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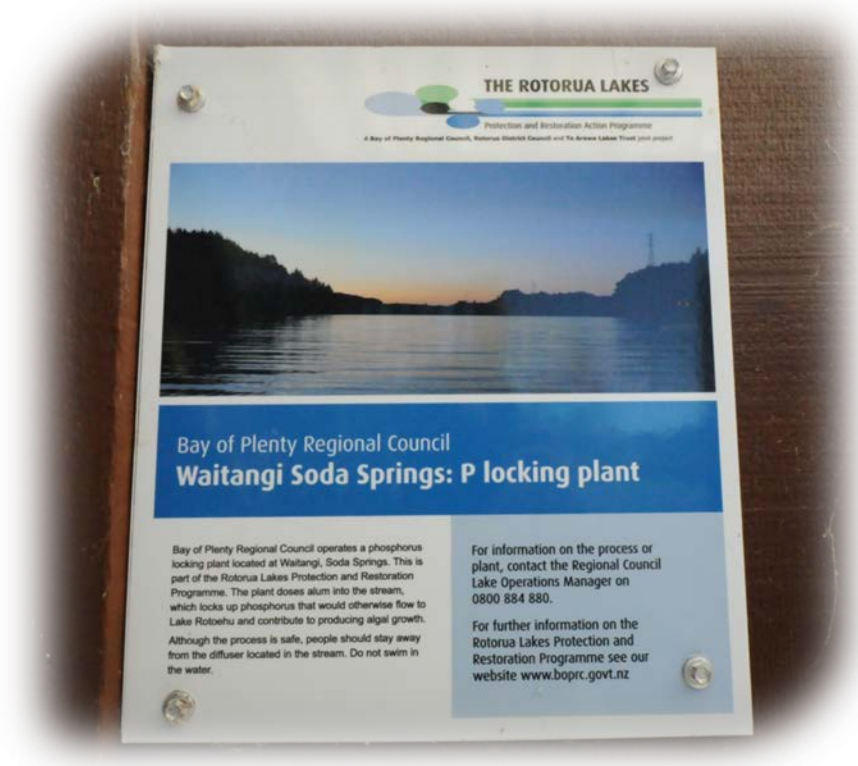
Waitangi Soda Springs Alum Dosing – Bioavailability of aluminium 2013



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Executive Summary

Continuous alum dosing of the Waitangi Soda Springs at Lake Rotoehu commenced in 2010 to reduce inflows of dissolved reactive phosphorus to Lake Rotoehu. Analyses of bioaccumulation in the tissues of kōura and goldfish from Lake Rotoehu were undertaken on animals collected in September 2013 to determine the bioavailability and bioaccumulation of aluminium. Comparative analyses were undertaken on kōura and goldfish collected from Lakes Rotorua and Rotoiti. Lake Rotoehu kōura and goldfish showed slightly elevated aluminium concentrations in the gills indicating enhanced exposure to aluminium but little evidence for significant bioaccumulation in tissues.

Contents

Introduction

The Lake Rotoehu Action Plan (Bay of Plenty Regional Council, 2007) proposed to lower the trophic level index (TLI) of Lake Rotoehu from 4.6 to 3.9 by reducing internal and catchment-derived nutrients (N and P). The Action Plan proposed a wide variety of actions to improve water quality and, following the successful establishment of continuous alum dosing plants on other streams in the Rotorua lakes district, an alum dosing plant was subsequently constructed in 2010 on one of the major inflows to the lake, the geothermal Waitangi Soda Springs. Alum dosing of this inflow is estimated to reduce dissolved phosphorus inputs to Lake Rotoehu by up to 0.7 tonnes per annum.

Alum dosing of the Utuhina Stream inflow to Lake Rotorua began on a trial basis in 2006 and the Bay of Plenty Regional Council granted a resource consent in November 2008 for the continuation of alum dosing until 2018. The Utuhina Stream carries an estimated 7.6 tonnes of P into Lake Rotorua each year, of which approximately 2 tonnes is in the form of dissolved reactive phosphorus (DRP). The Puarenga Stream discharges a similar annual phosphorus load to Lake Rotorua and continuous alum dosing began on the Puarenga Stream in early 2010. The Puarenga Stream discharges into Sulphur Bay, a continuously active geothermal area and a designated wildlife reserve on the southern shores of Lake Rotorua. Landman & Ling (2009) measured bioaccumulation of aluminium in a variety of Lake Rotorua biota to provide baseline data on natural aluminium bioavailability prior to the commencement of alum dosing and subsequent studies have assessed the potential for aluminium bioaccumulation as a result of alum dosing of both the Utuhina and Puarenga streams (Ling 2015a, Ling 2015b). However, no baseline assessments of aluminium bioaccumulation were undertaken on biota from Lake Rotoehu prior to the commencement of alum dosing and so comparisons can only be made by comparing samples taken from organisms sampled from other lakes in the region, albeit that the Rotorua lakes may differ substantially from one another with respect to water and sediment chemistry due to the differing influences of catchment, groundwater and geothermally derived inflows. This report provides data on aluminium concentrations in adult kōura and goldfish from Lake Rotoehu in 2013 along with comparative data from the same species in Lakes Rotorua and Rotoiti to assess whether alum dosing of the Waitangi Soda Springs is providing bioavailable aluminium to lake macrobiota resulting in bioaccumulation and potential toxicity.

Methods

Sampling

Samples of frozen adult kōura (*Paranephrops planifrons*) and goldfish (*Carassius auratus*) from Lake Rotoehu and Waitangi Soda Springs were collected and supplied by Ian Kusabs together with adult kōura collected from Lakes Rotorua and Rotoiti in September 2013. A lack of any comparative data to serve as a baseline measure of tissue aluminium values in goldfish that were not exposed to alum dosing necessitated the collection of additional adult goldfish for comparative purposes from the Ohau Channel (Lake Rotorua outflow) and Lake Rotoiti (Te Weta and Te Karaka bays) by boat electrofishing in early 2014.

Sample analysis

Samples of liver (goldfish) or hepatopancreas (kōura), flesh and gills were carefully dissected using acid-washed instruments. A suite of 28 elements (Appendix 1?) was measured in samples based on established methods (USEPA, 1987). Samples were dried at 60°C for 24 h, weighed to the nearest 0.0001 g (or 0.00001?) and digested using tetramethylammonium hydroxide, heat and mixing. The colloidal suspension was then partially oxidized by the addition of hydrogen peroxide and the metals were solubilised by acidification with nitric acid and heating. Samples were diluted and filtered prior to analysis by inductively-coupled plasma mass spectrometry (Waikato Mass Spectrometry Facility, School of Science, University of Waikato, Hamilton, NZ; http://www.mass-spec.co.nz/). All tissue element concentrations were determined on a dry weight basis. Method blanks and matrix certified reference material standards (DOLT and DORM; Canadian Research Council) were run in parallel with all samples. Only results for aluminium are presented here.

Results

Total tissue aluminium

Values for total tissue aluminium are presented in Figure 1. Tissue aluminium was significantly lower (ANOVA $p<0.05$) in flesh and hepatopancreas of kōura from Lake Rotorua compared with animals from Lakes Rotoehu and Rotoiti. Aluminium concentration was significantly greater in the gills of kōura from Lake Rotoehu compared with the other lakes.

No significant differences in flesh concentration were found when comparing goldfish from the three lakes; however, liver aluminium was significantly lower in fish from Lake Rotoiti compared with Lakes Rotoehu and Rotorua. Aluminium was significantly higher in the gills of goldfish from Lake Rotoehu compared with the other lakes.

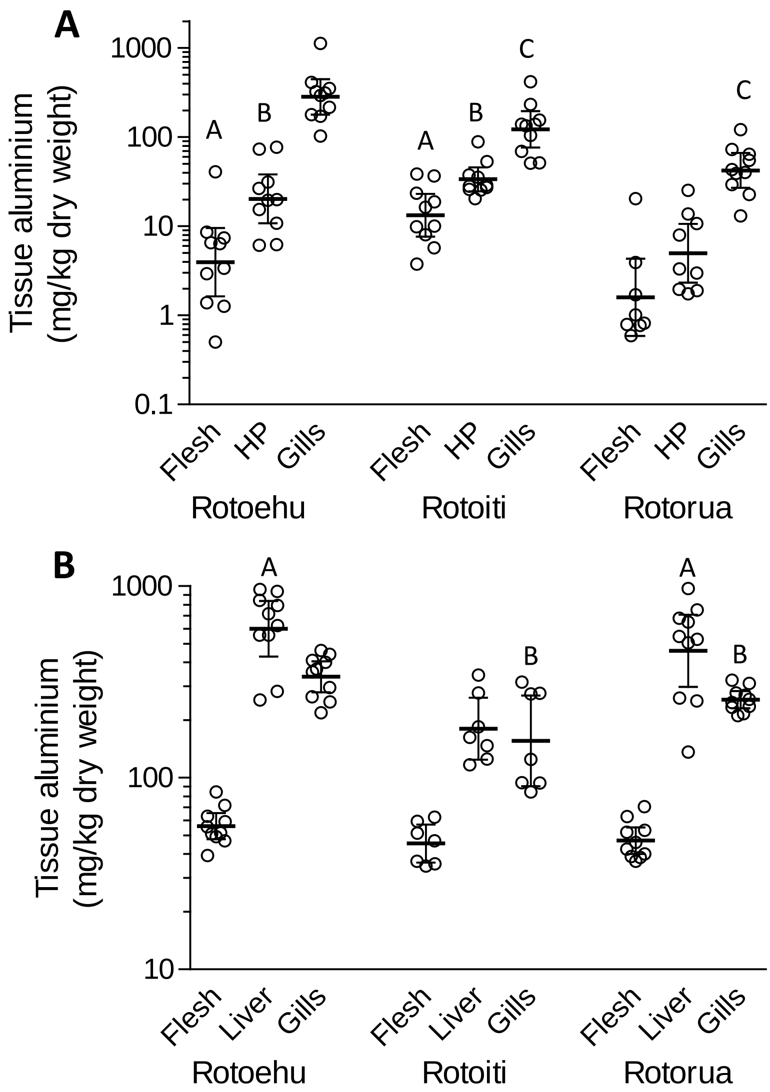

Fig. 1. Aluminium concentrations in tissues of (A) kōura and (B) goldfish from lakes Rotoehu, Rotoiti and Rotorua. Transverse bars are geometric means with 95% confidence intervals. Data indicated by the same letter are not significantly different ($p>0.05$).

Conclusions

Higher levels of aluminium in the gill tissue of both kōura and goldfish from Lake Rotoehu are evidence of greater water-borne exposure to this element, possibly as a result of the continuous addition of alum to the Waitangi Soda Springs inflow. However, because there are no published water or sediment aluminium concentration data for these lakes or the Waitangi Soda Springs, other interpretations are possible. Of particular interest is the relatively higher concentration of aluminium in the livers of goldfish from every site compared with concentrations in the gills. Because the gills are the main site of uptake for water-derived aluminium uptake in fish, concentrations in gill tissue are generally much higher than any internal tissue (Howells et al. 1990) although long-term studies on aluminium bioaccumulation are rare. Common bully downstream of the alum dosing station on the Utuhina Stream accumulated around 8-fold greater aluminium in the gills compared with the liver (Ling 2015b), and during short-term (48 hours) exposures, aluminium accumulated in the gills of common carp was approximately ten-fold greater than in visceral tissues (Muramoto 1981).

Exposure to aluminium through diet is another potential source as it is possible that goldfish benthic foraging contributes to the greater bioaccumulation in the liver via intestinal uptake from ingested sediment and benthic infauna. Although kōura are also benthic detritivores, they are probably more selective feeders that ingest less sediment mass than goldfish. Relatively little of the detritus ingested by kōura is assimilated compared to the importance of benthic invertebrates as a food source (Parkyn et al. 2001). No significant differences in the average concentration of aluminium was found in internal tissues of either kōura or goldfish when compared with the same species sampled from either one or both of the comparison lakes, but significant differences were observed in tissue aluminium concentrations between lakes Rotorua and Rotoiti. It is possible that the higher levels observed in goldfish from the Ohau Channel (Lake Rotorua outflow) may derive from long-term alum dosing of two major inflow streams to this lake, although the opposite trend for kōura (higher concentrations in Lake Rotoiti) tends to contradict this. Further interpretation of trends in aluminium bioaccumulation in these species from the Rotorua lakes is not possible without more comprehensive sampling of water, sediments and macrobiota from a greater range of lakes in the region. Further sampling of Lake Rotoehu kōura and goldfish is subsequent years may also shed more light on the possible role of the Waitangi Soda Springs alum dosing in providing bioavailable aluminium to lake biota.

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