Paleolimnology to Determine Lake Reference Conditions – Fact Sheet

Linking lake restoration with end users for positive environmental outcomes

LERNZ
Lake Ecosystem Restoration New Zealand

Paleolimnology

Paleolimnology is the study of the early history of lakes based on sediment composition. Lake sediments build up in undisturbed areas of lake bottoms (e.g. in deep central basins) over long periods of time. These sediments will reflect the prevailing conditions in the catchment, climate and in-lake processes at the time of deposition. Specific 'markers' can be used to determine when a particular layer of sediment was deposited. For example, in volcanic areas lakes sediments may contain volcanic ash layers from historical eruptions that can be used to date the sediment (Figure 1). Where it is possible to take long sediment cores in relatively undisturbed areas the historical record of the lake may stretch back far enough to give insights into historical climatic conditions and pre-human-settlement state of the lake. This pre-human condition is sometimes referred to as a "reference state". Defining the reference state is important as it provides an indication of the extent to which the current state differs from it. This difference provides a useful reference point for setting targets to improve the state of a lake (e.g., as part of the limiting-setting process envisaged under the National Objectives Framework for Freshwater Management 2011).

Figure 1. Retrieving a sediment core from Lake Okataina

Case Study—Lake Okataina

Lake Okataina (Rotorua-Te Arawa lakes) is a deep (65 m), oligotrophic lake of area 10.8 km^2, with a catchment area of 63 km^2. The current state of Lake Okataina may be considered close to its reference condition as at least 89% of its catchment has been in indigenous forest for over 800 years, apart from periods following major volcanic eruptions (e.g., Tarawera, 1886). However, like many other lakes its catchment is dynamic and may be affected by introduced mammalian grazers such as deer, possum and wallaby and changes in climatic conditions. In order to forecast how Lake Okataina may be affected by these changes, a study of the paleolimnological conditions was conducted using sediment cores to determine the timing and effects, if any, of past volcanic eruptions, periods of Māori settlement, trout introductions and lake water level fluctuations.

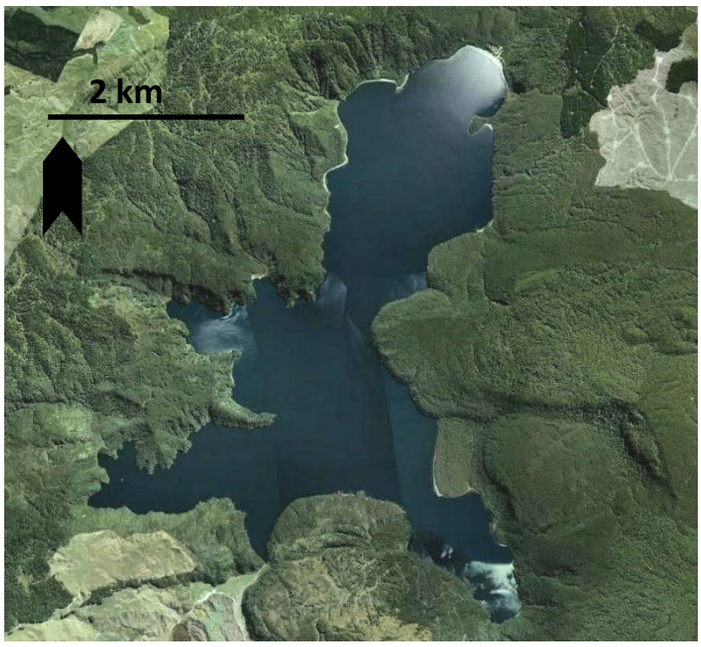

Figure 2. Lake Okataina is one of the Rotorua-Te Arawa lakes located to the east of Lake Rotorua in the Bay of Plenty region. The catchment has approximately 89% native vegetation. Image: Google Earth

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Dating Sediments

After retrieval of sediment cores, tephra or radioisotopes (e.g. ^{14}C and ^{210}Pb) can be used to indicate the approximate time when sediment layers were deposited. Dating can be cross-validated with the deposition of volcanic ash layers in cores in lakes of volcanic origin. Other indicators can be used to re-create the conditions at the time of sediment deposition. Some biological material markers are preserved in the sediments, including diatoms (specifically the silica cell wall of these phytoplankton), pollen grains, and pigments from phytoplankton. Mineralised forms of aluminium, calcium, iron from the catchment are also present in the sediment column. The quantity of these biological and chemical materials in each layer of soil provides a proxy for determining loads from catchments and the changing productivity of lakes.

Key Findings of Lake Okataina Study

Detailed analysis of a sediment core from Lake Okataina has shown the following:

- Cyanobacterial (blue-green algal) abundance has increased, and diatom abundance decreased over the past 150 years.
- Labile and iron-bound forms of phosphorus, have been increasing for the past 150 years resulting in a shift of the trophic state of the lake from oligotrophic towards mesotrophic, despite little change in catchment land-use.
- The variability in phytoplankton and phosphorus species was minimal during the period of Polynesian settlement, but since the Tarawera eruption (1886 AD) there have been relatively rapid changes in these variables consistent with more nutrient and sediment inputs to the lake.

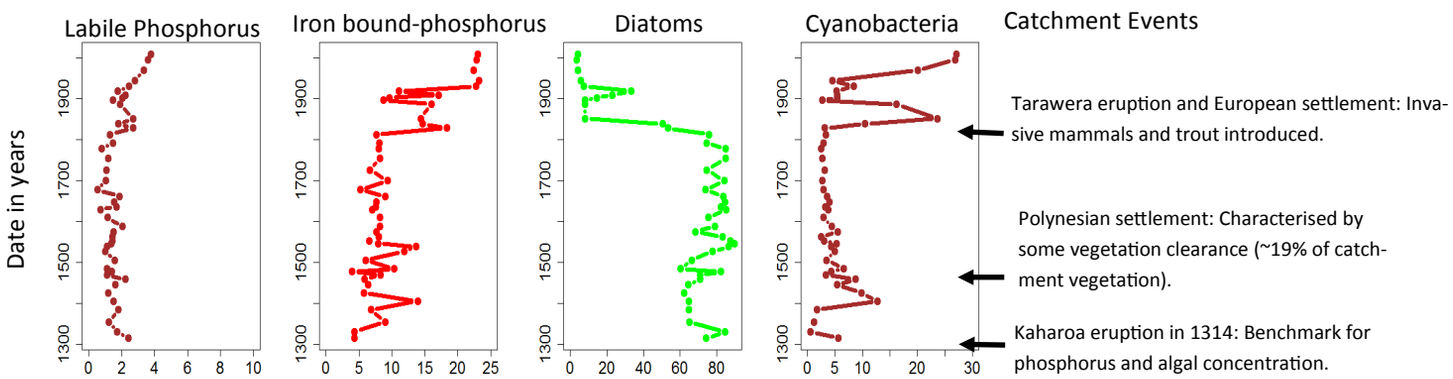

Figure 3. Changes in phosphorus and algal populations over time, derived from sediment cores taken from Lake Okataina.

Significance

Lake Okataina represents a valuable ecosystem as it is close to what may be considered a reference condition for volcanic lakes. However, reference lakes can still be very dynamic and may be subject to indirect anthropogenic pressures besides land use change:

- Invasive mammals have been introduced into the catchment and excessive browsing on native vegetation by these mammals (Figure 4) , coupled with steep slopes, could increase sediment and nutrient inputs to the lake, altering its trophic state.
- Changes in lake trophic state could activate 'dormant phosphorus' from lakebed sediments, which may be released back into the water column to increase primary productivity under anoxic conditions.
- A stable catchment with minimal disturbance is important to maintaining Okataina as an example of a reference-state lake.

Figure 4. Mammal exclusion fence in Okataina catchment. Mammals are excluded from the right-hand side enclosure.