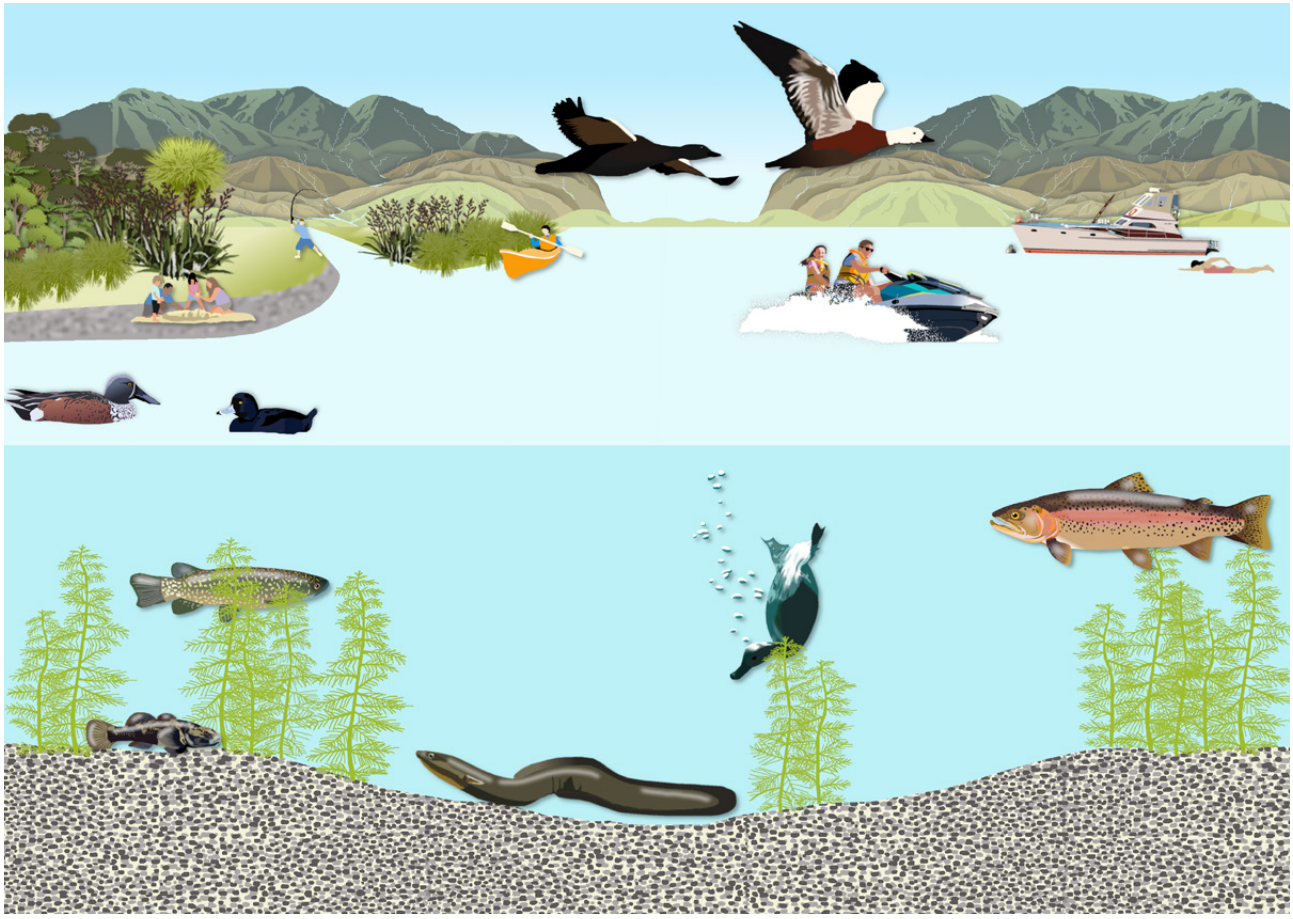
SOUTHLAND'S MONITORED LAKES

A guide to lake ecosystem health monitoring

environment SOUTHLAND
REGIONAL COUNCIL
Te Taiao Tonga



What are lakes?

Lakes are bodies of fresh or brackish water that are entirely or almost entirely surrounded by land. Lakes exist in all shapes and sizes and may be natural or artificially created.

There are over 900 lakes in Southland, most of them located in Fiordland National Park. Environment Southland focuses our monitoring efforts on areas of high ecological value and/or proximity to stress from human activity.

Lakes are generally defined as being greater than one hectare in surface area, any smaller and they are categorised as 'ponds'.

Why are lakes important?

Healthy ecosystems

Lakes support aquatic ecosystems, which have five important components:

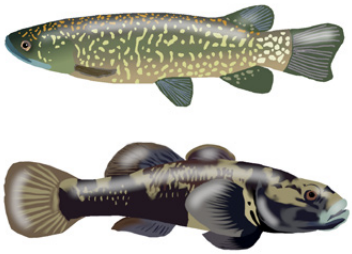
1. water quality: e.g. dissolved oxygen, temperature, nutrients, water clarity, toxicants
2. water quantity: e.g. water level, residence time, connectivity
3. habitat: e.g. form, extent, connectivity, substrate types, riparian areas
4. aquatic life: e.g. microbes, plants, invertebrates, fish, water birds
5. ecological processes: e.g. nutrient cycling and chemical processes

In a healthy freshwater ecosystem ecological processes are maintained, there is a range and diversity of indigenous plants and animals, and there is resilience to change.

Human health and water use

Freshwater in Southland is commonly used for recreational activities, such as swimming and boating, and for drinking water supplies to both reticulated networks and individual households. Poor water quality can have negative effects on human health, as well as lost opportunities for recreation and commercial use of water.

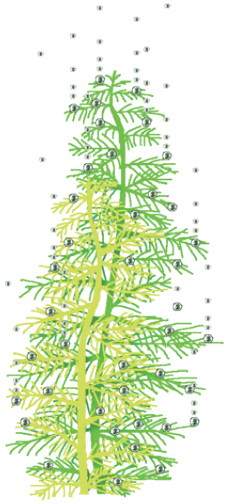
Biodiversity



Healthy lakes support a diverse range of life both within the lake and along their riparian margins. The range of life supported by lakes and their immediate surrounds directly affects lake 'health' and functioning.

There is a relatively low level of diversity of native fish and submerged plants in Southland lakes (and New Zealand generally) compared to some parts of the world. Many of the native species are only found in New Zealand.

Resilience to climate change



Healthy lakes can increase environmental resilience to the effects of climate change in two main ways: as a carbon 'sink'; and by storing excess water during extreme weather and flood events. Lakes form an important part of the carbon cycle*. They are able to store large amounts of carbon, reducing the amount lost to the atmosphere as carbon dioxide (a greenhouse gas).

*Carbon is a key element or building block for all forms of life on earth. Carbon is cycled from the atmosphere, to terrestrial and aquatic environments via plants and through the food chain. Carbon is also retained as fossil fuels such as oil and coal, which formed from plants buried millions of years ago. Carbon is released back to the atmosphere during respiration, when plants and animals decompose, and from activities such as burning fossil fuel.

Why are lakes important?

Sediment and nutrient buffer

Lakes are a natural ‘sink’ for sediment and nutrients, buffering downstream ecosystems from their effects. Nutrients are cycled within a lake system via a variety of physical, chemical and biological processes. Nutrients are cycled in all lakes, however a ‘healthy’ lake can buffer nutrients more effectively through uptake into plants and sediment. This helps to reduce the amount of nutrients leaving the lake and entering downstream waterbodies.

Recreation and tourism

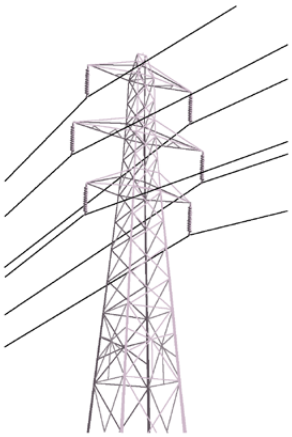
Lakes are an important place for food gathering and the enjoyment of various recreational activities. Recreational fishing for trout and salmon is a popular activity and provides a major attraction for visitors. A significant portion of the whitebait fishery is also believed to be supported by lake-dwelling populations of adult fish.

Cultural values

For local iwi Ngāi Tahu, water is woven deep into their identity and traditional cultural practices. A healthy fresh waterway enables mahinga kai (food gathering) to take place, a central pillar of Ngāi Tahu culture. Mahinga kai encompasses the resource harvested (e.g. food, fibres, muds, clays and soil, stonework), the ability to access the resource, the site where gathering occurs, the act of gathering and using the resource, and the good health of the resource. Mahinga kai is central to Ngāi Tahu ki Murihiku relationships with places, waterways, species and resources, and to their cultural, spiritual, social and economic wellbeing. It is also a vehicle for the intergenerational transfer of mātauranga (knowledge).

Hydroelectricity

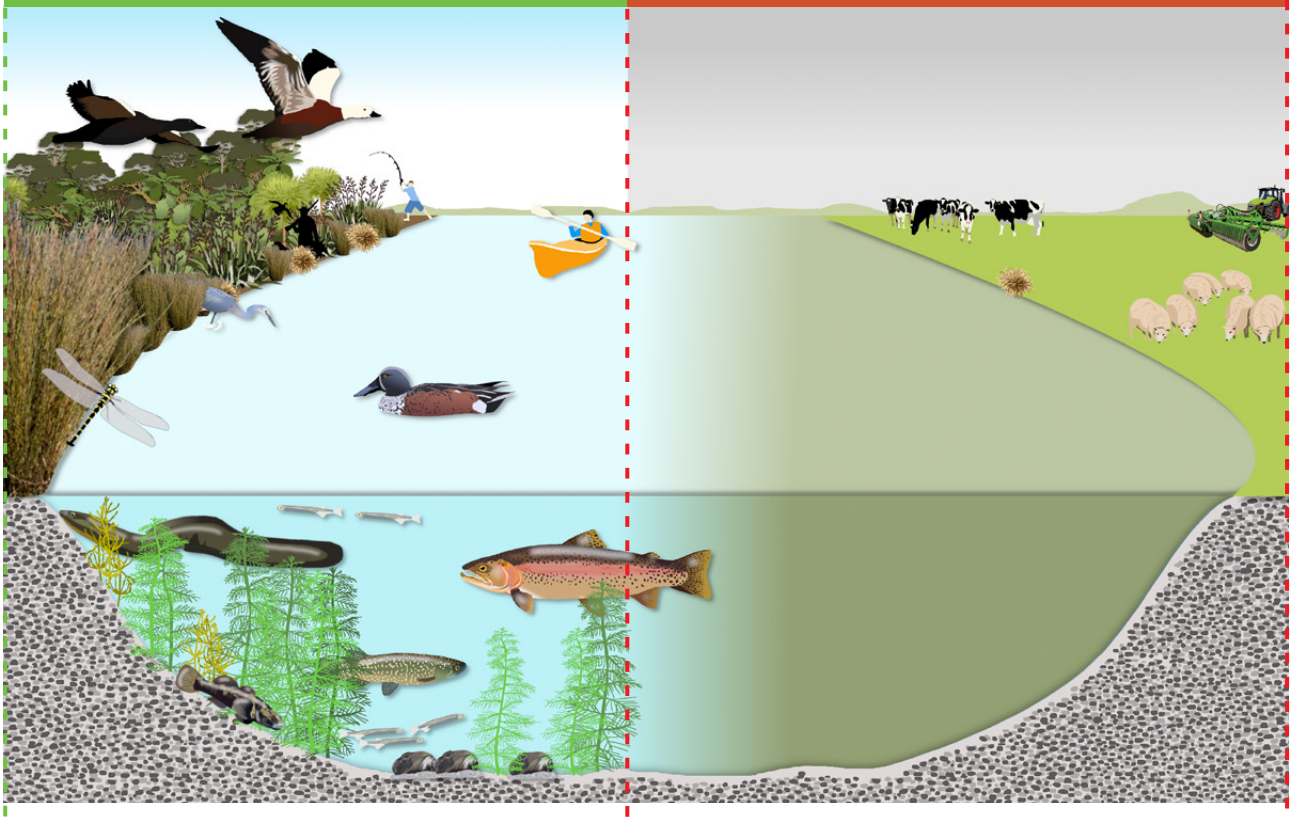
Hydroelectric power in New Zealand has been a part of the country's energy system for over 100 years and continues to provide more than half of the country's electricity needs. Southland examples include the Monowai Power Station, which opened in 1925 and was one of New Zealand's earliest hydroelectric power stations and is still in operation today. Southland also has New Zealand's largest hydroelectic power station, located at Lake Manapōuri.



Ecosystem health

Lake ecosystem health is strongly linked to catchment modification and human impacts. Lakes are particularly affected by drainage and flow changes (e.g. dams), nutrient and sediment inputs, habitat modification, and introduced plants and animals. Some of our lakes are more at risk than others, depending on their size and location within a catchment.

✔ Good outcome – healthy lake	✖ Poor outcome – unhealthy lake



Benefits to us

- Cultural and spiritual heritage maintained
- Maintenance of Te Mana o te Wai
- Community well-being and connectedness
- Ecosystem services e.g. as a sediment/nutrient sink and flood protection
- Production of food and raw materials
- Recreation and tourism opportunities
- Aesthetic appeal
- Biodiversity value
- Water supply

How this impacts us

- Cultural and spiritual heritage is compromised or lost
- Loss of Te Mana o te Wai
- Increased risk of disease or illness – people and animals
- Harmful cyanobacterial blooms or nuisance blooms of 'algae'
- Impacts on fisheries and aquatic ecosystems, including those downstream
- Economic costs due to loss of ecosystem services and aesthetic appeal
- Impacts on recreational activities – e.g. from algal blooms
- Impacts on infrastructure
- Loss of biodiversity

Lake types

Lakes can be categorised in many different ways. Southland's lakes fall into four broad classes based on their physical properties and location.

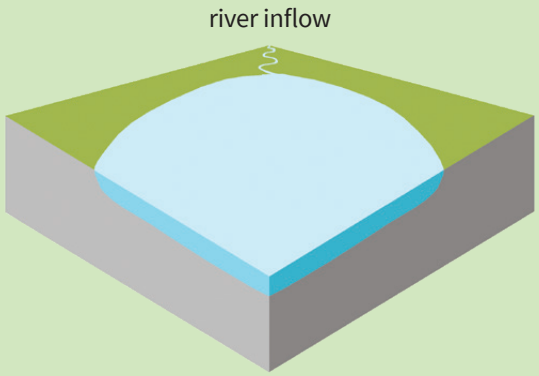
Lowland shallow lakes

Lowland shallow lakes are located below 300 metres elevation and are generally less than 15 metres deep. During the majority of the year, water in these lakes is well mixed, with strong interaction between sediment processes and the water column.

Lowland shallow lakes are naturally 'productive' environments due to their position in the landscape. However, intensive land use means that they are at high risk of eutrophication, due to high nutrient and sediment inputs.

SOUTHLAND EXAMPLES

Lake Vincent
The Reservoir
Lake George
Lake Murihiku



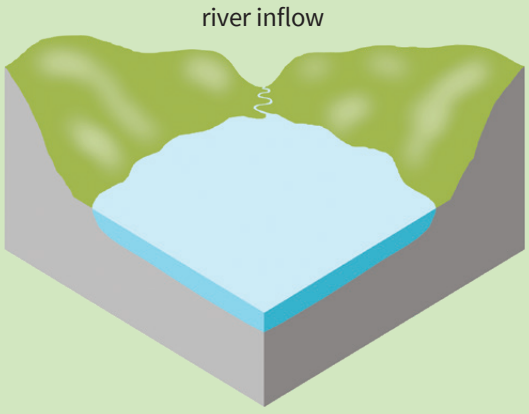
Upland shallow lakes

Upland shallow lakes are located above 300 metres and are generally less than 15 metres deep. Their higher elevations means these lakes have lower temperatures, different rainfall patterns and humidity to their lowland counterparts.

Upland shallow lakes in Southland are less affected by intensive land use. However, they may be affected by the impacts of forestry in some locations.

SOUTHLAND EXAMPLES

Acheron Lakes
Lake Ursula

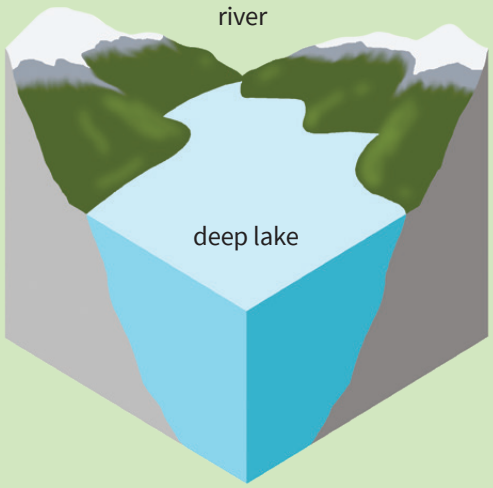


Deep lakes

Deep lakes are those that are greater than 15 metres deep. These lakes undergo seasonal water temperature stratification resulting in two distinct lake layers. There is reduced interaction between sediment and surface waters because they are separated by light, temperature and density gradients.

As summer proceeds, there may be less and less dissolved oxygen in the deeper, cooler water layer. This is due to both a lack of circulation with surface water (where it can pick up oxygen), and the decay of organic matter in the bottom waters (which uses oxygen).

Reduced oxygen levels in deeper water may affect aquatic life, particularly fish.



SOUTHLAND EXAMPLES

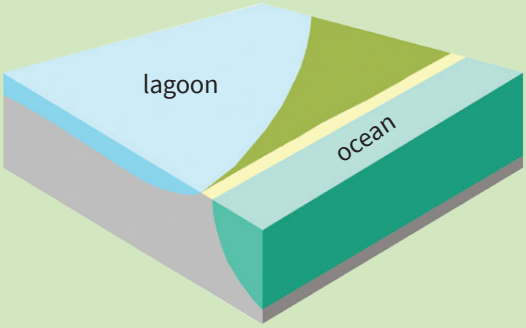
Lake Te Anau
Lake Manapōuri
Lake Hauroko

Brackish lakes and lagoons

Brackish lakes and lagoons are influenced by coastal waters, generally through two mechanisms mixing with salt water and/or water level changes with the tide. These lakes are enclosed lagoons that are usually closed to the sea, but occasionally open. They are typically shallow (average depth less than 3 metres deep) and fed by streams with relatively low flow and volume.

Brackish lakes can be permanently influenced by the ocean (e.g. Waiau Lagoon) or they can be enclosed lagoons that are usually closed to the sea, but occasionally open (e.g. Waituna Lagoon).

When an enclosed lagoon is closed to the sea these systems effectively act like a terminal catchment lake. When open to the sea, they act more like an estuary so can be classified as either a lake or estuary.



SOUTHLAND EXAMPLES

Waituna Lagoon
Waiau Lagoon
Lake Brunton

What affects ecosystem health?

Lakes and lagoons are a natural collection point for water (and the contaminants it carries) in a catchment. As we modify and develop catchments we change the way water flows and increase the amount of contaminants such as nutrients, sediment and micro-organisms. Lakes and lagoons become increasingly at risk of declining water quality and lake health. Shallow lakes and lagoons are at greater risk of reduced ecosystem health than the deep glacial lakes, because they have less volume, their position in the landscape, and the type of land use in surrounding catchments.

Why are some lakes and lagoons more prone to being 'unhealthy' than others?

Lakes and lagoons come in all shapes and sizes, but why are some more prone to becoming 'unhealthy' than others?

Key variables for lake health are:

Load

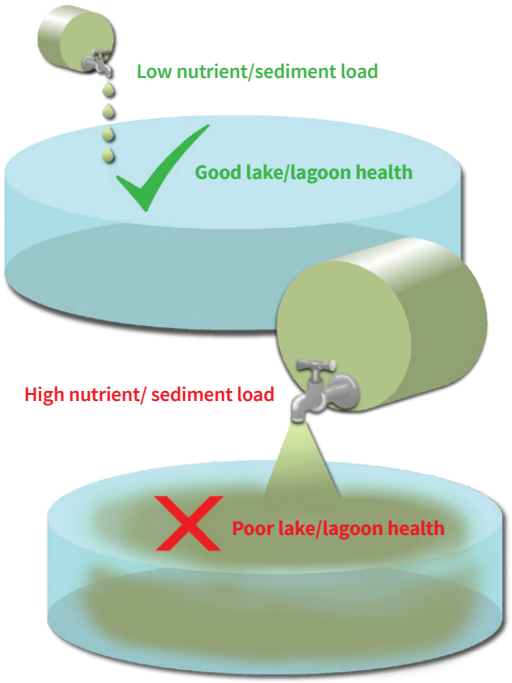
The amount of nutrients and sediment entering a lake or lagoon.

load = flow x concentration

Sensitivity

How sensitive the system is to excess nutrients and sediment.

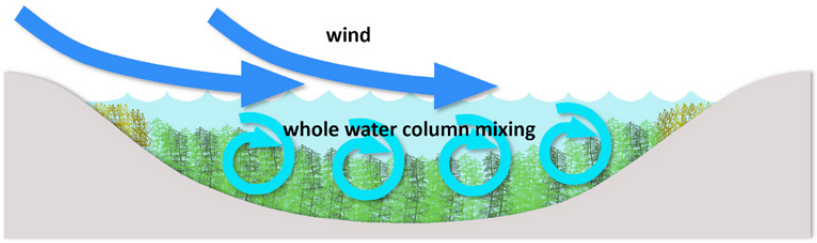
Lake volume, depth and water residence time (the rate water flows through a lake) can all affect how much load the lake can cope with.



Stratification and mixing

Shallow lake

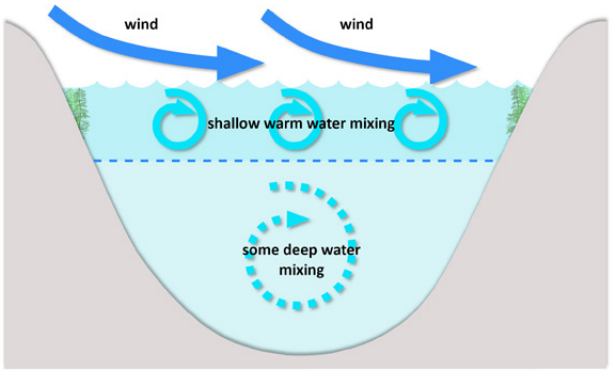
Nutrients mix vertically within a lake or lagoon in different ways depending on depth. Shallow lakes and lagoons have a water column that is relatively well mixed and even in temperature, resulting in nutrients being distributed throughout the lake. When nutrient levels are high this can fuel the excessive growth of aquatic plants or microalgae across the whole lake.



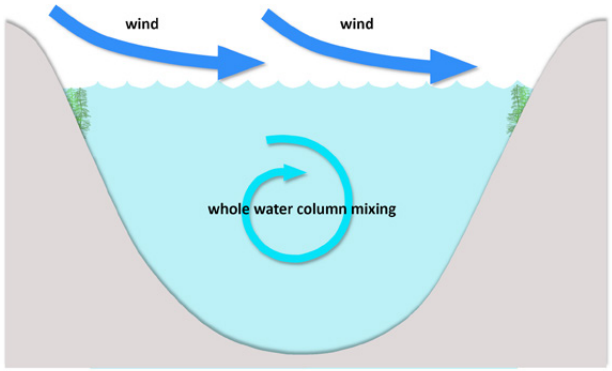
Shallow lake with well mixed water column

Deep lake

In contrast, deep lakes can behave differently. During the warmer months deep lakes tend to have a layer of warm water sitting on top of cooler deeper water. This separation can change the way in which nutrients are cycled in the two layers. In the cooler months the temperature of the surface water drops and is similar to the cooler deeper water. This drop in surface water temperature causes the water column to mix creating an even temperature in the water column.



Deep lake - summer, stratification



Deep lake - winter, no stratification

Nutrients – too much of a good thing

In a healthy lake or lagoon system, there are enough nutrients (e.g. nitrogen and phosphorus) for the growth of healthy amounts of algae (periphyton and phytoplankton) and aquatic plants. These provide food for grazing invertebrates and fish, and these in turn provide food for larger fish and birds.

However, as nutrient levels increase, large macrophytes (plants adapted to live in water) die-off and are replaced by microscopic algae, changing the water from clear to green. This process affects the overall health or 'trophic' state of a lake/lagoon, leading to changes in the composition of species from those that are sensitive to eutrophic conditions to those that are more tolerant. Highly eutrophic lakes/lagoons are too enriched with nutrients to sustain healthy diverse lake life (plants and animals) and are at greater risk of harmful or toxic algae or cyanobacteria blooms.

Healthy vs unhealthy states

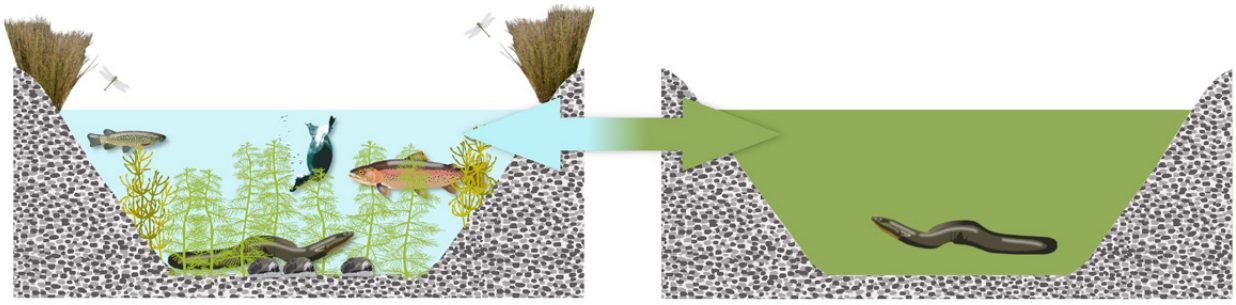
Lakes and lagoons generally have two distinct stable states or conditions:

Healthy (oligotrophic) lakes/lagoons

- low nutrients
- clear water
- dominated by underwater aquatic plants (macrophytes)
- balanced food web with a wide variety of life (plants and animals, big and small)

Unhealthy (eutrophic) lakes/lagoons

- high nutrients
- murky (turbid) water with low visibility
- dominated by microscopic algae (phytoplankton)
- variety of life is greatly reduced



Unstable states: Lakes/lagoons with moderate nutrient levels (mesotrophic) can 'switch' from a clear to turbid state, often suddenly. A switch in state can result from:

- increased nutrient levels entering the lake/lagoon, e.g. from changing land use within the catchment
- the introduction of plant or animal pests, which disrupt the ecosystem
- a change in temperature and/or the physical conditions of a lake
- water abstraction or diversion, which can lower the lake's water level and alter mixing and flow-through rate

A lake or lagoon can change back from turbid to clear water, but this may require substantial human effort to reduce nutrient and sediment levels. It may also require other interventions like managing appropriate flow and level regimes, reinstating macrophyte beds, managing invasive species and managing legacy loads of sediment and nutrients already in the system.

Foodwebs – keeping the balance

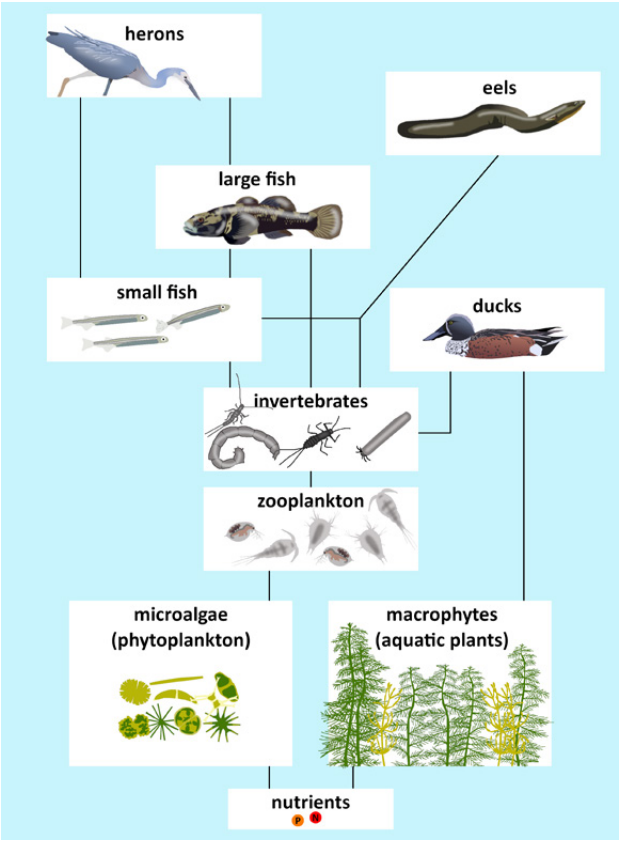
As well as excess nutrients, lake and lagoon health can be further complicated by pest species. In Southland these include fish such as perch, aquatic weeds, and nuisance algae such as 'lake snow'. Impacts from these species can be significant, including reduction in indigenous biodiversity, destabilisation of aquatic habitats, implications for human health, economic losses through lost power generation, impeded drainage or irrigation, loss of tourism, and reduced opportunity for recreational activities like boating and fishing.

Healthy foodweb
Resulting from a limited nutrient input and low populations of exotic (non-native) fish species.

In 'healthy' lakes and lagoons the input of nutrients* is low, but are sufficient to fuel the healthy growth of plant-life, which includes both microalgae (phytoplankton) and macrophytes (aquatic plants). Phytoplankton are microscopic algae that form the base of several aquatic foodwebs, including lakes.

This plant-life forms the base of a food web that feeds a wide variety of zooplankton (microscopic animals), which are food for invertebrates (animals without a backbone), which are then food for fish. Invertebrates and small fish are important sources of food for larger fish, eels and a variety of birdlife.

*Nutrients that fuel the growth of plant-life are various forms Phosphorus (P) and Nitrogen (N).



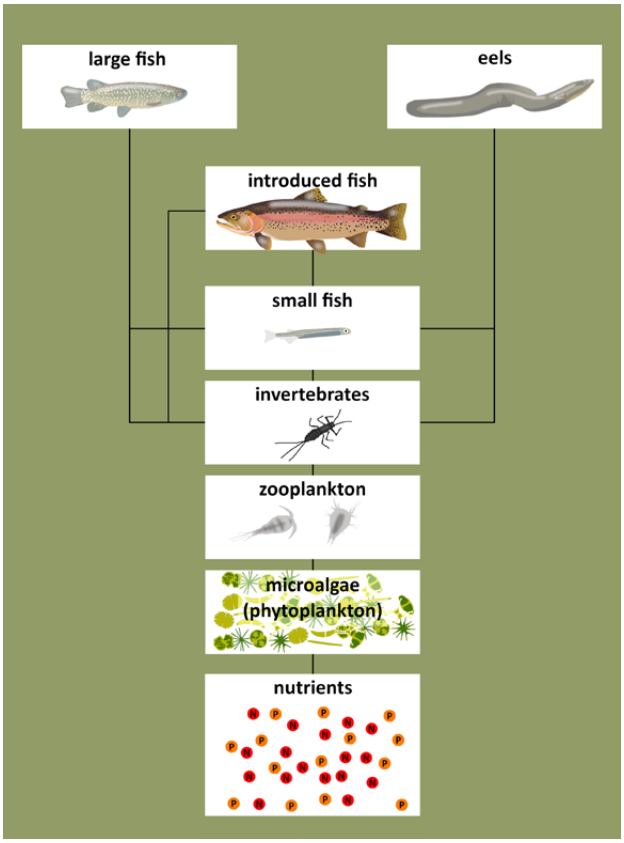
Unhealthy foodweb
Resulting from too many nutrients and larger populations of exotic (non-native) fish species.

Some lakes and lagoons receive too many nutrients. This results in the rapid growth of microalgae, which turn the water green. The resulting reduced light and oxygen conditions means that macrophytes are no longer able to grow.

Zooplankton also struggle under these conditions, resulting in less food for invertebrates. Fewer invertebrates result in fewer fish.

Introduced fish such as perch and trout further complicate the story. Aggressive predators like trout will outcompete native fish to take advantage of the already reduced food supply.

There is also less food available to support birdlife, such as ducks and herons. The end result is a much reduced and compromised foodweb that supports a limited range of life.



Lake health programme

Environment Southland has a programme that assesses the health of some lake systems across the region. Using a range of indicators, we can tell the health status. Some key indicators are discussed below.

Water quality

Physical and chemical measures of water are important for monitoring direct changes in water quality and aiding in the interpretation of lake health. At high levels, some measures (such as nitrate or temperature) can be toxic to lake life.

The key physical and chemical indicators routinely monitored in Southland are:

Type	Indicators	Type	Indicators
Nutrients	Total nitrogen Total phosphorus Nitrate Ammonia	Physical	Water temperature Dissolved oxygen
Ecosystem	Phytoplankton Cyanobacteria Invasive and native plants Trophic Lake Index (TLI)	Microbes	*E. coli*

Nutrients

Nitrogen and Phosphorus

Nitrogen and phosphorus are plant nutrients necessary for life. However, too much of these nutrients causes aquatic plants to grow faster than ecosystems can handle.

Increased nutrient richness in lakes stimulates the growth and abundance of fast-growing algae which can lead to blooms. Excessive macrophyte growth due to high nutrients can be a problem for recreational users and become even worse when the macrophytes die back and release the stored nutrients.

Ecosystem attributes

Phytoplankton

Like plants phytoplankton form the foundation of aquatic foodwebs, and are an important producer in lake environments. Phytoplankton need nitrogen and phosphorus to grow. However, if there are too many nutrients, this can affect phytoplankton population growth and structure.

Increased nutrient richness in lakes stimulates the growth and abundance of phytoplankton, resulting in discolouration of the water. When they are present in high numbers this can lead to algal blooms.

Changes in phytoplankton population structure and density can tell us how a lake is changing, and whether it is showing signs of 'stress'.

Cyanobacteria (toxic algae)

Cyanobacteria (or blue-green algae) are microscopic organisms that are an integral part of many terrestrial and aquatic ecosystems. Under favourable conditions, they can increase to high concentrations forming planktonic (suspended in the water column) blooms or dense benthic (attached to substrate) mats. These can impact on aquatic ecosystems by reducing dissolved oxygen and light in the water column. Some cyanobacteria species produce poison or toxins which can be a threat to human and animals if consumed or through contact during recreational activities.

Invasive and native plants

Macrophytes are aquatic plants growing in or near water. They may be emergent (with upright portions above the water surface), submerged or floating. Macrophytes are a natural component of lake systems. However, abundant growth of instream plants can become problematic, impacting upon human and ecological values.

Generally, macrophytes (both native and introduced) can form nuisance growths when nutrient inputs into a lake are high. However, other environmental characteristics also affect plant growth, such as the amount of light reaching the lake bed, temperature, and substrate type.

Trophic Lake Index - A measure of lake health

The Trophic lake Index (TLI) is used to give an overall picture of lakes ecosystem health.

Parameters

Total Nitrogen	+	**Total Phosphorus**	+	**Water clarity**	+	**Chlorophyll-a**	=	**Trophic Lake Index**
Nitrogen is a key nutrient for plant growth. However, too much Total Nitrogen can lead to excessive growth of phytoplankton (microalgae), which can lead to poor water quality.		Phosphorus is a key nutrient for plant growth. However, too much Total Phosphorus can lead to excessive growth of phytoplankton (microalgae), which can lead to poor water quality.		Water clarity is a measurement of how clear the water in the lake is. In general, the clearer the water, the better the water quality.		Chlorophyll-a is the green colour in plants. Knowing how much chlorophyll there is in a lake gives us a good idea of how much phytoplankton is present in the lake. The more phytoplankton present, the poorer the water quality.		It combines the results of four parameters into one number, which then corresponds to a 'trophic status'.

Trophic Lake Index categories

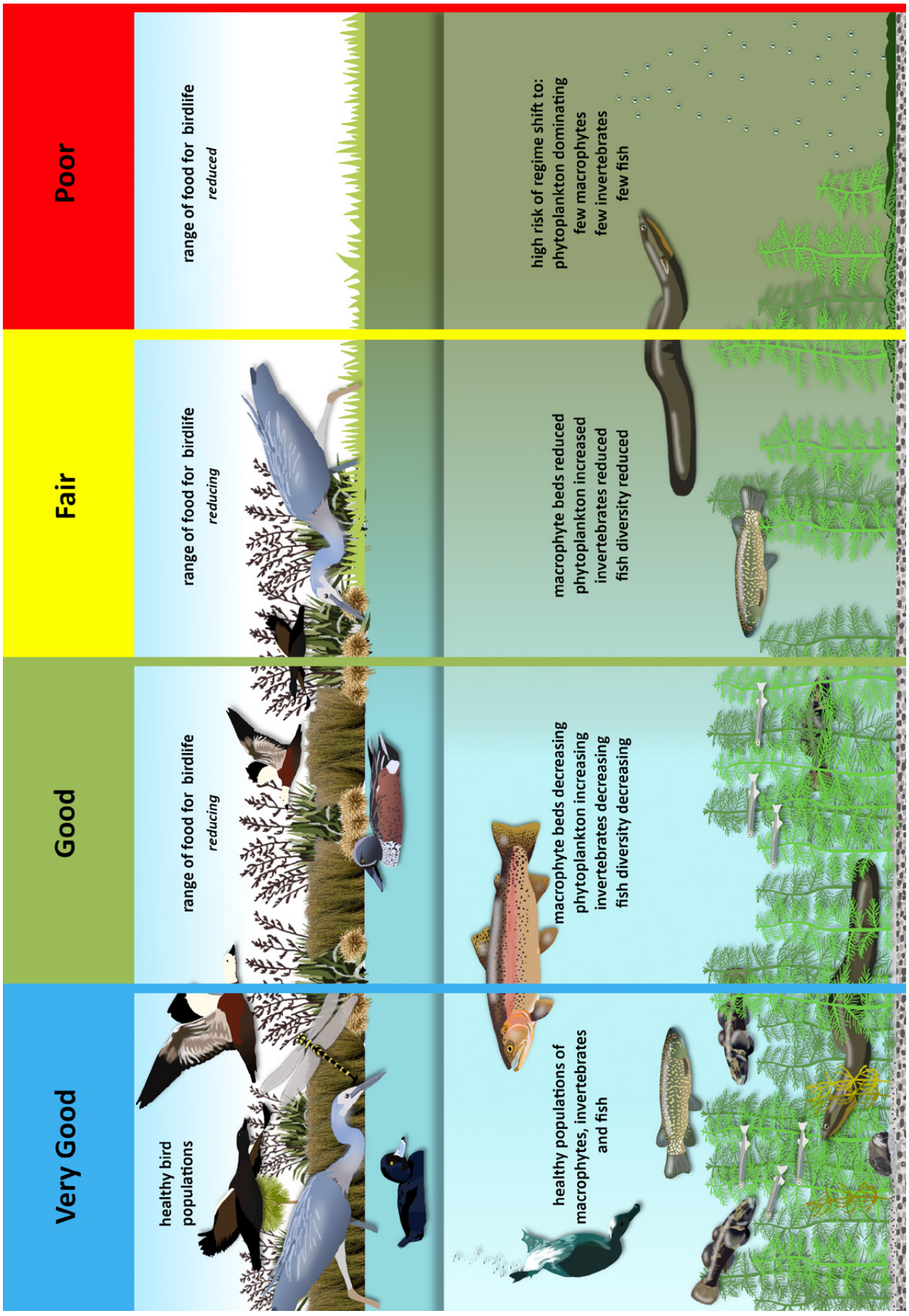
Based on the four parameters described above, each lake is assigned a number between 1 and 7. The lower the number, the better the water quality.

Numbers correspond to a category, ecosystem health rating, and description, as shown below.

Index number	Category	Ecosystem Health Rating	Description
Less than 2	Microtrophic	Very Good	The lake is with very low levels of nutrients and algae
2 to 3	Ogliotrophic	Good	The lake is clear with low levels of nutrients and algae
3 to 4	Mesotrophic	Average	The lake has moderate levels of nutrients and algae
4 to 5	Eutrophic	Poor	The lake is green and murky, with higher amounts of nutrients and algae
Greater than 5	Supertrophic	Very Poor	The lake is green and murky and saturated in phosphorus and nitrogen and often associated with poor water clarity

Lake health ratings

Lake health ratings, including causes and effects



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