UTUHINA STREAM MONITORING 2013:

EFFECTS OF CONTINUOUS ALUM DOSING ON FISH AND AQUATIC INVERTEBRATES

NICHOLAS LING

Utuhina Stream monitoring 2013: effects of continuous alum dosing on fish and aquatic invertebrates

Nicholas Ling

School of Science, The University of Waikato, Private Bag 3105, Hamilton 3240, New Zealand. nling@waikato.ac.nz

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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 2013, 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 July 2013. Catch rates for common bully, juvenile trout and koura have fluctuated across all sites since monitoring began in 2006. Common bully and koura were abundant at Site 3 (250 m downstream of the alum diffuser) and more common at the upstream control site than in 2012. All species (bully, koura and trout) were less abundant at site 2 immediately downstream of the alum diffuser than in 2012 but this is most likely due to changes in stream bank habitat rather than effects of alum dosing. It is possible that continuing alterations in stream bank habitat and stream morphology arising from large flood flows throughout winter 2012, and following extreme floods in early 2011, contributed to the observed decline at site 2. 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. Tissue concentrations of aluminium were slightly greater in the gills and hepatopancreas of koura and the gills and liver of common bully at both downstream sites compared with the upstream control site but this does not appear to affect the health or abundance of these species in the stream.

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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 July 2013, 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 2013 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 2nd July 2013. 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).

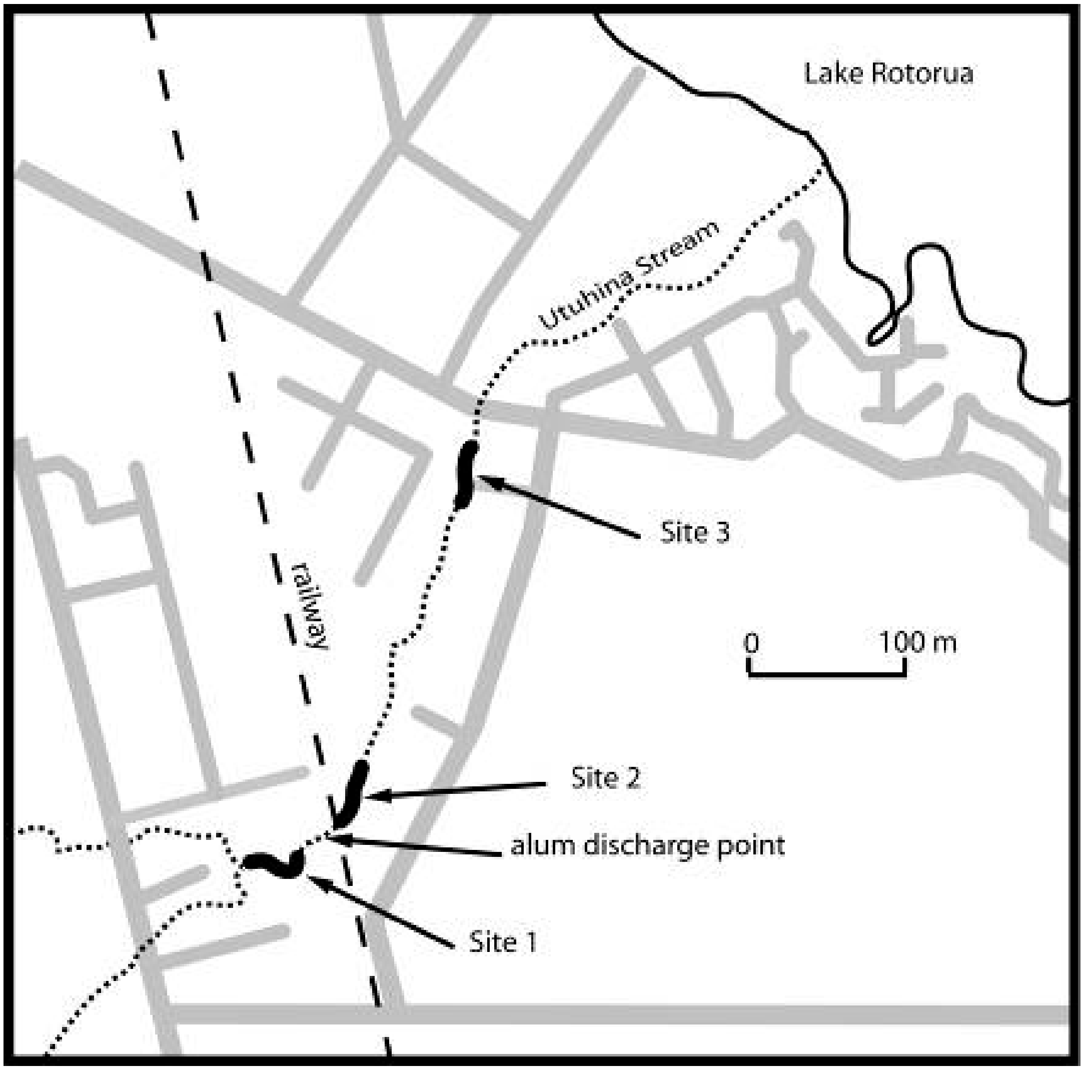


Fig. 1. The Utuhina Stream with fish community survey sites marked above the alum discharge (Site 1), in the alum mixing zone (Site 2) and upstream of Lake Rd (Site 3).

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 3).

BIOACCUMULATION OF ALUMINIUM IN COMMON BULLY AND KOURA

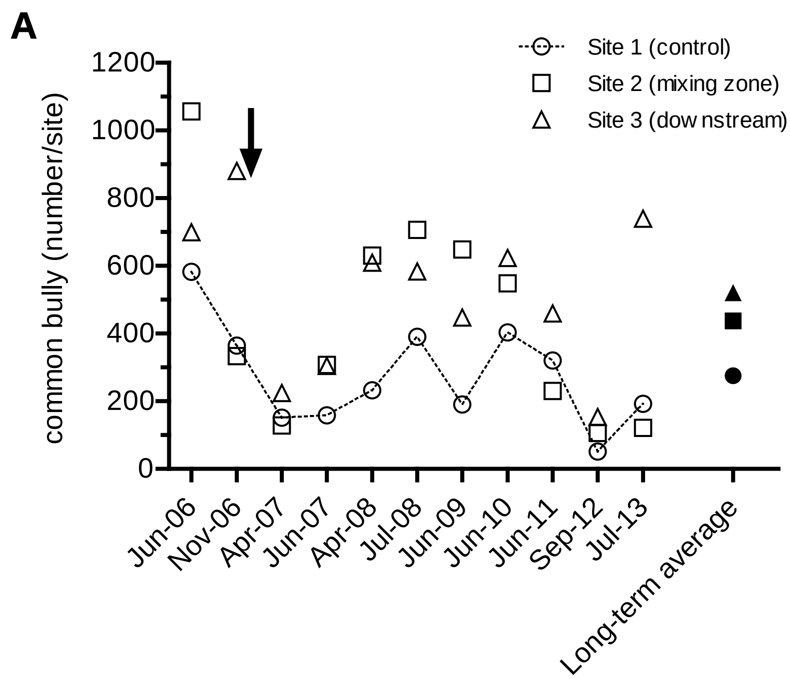
A suite of 28 elements was measured in bully and koura tissue samples based on established methods (USEPA, 1987). In brief, tissue samples were accurately weighed and digested using tetramethylammonium hydroxide, heat and mixing. The colloidal suspension was then partially oxidized by the addition of 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. A collection of koura from the Utuhina Stream

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. No other fish species were captured or observed in 2013. Common bully relative density (fish per 50 m reach) and CPUE (fish/h) were higher at sites 1 and 3 than the record lows of the previous year, especially at site 3 which recorded the highest catches of common bully and koura since the commencement of alum dosing (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. Significant scouring and loss of stream bank vegetation was observed at all sites in June 2011 compared to previous years as well as a slight lowering of the stream bed at site 3, probably as a result of two very large flood flows (2.5 m and 2.9 m) that occurred in late January 2011. These were the highest flows recorded in the Utuhina Stream since the start of the monitoring programme in 2006. Large flood flows also occurred throughout the winter of 2012 and reduced stream bank vegetation was again observed. Although the level of the stream bed at site 3 had recovered in July 2013 from its lowered condition in 2011 and 2012, significant changes in stream bed morphology and bankside vegetation were still apparent at sites 1 and 2. Numbers of juvenile trout were much lower at site 2 than in 2012 but close to the long-term average at the other sites (Fig. 5).



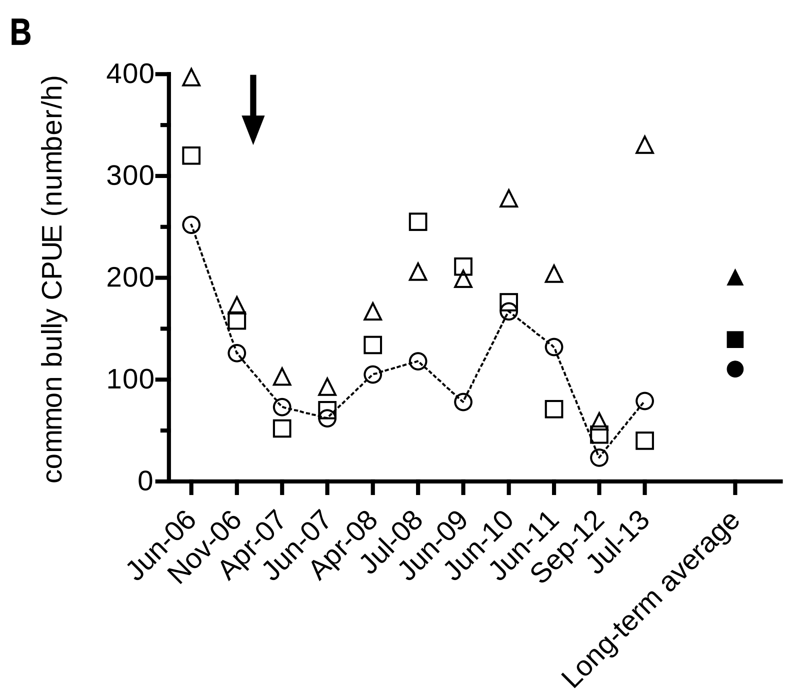


Figure 4. Relative density (A) and CPUE (B) of common bully in the Utuhina Stream since June 2006. Arrows indicate the commencement of alum dosing in the stream.

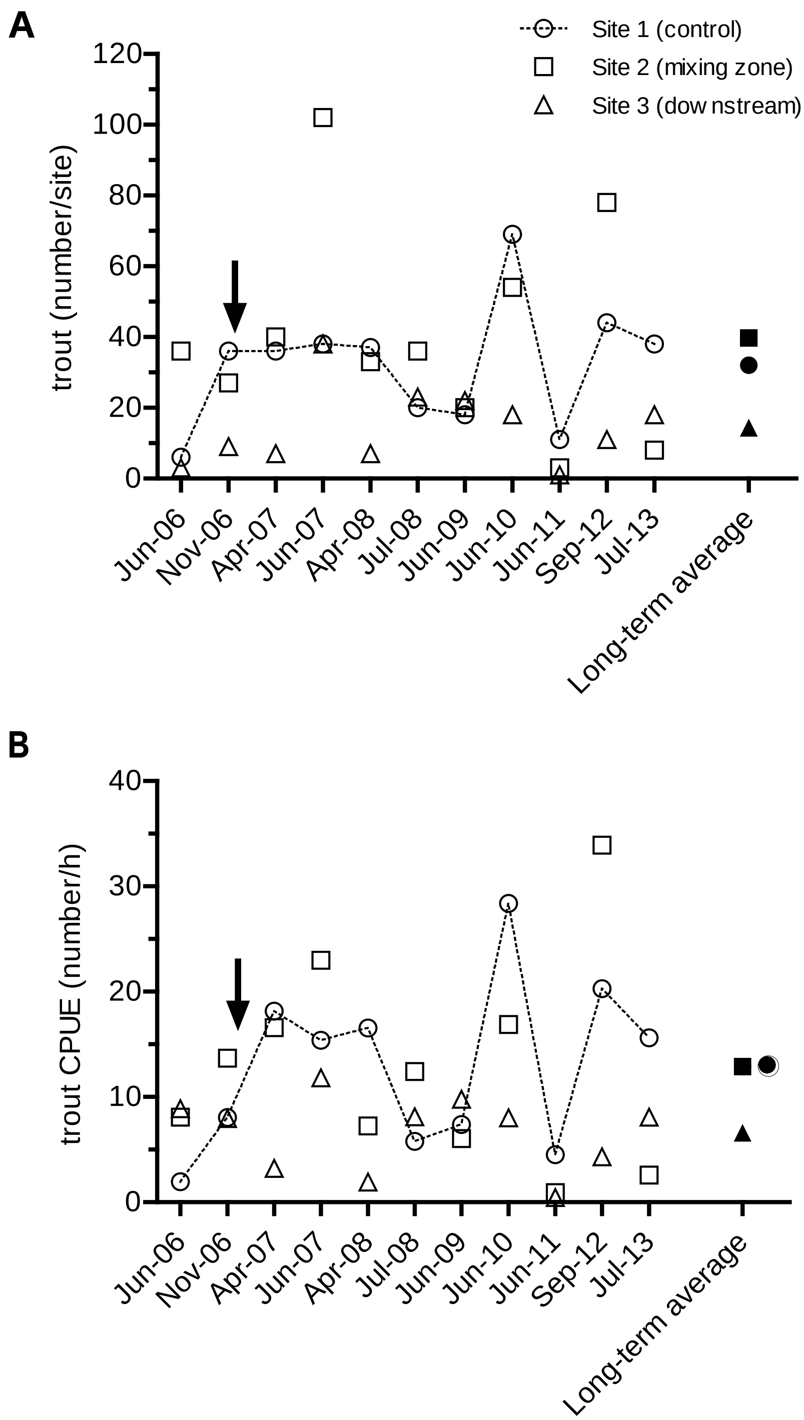


Figure 5. Relative density (A) and CPUE (B) of juvenile trout in the Utuhina Stream. Arrows indicate the commencement of alum dosing in the stream.

Koura abundance and CPUE was much higher at sites 1 and 3 compared with 2012 and although slightly lower at site 2, close to the long-term average for that site (Fig. 5).

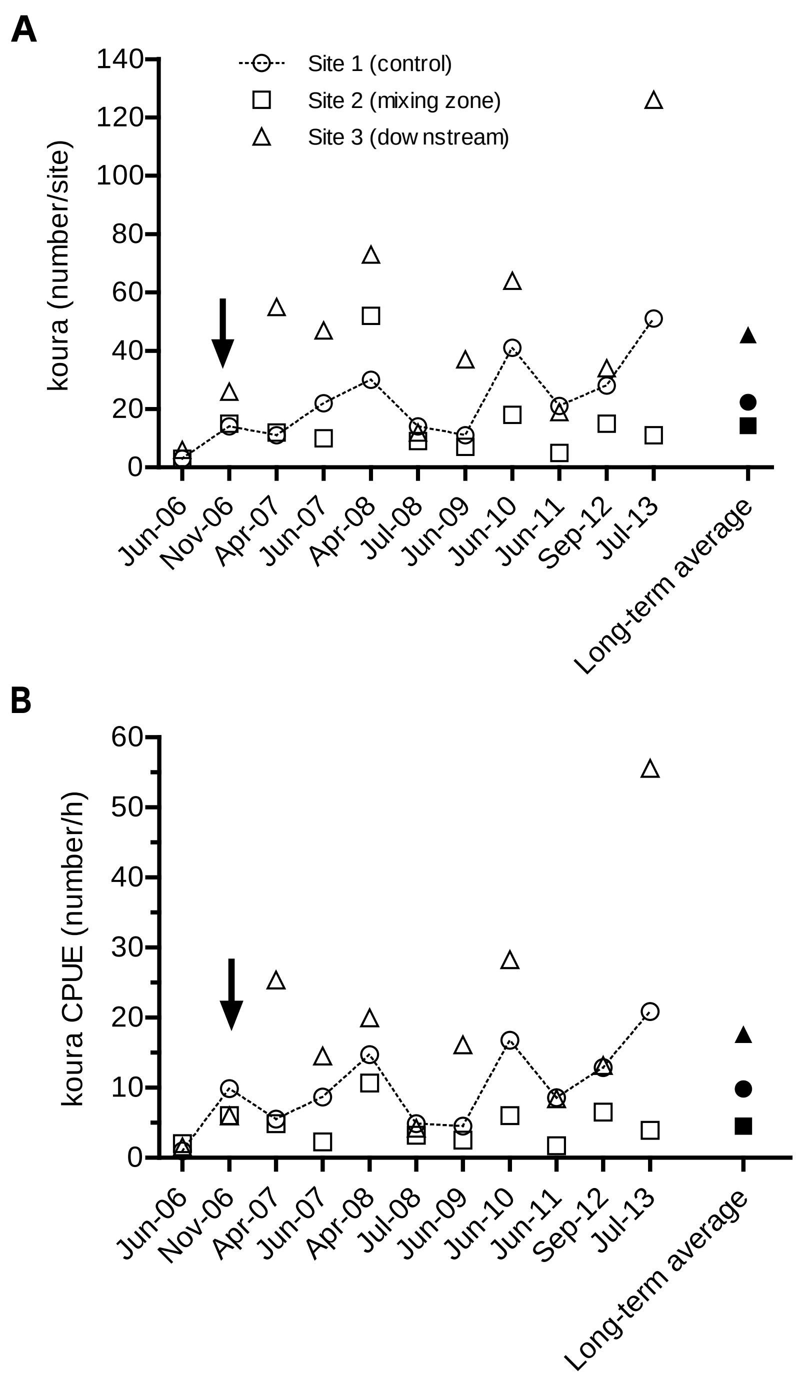


Figure 6. Relative density (A) and CPUE (B) of koura in the Utuhina Stream. Arrows indicate the commencement of alum dosing in the stream.

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.

AQUATIC MACROINVERTEBRATES

Semi-quantitative macroinvertebrate community analysis (for soft-bottomed streams) showed no obvious differences between sites and a slight improvement at all sites compared with the previous year (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).

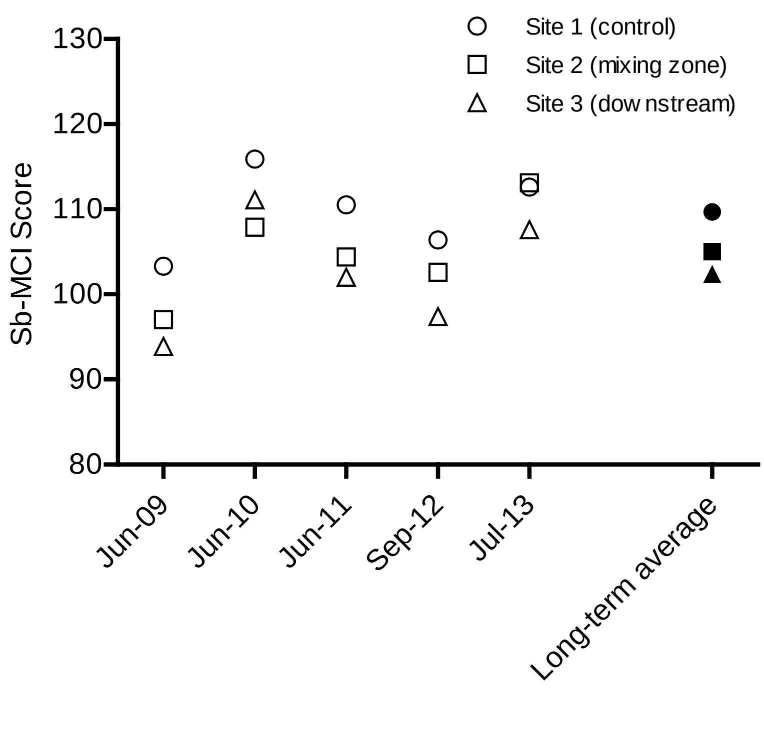


Figure 7: Soft-bottom stream semi-quantitative macroinvertebrate community assessment (Sb-MCI) for the Utuhina Stream since June 2009.

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

Relatively little research has been conducted on the effects of alum on stream ecosystems. Eriksen et al. (2009) studied the effects of alum dosing a stream in combination with sulphuric acid (reducing the stream pH from 6.5 to 5.5) to enhance the toxicity of aluminium to the salmon ectoparasite *Gyrodactylus salaris*. They found that the treatment induced catashrophic drift in some but not all macroinvertebrate groups. Those most affected were ephemeroptera and trichoptera, whilst the plecoptera were least affected. No evaluations have so far been undertaken on the sensitivities of New Zealand stream macroinvertebrates to alum. Barbiero et al. (1988) also found catastrophic effects of continuous alum dosing for one week in the Cuyahoga River, however, the dose rate in this study was extremely high resulting in massive accumulation of an anaerobic, benthic alum floc downstream of the alum diffuser. Invertebrate drift and mortality was assumed to have resulted from significant decrease in stream pH or anaerobic smothering by the alum floc. Some recent studies (Mortula et al. 2013, Driscoll et al 2014) have examined the potential for alum flocs or water treatment plant alum residuals to produce levels of dissolved aluminium that could potentially be toxic to aquatic life and conclude that such conditions are only likely under conditions of low pH (generally <5.5) and low buffering capacity, neither of which occur in the Utuhina Stream.

No adverse impacts of continuous alum dosing have been seen in the Utuhina Stream since the initiation of alum dosing probably because the dose rate is low and highly controlled, being dependent on stream discharge, and the low dose rate does not significantly decrease stream pH which would cause greater toxicity and an increase in bioavailable aluminium species.

BIOACCUMULATION OF ALUMINIUM

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

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 (Figs. 8 & 9). 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. Because the gills are a major site of aluminium accumulation in fish, particularly at pH values below 6.5, Ling & Brijs (2009) recommended that the gills of common bully should be analysed for comparison with other tissues and this was done in the 2011 assessment and repeated in 2012 and 2013 for both common bully and koura. Aluminium concentrations were higher in gill tissue than other tissues at all sites and there was evidence of higher aluminium in the gills and liver of common bully and the gills and hepatopancreas of koura downstream of the alum diffuser (sites 2 and 3), however, 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.

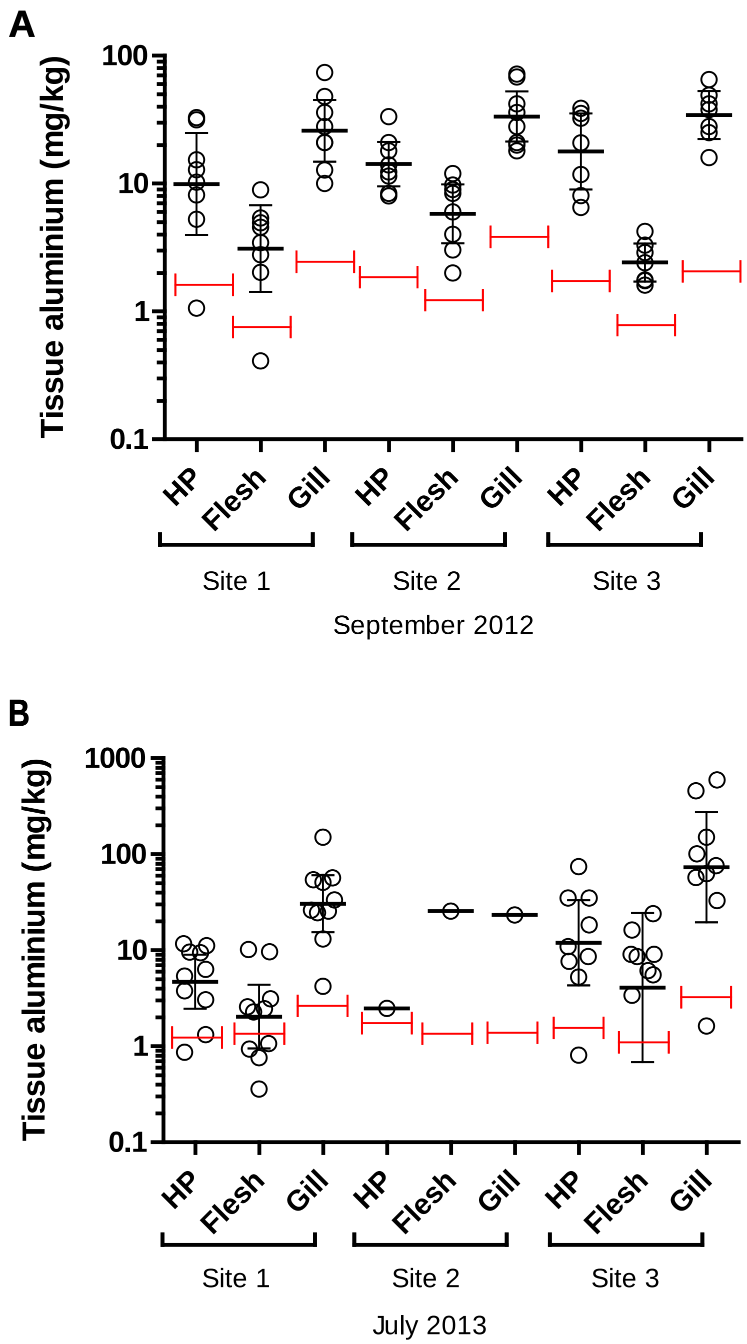
METHOD DETECTION LIMITS AND REPORTING

The Method Detection Limit (MDL) is the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero, and will vary depending on the analyte, the sample matrix, and the sample volume/weight. A common problem encountered in tissue contaminant analysis is values that lie below the nominal method detection limit. Non-reporting of such values leads to overestimation of average tissue concentration (left censored data). A variety of simple solutions have been employed to deal with such data including reporting these values as zero concentration, as equal to the MDL (Environment Canada), as equal to the MDL divided by 2 (Environment Canada), as equal to the

MDL divided by √2 (Centres for Disease Control). However, Succop et al. (2004) determined that such procedures may generate considerable bias, particularly when a significant proportion of values lie below the MDL. They recommended that numerical values be reported for all samples but that values below the MDL are indicated accordingly. This approach has been adopted here for aluminium values. Alternative and more complicated approaches (Shumway et al. 2002, Helsel 2005) employ statistical methods based on the distribution of data to provide estimates for data values below the method detection limit, however such methods typically require relatively larger sample sizes (>25) than available here.

Results for common bully tissues analysed in 2009 were compromised by low tissue sample weight, with many samples returning values at or below the average method detection limit (Ling & Brijs 2009). Subsequent refinements to the analytical method have resulted in a decrease in method detection limit and more than 99% of samples returning values above the MDL.

Figure 8. Tissue aluminium concentrations (mg/kg) for hepatopancreas, flesh and gills of koura from the Utuhina Stream from A. 2012 and B. 2013. Site 1 is upstream of the alum discharge diffuser. Site 2 is within the alum mixing zone. Site 3 is 500 m downstream of the alum diffuser. Summary statistics are geometric mean (bold lines) ± 95% confidence limits. Transverse bars represent average method detection limits for each sample.



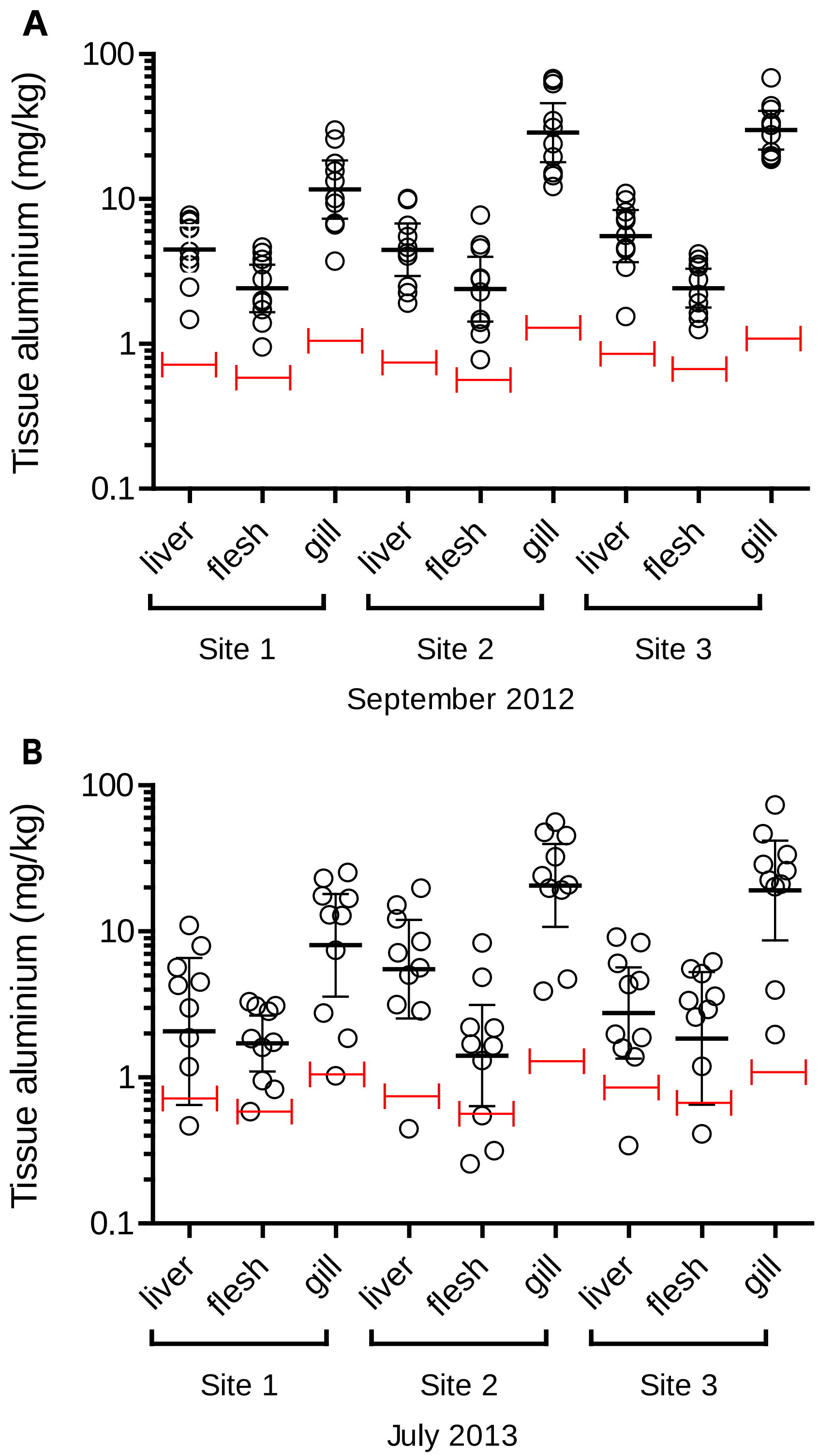


Figure 9. Tissue aluminium concentrations (mg/kg) for liver, flesh and gill tissues of common bully from the Utuhina Stream from A. 2012 and B. 2013. See Figure 8 caption for details.

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