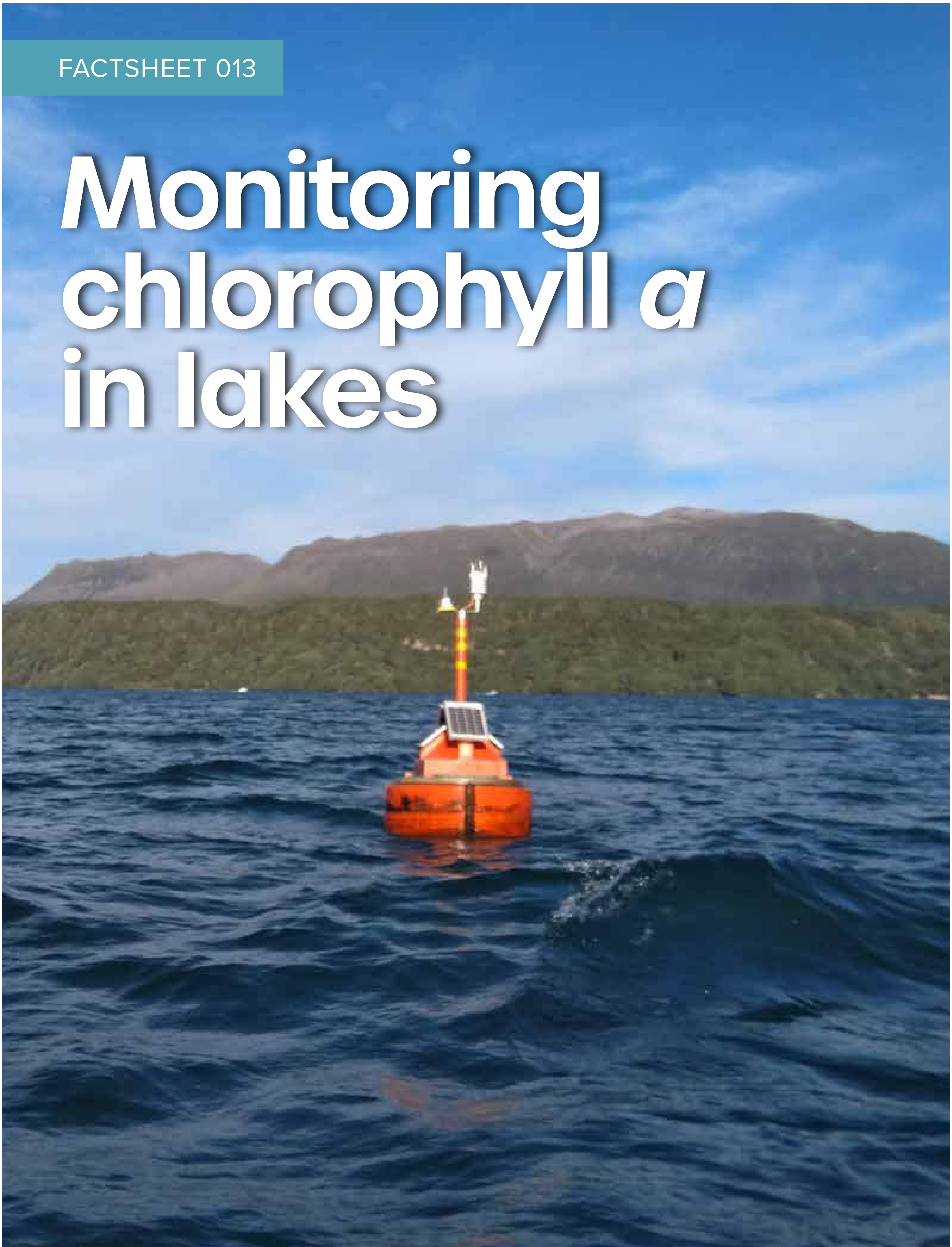
FACTSHEET 013

Monitoring chlorophyll *a* in lakes



OUR LAND AND WATER
Toitū te Whenua, Toiora te Wai
National SCIENCE Challenges
Monitoring Freshwater Improvement

Chlorophyll *a* is a photosynthetic pigment found in plants and algae, including in phytoplankton (microscopic algae suspended in a water column). High concentrations of chlorophyll *a* indicate high phytoplankton biomass and, sometimes, the proliferation of potentially toxic cyanobacteria blooms.

Phytoplankton or cyanobacteria blooms are a symptom of nutrient enrichment (eutrophication) of a lake and can cause poor water clarity and anoxia of bottom waters as phytoplankton cells die and sink. They can also impact the recreational and aesthetic values of a lake.

Chlorophyll *a* is used as a proxy for phytoplankton biomass in lakes as it can be readily measured through chemical or fluorescence methods. In contrast, direct measurements of phytoplankton biomass usually involve laborious microscopy methods.

Monitoring chlorophyll *a* is a key part of evaluating the trophic status of a lake, which is a common measure used to describe lake health in New Zealand. Trophic state provides an indication of how much growth or productivity occurs in the lake, with productivity directly related to the availability of nutrients. Chlorophyll *a* is one of four attributes (along with total phosphorus, total nitrogen and Secchi depth) used to determine the 'Trophic Level Index' for New Zealand lakes[1].

Phytoplankton bloom at a lake edge. Photo: David Hamilton

Sampling a lake for chlorophyll *a*

In lakes, the concentration of chlorophyll *a* can be measured by taking a water sample and having it tested in a laboratory. The sample may need to be filtered at the time of sampling; the laboratory provider should be able to advise on whether this is required or can be done in the laboratory.

In some small or shallow lakes, sampling may be possible by wading from the lake edge. However, in many cases, a boat will be required to sample from an appropriate site, often located at the deepest point of the lake. A special type of sampler, such as a Van Dorn, may be required to sample from different depths.

[1] *Burns, N.M., Rutherford, J.C., Clayton, J.S. 1999. A monitoring and classification system for New Zealand lakes and reservoirs. Lake and Reservoir Management 15:4: 255-271, DOI: 10.1080/07438149909354125.*

The protocol for collection and measurement of chlorophyll *a* is critical as concentrations can be highly variable across a lake, with depth and over time. Variations are often characterised by high levels in the surface mixed layer of lakes and lower levels below, but there can also be high concentrations in deep layers or at centimetre-scale at the water surface when there are buoyant cyanobacteria blooms. This variation means it is critical to know the depth(s) of collection of water samples and any integration (e.g., tube sampler) or aggregation of samples from different depths or places, including for comparisons between water grab samples and fluorometers within the lake.

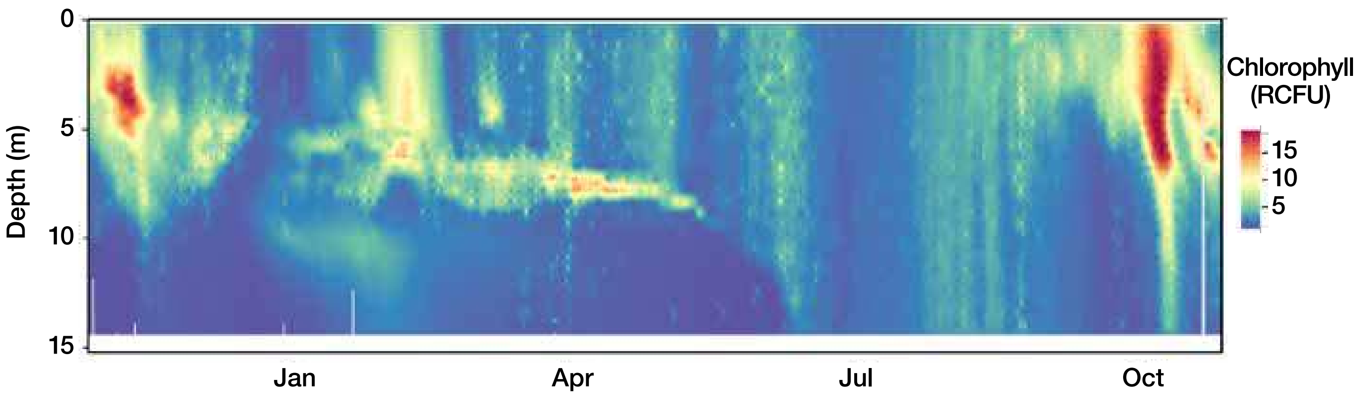
For information on the collection, storage and transport of lake samples for analysis of chlorophyll *a*, refer to the relevant National Environmental Monitoring Standard[2].

Measuring chlorophyll *a* using a sensor

Chlorophyll *a* can be measured directly in a lake using a fluorescence sensor (fluorometer), which exposes cells in the water to a bright light and then measures the fluorescence produced by the cells (which is a small percentage of the light energy that is used for photosynthesis). A portable sensor can be used to take measurements periodically, or a high-frequency sensor can be deployed from a buoy.

Ideally, the fluorometer should be calibrated in the factory, in the laboratory against chlorophyll *a* standards, and against chlorophyll *a* measured from water samples collected in the field. In addition, ongoing sampling (several times a year) should be carried out to validate the fluorometer measurements.

Several potential interferences also exist for chlorophyll fluorescence, including quenching of the fluorescence signal at high chlorophyll concentrations, non-photochemical quenching, which reduces the fluorescence under high light exposure, and temperature sensitivity. Nevertheless, when properly operated and calibrated, fluorescence measurements can provide an excellent opportunity to obtain chlorophyll *a* autonomously at high frequency, including water column profiles when deployed from a profiling buoy or high-resolution vertical and horizontal profiles when a fluorescence sensor is deployed from a boat.



Vertical fluorescence profiles from Lake Okaro, Bay of Plenty, every three hours for one year. Chlorophyll fluorescence (Relative Chlorophyll Fluorescence Units) is represented by the colour scale at right. Profiles show vertical variability in fluorescence, including periods of strong signal in the surface mixed layer (October), as well as periods of a deep chlorophyll layer (April – May). Data: Limnotrack.

An area of emerging technology is detection of chlorophyll *a* using remote sensing methods; for example, through images of the lake surface captured by satellite or drones[3].

[2] *National Environmental Monitoring Standard (NEMS): Water Quality, Part 3 of 4: Sampling, Measuring, Processing and Archiving of Discrete Lake Water Quality Data. Available from: https://nems.org.nz/documents/*

[3] *Allan, M.G., McBride, C.G. 2018. Remote Sensing of Water Quality. In: Hamilton, D., Collier, K., Quinn, J., Howard-Williams, C. (eds) Lake Restoration Handbook. Springer, Cham. https://doi.org/10.1007/978-3-319-93043-5_14*

How much will it cost?

The cost of carrying out a chlorophyll *a* monitoring programme based on collection of grab samples will depend on how often samples are collected, the location and characteristics of the lake (e.g., a boat, helicopter or drone may be required) and laboratory charges for analysing the samples. Some approximate operational costs for a single boat sampling occasion, based on results from a survey of regional councils in 2023, are shown in Table 1. Using these estimates, monthly monitoring of chlorophyll *a* at one site will cost about $8,400 per year. It is important to note that if other indicators are monitored (e.g., nutrients), the boat operational costs and staff time will remain the same. In addition to these operational costs, some capital expenditure will be required; for example, a Van Dorn sampler may need to be purchased. For more information on the costs associated with running a lake monitoring programme, see the Monitoring Costs document on the Monitoring Freshwater Improvements website.

Table 1: *Operational costs of sampling a lake for chlorophyll a using a boat.*

	Cost per sampling occasion
Laboratory analytical testing	$55*
Boat operational costs	$260
Mileage*	$35
Staff time – sampling and data processing	$330
Consumables (e.g., ice, courier charges)	$20
Total per sampling occasion	**$700**

**Laboratory cost is for one sample. However, depending on depth and stratification of the lake, several samples may be required at each site. Mileage is based on average distance to a lake monitoring site, derived from regional council survey results.*

The cost of operating a high-frequency fluorometer on a lake buoy monitoring site will depend on several factors, such as:

- The type of sensor chosen
- Sensor and buoy set-up and maintenance requirements
- Frequency of sensor calibration

Table 2 shows the approximate annual costs of setting up and running a lake buoy with a fluorometer based on a survey of regional councils in 2023 and information from Limnotrack. Alternatively, a multi-parameter probe (such as a sonde) could be used instead of a fluorometer; these cost about $35,000.

Despite the relatively high initial set-up costs of a high-frequency site, our analysis suggests that after about 3 years of monitoring the total cost will be about the same or slightly less than a weekly or fortnightly sampling programme. Note, however, that the fluorometer may need to be replaced after 7-10 years of operation.

Table 2. *Estimated cost (CAPEX = capital expenditure and OPEX = operating expenditure) for monitoring chlorophyll fluorescence autonomously at high frequency from a low-cost lake buoy (based on Limnotrack approximations). Calibration cost for chlorophyll a is based on 8 calibration samples per year. CAPEX relating to vehicles not included.*

	CAPEX	OPEX p.a.
Fluorometer sensor (with built-in wiper)	$9,000	
Telemetry unit (with data)	$3,000	$200
Installation and ongoing cost (buoy, telemetry set-up, data logger, staff time, maintenance, average mileage, boat and running costs)	$15,000	$8,000
Calibration sample laboratory costs (8 x $55 per year)		$440
Staff time for data processing, QA/QC		$960
Total	**$27,000**	**$9,600**

Monitoring Freshwater Improvement

www.monitoringfreshwater.co.nz

Research Team | *Te hunga i whai wāhi mai*

PROGRAMME LEADER, IMPLEMENTATION LEAD
Olivier Ausseil
Traverse Environmental

TE AO MĀORI LEAD
Joanne Clapcott
Cawthron Institute

SCIENCE LEAD
David Hamilton
Griffith University

MATHEMATICS LEAD
Alasdair Noble
AgResearch

PHASE 1 CO-LEAD
Rogier Westerhoff
GNS Science

WEBAPP DEVELOPER
Mike Kittridge
Headwaters Hydrology