Puarenga Stream alum dosing –
Summary of effects on lake biota 2012

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Executive Summary

Continuous alum dosing of the Puarenga Stream commenced in early 2010 to reduce inflows of dissolved reactive phosphorus to Lake Rotorua. Analyses of bioaccumulation in the tissues of macrobiota were undertaken in February 2012 for comparison to comparable samples obtained in 2009 prior to the commencement of alum dosing. No significant effects of alum dosing could be distinguished. Bioavailable aluminium in the vicinity of Sulphur Bay appears to be primarily influenced by the major geothermal activity of this region. No significant differences in aluminium bioaccumulation were observed in any species compared to 2009 samples. Continuous alum dosing of the Puarenga Stream since 2010 apparently has not resulted in adverse effects to Lake Rotorua shoreline biota nor caused any apparent increase in aluminium bioaccumulation in lake biota in the vicinity of Sulphur Bay.

Client report prepared for Bay of Plenty Regional Council.

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Contents

Introduction

The Lakes Rotorua and Rotoiti Action Plan (Bay of Plenty Regional Council, 2009) proposed to lower the trophic level index (TLI) of Lake Rotorua from 4.9 to 4.2 by reducing internal and catchment-derived nutrients (N and P). Annual catchment reduction targets of 250 tonnes N and 10 tonnes P have been established. The Action Plan proposed P-locking in up to three streams (Utuhina, Puarenga and one other) to reduce 6 tonnes of DRP entering into Lake Rotorua using continuous alum (aluminium sulphate) treatment. 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 phosphorous (DRP). Alum dosing of the Utuhina Stream 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 Puarenga Stream carries a similar annual phosphorus load 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. This report provides information on aluminium concentrations in the same biota two years after alum dosing began to determine possible impacts of increased addition of soluble and potentially bioavailable aluminium to the Puarenga Stream / Sulphur Bay receiving environment.

Methods

Sampling

Baseline monitoring of Sulphur Bay biota prior to the commencement of alum dosing (Landman & Ling 2009) examined a wide variety of macrobiota to determine both the availability of indicator species and the inherent variability in aluminium across organisms and tissue types. On the basis of those findings the current sampling programme examined a reduced suite of organisms and tissue types. Some species sampled in 2009 were not sampled in 2012 and for those biota where more than one tissue was analysed in 2009, only the tissue with the highest aluminium concentration was sampled for this study. A feasibility study was also undertaken in response to requests by the Bay of Plenty Regional Council to examine the possible impacts of Puarenga Stream alum dosing on local fish populations in Lake Rotorua. The latter involved electroseining at night for common smelt (*Retropinna retropinna*) and common bully, however, several hours of fishing at the reference site 4 yielded so few fish that the method was deemed to be so unproductive that quantitative data on fish abundance could not be obtained at a reasonable cost.

Water and biota samples were obtained in February 2012 from the same four sites used by Landman & Ling (2009). Three sampling locations were within Sulphur Bay and its receiving environment in Lake Rotorua (Sites 1-3) and an additional site was located outside the bay (Site 4) for reference purposes (see Figure 1). A summary of biota samples analysed from each locality is given in Table 1.

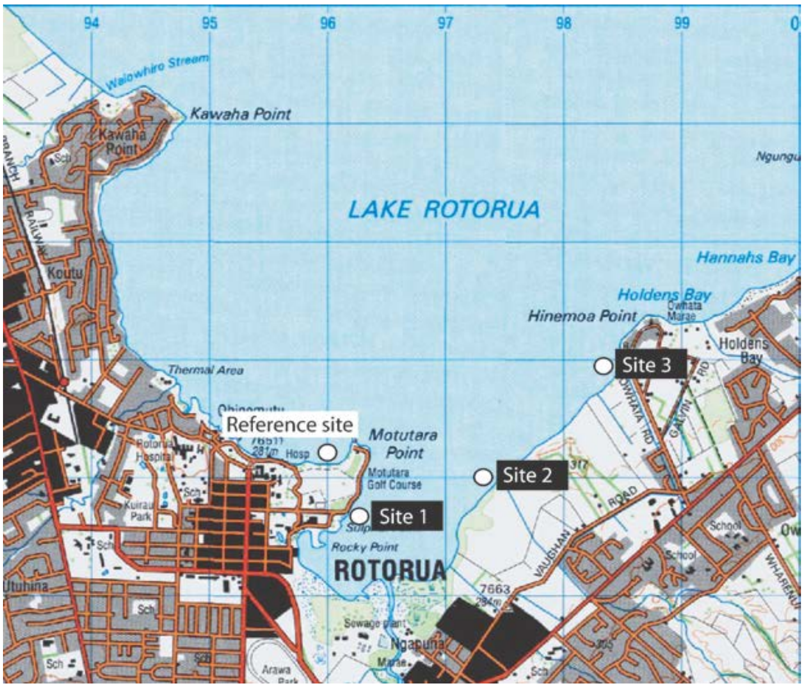

Figure 1: Sample site locations in and around Sulphur Bay.

	Site 1	Site 2	Site 3	Site 4
Water	X 2	X 2	X 2	X 2
Chironomids	X 5	X 5	X 5	X 5
Kakahi	-	X 5	X 5	X 5
Fish	-	-	X 5	X 5
Plants	-	X 5	X 5	X 5

Table 1: Summary of plant and animal species availability at each of the selected monitoring sites in and around Sulphur Bay in February 2012. Numbers represent the number of sample replicates analysed by ICPMS. Chironomids = *Chironomus zealandicus* (pooled whole larvae), kakahi = *Echyridella menziesii* (digestive gland only), fish = *Gobiomorphus cotidianus* (whole fish), plants = *Eleocharis acuta* (roots only).

Sample Analysis

A suite of 28 elements was measured in biota samples based on established methods (USEPA, 1987). Water samples were filtered (0.45 µ) and then acidified with 2% nitric acid prior to ICPMS analysis for dissolved metals. Tissue samples were dried (60°C for 24 h), accurately weighed and digested using tetramethylammonium hydroxide, heat and mixing. The colloidal suspension was then partially oxidized by the addition of hydrogen peroxide and metals solubilised by acidification with nitric acid and heating. Samples were diluted and filtered prior to analysis by inductively-coupled plasma mass spectrometry (Department of Chemistry, Waikato University, Hamilton, 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

Previous findings

A summary of aluminium results measured in water, sediment and biota samples from the baseline study of Landman & Ling (2009) is presented in Figure 2. This study indicated that dissolved aluminium was greatest within Sulphur Bay, decreasing outwards into Lake Rotorua. Sediment aluminium was relatively high at all sites and increased in concentration along the geothermal gradient/plume (i.e. Site 1 to Site 3) into Lake Rotorua. Sediments were not sampled in 2012 because sediment aluminium is notoriously unreliable as a measure of bioavailable aluminium due to the very high abundance of aluminium in clays and its relative solubility in harsh extractants such as aqua regia (Matúš 2007). The mobility of geothermal sediment-derived aluminium from Sulphur Bay is due to the very low pH that persists within the bay (~pH 2.5 – 3.0). Aluminium solubility is greatest at low and high pHs but is comparatively insoluble at neutral pH (Gensemer & Playle 1999). A plume of geothermal water containing colloidal sulphur and with low pH exits Sulphur Bay and is carried eastwards along the southern shore of Lake Rotorua towards Hinemoa Point where it finally mixes with the main body of lake water, disperses, and reaches near neutral pH.

Total tissue aluminium

Of all biota sampled by Landman & Ling (2009) concentrations were highest in chironomid larvae sampled from all sites, although the greatest concentrations were observed at the reference site (Site 4) outside the bay. Aluminium was generally low in both kakahi and fish samples, with low to moderate aluminium concentrations in rushes (*Eleocharis* spp.) where greatest concentrations were observed in the roots, possibly as a result of sediment contamination. Samples from February 2012 mirrored those obtained in January 2009 and do not indicate any increased bioavailability of aluminium resulting from the continual alum dosing of the Puarenga Stream. Aluminium in the area of Sulphur Bay is clearly dominated by geothermal sources. Landman & Ling (2009) noted that geothermal fluids are known to be significant sources of environmental aluminium (Martin et al., 2000) and that the highest environmental concentrations of aluminium were not mirrored in biota implying that natural aluminium present within Sulphur Bay is less bioavailable than at the reference site. Aluminium chemical speciation is highly complex and its bioavailability can be influenced by a number of factors including pH and complexation with dissolved organic matter and silicon (Sparling et al., 1997; Gensemer and Playle, 1999). The consistency of results between the pre-dosing and post- dosing periods indicates that alum dosing of the Puarenga Stream does not significantly influence bioavailability of aluminium to macrobiota in the area of Sulphur Bay nor is it likely to cause adverse effects to biota.

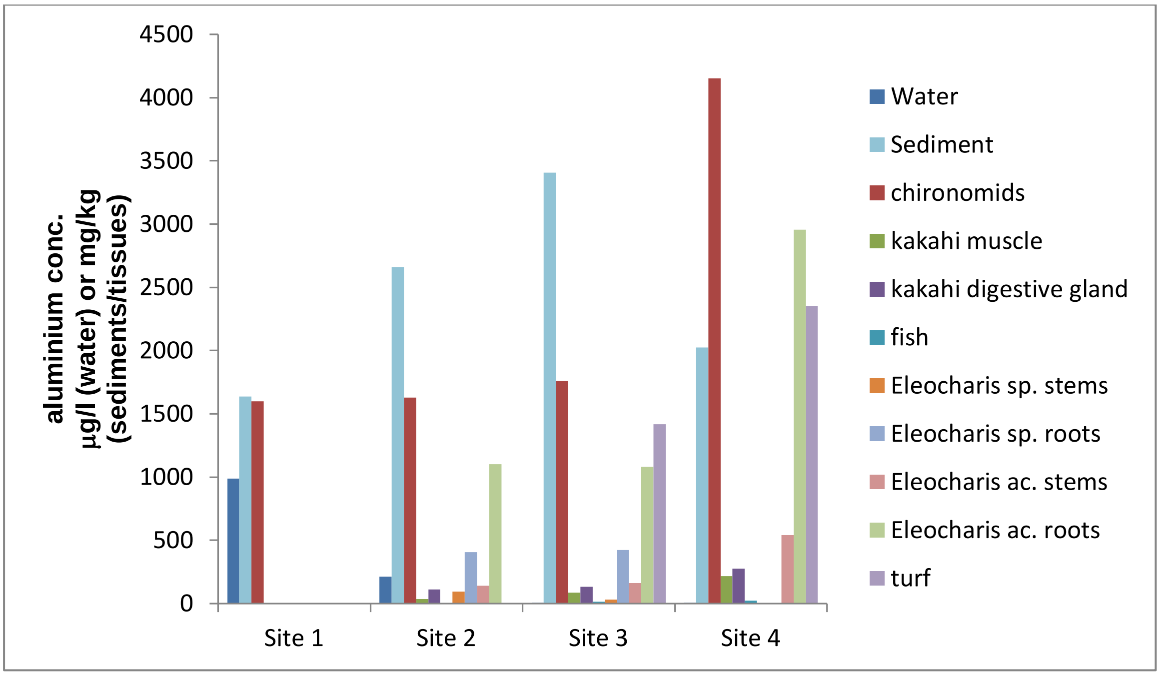

Fig. 2. Aluminium concentrations in water (=g/l), sediment (mg/kg) and tissues (mg/kg) of plant and animal species sampled within and around Sulphur Bay in 2009. See Figure 1 for site locations (from Landman & Ling 2009).

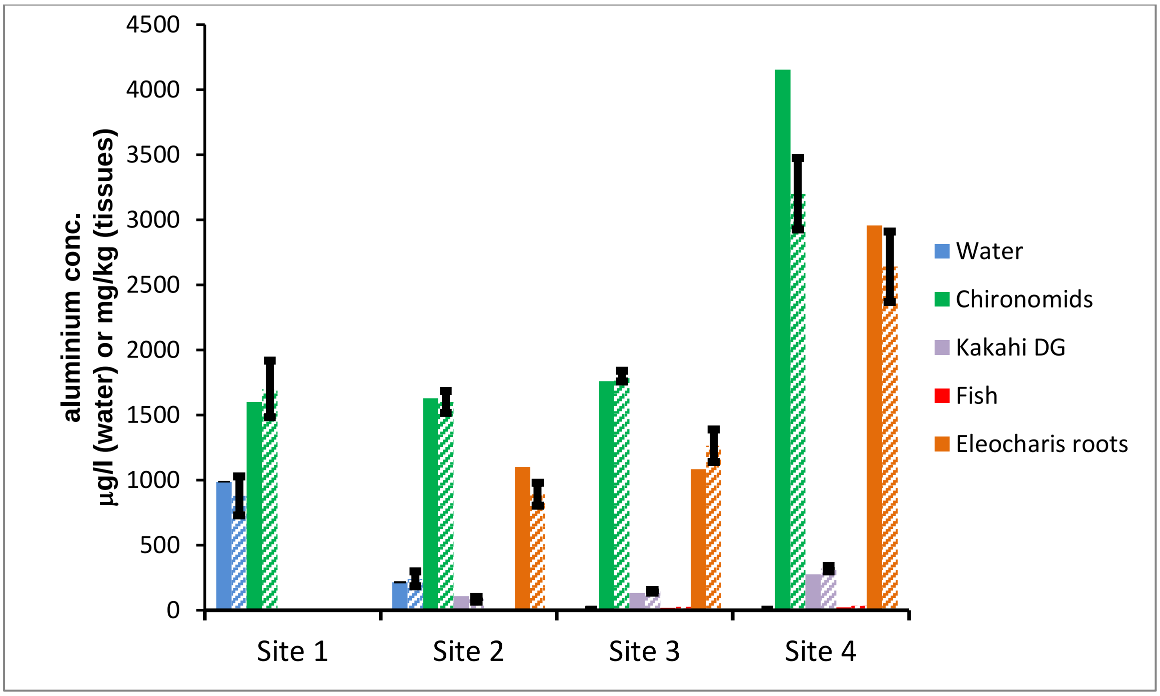

Figure 3: Dissolved (water; µg/l) and tissue aluminium concentrations (mg/kg dry weight) from sites within and around Sulphur Bay from January 2009 (solid bars) and February 2012 (hatched bars). Black bars represent means ± SEM.

The discharge of extremely acidic geothermal waters from Sulphur Bay remains the primary factor controlling shoreline benthic ecology in the vicinity of Sulphur Bay. All of the species of macrobiota sampled in January 2009 were still present in February 2012, two years after commencement of continual alum dosing, however, the influence of the Sulphur Bay geothermal plume is clearly evident along the Lake Rotorua shoreline. No common bully were caught at site 2 in either years and kakahi at site 2 are sparsely distributed and apparently do not occur within 200 m of the shore. Common bully are therefore apparently absent and kakahi much less common at site 2 than at site 3, with greatly increased abundance of both species at the control site 4. It is highly unlikely that the observed absence of common bully at site 1 (inside Sulphur Bay) and site 2 (Rotorua shoreline near to Sulphur Bay) is due to the alum dosing given that common bully were also not caught at these sites in 2009 and no apparent effects have been observed on common bully abundance in the Utuhina Stream after 6 years of continuous alum dosing (Ling 2013). In summary, alum dosing of the Puarenga Stream apparently has not resulted in adverse effects to Lake Rotorua shoreline biota nor caused any apparent increase in aluminium bioaccumulation in lake biota in the vicinity of Sulphur Bay.

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