The Contribution of Lakes to Greenhouse Gas Emissions – Fact Sheet

Linking lake restoration with end users for positive environmental outcomes

LERNZ
Lake Ecosystem Restoration New Zealand

The Release and Production of Greenhouse Gases (GHGs) in Lakes

Greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) trap heat in the atmosphere. Lakes can play an important role in regulating these gases at global scales. Total carbon uptake by lakes is of the same magnitude as that of oceans or forests, despite lakes occupying <1% of the Earth's area. In lakes, GHGs are mostly produced in the bottom sediment as products of organic matter decomposition. Geothermal activities – of importance to some Rotorua lakes – may also contribute substantial amounts of CO_2 and CH_4. In the water column, some CO_2 is processed into organic matter by plants during photosynthesis rather than released to the atmosphere. In addition, in high-oxygen environments, such as found in the surface waters of lakes, methanotrophs will oxidise most CH_4 produced in the bottom sediments to CO_2. However, CO_2 and CH_4 can be emitted to the atmosphere directly from the sediment via bubbles (ebullition). This form of release is sporadic but can be significant as gases are highly concentrated and minimally influenced by water column processes before being released to the atmosphere.

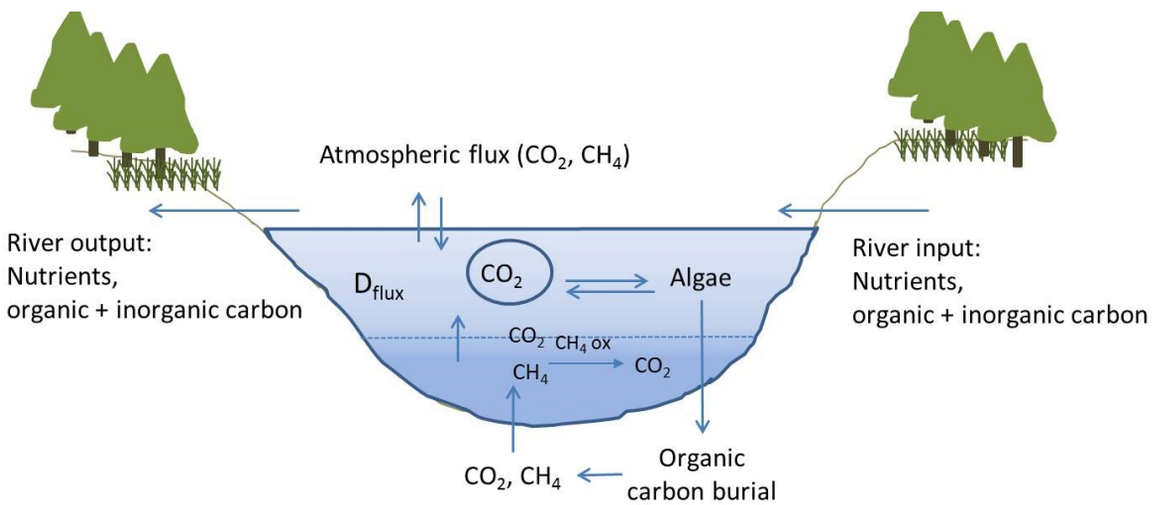

Figure 1. Production and release of GHG's (CO_2 and CH_4) in a lake ecosystem.

Variation in Lake Emissions

Rates of GHG emission vary amongst lakes due to contrasting lake characteristics. In lakes that mix once a year, large GHG releases can occur during the winter mixing period. The gas released from winter mixing occurs as a result of CO_2 and CH_4 accumulation in low-oxygen (anoxic) bottom waters over summer. The accumulated GHGs are then mixed throughout the lake at the start of winter and greatly increase GHG exchanges with the atmosphere during this time. In lakes which mix throughout the year pulsed emissions are reduced, as bottom water generally does not become sufficiently reduced to generate large build-ups of GHGs.

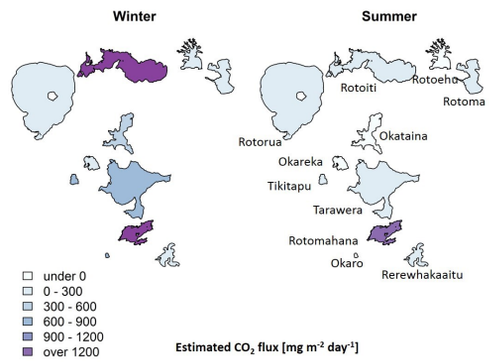

Figure 2. Predicted CO_2 emissions in Rotorua lakes in winter and summer. Values under zero (in summer) indicate that lakes take up CO_2, instead of releasing it.

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Do Climate Change or Eutrophication affect GHG Emissions?

In eutrophic lakes (Figure 3) with high levels of nutrients, CO_2 is more likely be consumed (taken up). These lakes have a higher rate of algal production in the surface waters, with increased respiration rates in the bottom water layers. The production of CH_4 and N_2O from the sediment is also likely to increase due to the high organic input from the upper water layer. A warmer climate may drive a lake to produce more CO_2 and CH_4. These accumulated gases will be emitted during seasonal lake mixing (e.g. in winter for lakes that mix once a year). A great deal of research effort is being focused towards better understanding how eutrophication and climate change affect GHG emissions from lakes.

A Ph.D. study of GHGs in 11 Rotorua lakes by LERNZ researcher Arianto Santoso shows that a number of physical and biological factors, as well as geothermal activity, affect gas release. Lake Okaro, for example, is monomictic and eutrophic, and takes up high amounts of CO_2 in summer due to high rates of uptake by the abundant algae, and then releases large amounts of CO_2 and CH_4 during mixing (Figure 4). Release rates of GHGs from Lake Rotomahana are an order of magnitude higher than other lakes in Rotorua region because of very high rates of emission from geothermal sources (Figure 5).

Figure 3. Lake Okaro is an eutrophic lake in the Rotorua district.

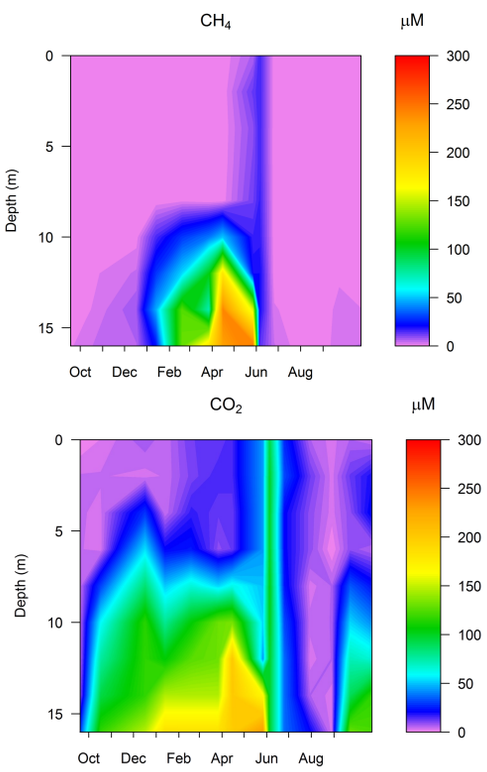

Figure 4. CH_4 (top) and CO_2 (bottom) and concentrations in Lake Okaro, observed from September 2013 to October 2014. Contours represent levels of CH_4 and CO_2 (see scale bar on right).

Figure 5. Geothermal gas release at Lake Rotomahana