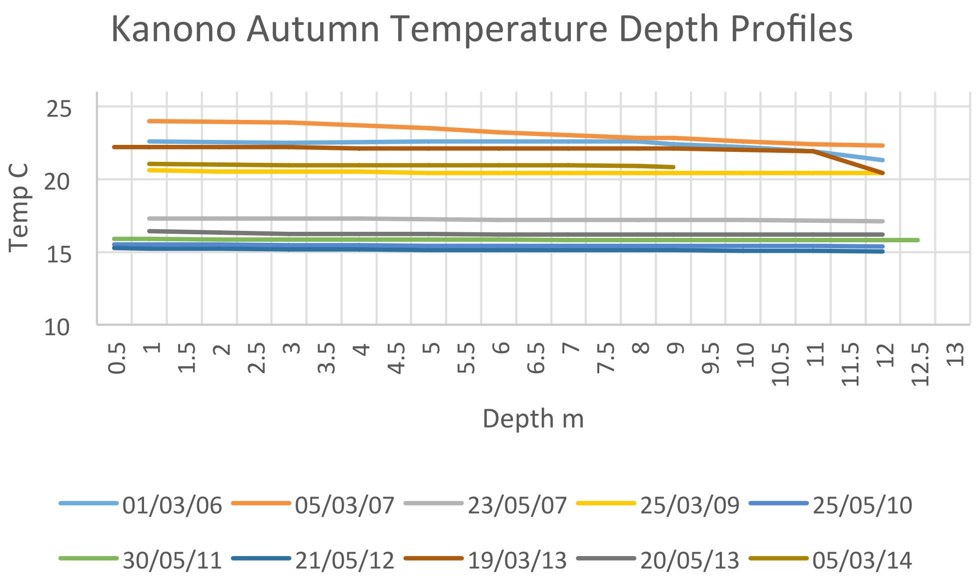


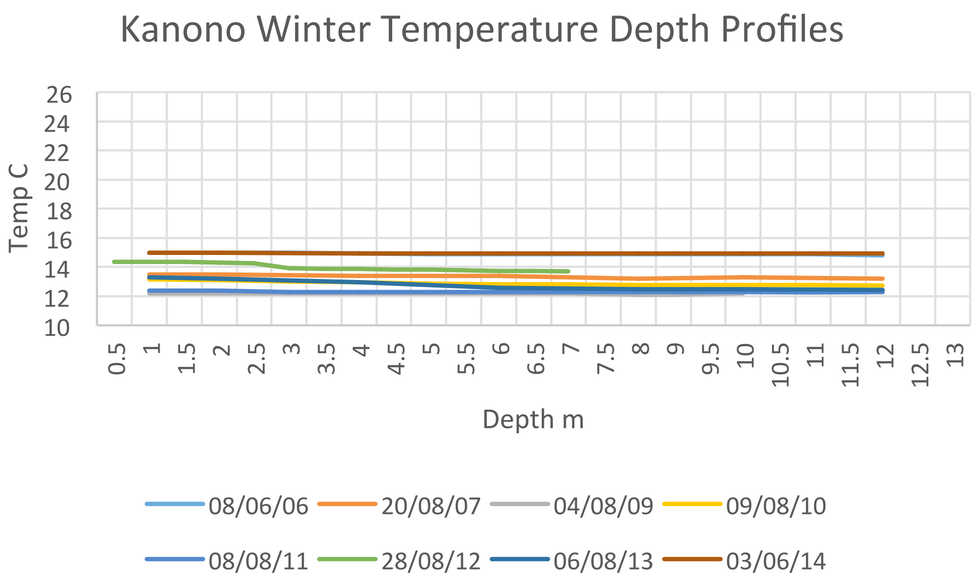
6.9. Thermal stratification

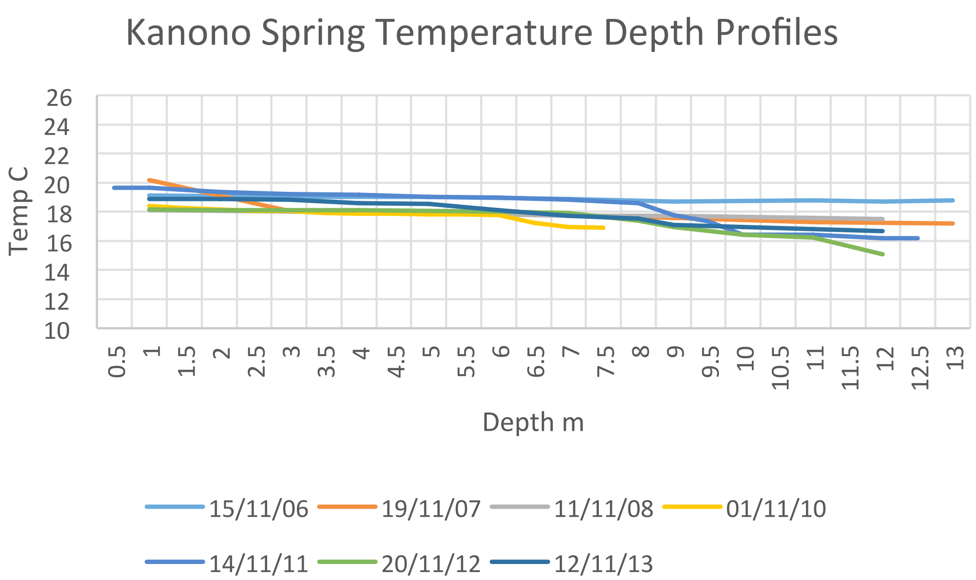
The graphs below show temperature at depth throughout the water column, by season. Each coloured line represents one sample. Water temperatures throughout the year range from 12.1 degrees C to 24.0 degrees C.

The lake stratifies in summer at 10 m only to a very minor degree due to its shallow mean depth.



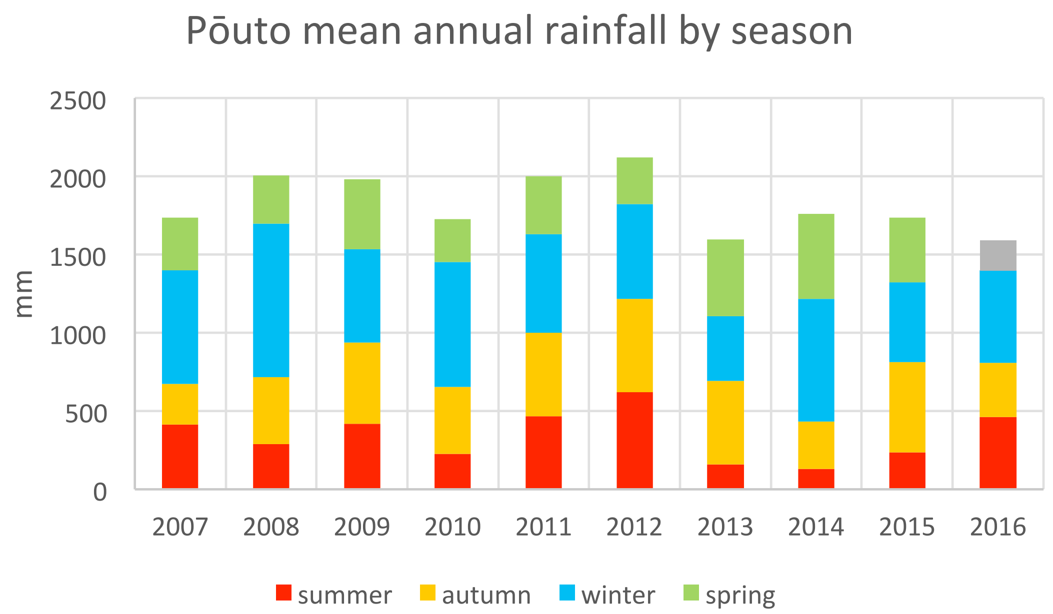

Kanono Autumn Temperature Depth Profiles
Temp C
25
20
15
10
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 9 9.5 10 10.5 11 11.5 12 12.5 13
Depth m
01/03/06
05/03/07
23/05/07
25/03/09
25/05/10
30/05/11
21/05/12
19/03/13
20/05/13
05/03/14


Kanono Winter Temperature Depth Profiles
Temp C
26
24
22
20
18
16
14
12
10
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 9 9.5 10 10.5 11 11.5 12 12.5 13
Depth m
08/06/06
20/08/07
04/08/09
09/08/10
08/08/11
28/08/12
06/08/13
03/06/14


Kanono Spring Temperature Depth Profiles
Temp C
26
24
22
20
18
16
14
12
10
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 9 9.5 10 10.5 11 11.5 12 12.5 13
Depth m
15/11/06
19/11/07
11/11/08
01/11/10
14/11/11
20/11/12
12/11/13

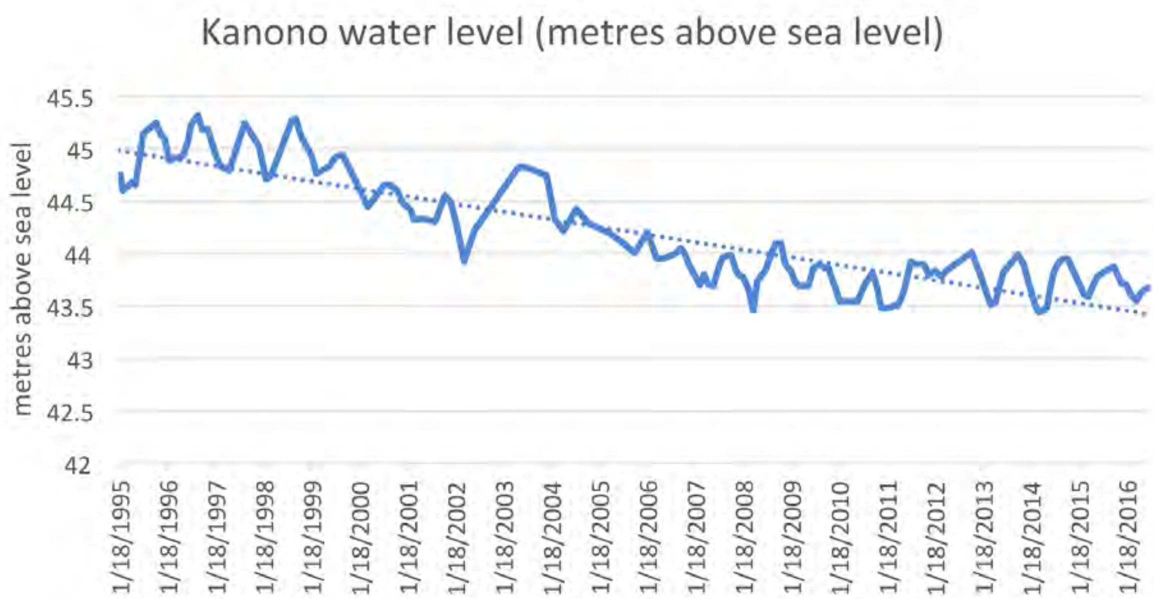
6.10. Rainfall and drought

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 of that season has no data available, meaning this portion of the bar is underestimated.

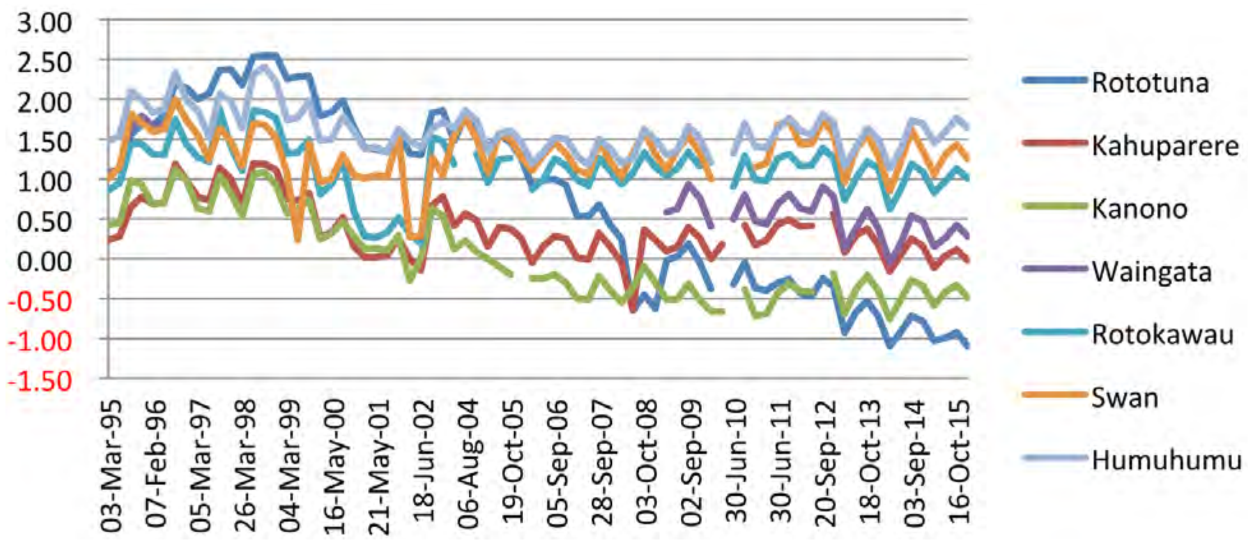


6.11. Lake level

Lake levels in Kanono have varied by 1.87 metres and have declined through time.

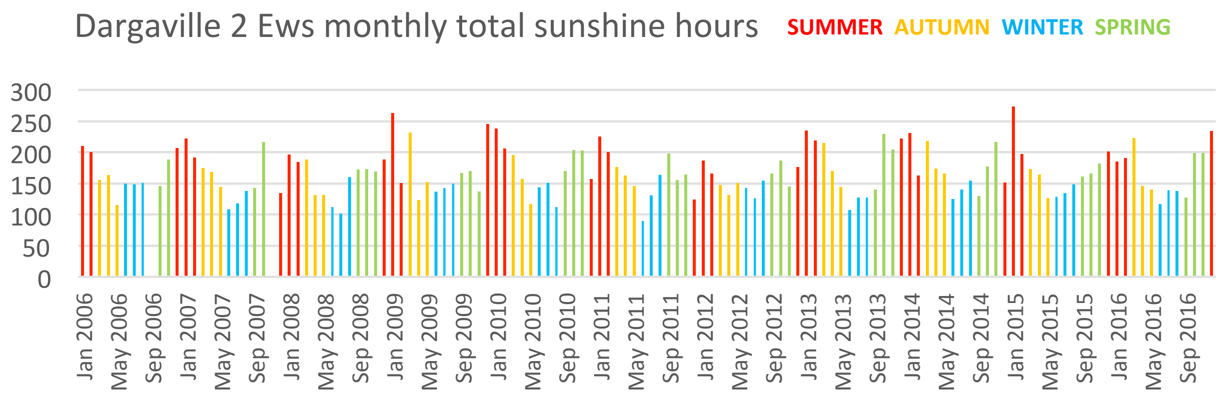


However, a longer time series comparing lake levels between Pōuto dune lakes shows how Kanono, along with Rototuna, has experienced relative loss of water level through time. The Y axis represents variation in mm from a fixed altitude mark on the staff gauge.



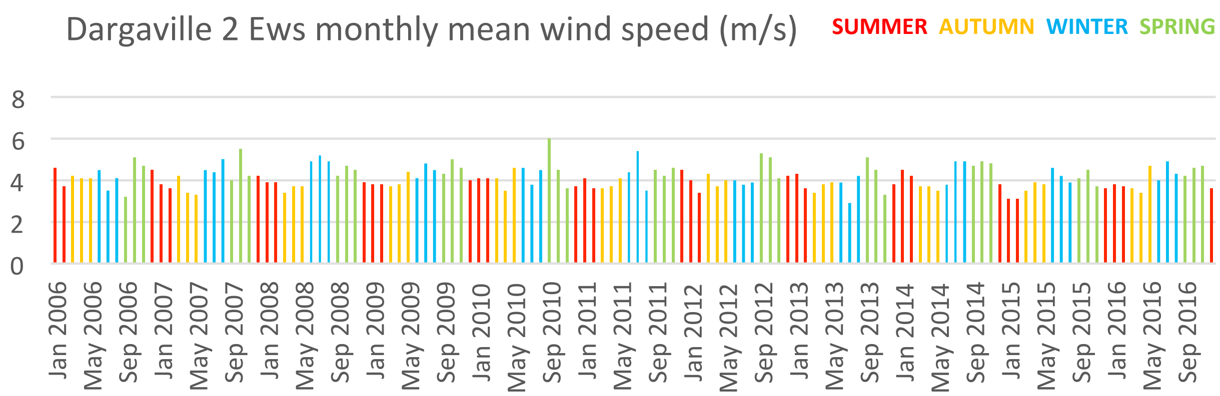
6.12. Sunshine

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



6.13. Wind Speed

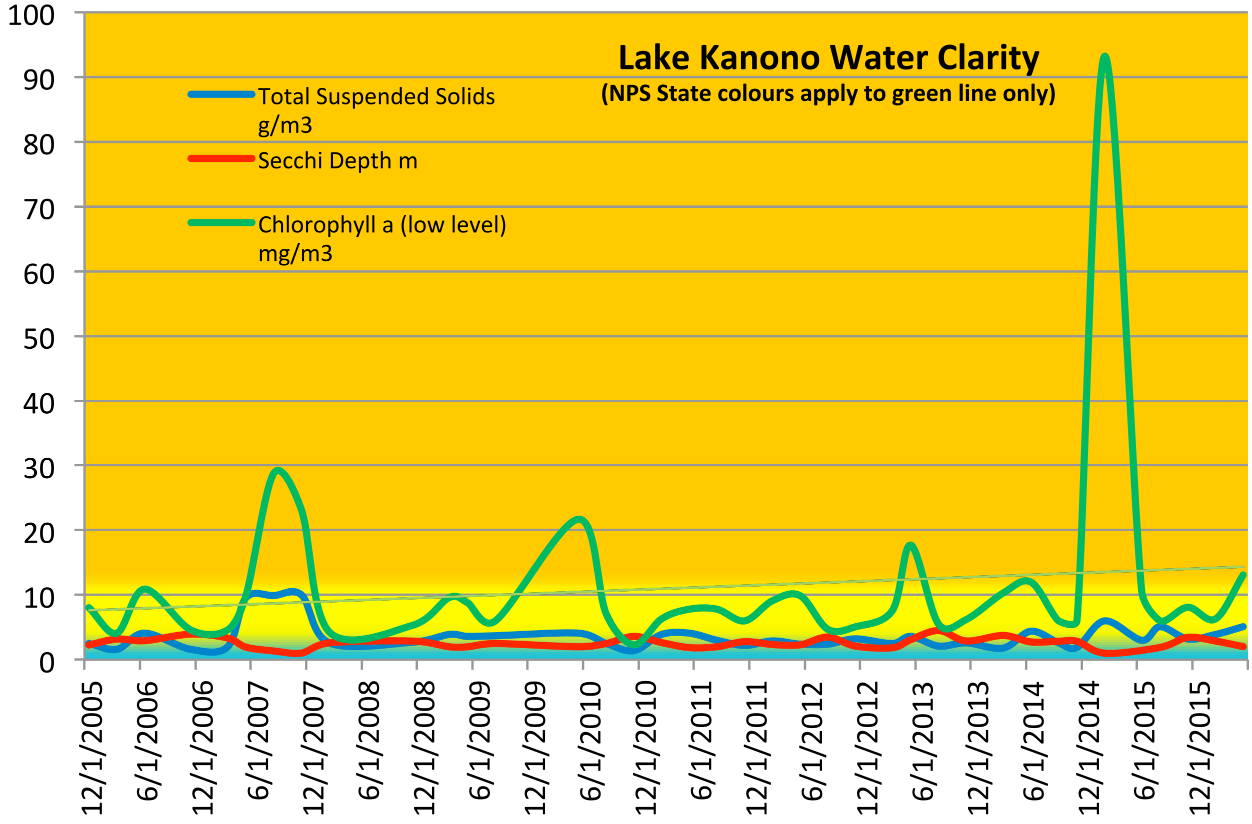
Recording of wind speed at Dargaville wind are used as a proxy.



6.14. 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, the lake has recently experienced an extreme algal bloom in February 2015 (green line) and associated loss of water clarity (Secchi). The chlorophyll-a trend is likely due an event which spiked both nitrogen and phosphorus levels.

The table below the graph shows the National Policy Statement for Freshwater Management states for phytoplankton (chlorophyll-a). The number of pulses of Chlorophyll-a into State D are a concern and suggestive of a permanent regime shift from macrophytes to phytoplankton. Severe diebacks of macrophytes caused by shading could result in deoxygenation of lake waters and subsequent collapse of the lake's ecology.



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

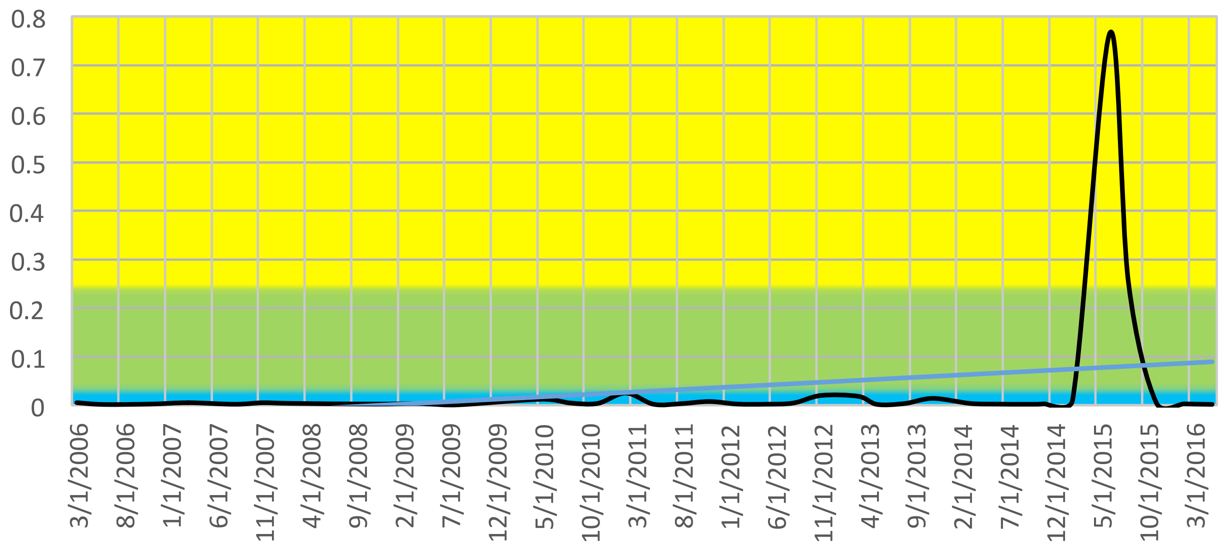
Max Gibbs (pers. comm.) from NIWA conducted limiting nutrient assays on several lakes including Kanono. Significant results are highlighted. For the years and seasons assayed, phosphorus in autumn and both nitrogen and phosphorus, independently, in summer are limiting nutrients. Limiting nutrient means that, between nitrogen and phosphorus, one will be harder to acquire for plant growth, thereby limiting the plant community's ability to grow.

7.1.1.2. Ammoniacal Nitrogen (Toxicity)

Ammoniacal nitrogen (NH4-N), also often called 'ammonium', covers two forms of nitrogen; ammonia (NH3) and ammonium (NH4). 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. Kanono has generally had very low ammonia levels until the event in June 2015 when the peak entered State C.

	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
Kanono	3.5	21.6	0.69	1.00	1.08	1.43	1.45	0.02	1.38	1.25	1.31

Kanono Ammoniacal Nitrogen pH (lab) Adjusted g/m³

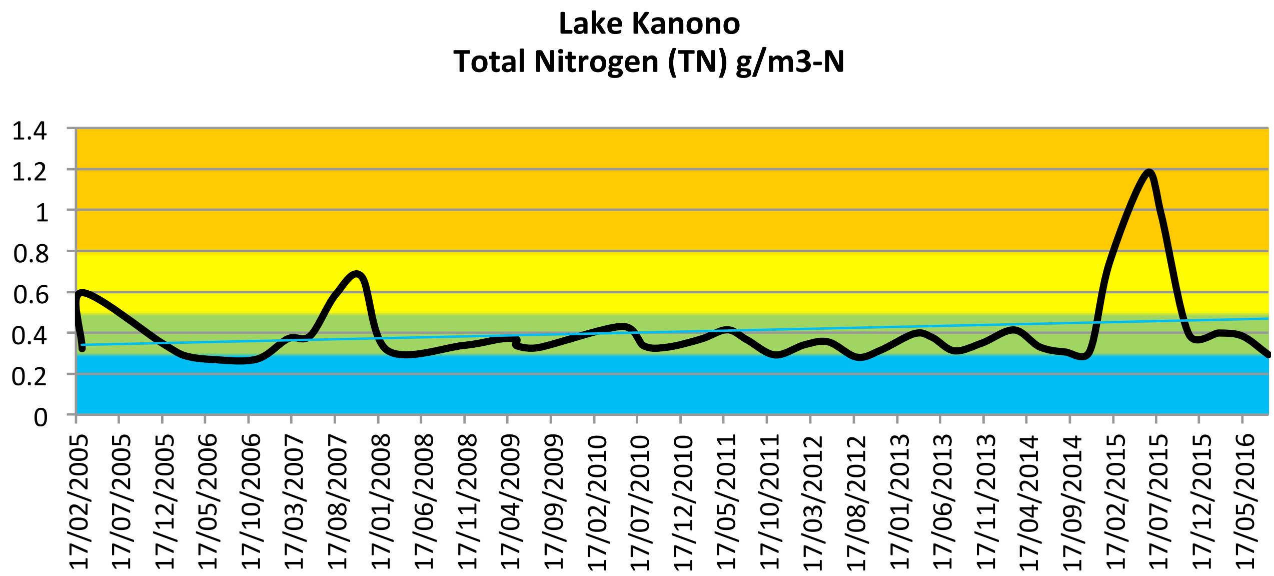


Attribute	Unit	Lake Type	State	Annual Median	Annual Maximum	Narrative State
Ammonia (Toxicity)	mg NH4-N/L (mg ammoniacal-nitrogen per litre)	All	A	≤0.03	≤0.05	99% species protection level: No observed effect on any species tested
Ammonia (Toxicity)	mg NH4-N/L (mg ammoniacal-nitrogen per litre)	All	B	>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 NH4-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 NH4-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 NH4-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 shows a moderate and increasing total nitrogen level. This is likely part of the issue driving increased algal bloom activity.

The table following the chart shows the National Policy Statement for Freshwater Management limits for lake state. The trend generally remains in State B, other than events where it has pushed into State C in November 2007 and, more recently, into State D in June 2015.

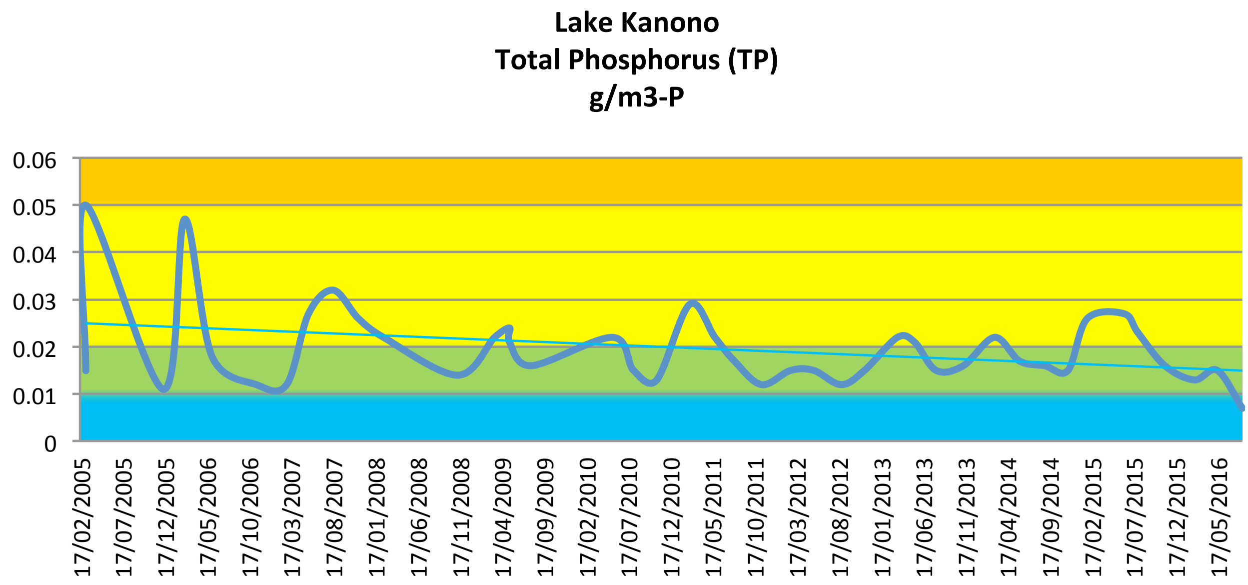


Attribute	Unit	Lake Type	State	Annual Median	Narrative State
Total Nitrogen (Trophic state)	g/m3	Polymictic	A	≤.3	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
Total Nitrogen (Trophic state)	g/m3	Polymictic	B	>.3 and ≤.5	Lake ecological communities are 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 variable through time and the timing of peaks mimics that for nitrogen, indicating weather events increasing nutrient run-off from the pastureland.

The table following the chart shows the National Policy Statement for Freshwater Management limits for lake state. The trendline wavers between States B and C.

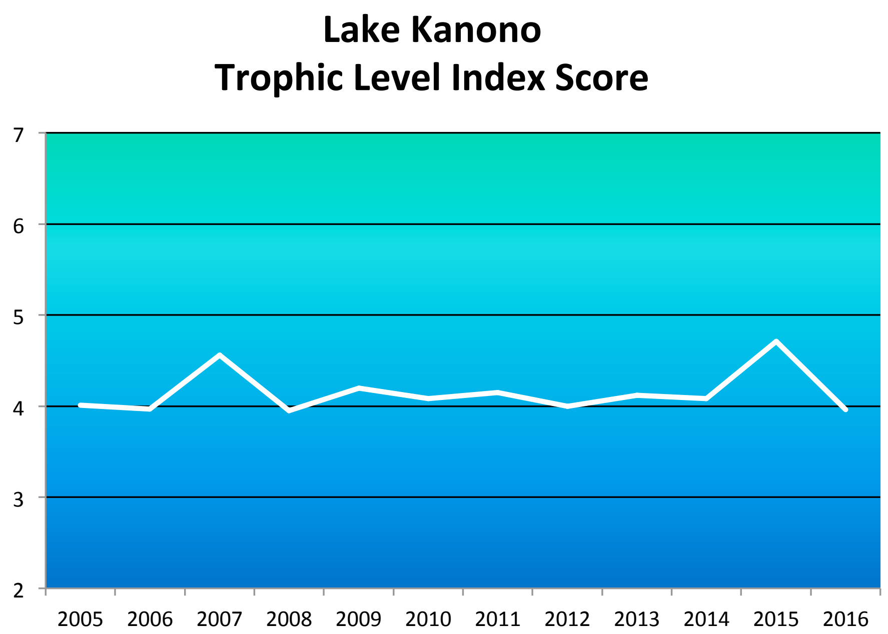


Attribute	Unit	Lake Type	State	Annual Median	Narrative State
Total Phosphorus (Trophic state)	g/m3	All	A	≤.01	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
Total Phosphorus (Trophic state)	g/m3	All	B	>.01 and ≤.02	Lake ecological communities are slightly 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.

7.1.2 Trophic Level Index

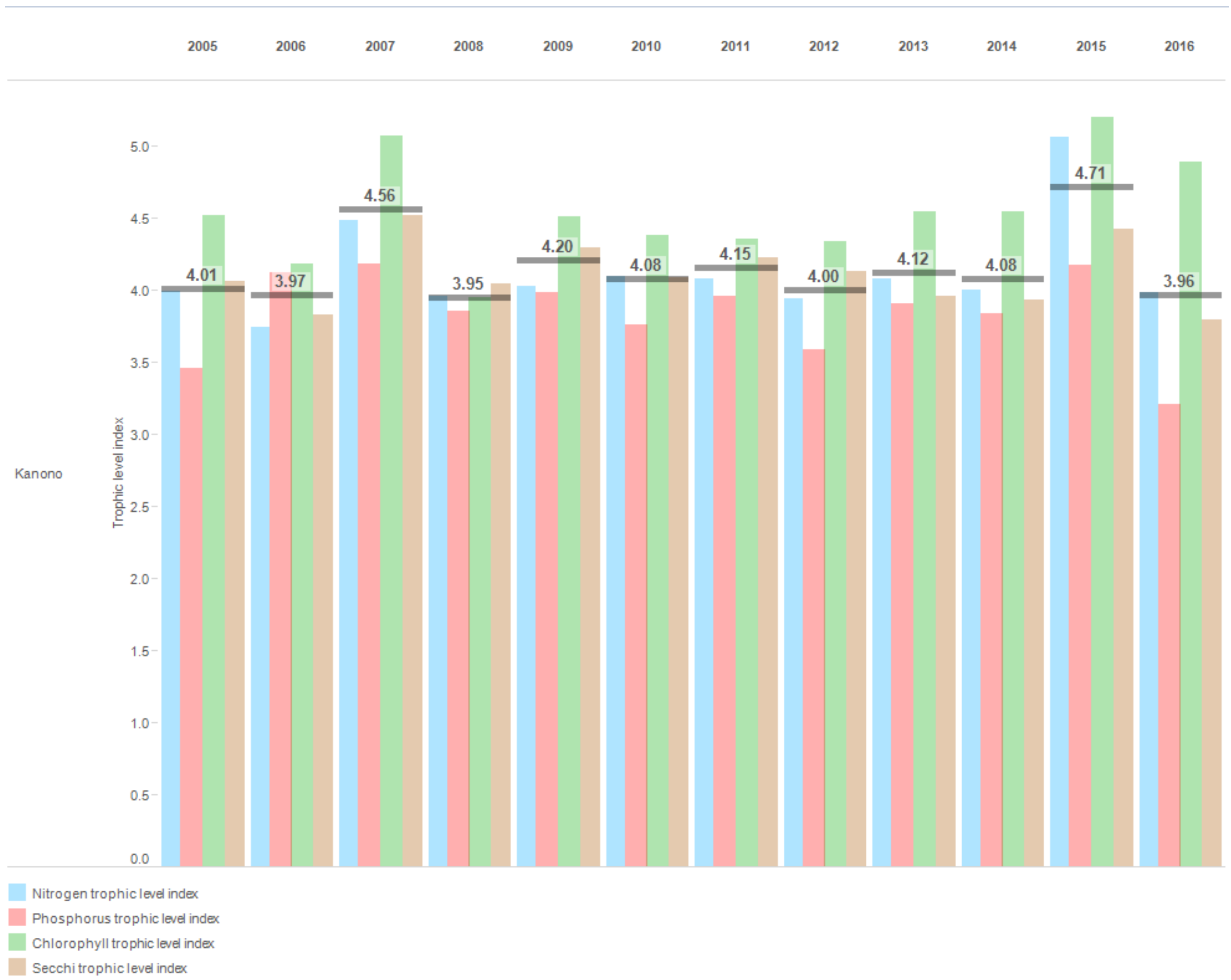
The trophic level index (TLI) is used in New Zealand as a measure of the nutrient status of lakes. The index combines four variables; phosphorus, nitrogen, visual clarity (Secchi disk depth) and algal biomass, each weighted equally.

A low TLI score indicates a healthy lake with clear water and little algal bloom occurrence. 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 poor water quality (low level eutrophic) with two years of spikes of even poorer water quality (2007 and 2015) with recovery from each of these events. Both total nitrogen and total phosphorus spiked at the same period and were followed by a response in Chlorophyll-a spikes (algal blooms).



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 a new type of display of TLI scores. This allows interpretation of the four contributing variables which are combined into the overall TLI score. From this chart, chlorophyll a (algal bloom) triggered by nitrogen are the key contributing variables to overall TLI for this lake.

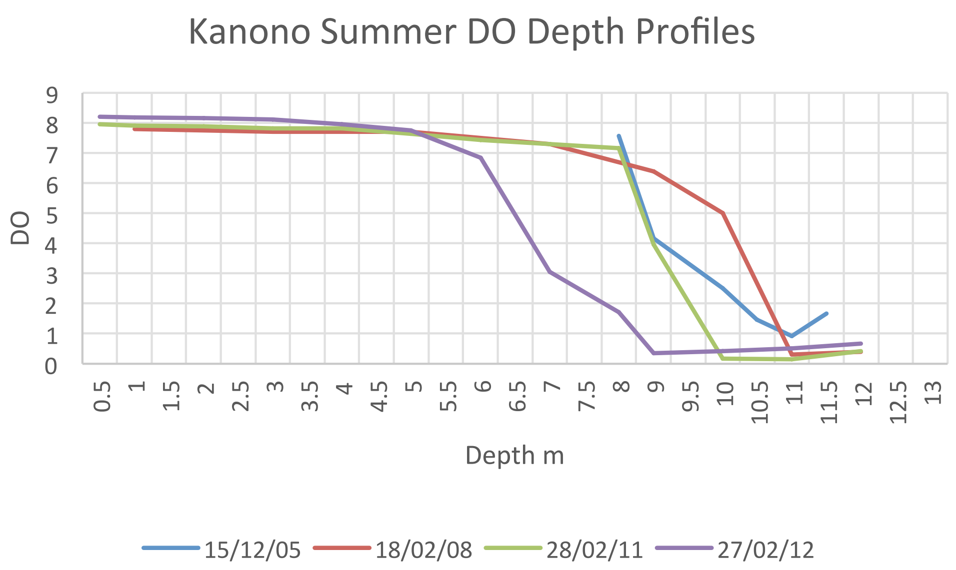


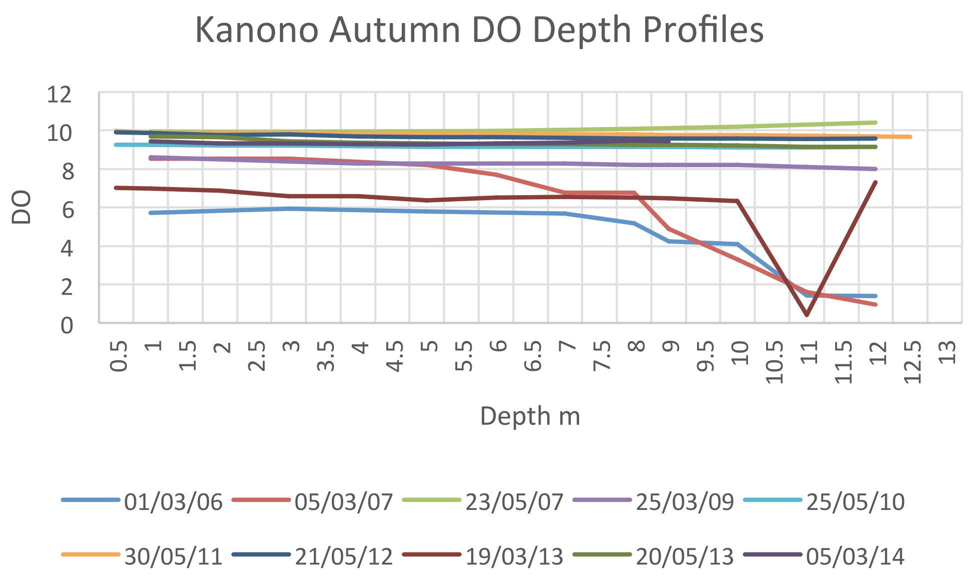
7.1.3. Dissolved Oxygen g/m³

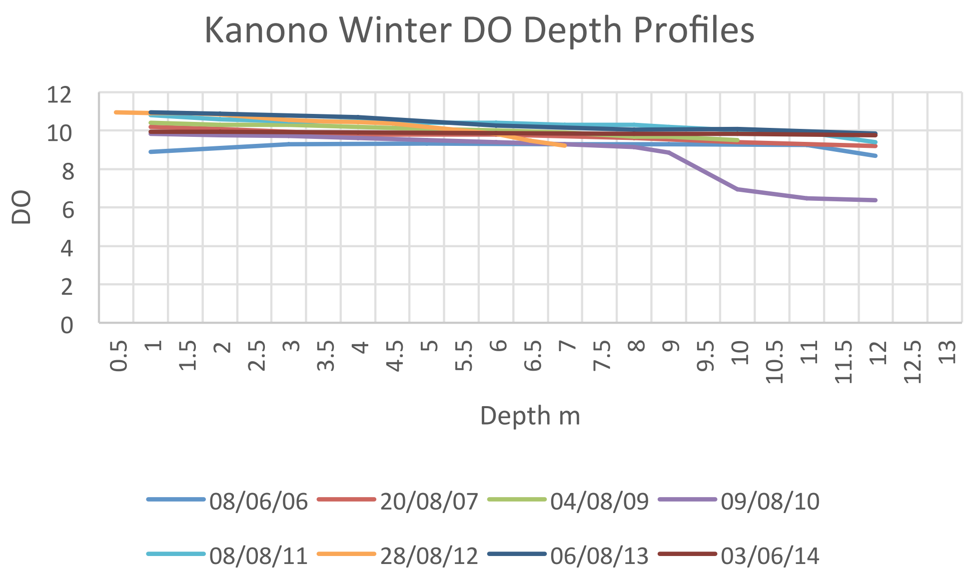
Although the lake only marginally thermally stratifies in summer due to its moderate shallowness, there is a slight oxygen depletion in water below 4.5 meters beginning in February and extending into March, as seen in the graphs below.

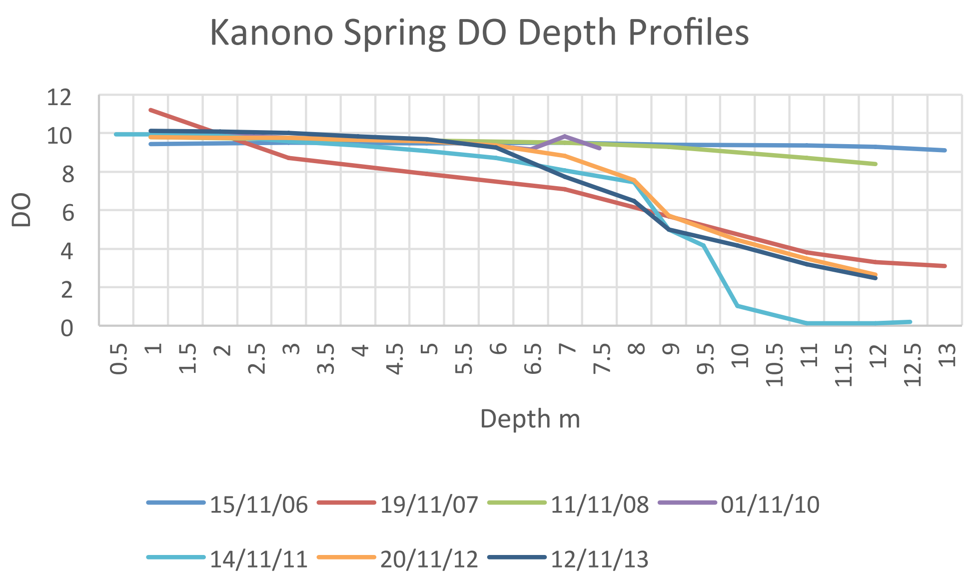
The table below shows the dissolved oxygen (at 15 degrees C) limits for New Zealand freshwater fish from https://www.niwa.co.nz/freshwater-and-estuaries/research-projects/dissolved-oxygen-criteria-for-fish. These guidelines help interpret the depth profiles as to the depth of the water column usable 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	6.0	4.0
	Imperative	4.0	3.0



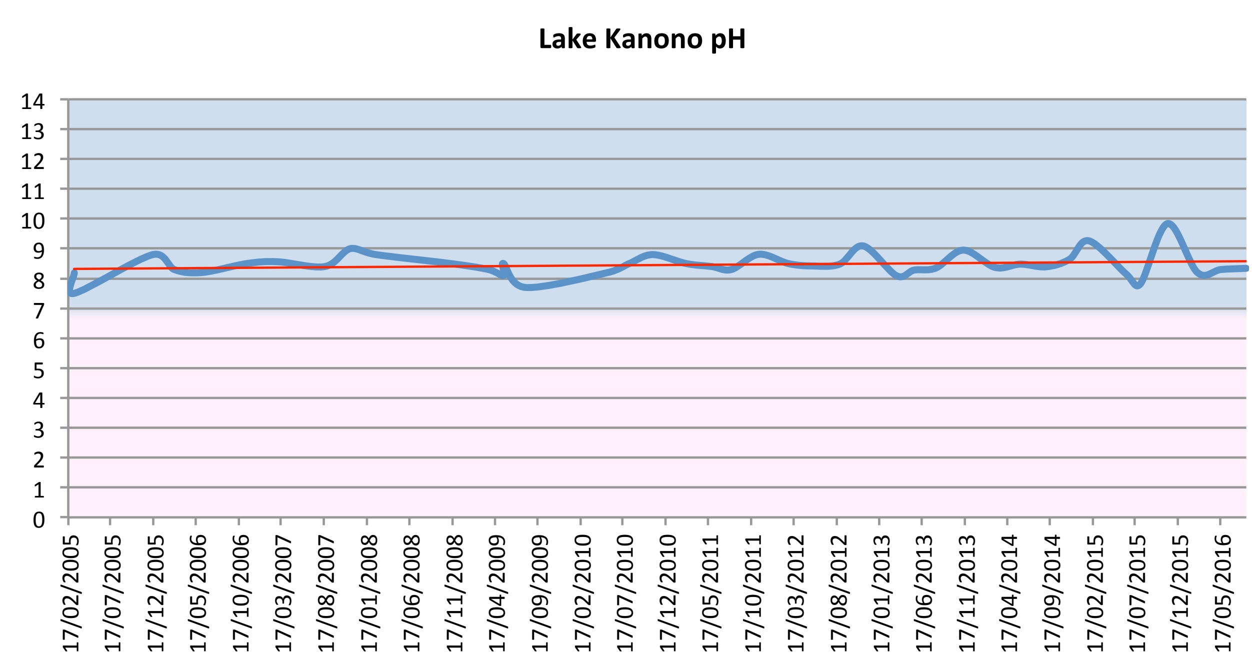

Kanono Autumn DO Depth Profiles
12
10
8
6
4
2
0
DO
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
9
9.5
10
10.5
11
11.5
12
12.5
13
Depth m
01/03/06
05/03/07
23/05/07
25/03/09
25/05/10
30/05/11
21/05/12
19/03/13
20/05/13
05/03/14


Kanono Winter DO Depth Profiles
12
10
8
6
4
2
0
DO
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
9
9.5
10
10.5
11
11.5
12
12.5
13
Depth m
08/06/06
20/08/07
04/08/09
09/08/10
08/08/11
28/08/12
06/08/13
03/06/14


Kanono Spring DO Depth Profiles
12
10
8
6
4
2
0
DO
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
9
9.5
10
10.5
11
11.5
12
12.5
13
Depth m
15/11/06
19/11/07
11/11/08
01/11/10
14/11/11
20/11/12
12/11/13

7.1.4. pH

The pH of this lake varies consistently between 8 and 9. This alkaline condition is a positive environment for native fish species, perhaps explaining why dwarf inanga are thriving there.



8. BIOLOGICAL CHARACTERISTICS

8.1. Lake Biodiversity and Biosecurity species

8.1.1. Plants

Kanono has a native aquatic plant diversity of 19 species, shown in the table below. No rare native plants are present. The table is organised as a depth gradient, from emergent plants to those which are submerged, for each of the exotics and natives.

In addition to the natives, there is only one exotic, non-invasive species, this being *Potamogeton crispus.*

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

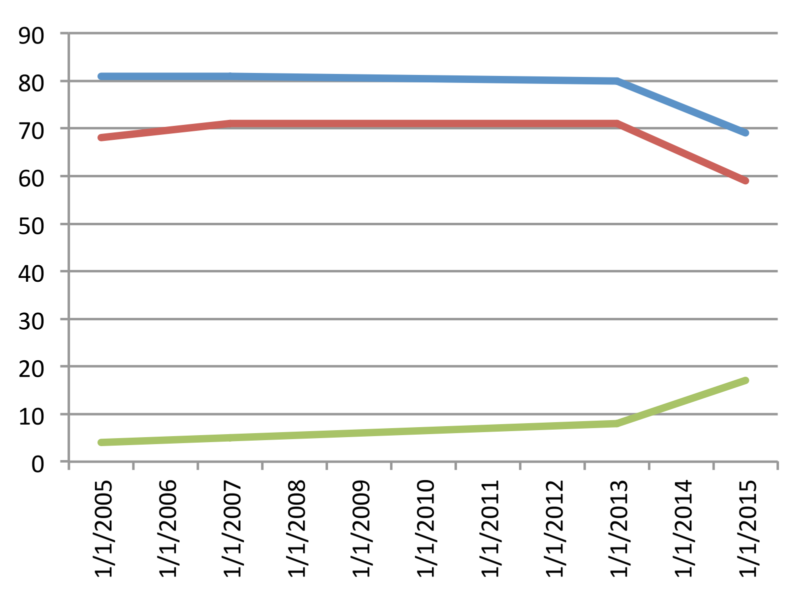
Phoebe's Lake has been successfully treated with the herbicide endothall for the eradication of *Lagarosiphon major* (purple absence on the chart).

The table presents plant communities in Pōuto dune lakes as a comparison and indication of biosecurity species of concern which should be contained wherever possible such that they do not spread to other lakes like Kanono. Data is derived from annual NIWA ecological surveys.

Depth and Plant Type Zone	Biogeography	Common Name	Species	Grevilles Lagoon	Kapoai	Parawanui	Wainui	Rototuna	Wairere	Phoebe's	Rotopouua	Humuhumu	Roto-otuauru/Swan	Rotokawau (P)	Waingata (P)	Kanono	Kahuparere	Karaka	Mokeno	Whakaneke	Frequency
Erect emergent	Invasive exotic	African feather grass	Cenchrus macrourus		x																1
Erect emergent	Invasive exotic	royal fern	Osmunda regalis									x		x					x		3
Erect emergent	Invasive exotic	Manchurian wild rice	Zizania latifolia							x											1
Erect emergent	Non-invasive exotic	bulbous rush	Juncus bulbosus					x						x							2
Sprawling emergent	Invasive exotic	alligator weed	Alternanthera philoxeroides	x								x	x		x						4
Sprawling emergent	Invasive exotic	glyceria, swamp grass, water meadow grass	Glyceria maxima					x													1
Sprawling emergent	Invasive exotic	primrose willow, water primrose	Ludwigia peploides				x														1
Sprawling emergent	Invasive exotic	mercer grass, paspalum	Paspalum distichum						x												1
Sprawling emergent	Non-invasive exotic	water purslane	Ludwigia palustris									x		x			x				3
Floating leaved	Non-invasive exotic	swamp lily	Ottelia ovalifolia				x														1
Free floating	Non-invasive exotic	ferny azolla	Azolla pinnata									x									1
Free floating	Non-invasive exotic	bladderwort, yellow bladderwort	Utricularia gibba						x	x	x	x	x	x			x				7
Submerged tall pondweed	Invasive exotic	lakeweed, egeria	Egeria densa										x	x							2
Submerged tall pondweed	Invasive exotic	canadian pondweed	Elodea canadensis											x	x						2
Submerged tall pondweed	Invasive exotic	lagarosiphon, lakeweed, oxygen weed	Lagarosiphon major																		0
Submerged tall pondweed	Non-invasive exotic	curly leaved pondweed, curled pondweed	Potamogeton crispus			x		x				x				x					4
Erect emergent	Native	oioi, jointed wire rush	Apodasmia similis									x		x				x			3
Erect emergent	Native	marsh clubrush	Bolboschoenus fluviatilis									x				x	x				3
Erect emergent	Native	maori sedge	Carax maorica						x									x			2
Erect emergent	Native	pukio	Carex secta						x		x						x	x	x		5
Erect emergent	Native	swamp sedge, pukio, toitoi, toetoe	Carex virgata						x												1
Erect emergent	Native	giant umbrella sedge, Upokotangata	Cyperus ustulatus						x			x				x	x	x			5
Erect emergent	Native	sharp spike sedge	Eleocharis acuta				x	x	x			x	x	x		x	x	x	x	x	11
Erect emergent	Native	bamboo spike sedge, tall spike sedge	Eleocharis sphacelata		x		x	x	x	x	x	x	x	x			x		x	x	12
Erect emergent	Native	leafless rush	Juncus pallidus						x			x		x			x	x			5
Erect emergent	Native	manuka, tea tree, kahikatoa	Leptospermum scoparium																x		1
Erect emergent	Native	sedge	Machaerina arthrophylla (syn. Baumea arthrophylla)						x			x						x	x		4
Erect emergent	Native	jointed baumea, jointed twig rush	Machaerina articulata (syn. Baumea articulata)				x	x	x	x	x	x	x	x		x	x	x	x	x	13
Erect emergent	Native	sedge, tussock swamp twig rush	Machaerina juncea (syn. Baumea juncea)						x		x	x		x				x	x		6
Erect emergent	Native	baumea	Machaerina rubiginosa (syn. Baumea rubiginosa)																x		1
Erect emergent	Native	flax, harakeke, korari	Phormium tenax																x		1
Erect emergent	Native	softstem bulrush, grey club-rush, great bulrush	Schoenoplectus tabernaemontani	x	x	x	x	x	x		x	x	x	x		x	x	x	x	x	15
Erect emergent	Native	raupo	Typha orientalis	x			x	x	x	x	x	x	x	x		x	x	x	x	x	14
Erect emergent	Rare native	Fimbristylis	Fimbristylis velata		x	x															2
Erect emergent	Rare native	Marsh fern, swamp fern	Thelypteris confluens								x	x						x	x		4
Sprawling emergent	Native	nahui	Alternanthera nahui		x																1
Sprawling emergent	Native	centella	Centella uniflora											x							1
Sprawling emergent	Native	swamp millet	Isachne globosa						x			x						x		x	4
Sprawling emergent	Native	swamp willow weed	Persicaria decipiens						x								x			x	3
Sprawling emergent	Rare native	New Zealand sneezewort	Centipeda aotearoana		x																1
Low growing turf	Native	starwort	Callitriche petriei		x																1
Low growing turf	Native	waterwort	Elatine gratioloides												x						1
Low growing turf	Native	none known	Glossostigma elatinoides					x				x	x	x	x	x			x		7
Low growing turf	Native	gratiola	Gratiola sexdentata										x								1
Low growing turf	Native	none known (sedge)	Isolepis prolifera						x			x		x				x			4
Low growing turf	Native	Zelandiae chain sword	Lilaeopsis novae-zelandiae					x				x		x	x	x			x		6
Low growing turf	Native	mudwort	Limosella lineata		x							x		x		x					4
Low growing turf	Native	arrow grass	Triglochin striata									x	x	x							3
Low growing turf	Rare native	hydatella	Trithuria inconspicua (syn Hydatella inconspicua)									x	x	x							3
Floating leaved	Native	red pondweed	Potamogeton cheesemanii	x			x	x	x			x		x		x		x	x		9
Submerged milfoil	Native	common water milfoil	Myriophyllum propinquum		x							x		x			x				4
Submerged milfoil	Native	water milfoil	Myriophyllum triphyllum				x	x	x			x				x	x		x	x	8
Submerged milfoil	Rare native	small water milfoil	Myriophyllum votschii									x		x							2
Submerged tall pondweed	Native	blunt pondweed	Potamogeton ochreatus	x	x		x	x	x	x	x	x		x		X	x		x		12
Submerged tall pondweed	Native	horses mane weed, lakeweed	Ruppia polycarpa									x				x					2
Submerged tall pondweed	Native	fennel-leaved pondweed, sago pondweed	Stuckenia pectinata					x								x					2
Submerged charophyte	Native	stonewort	Chara australis	x			x	x	x		x	x		x	x	X	x	x	X	x	13
Submerged charophyte	Native	stonewort	Chara fibrosa									x		x		x					3
Submerged charophyte	Native	stonewort	Chara globularis				x		x			x				X		x	x		6
Submerged charophyte	Native	stonewort	Nitella hyalina					x													1
Submerged charophyte	Native	stonewort	Nitella leonhardii											x							1
Submerged charophyte	Native	stonewort	Nitella pseudoflabellata					x				x		x		x					4
Submerged charophyte	Native	stonewort	Nitella sp. aff. cristata	x			x	x		x	x	x		x		X					8
			Total Plant Diversity	7	10	3	13	18	22	7	11	36	12	30	6	20	16	17	20	9	
			Exotic Plant diversity	1	1	1	2	3	2	2	1	6	3	6	2	1	2	0	1	0	
			Native Plant Diversity	6	9	2	11	15	20	5	10	30	9	24	4	19	14	17	19	9	

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 Impact Index. From the timeline below, it is evident that this lake is in good ecological health, due to its relative high native plant diversity compared to the low number of exotic plant species present.



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 Kanono appears in yellow. The lake has a low level of fish diversity and is free of pest fish.

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

Common bully and dwarf inanga are commonly found in the Pōuto lakes, including Lake Kanono but the lake has an absence of short-finned eels found in other Pōuto Lakes.

Although removed from Lake Karaka but their east/west divide, the common bully of Lake Karaka have parasites also found in Lake Te Riu to the north in Waipoua and may pose a threat to common bully in Lake Kanono.

common name	species	Conservation status	Degree of loss	Kapoai	Parawanui	Wainui	Rototuna	Wairere	Phoebe's	Rotopouua	Humuhumu	Roto-otuauru/Swan	Rotokawau (P)	Waingata (P)	Kanono	Kahuparere	Karaka	Mokeno	Whakaneke	frequency
golden bell frog	Litoria Aurea								x											1
grass carp	Ctenopharyngodon idella											x		x						2
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													3
tench	Tinca tinca			x																1
shortfinned eel	Anguilla australis			x	x			x	x			x	x				x	x		8
longfinned eel	Anguilla dieffenbachii	at risk	declining					x									x			2
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				8
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	13
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 Pōuto Peninsula. Game birds are shown in green and non-game birds native species in pink. Lake Kanono appears in yellow. The lake has a high level of bird diversity and has the black swan is present which is listed as a game species. Dabchicks, Australasian bittern and New Zealand scaup occur widely in this sub-region. The only sightings of the eastern little tern have been at this lake and neighbouring Lake Kahuparere.

common name	species	Conservation status (DOC, *Conservation status of NZ birds*, 2016)	Criteria / Degree of loss	Grevilles Lagoon	Kapoai	Parawanui	Wainui	Rototuna	Wairere	Phoebe's	Rotopouua	Humuhumu	Roto-otuauru/Swan	Rotokawau (P)	Waingata (P)	Kanono	Kahuparere	Karaka	Mokeno	Whakaneke	frequency
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 novazeelandiae	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 Kanono, the presence of koura/kewai, freshwater mussels/torowai and *Ceratopogonidae* midges which require a standard of clean water to survive and the Oribatida mite, which is tolerant of mild pollution at best, is a good sign.

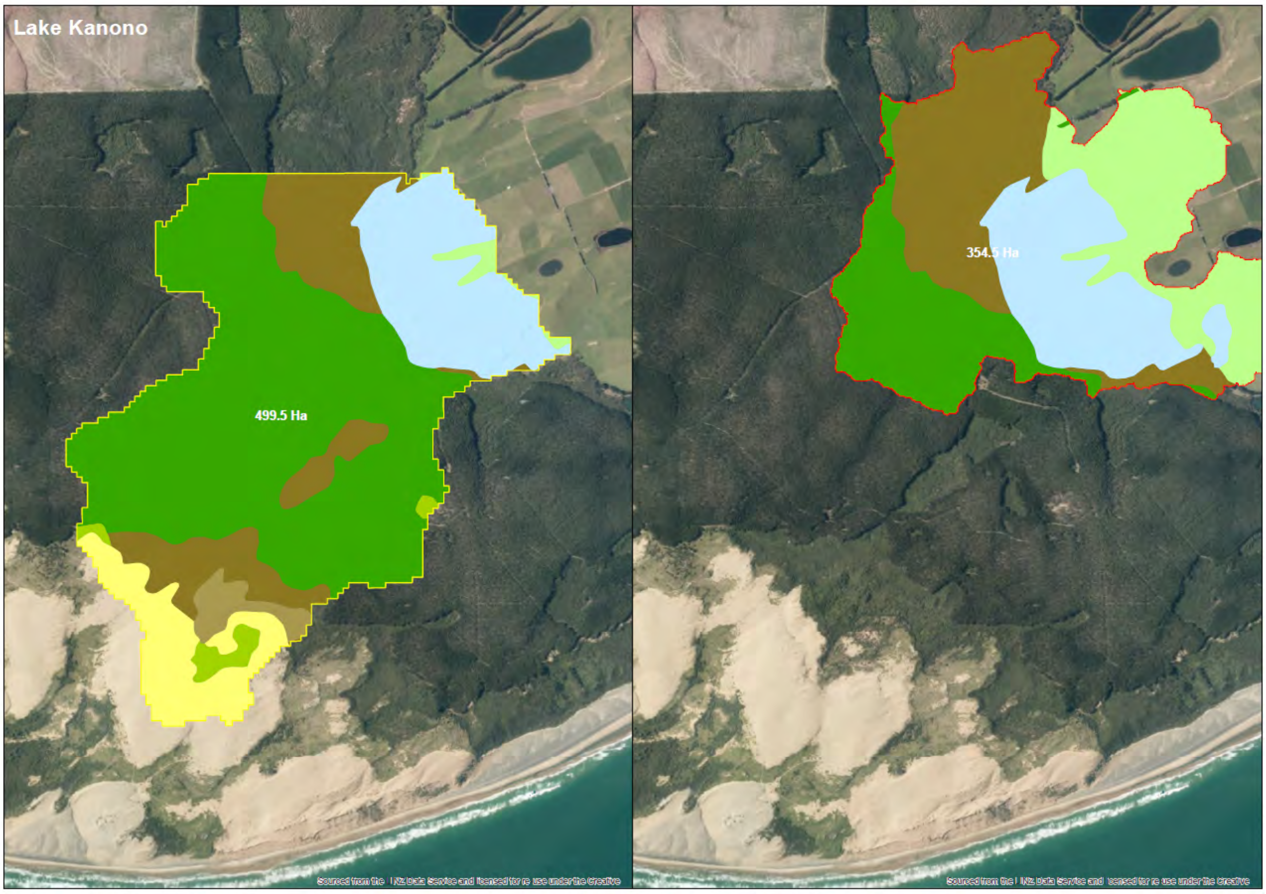
Order or phylum and common name	Family or species	Pollution minimum tolerance - Clean Water (>5.99) Mild Pollution (5.00-5.90) Moderate Pollution (4.00-4.99) Severe Pollution (<4.00)	Parawanui	Wainui	Rototuna	Rotopouua	Humuhumu	Roto-otuauru/Swan	Rotokawau (P)	Kanono	Kahuparere	Karaka	Mokeno	Whakaneke	frequency
Hydrozoa, freshwater jellyfish medusae	*Craspedacusta sowerbyi*						x						x		2
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		5
Acarna, mite	Oxidae	5.2							x		x				2
Amphipoda, hopper	Paracalliope sp			x											1
Crustacea, Cladocera	sp	0.7		x					x		x		x		4
Crustacea, Copepoda	sp	2.4		x					x		x		x		4
Crustacea, Ostracoda, koura	*Paranephrops planifrons*	8.4					x			x	x				3
Crusteacea, Ostracoda	*Herpetocypris*	*1.9*		x					x	x	x				4
Diptera, house fly	Muscidae	1.6							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	*Chironomas sp*	3.4		x					x	x	x		x	x	6
Diptera, midge, non-biting, Chironomid	Orthocladiinae	3.2		x					x	x	x		x		5
Diptera, midge, non-biting, Chironomid	Tanypodinae	6.5									x		x		2
Ephemeroptera, mayfly	*Deleatidium*	5.6							x						1
Hemiptera, bug	*Microvelia macgregori*	4.6											x		1
Hemiptera, bug, backswimmer	*Sigara arguta*	2.4		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						2
Hydrozoa, hydra	*Hydra* sp					x							x		2
Lepidoptera, aquatic moth	*Hygraula nitens*	1.3									x		x		2
Mollusca, bivalve	Sphaeridae			x					x						2
Mollusca, freshwater mussel	*Echyridella menziesi*					shells	x	x	x				x		5
Mollusca, freshwater mussel	*Hyridella menziesi*	6.7	x							x	last 2001				3
Mollusca, snail	*Gyraulus corinna*	1.7		x											1
Mollusca, snail	Lymnaea sp			x											1
Mollusca, snail, native	*Glyptophysa variabilis*	0.3					x			x	x				3
Mollusca, snail, native	*Potamopyrgus antipodarum*	2.1				x			x			x		x	4
Nematoda, roundworm	sp	1.8		x					x	x			x		4
Nemertea, proboscis worm	sp	1.8		x							x				2
Odonata, damselfly	*Xanthocnemis sp*	1.2		x							x				2
Odonata, dragonfly	*Aesha brevistyla*	1.4		x					x						2
Odonata, dragonfly	*Hemianax papuensis*	1.1		x							x				2
Odonata, dragonfly	*Hemicordulia australiae*	0.4		x					x	x	x				4
Oligocheate worm	Oligochaeta sp	3.8							x	x	x		x		4
Ostracod crusteacean	*Cypretta*										x				1
Ostracod crusteacean	Cypridopsis								x	x					2
Ostracod crusteacean	*Ilyodromus*								x	x	x		x		4
Platyhelminthes, flatworm	sp	0.9		x					x	x	x				4
Porifera, freshwater sponge	sp					x									1
Trichoptera, caddisfly	*Paroxyethira hendersoni*	3.7		x					x	x	x				4
	diversity invasive		0	1	1	0	1	0	0	0	1	0	1	1	6
	diversity native		1	22	0	4	3	1	24	15	27	1	17	3	

9. LAND USE

9.1. Catchment land cover table and map

The following catchment cover areas are based on the FENZ database and on LiDAR. FENZ has now been superseded by newer, more accurate, LiDAR catchment boundaries for which cover areas are not yet available. The catchment is dominated by high producing exotic grassland, manuka/kanuka scrub and closed canopy exotic pine forest. The northern side of the lake is bordered by pastoral farming (light green in the map). Forestry is dominant in the catchment to the south-west of the lake.

Lake	Cover Type	Total FENZ (ha)	Total LiDAR (ha)
Lake Kanono	Broadleaved Indigenous Hardwoods	11.58	0.00
Lake Kanono	Exotic Forest	277.34	75.37
Lake Kanono	High Producing Exotic Grassland	5.16	98.53
Lake Kanono	Lake or Pond	76.69	82.72
Lake Kanono	Low Producing Grassland	8.49	0.00
Lake Kanono	Manuka and/or Kanuka	77.20	97.86
Lake Kanono	Sand or Gravel	43.01	0.00
Lake Kanono Total		499.48	354.49



9.2. Stock exclusion

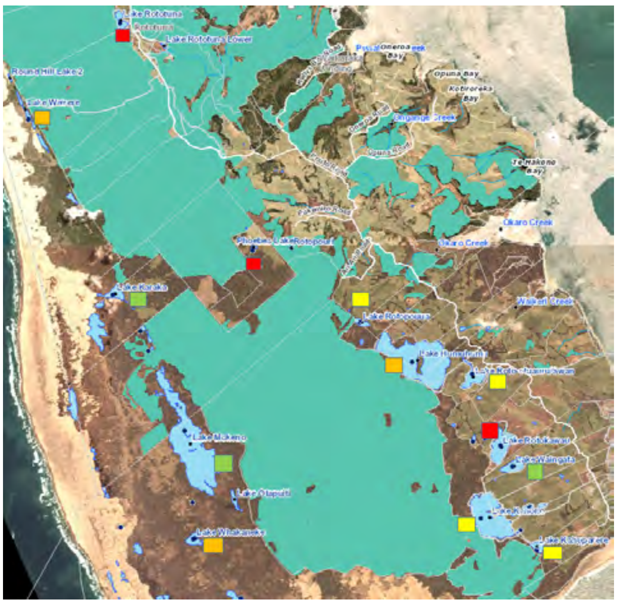
The lakefront has been fully fenced (purple and orange lines on the map below)so there is no stock access.

9.3. Forestry mitigations

Harvest of the forest block to the west of the lake has been undertaken.

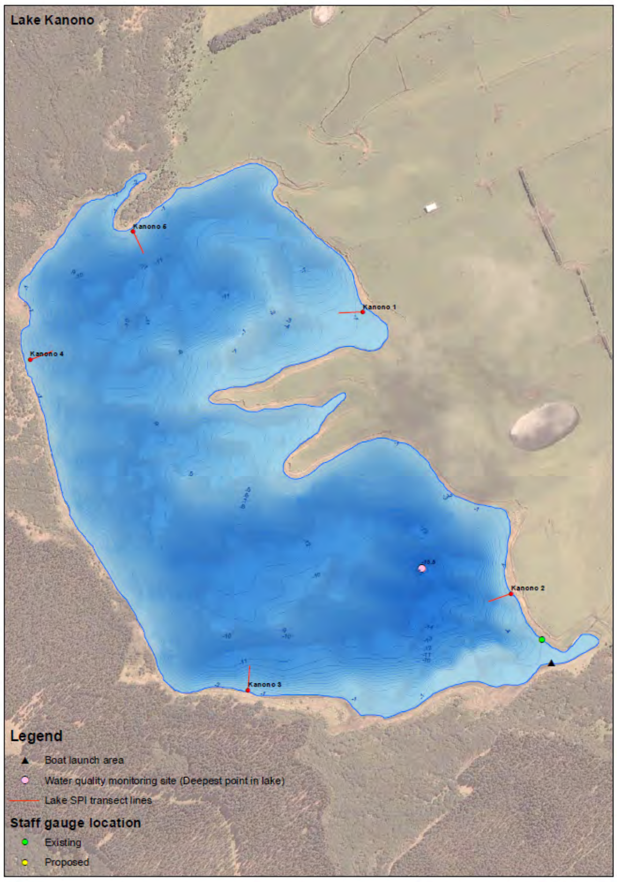
9.4. Fire-fighting mitigations

Kanono, due to the presence of the exotic non-invasive aquatic plant *Potamogeton crispus*, has been identified as a lower-risk water take for fire-fighting, indicated by the yellow marker at this lake in the map below. Given that this species is not present in nearby lakes, it is best to avoid fire-bucket water-take from Kanono.



10. MONITORING PLAN

The diagram below shows the five transect lines surveyed during ecological surveys. The dark triangle to the south-east is the access point for the NRC vessel for water quality sampling. The pink point in the south basin of the lake is the water quality sampling point.



10.1. NIWA ecological monitoring

Lake Kanono had full ecological surveys in 1985, 1988, 2001, 2005, 2007, 2013 and 2015. It is next scheduled to be surveyed in 2018.

Survey recommendations - Lake native biodiversity value monitoring every 5 years and pest plant surveillance every 3-5 years.

Lake	Eco Survey (yr)	Weed survey (yr)	1984	1985	1986	1987	1988	1989	1990	1991	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Grevilles Lagoon															M																
Humuhumu	5	1													O		O					O		O							
Kahuparere	5														H		H					H			O						
Kanono	5	3-5													O		O						O		O			?			
Kapoai	5														L-M		L-M							L				?	?	?	
Karaka	10	5-10													H		H					H			O			?			
Mokeno	5	5													O		O					O			M-H	H					
Parawanui															L											M-H		?			
Phoebe's																		L													
Rotokawau (P)	5														H		H					H			O						
Roto-otuauru/Swan		1													M				M carp	M	M	M	M		carp			carp	carp	carp	carp
Rotopouua	5																	O				O									
Rototuna	5														H		H					H		M				?			
Waingata (P)															L					L					L						
Wainui	5														M-H		M-H							H				?			
Wairere and Round Hill Lake 2	10														M-H									M-H							
Whakaneke															H							M						?			

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.

11. WORK IMPLEMENTATION PLAN

Ongoing work includes:

The NRC/NIWA ecological surveys will continue every five years with weed surveillance every 3-5 years. The next full survey will be in 2018. Quarterly NRC water quality monitoring will continue.

The NRC's Freshwater Improvement Fund (FIF) Dune Lakes project includes work at Lake Kanono, including:

- Lake Kanono has been selected for a more detailed modelling benefit-cost analysis for nutrient mitigation. This process involves walking the catchment and its sub-catchments, documenting required works. The model, based on monitoring of nutrient loads in each drain will estimate the nutrient load mitigated by works such as sediment detention structures and compare it to the cost of the work. The FIF work commits to earthworks for sediment/phosphorus detention on the eastern side of the lake valued at $15,000.
- Due to the presence of the exotic non-invasive aquatic plant *Potamogeton crispus*, Kanono has been identified as a lower-risk water take for fire-fighting. Given the absence of this species in nearby lakes, it is best to avoid fire-bucket water-take from this lake.
- Currently, a staff gauge is used to measure lake level but a continuous electronic water-level recorder is due to be installed.
- Riparian planting is being undertaken by DOC but volunteer numbers to assist with the work are low. Introducing the Million Metres planting programme (https://millionmetres.org.nz/) may improve this.
- Fence the north-east side of the lake including the inlet stream and drains.
- Evaluate the threat from pine harvesting and work with the forestry company to ensure methods are used that pose the least risk to water quality in Lake Kanono.
- Dwarf inanga appear to be stable at this site, but are declining at other lakes. The current status of all dwarf inanga populations in Northland lakes needs assessment.
- Develop a program including the Check, Clean, Dry method to prevent the spread of pest weeds and fish in Pōuto which uses advocacy and other tools to target duck hunters and other lake users.

Proposed sub-catchment-specific work includes (see Appendix 2 for detail):

Reduce phosphorus loss from sub-catchment 1 by:

- Building a detention bund and wetland in the large gap, to reduce contaminant yields before it drains to the lake.

- Drains in the peat area should be left alone. Rather, treatment should occur in the wetland area.
- Fence and plant the drainage line extending from the large gap to the lake. This will have benefits for reducing salmonella ingestion by livestock.
- Cull waterfowl for benefits in lake condition and reduction of salmonella.
- Fence and plant the entry point into the lake. De-channelise this area.
- Provide wider buffers to and plant the riparian area.
- As a last resort, investigate the blockage of the gap in the embankment, to decrease inputs of contaminants from the peat basin. This will have impacts on the drainage of the peat basin on production and profit from this farm area.

Reduce phosphorus loss from sub-catchment 2 by

1. Requiring wide setbacks in crop areas, in the order of 20 metres plus.
2. Restriction of the use of cropping and/or phosphatic fertilisers in sensitive lake catchments, including Kanono.
3. Only allowing cropping where riparian vegetation is sufficiently mature to deal with associated contaminant inputs.
4. Conducting a farmer survey to identify how people would respond to restrictions of this kind.
5. Allowing natural regeneration to reduce cost of planting the riparian area (will require regular follow up weed control for at least 10 years).
6. Targeting additional planting at hot spots, particularly those where surficial flow is a problem.
7. Planting littoral plants to add to the mitigation potential; this will also develop seed stock.

Reduce phosphorus loss from sub-catchment 3 by

- Following points in sub-catchment 2 above.
- Sub-catchment 3 contains a wide buffer area, which has recently been planted with young native plants. A large area of crop has recently been planted in this sub-catchment. This is potentially a source of high sediment and phosphorus inputs to the lake and should be avoided in the future

Reduce phosphorus loss from sub-catchment 3 by:

- Following points in sub-catchment 2 above.
- Determine whether the wetland flows to Lake Kanono or Lake Kahuparere.

On the non-pastoral (eastern) side of lake:

- Consider nitrogen and phosphorus losses from manuka conversion of the western shore of the lake.
- Identify the potential for gully erosion and explore the mitigation options to put in place if this were to occur.
- Determine the full set of options to decrease phosphorus and sediment loss from forest land into the lake, especially during harvest.

12. BIBLIOGRAPHY

AgResearch Ltd. for Northland Regional Council 2016. Lucci, G., 2016. Revisiting the Guidelines for Pastoral Management in the Catchment of Dune Lakes in Northland.

Cawthron Institute for the Northland Regional Council, 2016. Kelly, D., L. Peacock and W. Jiang, 2016. Nutrient Management for Northland's Dune Lakes.

Department of Conservation, Freshwater Ecosystems of New Zealand (FENZ) database, www.doc.govt.nz/our-work/freshwater-ecosystems-of-new-zealand.

Doole, G. and D. Marsh, 2015. Conceptual modelling of shallow dune lakes in the Northland region of New Zealand.

Jacobs for the Northland Regional Council, 2017. Hydrological Assessment for Potential Window Lakes (Update).

LWP for Northland Regional Council, 2016. Lake FMUs for Northland, Recommendations for Policy development.

Ministry for the Environment, 2014. National Policy

Statement for Freshwater Management 2014.

Nicol, E. R., 1997. Common Names of Plants in New Zealand, Press, Lincoln, Canterbury, New Zealand, Manaki Whenua press.

NIWA for the Ministry for the Environment, 2002. Champion, P., J. Clayton and D. Rowe, 2002. Lake Manager's Handbook, Alien Invaders.

NIWA for the Ministry for the Environment, 2002. Rowe, D. and E. Graynoth, 2002. Lake Manager's Handbook, Fish in New Zealand Lakes.

NIWA for the Northland Regional Council, 2012. Champion, P. and de Winton, M. (2012). Northland Lakes Strategy, NIWA Project: ELF12213, NIWA Client Report No: HAM2012-121, prepared for Northland Regional Council: 42.

NIWA for the Northland Regional Council, 2014. Champion, P. (2014) Northland Lakes Strategy Part II update and implementation strategy. NIWA Client Report No: HAM2014-038, prepared for Northland Regional Council: 35.

NIWA for the Department of Conservation, 1996. Collier, K. J. 1996. Potential impacts of plantation forestry on dune lakes in Northland with interim guidelines for riparian management.

NIWA for the Northland Regional Council, 2015. de Winton, M., Taumoepeau, A. and Macdonald, A. (2015). Northland Lakes hydro-acoustic survey and bathymetric resources, NIWA CLIENT REPORT No: HAM2015-116, Prepared for Northland Regional Council. 56 pp.

NIWA for the Northland Regional Council, 2017. Gee, E. 2017. Dune lake galaxias in the Kai Iwi Lakes.

NIWA for the Northland Regional Council, 2014. Rowe, D., 2014. Biosecurity status of non-native freshwater fish species in Northland.

NIWA for the Northland Regional Council, 2014. Wells, R., and P. Champion, 2014. Northland Lakes Ecological Status 2014.

NIWA for the Northland Regional Council, 2014. Wells, R., P. Champion and T. Edwards, 2014. Northland Lakes – Annual Report 2014.

NIWA for the Northland Regional Council, 2015. Wells, R. and P. Champion, 2015. Northland Lakes – Annual Report 2015.

NIWA for the Northland Regional Council, 2016. Wells, R. and P. Champion, 2016. Northland Lakes – Annual Report 2016.

Northland Regional Council, 2013. Cathcart, B., 2013. Soils of Northland.

Northland Regional Council, 2017. Draft P uto Catchment Management Plan.

Pingram, M. A., 2005. Ecology of freshwater fish in the littoral zone of Lake Waikere, Kai Iwi Lakes, Northland, New Zealand: for the conservation of the dune lakes galaxias (Galaxias sp.). A thesis submitted for the degree of Master of Science at the University of Otago, Dunedin, New Zealand.

Rowe, D., 1993. Management options for dwarf inanga. Conservation Advisory Science Notes No. 18, Department of Conservation, Wellington. 3p.

Te Puni Kokiri, Te Kāhui Māngai (Directory of Iwi and Māori Organisations) http://www.tkm.govt.nz

Te Uri o Hau, 2011. Te Uri o Hau Kaitiakitanga o te Taio.

Timms, B.V., 1982. Coastal dune waterbodies of north-eastern New South Wales.

Australian Journal of Marine and Freshwater Research 33: 203–222.

13. APPENDIX 1. . Notes from field visit towards nutrient mitigations

Review of mitigation strategies for individual sub-catchments of Lake Humuhumu and Lake Kanono on the Pōuto Peninsula, Northland

Graeme Doole, 30 November 2016

Summary of field visit (1 November 2016) and GIS review (2 November 2016)

LAKE KANONO
Sub-catchment 1

Sub-catchment 1 is of significant size and drains productive pastures currently used for grazing cattle (Figure 10A). Its entry to the lake is through an eroded gully, which shows evidence of peat staining (Figure 10B). This area has an iron pan present, which increases sub-surface flow through the A horizon.

Figure 10. (A) The sub-catchment contains a large area of pastoral land, which is cropped regularly. The top of this drainage basin is where the peat basin referred to below is located. (B) A drain showing peat staining, located in a gully showing well-developed erosion from stock.

The peat stain emerges from a sub-catchment above this one, which is now linked to this one because the embankment between them has been removed with digging machinery. The peat basin that connects at the top of sub-catchment 1 is shown in Figure 11A, with the cut through the embankment presented in Figure 11B.

Figure 11. (A) The peat basin at the top of sub-catchment 1. The embankment that has been cut to drain the peat is located at the base of the first ridge on the left. (B) The cut in the embankment that has been formed to drain the historic peat swamp. This cut is located at the bottom of the first ridge line on the left shown in Figure 10A.

Key strategies to reduce phosphorus loss from this sub-catchment to the lake are:

1. An option is to build a detention bund and wetland in the large embankment gap, to reduce contaminant yields before it drains to the lake.

2. Drains in the peat area should be left alone; rather, treatment should occur in the wetland area described in point #1 above.

3. The drainage line extending from this large embankment gap to the lake should be fenced and vegetated. This will have benefits for reducing salmonella ingestion by livestock.

4. Culling waterfowl will have benefits for improving lake condition and reducing salmonella ingestion by livestock.

5. The entry point into the lake shown in Figure 10B should be planted and fenced. It may be useful to de-channelise this area.

6. The riparian area could benefit from wider buffers and more vegetation (e.g. Figure 10B).

7. As a last resort, investigate the blockage of the gap in the embankment (Figure 11B), to decrease inputs of contaminants from the peat basin. This will have deleterious impacts on the drainage of the peat basin, and concomitant impacts on production and profit from this farm area.

Sub-catchment 2

Sub-catchment 2 contains a wide buffer area, which has recently been planted with young native plants (Figure 12A). A large area of crop has recently been planted in this sub-catchment (Figure 12B); this is potentially a source of high sediment and phosphorus inputs to the lake. The raupo and algae evident in Figure 13 are a sign of N and P enrichment of this lake.

Figure 12. (A) Sub-catchment 2 has a wide buffer strip containing young native plantings. (B) Cropping activity is under way within this sub-catchment.

Figure 13. Raupo and algae indicating N and P enrichment of the lake.

Key strategies to reduce phosphorus loss from this sub-catchment, and others like it, are:

8. Require wide setbacks in crop areas, in the order of 20 metres.

9. Restrict the use of cropping and/or phosphatic fertilisers in sensitive lake catchments.

10. Allow natural regeneration to reduce cost of planting the riparian area.

11. Only allow cropping where riparian vegetation is sufficiently mature to deal with associated contaminant inputs.

12. Conduct a farmer survey to identify how people would respond to restrictions of this kind.

13. Target additional planting at hot spots, particularly those where surficial flow is a problem.

14. Plant littoral plants to add to the mitigation potential; this will also develop seed stock.

Sub-catchment 3

Sub-catchment 3 contains a wide buffer area, which has recently been planted with young native plants (Figure 14A). A large area of crop has recently been planted in this sub-catchment (Figure 14A); this is potentially a source of high sediment and phosphorus inputs to the lake.

Figure 14. Sub-catchment 2 has a wide buffer strip containing young native plantings. Cropping activity is under way within this sub-catchment.

Key strategies to reduce phosphorus loss from this sub-catchment, and others like it, are presented above in the discussion provided for sub-catchment 2.

Figure 14.

Sub-catchment 4

Sub-catchment 4 is found at the southern end of the lake. A riparian buffer is present, and some vegetation is present in this area. Options for improving phosphorus mitigation in this zone are listed above in the discussion provided for sub-catchment 2. A key action for this sub-catchment is also understanding whether the wetland present there (not shown in Figure 15) flows to Lake Kanono or Lake Kahuparere. Understanding the hydrology of this part of the sub-catchment will highlight the value of fencing and revegetating this area.

Figure 15. The sub-catchment present at the southern end of the lake.

Non-pastoral side of lake

The western shore of the lake is being converted to manuka after the current forest rotation is harvested (Figure 16). The presence of raupo on the margin of this area is indicative of nutrient enrichment.

Figure 16. The lake margin of the forested side of the lake, with raupo indicating nutrient enrichment.

There is a need to understand nitrogen and phosphorus losses under manuka; though it is likely to be very low.

Confirm the exact catchment boundary on the western, non-pastoral side.

Identify the potential for gully erosion to occur on the western, non-pastoral side of the lake and explore the potential utility of different mitigation options.

A conversation needs to be had with the foresters. Who leads this discussion? What are they doing? What are the full set of options to decrease phosphorus and sediment loss from forest land into the lake, especially during harvest? Losses will likely be especially high in certain places, such as skid sites.

14. APPENDIX 2. 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.

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