Puarenga Stream alum dosing –
Summary of effects on lake biota 2015

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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 2015 for comparison to comparable samples obtained prior to and since the commencement of alum dosing to satisfy annual resource consent conditions 8.7 and 8.8 of resource consent 65559.

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. Lake water chemistry in the vicinity of Sulphur Bay is heavily influenced by the direction of geothermal flows emanating from the Bay. No significant differences in aluminium bioaccumulation were observed in any species compared to samples obtained prior to the commencement of alum dosing. 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.

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, and annual monitoring has continued since 2012. This report provides data on aluminium concentrations in the same biota from 2015 to determine possible impacts of increased addition of soluble and potentially bioavailable aluminium to the Puarenga Stream / Sulphur Bay receiving environment in compliance with the resource consent requirements of the Bay of Plenty Regional Council.

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 subsequent sampling programme examined a reduced suite of organisms and tissue types. Some species sampled in 2009 were not sampled in subsequent years, 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 2012 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 (Ling 2013a).

Water and biota samples were obtained in February 2015 from the same four sites used by Landman & Ling (2009) and subsequent annual monitoring (Ling 2014). 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.

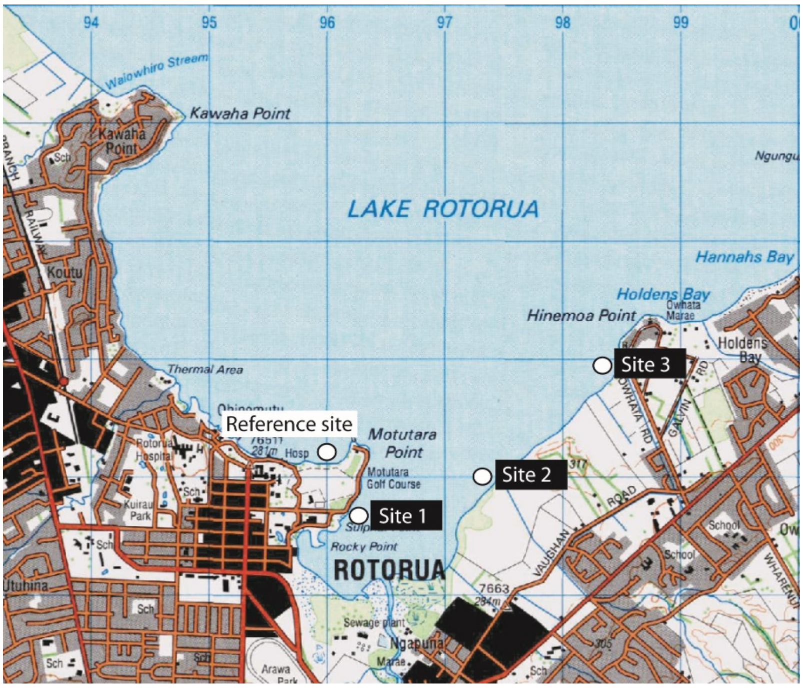

Figure 1: Sample site locations in and around Sulphur Bay.

	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	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 2015. 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 (School of Science, 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

Landman & Ling (2009) observed 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 have not been sampled since this study 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 did not indicate any increased bioavailability of aluminium resulting from the continual alum dosing of the Puarenga Stream. Samples in subsequent years (2013 to 2015; see Figures 2 to 6) generally confirm the pattern of increasing tissue aluminium with decreasing influence from Sulphur Bay water observed in 2009 although there are some inconsistencies in the data obtained from chironomid larvae and common bully. It is possible that the pattern is more consistent and better defined in long-lived species that are site resident (*Eleocharis* and kakahi) than species that are short-lived (chironomid larvae) or more mobile (common bully).

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

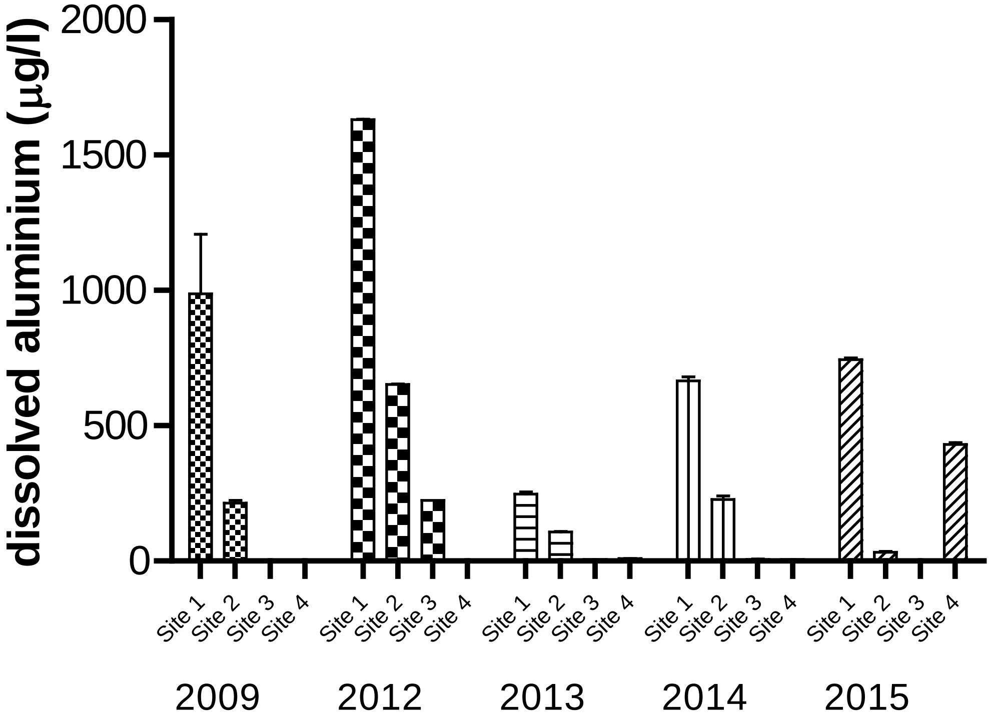

Fig. 2. Aluminium concentrations in water (µg/l) within and around Sulphur Bay. See Figure 1 for site locations (means ± SEM, n = 2).

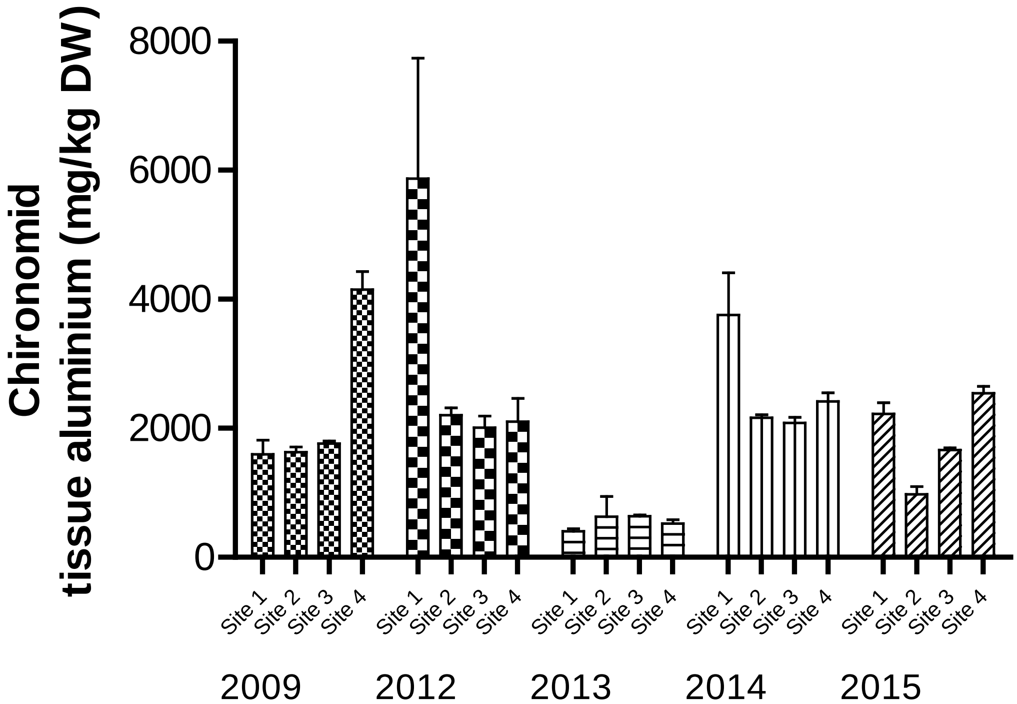

Figure 3: Whole body tissue aluminium concentrations in chironomid larvae (mg/kg dry weight) from sites within and around Sulphur Bay since January 2009 (means ± SEM, n = 5).

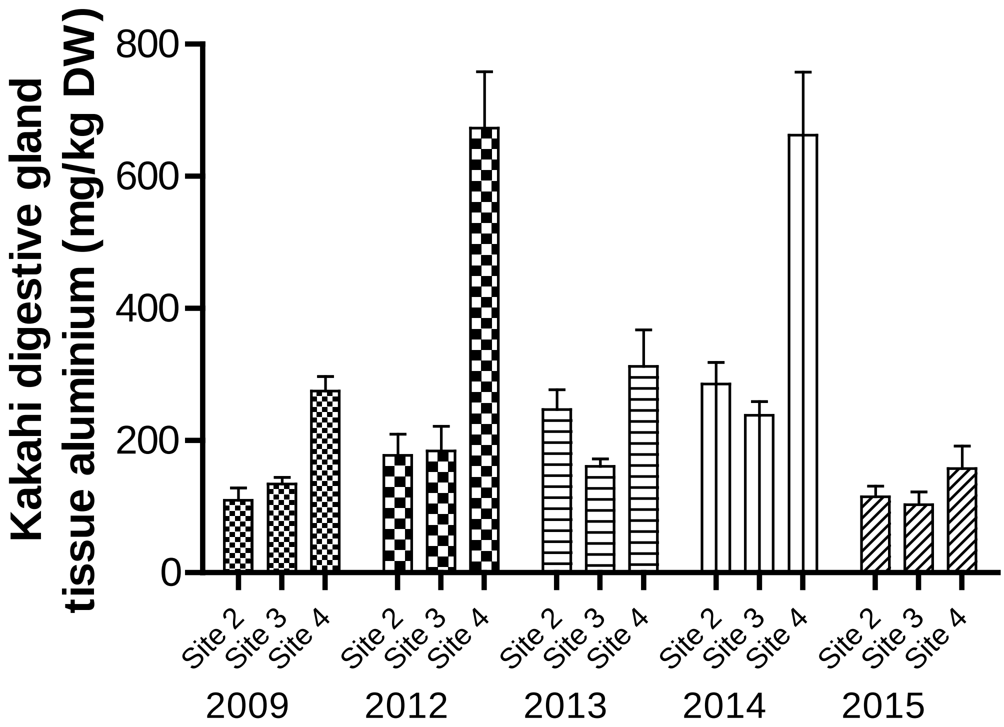

Figure 4: Aluminium concentrations in the digestive gland of kakahi (mg/kg dry weight) from sites within and around Sulphur Bay since January 2009 (means ± SEM, n = 5).

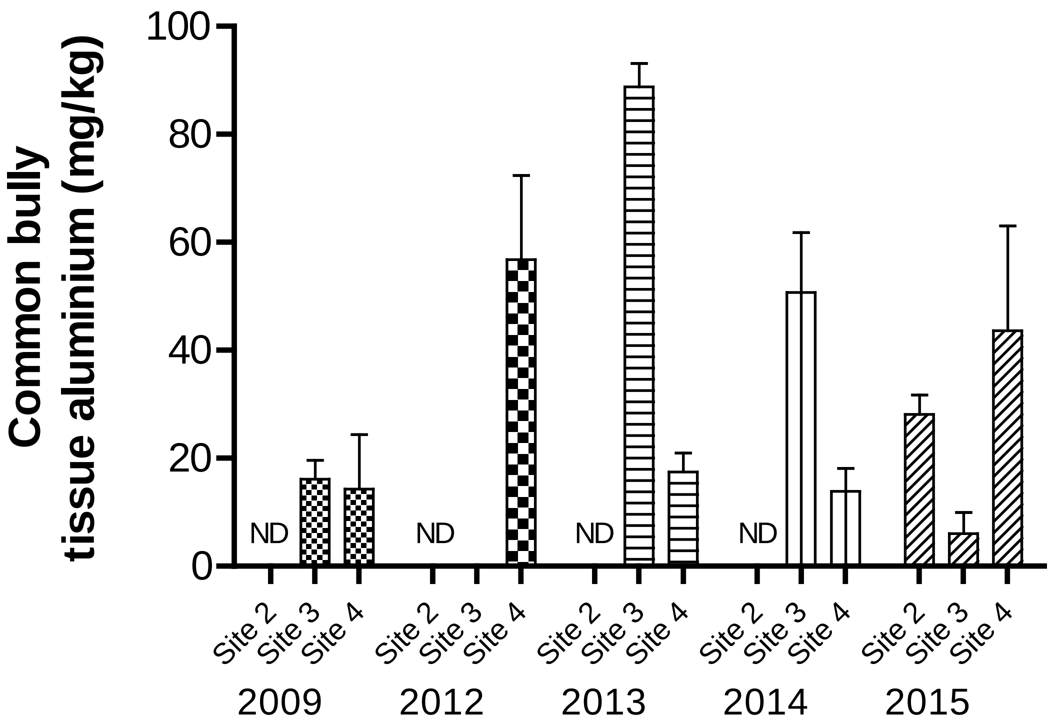

Figure 5: Whole body tissue aluminium concentrations in common bully (mg/kg dry weight) from sites within and around Sulphur Bay since January 2009 (ND = no data; means ± SEM, n = 5).

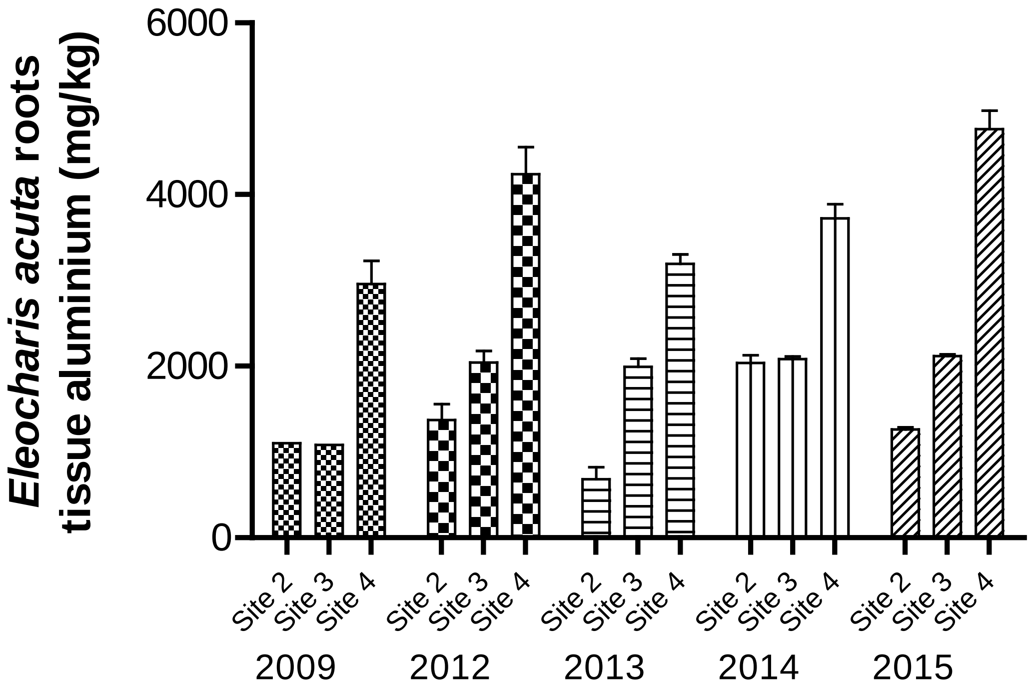

Figure 6: Aluminium concentrations in the roots of the sedge *Eleocharis acuta* (mg/kg dry weight) from sites within and around Sulphur Bay since January 2009 (means ± SEM, n = 5).

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 over and above that already present due to the combination of low pH water naturally high is dissolved aluminium (conditions known to be toxic to aquatic biota (Gensemer & Playle, 1999).

The discharge of extremely acidic geothermal waters from Sulphur Bay remains the primary factor controlling shoreline benthic ecology in the vicinity of Sulphur Bay. As outlined by Landman & Ling (2008), this geothermal water discharging from Sulphur Bay at around pH 3.5 typically hugs the shoreline towards Hinemoa Point, although the extent to which it disperses and becomes well mixed with lake water depends on the prevailing weather. Onshore (north easterly) winds break up the shoreline plume and tend to push lake water in to the outer reaches of Sulphur Bay whereas the plume remains strongly associated with the shore and well defined as far as Hinemoa Point in southwesterly winds. Abell & Hamilton (2014) identified a double gyre system in Lake Rotorua and the stronger anticlockwise gyre appears to dominate the entrainment of the Sulphur Bay plume. The influence of this plume is clearly discernable in the relative abundance of macrobiota at the sites sampled. Kakahi are rare and common bully rarely encountered at site 2 closest to the mouth of Sulphur Bay whereas both are more common at site 3 and abundant at the control site which is protected from the Sulphur Bay plume by Motutara Point. However, the water chemistry results from February 2015 differ significantly from earlier years with substantially lower pH (pH 4.8) and higher dissolved aluminium recorded at the control site (site 4; Figure 2) and higher pH (pH 6.3) and lower aluminium at Site 2. This was due to a prolonged period of low wind speeds preceding the sampling period which abolished the typical westward shoreline current and allowed geothermal waters from Sulphur Bay to diffuse around to the east of Motutara Point.

All of the species of macrobiota sampled in January 2009 were still present in February 2015, five 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 2013 or 2014, but large numbers were caught at site 2 in 2015, presumably due to a reduced inundation by geothermal water at this site, whilst lower numbers than is typical were caught at the control site. It is highly unlikely that the observed absence of common bully at site 1 (inside Sulphur Bay) and also typically at 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 2013b). 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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