UTUHINA STREAM MONITORING 2014:

EFFECTS OF CONTINUOUS ALUM DOSING ON FISH AND AQUATIC INVERTEBRATES

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SUMMARY

This report presents the results of an ongoing assessment of the fish and aquatic macroinvertebrate communities of the Utuhina Stream from 2006 to 2014, and an assessment of the bioavailability of aluminium in fish and koura to satisfy annual resource consent conditions 9.6, 9.8 and 9.7, respectively, for the discharge of alum.

Macroinvertebrates, fish and koura were sampled from one control and two treatment reaches of the Utuhina Stream in August 2014. Catch rates for common bully, juvenile trout and koura have fluctuated across all sites since monitoring began in 2006. Common bully, koura and juvenile trout were present at all sites. Differences in species abundance compared with previous years is most likely due to flood related disturbances to stream bank morphology and vegetative cover. No obvious effects of alum dosing on stream fish or macroinvertebrate communities were observed.

Semiquantitative analysis of stream macroinvertebrates showed no differences between upstream control and alum-exposed sites, with similar MCI scores to previous samples obtained before and after commencement of alum dosing in 2006. Overall, all sites were characterised as good quality for a soft bottomed stream.

Some evidence of aluminium bioaccumulation was seen in some tissues of koura and common bully resulting from continuous alum dosing of the Utuhina Stream. Statistical analysis of tissue aluminium concentrations provides evidence of elevated aluminium in the gills of common bully from both the mixing and receiving zones (sites 2 and 3, respectively) but little evidence of aluminium accumulation in other tissues. Data for koura provide some evidence for accumulation on gills but no evidence for accumulation in internal tissues. Alum exposure in these species does not appear to affect their health or abundance in the stream.

Table of Contents

INTRODUCTION

The Lakes Rotorua and Rotoiti Action Plan (Bay of Plenty Regional Council, 2007) 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). Catchment reduction targets of 250 tonnes N and 10 tonnes P have been established. 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). 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. It has been estimated that an alum dosing rate of 1 ppm (1 g/m3) should remove the majority of DRP (i.e. ~2 tonnes) in the Utuhina Stream. 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. This report presents the results of an assessment of the fish and aquatic macroinvertebrate communities of the Utuhina Stream sampled in August 2014, and an assessment of the bioavailability of aluminium in fish and koura to satisfy annual resource consent conditions 9.6, 9.8 and 9.7, respectively, for the discharge of alum. Results from 2014 are compared with those from previous years since the commencement of alum dosing in the Utuhina Stream in 2006.

METHODS

FISH COMMUNITY SURVEY

The occurrence of fish species, approximate relative density and catch per unit effort (CPUE) were determined for three 50 m reaches of the Utuhina Stream (Fig. 1) on 7th August 2014. Site 1 (control) was 50 to 100 m upstream of the alum discharge in-stream diffuser, site 2 was 50 to 100 m downstream of the diffuser, and site 3 was 400 meters further downstream in the vicinity of Lake Rd. Relative fish density and CPUE (fish captured per hour) were estimated using a two-pass electrofishing procedure according to the method of Landman et al. (2008). A MAF Aquatronics pulsed DC mains set electrofishing machine, powered by a Honda 3-kVA petrol generator, operating at 420 V and approximately 3 A with two hand-held anodes was used to enable simultaneous fishing of each stream side (Fig. 2). Two teams of three people performed the fishing while one person remained on the bank for machine operation and safety. Estimates of total fish numbers (absolute density) in this stream could not be calculated from the two-pass removal method as variable and occasionally greater fish numbers are captured in the second fishing passes. Common bully, *Gobiomorphus cotidianus*, is the most abundant species in the Utuhina Stream and obtaining consecutive reductions in this species using multiple pass electrofishing is notoriously difficult. For practical purposes, an estimate of minimum fish density was determined by simply adding the total catch from both passes at each site. Total CPUE and CPUE for each pass at each site could be determined normally based on fish caught and fishing effort (time fishing). All fish/koura were counted, adult trout were measured (if captured) or their size estimated if observed, and all fish were returned alive to their respective stream reaches, except for those retained for elemental analysis (see below).

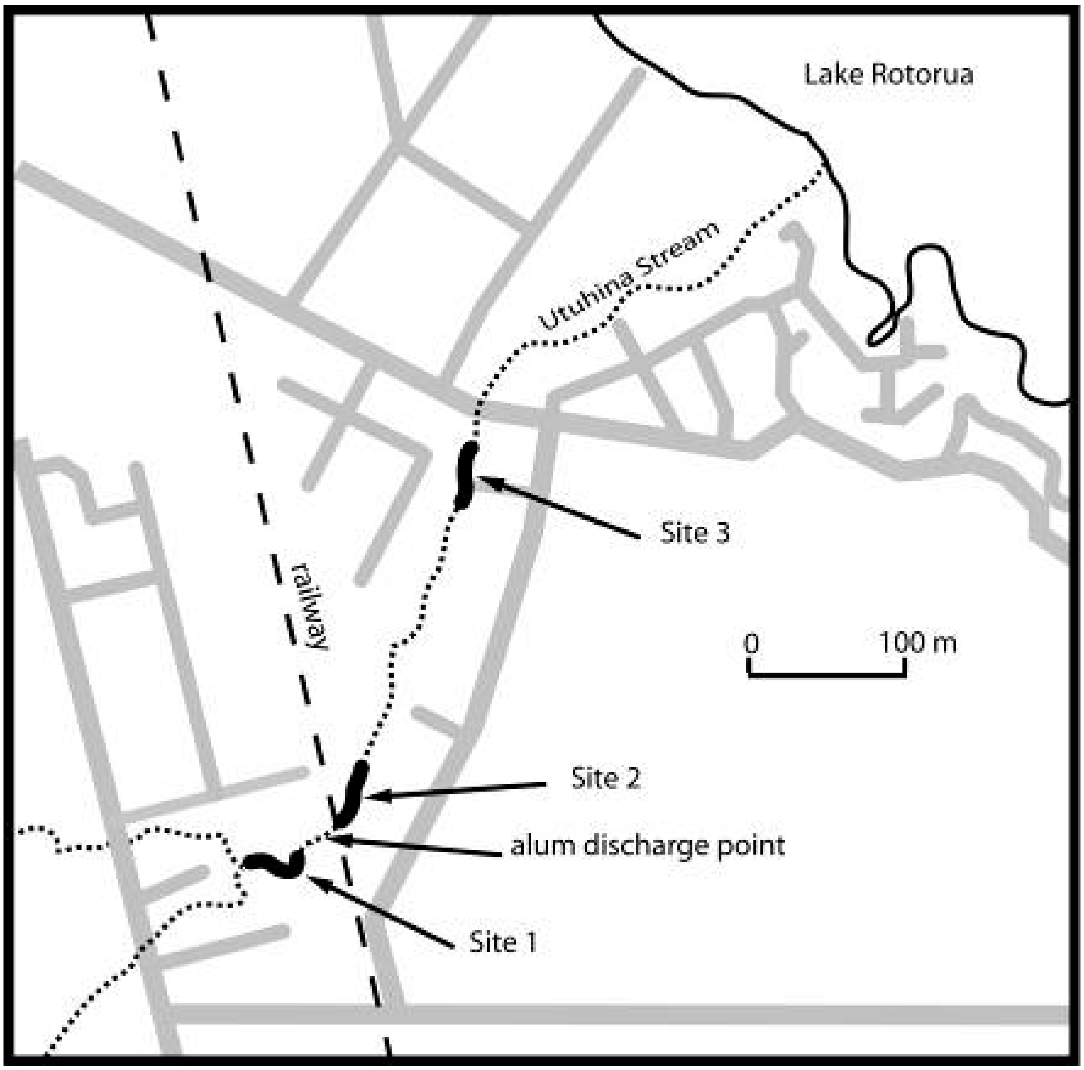

Fig. 1. The Utuhina Stream with fish community survey sites marked above the alum discharge (Site 1), in the alum mixing zone (Site 2) and upstream of Lake Rd (Site 3).

AQUATIC MACROINVERTEBRATE COMMUNITY SURVEY

Semiquantitative analysis of aquatic macroinvertebrates was undertaken within the same three stream reaches examined for relative fish abundance above. Sampling and analysis was carried out as prescribed for soft-bottomed streams by Stark et al. (2001). Briefly, a 0.5 mm mesh, 0.3 m-wide D-net was used to provide ten replicated 1-m sweeps through representative stream bank habitat, sampling a total area of approximately 3 m^2 at each site. True left and true right banks were sampled and enumerated separately at each of the three stream reaches. Samples were preserved in isopropyl alcohol. Macroinvertebrate sampling was carried out one week prior to electrofishing to reduce the likelihood of either sampling method impacting upon the other.

Fig. 2. One of two teams electrofishing the Utuhina Stream bank habitat (site 1).

BIOACCUMULATION OF ALUMINIUM IN COMMON BULLY AND KOURA

A suite of 28 elements was measured in bully and koura tissue samples based on established methods (USEPA, 1987). In brief, tissue samples were 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 wet weight basis. Skeletal muscle, liver and gills were analysed from ten common bully from each site. Hepatopancreas, tail muscle and gills were analysed from up to ten koura from each site. Method blanks and matrix certified reference material standards (DOLT and DORM; Canadian Research Council) were run in parallel with all samples.

Fig. 3. Utuhina Stream koura

RESULTS AND DISCUSSION

UTUHINA STREAM FISH COMMUNITY

Four species, common bully (*Gobiomorphus cotidianus*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), and koura (*Paranephrops planifrons*), were captured across all three stream sites, and one shortfin eel was observed at the upstream control site. Common bully relative density (fish per 50 m reach) and CPUE (fish/h) were higher at all sites than the record lows recorded in 2012 but lower at site 3 than in 2013 (Fig. 4). The continuing low catch of common bully at site 2 within the alum mixing zone appears to be mainly due to a significant change in stream bed morphology on the true left bank, possibly as a result of the floods of 2011 scouring a deeper channel on the true right and a subsequent accumulation of sediment on the true left downstream of the old railway bridge. Juvenile trout were less abundant at site 1 than in 2013 but similar to 2013 values at the other sites (Fig. 5). Numbers of koura were lower at sites 2 and 3 compared with 2013 but much higher at site 1 (Fig. 6).

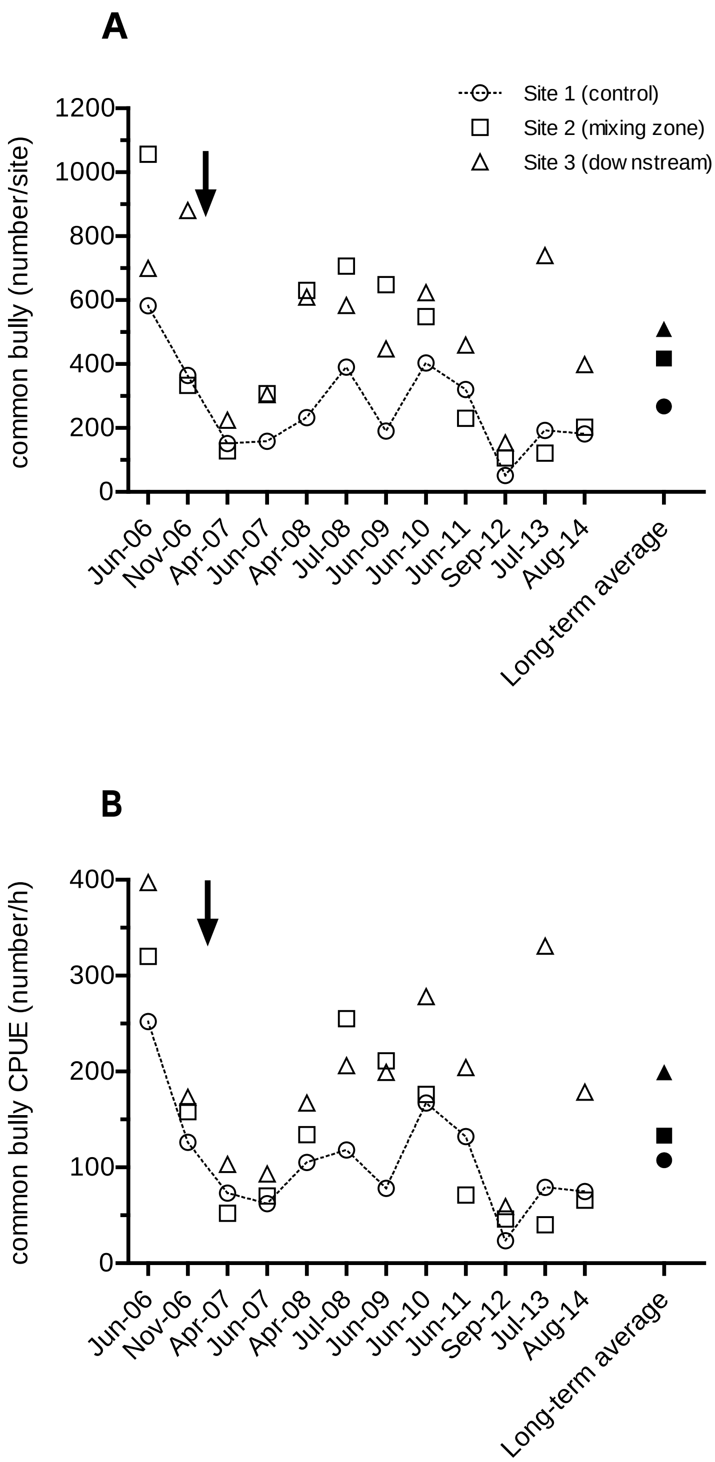

Figure 4. Relative density (A) and CPUE (B) of common bully in the Utuhina Stream since June 2006. Arrows indicate the commencement of alum dosing in the stream.

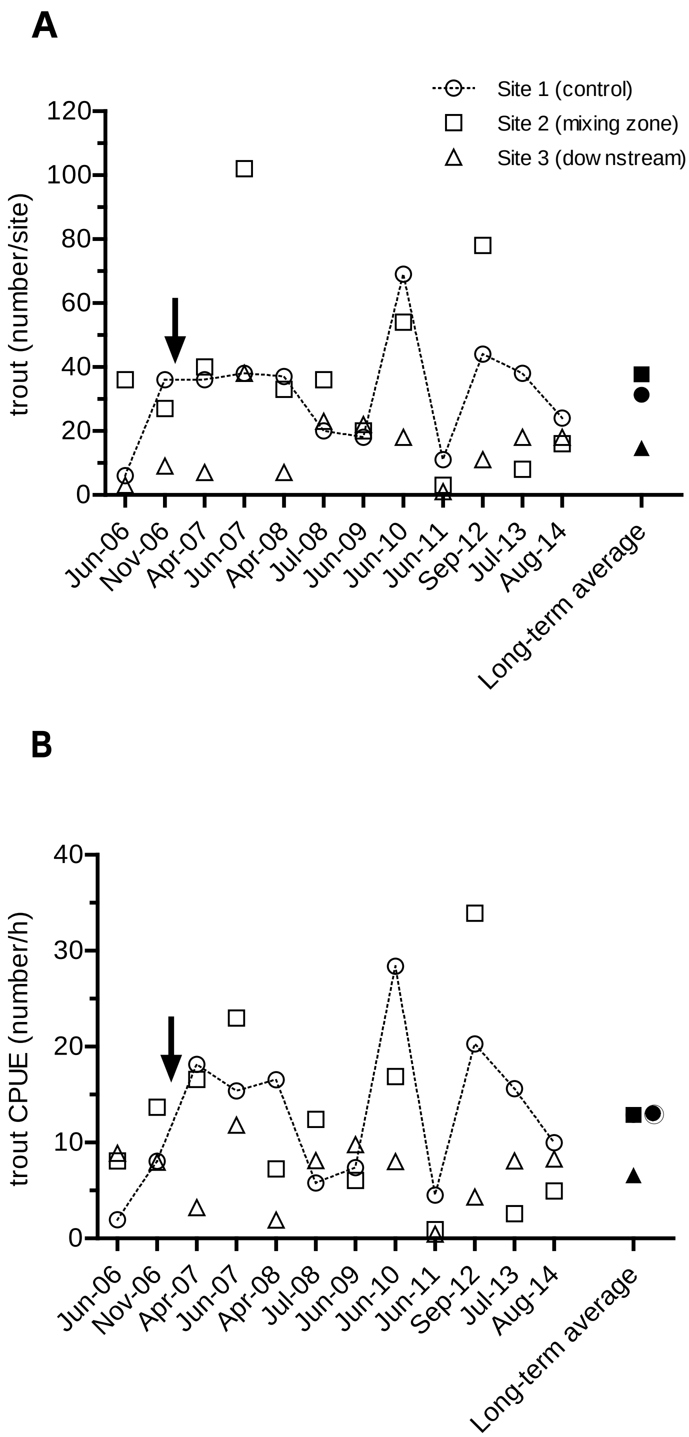

Figure 5. Relative density (A) and CPUE (B) of juvenile trout in the Utuhina Stream. Arrows indicate the commencement of alum dosing in the stream.

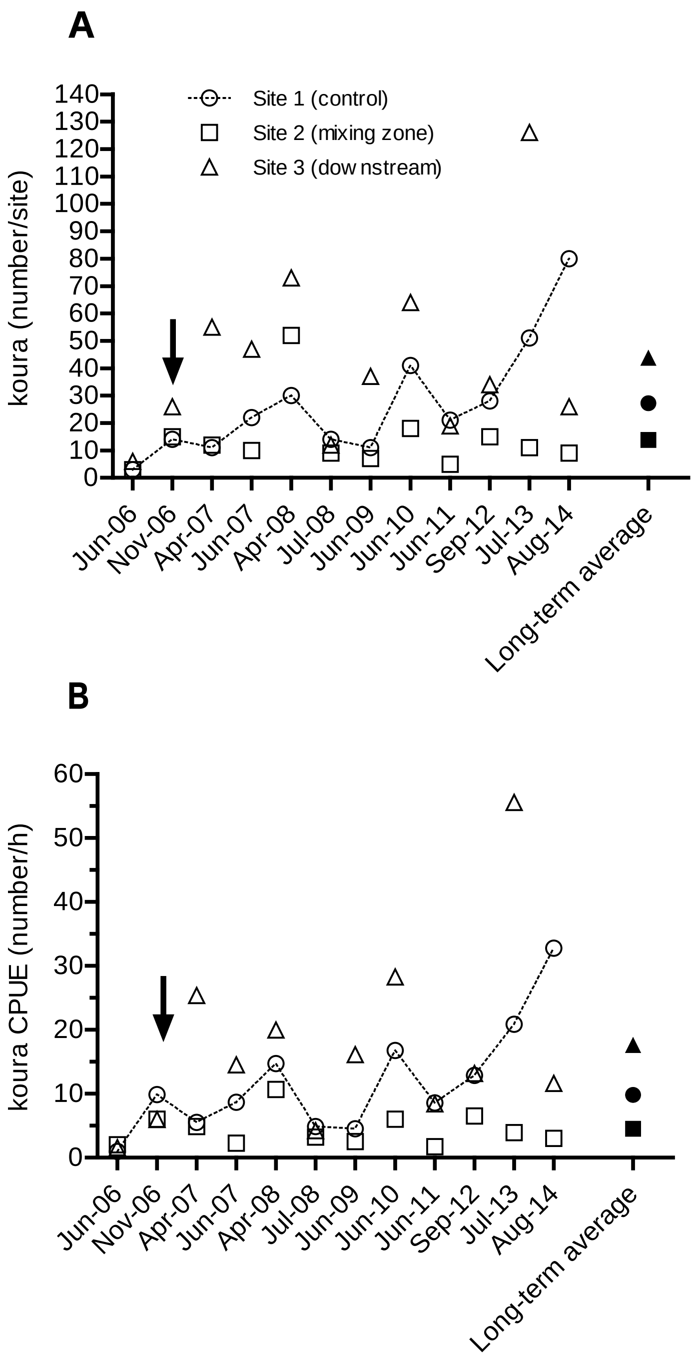

Figure 6. Relative density (A) and CPUE (B) of koura in the Utuhina Stream. Arrows indicate the commencement of alum dosing in the stream.

Figure 7. A fallen willow and bamboo blocking a section of the true left bank at site 1 (control).

Ling (2013) noted that significant modification of the true right bank had occurred at site 1 in 2012 due to scouring downstream of a poorly installed stormwater drain. In July 2013 it was observed that bank remediation had occurred at that site, however, a fallen willow (Fig. 7) on the opposite bank had created a narrowing and deepening of the channel close to the true right bank creating a section (approximately 5 m) of unfishable water. Accumulation of a large bank of fine muddy sediment immediately downstream of the fallen tree has caused significant changes in stream habitat for fish, however the abundance of all species seems unaffected. This feature on the true left bank was still present in August 2014.

AQUATIC MACROINVERTEBRATES

Semi-quantitative macroinvertebrate community analysis (for soft-bottomed streams) showed no obvious differences between sites and values close to the long-term average for years 2009-2014 (Figure 7). Values for the MCI-sb index fell within the “good” quality class (Table 1) of Stark & Maxted (2007) for all three sites. As has been observed in previous years, there was no pattern of change across the sites that could indicate impacts of the alum dosing on macroinvertebrate community composition. Previous studies of macroinvertebrates at the same study sites, both prior to the commencement of alum dosing (May/June 2006), and subsequently (June/July 2006, Feb 2007) showed very similar MCI scores with no significant differences between sites (Clarke 2006, EBOP Unpubl. Data).

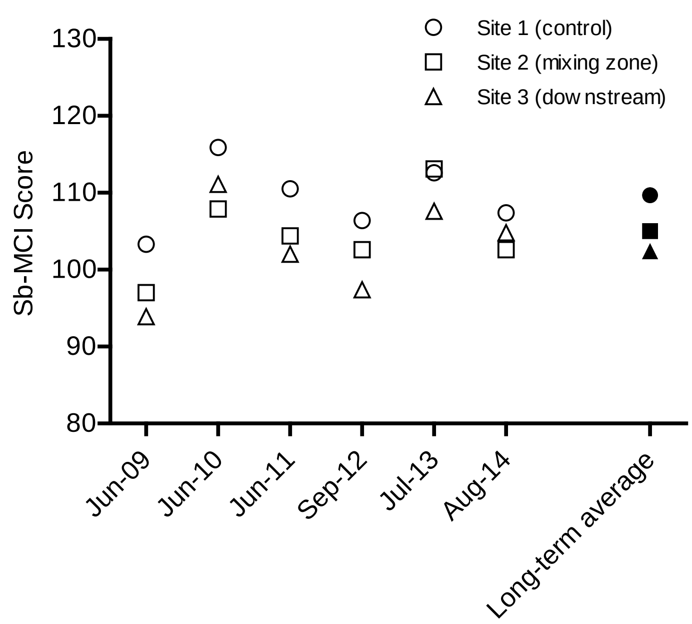

Figure 7: Soft-bottom stream semi-quantitative macroinvertebrate community assessment (Sb-MCI) for the Utuhina Stream since June 2009.

Table 1. Interpretation of soft-bottomed stream MCI indices.

Stark & Maxted (2007) quality class	Stark (1998) descriptions	MCI-sb
Excellent	Clean water	>119
Good	Doubtful quality or possible mild pollution	100-119
Fair	Probable moderate pollution	80-99
Poor	Probable severe pollution	<80

BIOACCUMULATION OF ALUMINIUM

Only five koura captured at site 2 (alum mixing zone) were large enough for tissue aluminium analysis but a sufficient number of large koura were obtained at the other sites.

As observed in previous years there was some evidence of aluminium bioaccumulation downstream of the Utuhina Stream alum diffuser, but total aluminium concentrations were low in tissues from both species (Table 2). Concentrations of aluminium in the tissues of koura and common bully are highly consistent across years with higher aluminium in the hepatopancreas and liver of koura and common bully, respectively, than in the flesh. Statistical analysis (one-way ANOVA followed by Tukey's multiple comparison test) of tissue aluminium in both species across several years revealed a consistent pattern of elevated gill aluminium in common bully at sites 2 and 3 and some evidence for the same in koura in some years but little evidence for accumulation in any internal tissues (Table 2). All animals appeared healthy and unaffected by these relatively low tissue aluminium levels.

It is possible that comparisons of aluminium accumulation between sites may be compromised by the movement of bully and koura within the stream, however, adult common bully and koura are more likely to be locally resident than would be the case for juveniles. There are no studies of aluminium depuration from fish or crayfish internal organs, but fish gills can depurate aluminium within 2 days of removal from exposure (Allin & Wilson 2000). If the internal half-life for aluminium is short enough then movement between sites would have to be rapid and regular to eliminate inter-site comparisons. The slightly elevated gill aluminium concentrations in common bully and koura downstream of the alum diffuser suggests that these species are locally resident rather than highly mobile and therefore tolerant of the instream alum plume.

	2009	2010	2011	2012	2013	2014
KOURA						
Gills						
Upstream control - Site 1	ND	ND	ND	49.5 (24.5, 99.9)	30.6 (15.4, 60.7)	6.0 (0.5, 70.3)
Mixing zone - Site 2	ND	ND	ND	10.2 (- , -)	23.4 (- , -)	50.2 (13.2, 190.8)
Receiving zone - Site 3	ND	ND	ND	2.0 (0.1, 31.5)	**73.4** (19.6, 274.6) *	47.7 (24.1, 94.2)
Hepatopancreas						
Upstream control - Site 1	13.0 (- , -)	10.6 (7.1, 15.7)	9.9 (4.0, 24.9)	3.4 (1.3, 8.5)	4.7 (2.5, 9.0)	0.2 (0.0, 1.9)
Mixing zone - Site 2	10.0 (- , -)	ND	14.2 (9.5, 21.3)	8.1 (1.3, 52.4)	2.5 (-, -)	1.6 (0.0, 58.9)
Receiving zone - Site 3	17.5 (10.6, 29.0)	13.6 (5.2, 35.2)	17.8 (9.0, 35.4)	4.7 (1.1, 21.4)	12.0 (4.3, 33.3)	1.9 (0.3, 13.8)
Flesh						
Upstream control - Site 1	2.2 (0.1, 115.7)	3.1 (2.1, 4.5)	3.1 (1.4, 6.8)	2.2 (0.5, 10.1)	2.0 (0.9, 4.4)	1.4 (0.7, 2.8)
Mixing zone - Site 2	6.3 (3.5, 11.3)	ND	5.6 (2.3, 13.8)	0.8 (0.1, 10.9)	25.6 (- , -)	1.7 (0.5, 5.2)
Receiving zone - Site 3	6.3 (2.6, 15.3)	3.4 (1.6, 7.2)	2.4 (1.7, 3.4)	1.3 (0.2, 8.3)	4.1 (0.7, 24.5)	1.0 (0.2, 5.4)
COMMON BULLY						
Gills						
Upstream control - Site 1	ND	ND	13.7 (9.7, 19.5)	11.6 (7.3, 18.5)	10.9 (1.7, 71.2)	17.3 (11.1, 26.8)
Mixing zone - Site 2	ND	ND	**36.3** (22.7, 57.9) *	**28.7** (18.0, 45.9) *	**95.4** (70.2, 129.5) *	28.0 (21.7, 36.1)
Receiving zone - Site 3	ND	ND	**35.3** (27.7, 45.0) *	**29.9** (22.0, 40.7) *	**66.6** (35.7, 124.2) *	**63.4** (51.7, 77.7) *
Liver						
Upstream control - Site 1	3.5 (1.5, 8.6)	9.0 (5.5, 14.5)	5.3 (3.8, 7.4)	4.5 (3.1, 6.6)	15.0 (7.7, 29.1)	2.0 (0.3, 15.2)
Mixing zone - Site 2	1.1 (0.4, 2.9)	ND	5.3 (3.9, 7.2)	4.5 (2.9, 6.8)	4.1 (0.4, 42.7)	3.6 (0.8, 16.9)
Receiving zone - Site 3	1.5 (0.6, 3.7)	7.7 (1.5, 38.6)	**15.4** (10.2, 23.2) *	5.5 (3.7, 8.4)	0.1 (0.0, 2.0)	**27.2** (10.0, 73.8) *
Flesh						
Upstream control - Site 1	0.8 (0.6, 1.1)	2.1 (1.6, 2.7)	2.9 (2.2, 3.7)	2.4 (1.7, 3.5)	0.5 (0.1, 3.6)	2.5 (1.9, 3.3)
Mixing zone - Site 2	0.5 (0.2, 1.8)	ND	2.8 (1.9, 4.2)	2.4 (1.4, 4.0)	2.0 (0.4, 9.1)	0.7 (0.2, 2.6)
Receiving zone - Site 3	0.5 (0.3, 0.8)	1.7 (1.0, 3.0)	2.9 (2.4, 3.5)	2.4 (1.8, 3.3)	2.3 (0.6, 9.8)	1.2 (0.3, 4.4)

Table ??? Tissue aluminium concentrations (mg/kg) - geometric mean with lower and upper 95% confidence intervals (CI) in parentheses. Mean values in bold and indicated by * are significantly different from control site values ($P<0.05$). – indicates too few data points to calculate 95% CI.

REFERENCES

Allin, C.J., Wilson, R.W. (2000) Effects of pre-acclimation to aluminium on the physiology and swimming behaviour of juvenile rainbow trout (*Oncorhynchus mykiss*) during a pulsed exposure. *Aquatic Toxicology* 51: 213-224.

Bay of Plenty Regional Council (2007) Proposed Lakes Rotorua and Rotoiti Action Plan: A programme for the long-term restoration of Lakes Rotorua and Rotoiti's water quality. Environmental Publication 2007/11. Environment Bay of Plenty, Whakatane, New Zealand. 165 pp.

Clarke, H. (2006) The effects of alum on the macroinvertebrate community index (MCI) in the Utuhina Stream. Unpublished project report. Auckland University of Technology.

Landman, M., Ling, N., Taylor, S. (2008) Fish community surveys and biomonitoring in selected Rotorua Streams. Technical report prepared for Environment Bay of Plenty. Scion, Rotorua New Zealand. 28 pp.

Ling, N. (2013) 2013. Utuhina Stream monitoring 2012: effects of continuous alum dosing on fish and aquatic invertebrates. Client Report prepared for Environment Bay of Plenty. University of Waikato, Hamilton. 18 pp.

Stark, J.D., Maxted, J.R. (2007) A user guide for the Macroinvertebrate Community Index. Prepared for the Ministry for the Environment. Cawthron Report No. 1166. 58 p.

Stark, J.D., Boothroyd, I.K.G., Harding, J.S., Maxted, J.R., Scarsbrook, M.R. (2001) Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Macroinvertebrate Working Group Report No. 1. Prepared for the Ministry for the Environment. Sustainable Management Fund Project No. 5103. 57p.

United States Environmental Protection Agency (USEPA). (1987) Determination of Metals in Fish Tissue by Inductively Coupled Plasma – Atomic Emission Spectrometry. EPA Method 200.11, Revision 1.3, April 1987.