UTUHINA STREAM MONITORING 2016:

IN-STREAM ALUM DOSING EFFECTS ON FISH AND AQUATIC INVERTEBRATES

ERI REPORT NUMBER 101

Client report prepared for Bay of Plenty Regional Council

May 2017

Nicholas Ling

Environmental Research Institute

Faculty of Science and Engineering

University of Waikato, Private Bag 3105

HAMILTON 3240, NEW ZEALAND

Utuhina Stream monitoring 2016: In-stream alum dosing effects 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

This report should be cited as:

Ling, N. 2017. Utuhina Stream monitoring 2016: In-stream alum dosing effects on fish and aquatic invertebrates. ERI Report No 101. Client Report prepared for Environment Bay of Plenty. University of Waikato, Hamilton. Environmental Research Institute, Faculty of Science and Engineering, University of Waikato, Hamilton, New Zealand.17 pp.

Reviewed by:

Brendan Hicks

School of Science

University of Waikato

Hamilton, New Zealand

Approved for release by

John Tyrrell

Environmental Research Institute

University of Waikato

Hamilton, New Zealand

SUMMARY

This report presents the results of an ongoing assessment of the fish and aquatic macroinvertebrate communities of the Utuhina Stream from 2006 to 2016, and an assessment of the bioavailability of aluminium in fish and koura to satisfy Bay of Plenty Regional Council's annual resource consent conditions 9.6, 9.8 and 9.7, respectively, for consent 65321 for the discharge of alum to the Utuhina Stream.

Macroinvertebrates, fish and koura were sampled from one control and two treatment reaches of the Utuhina Stream in August 2016. Common bully numbers in 2016 were the highest recorded at all sites since alum dosing began in 2006. Koura and juvenile trout were present at all sites but variable in abundance. Differences in species abundance from year to year is 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 difference between upstream control and the alum mixing zone, with similar MCI scores to previous samples obtained before and after commencement of alum dosing in 2006. The MCI score for the downstream site was lower than in previous years but this is most likely due to intersample or interannual variability rather than effects of alum discharge. Overall, all sites were characterised as fair to good quality for a soft-bottomed stream.

Some evidence of aluminium bioaccumulation was seen in some tissues of common bully (gills and liver) resulting from continuous alum dosing of the Utuhina Stream but there was no evidence of bioaccumulation of aluminium in the tissues of koura. Alum exposure in these species does not appear to affect their health or abundance in the stream.

TABLE OF CONTENTS

LIST OF FIGURES

1.

INTRODUCTION

The Lakes Rotorua and Rotoiti Action Plan (Bay of Plenty Regional Council, 2007) proposed to lower the trophic level index (TLI; Burns et al. 1999) 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/m^3) 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 2016, 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 consent 65321 for the discharge of alum to the Utuhina Stream. Assessments of fish abundance in the Utuhina Stream began prior to the commencement of alum dosing in 2006 and have been undertaken annual since then. Measures of aluminium bioaccumulation in fish and koura have also been undertaken annually since 2009. Results from 2016 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 31st August 2016. 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 m 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 and koura were counted, captured adult trout were measured 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).

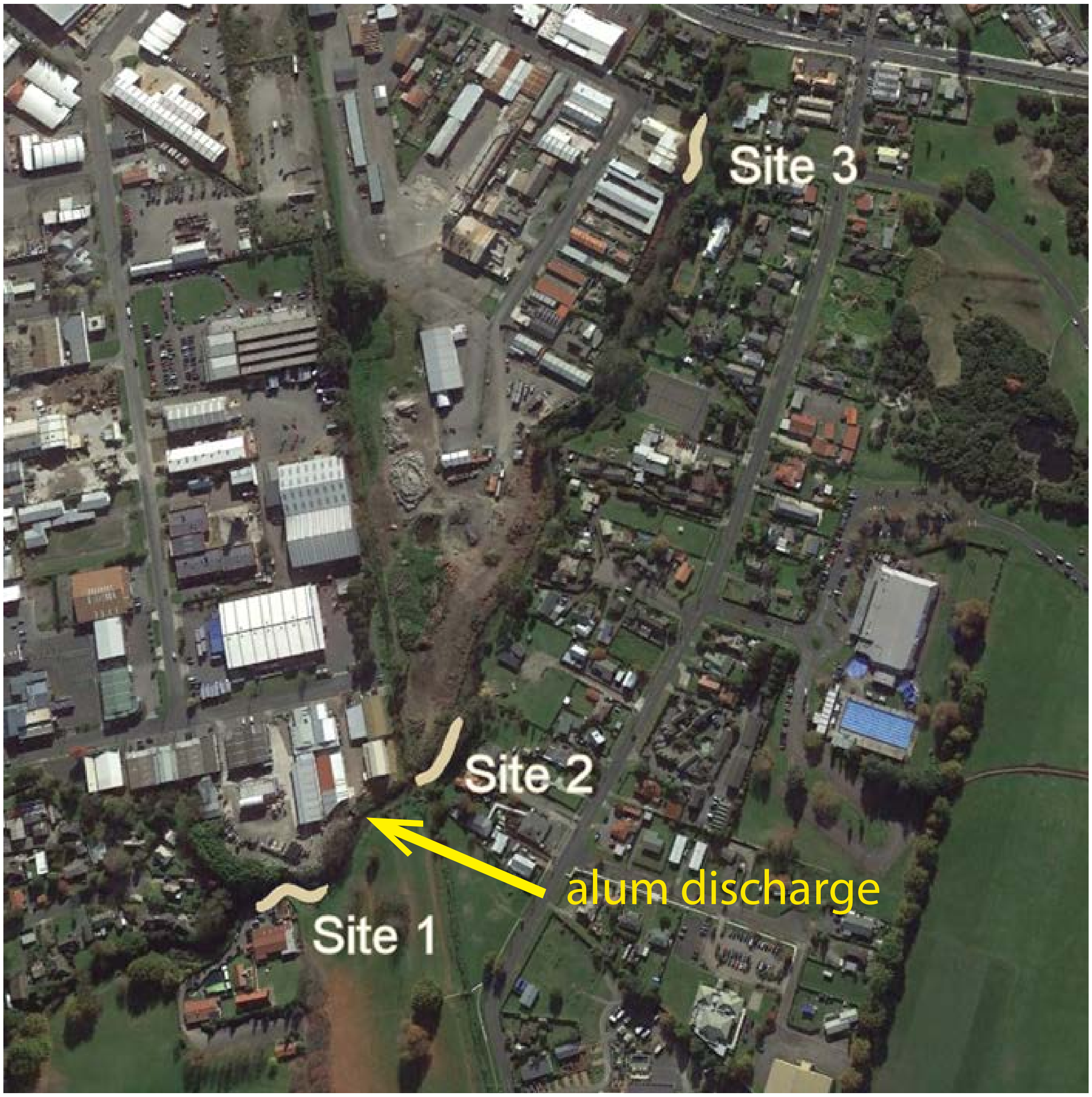


Figure 1. The Utuhina Stream with fish community survey sites marked above the alum discharge (site 1), in the alum mixing zone (Site 2) and upstream of Lake Rd (Site 3).

Figure 2. Electrofishing bankside vegetation at site 2 of the Utuhina Stream..

AQUATIC MACROINVERTEBRATE COMMUNITY SURVEY

Semiquantitative analysis of aquatic macroinvertebrates was undertaken in September 2016 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 to provide a value for the macroinvertebrate community index for soft bottomed streams (MCI-sb) according to Stark & Maxted (2007). Samples were preserved in isopropyl alcohol until sorted and enumerated.

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 then digested using tetramethyl-ammonium hydroxide, heat (60°C) and mixing. The colloidal suspension was then partially oxidized by the addition of hydrogen peroxide and metals solubilised by acidification with nitric acid and further heating (90°C). Samples were diluted and filtered prior to analysis by inductively-coupled plasma mass spectrometry (School of Science, University of Waikato, 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.

Figure 3. A sample of Utuhina Stream koura from site 3.

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. In addition, one very large longfin eel (*Anguilla dieffenbachii*; approximately 1.3 m total length) was captured at the upstream control site, and galaxiid (koaro: *Galaxias brevipinnis*; Figure 4) larvae were captured at sites 1 and 2 (4 individuals at site 2 and 2 at site 1). Common bully relative density (fish per 50 m reach) and CPUE (fish/h) were significantly higher at all sites than in previous years and the highest recorded since alum dosing commenced in 2006 (Fig. 5). Juvenile trout numbers were low at sites 2 and 3 but close to the long-term average at site 1 (Fig. 6). Koura were relatively abundant at sites 1 and 3 but almost absent (only 3 individuals captured) at site 2 (Fig. 7). Koura numbers have remained consistently low at site 2 (alum mixing zone) since before the commencement of alum dosing and numbers at the downstream reach (site 3) have fluctuated widely since before dosing began, presumably due to interannual variability in habitat quality, particularly the impacts of floods on stream bank vegetation. Overall, there has been no discernable impact of alum dosing on the fish community of the stream and the apparent upstream recruitment of koaro whitebait to sites 1 and 2 is an encouraging indicator of the overall fish community health of the stream.

Figure 4. Galaxiid (koaro) whitebait captured at sites 2 & 3.

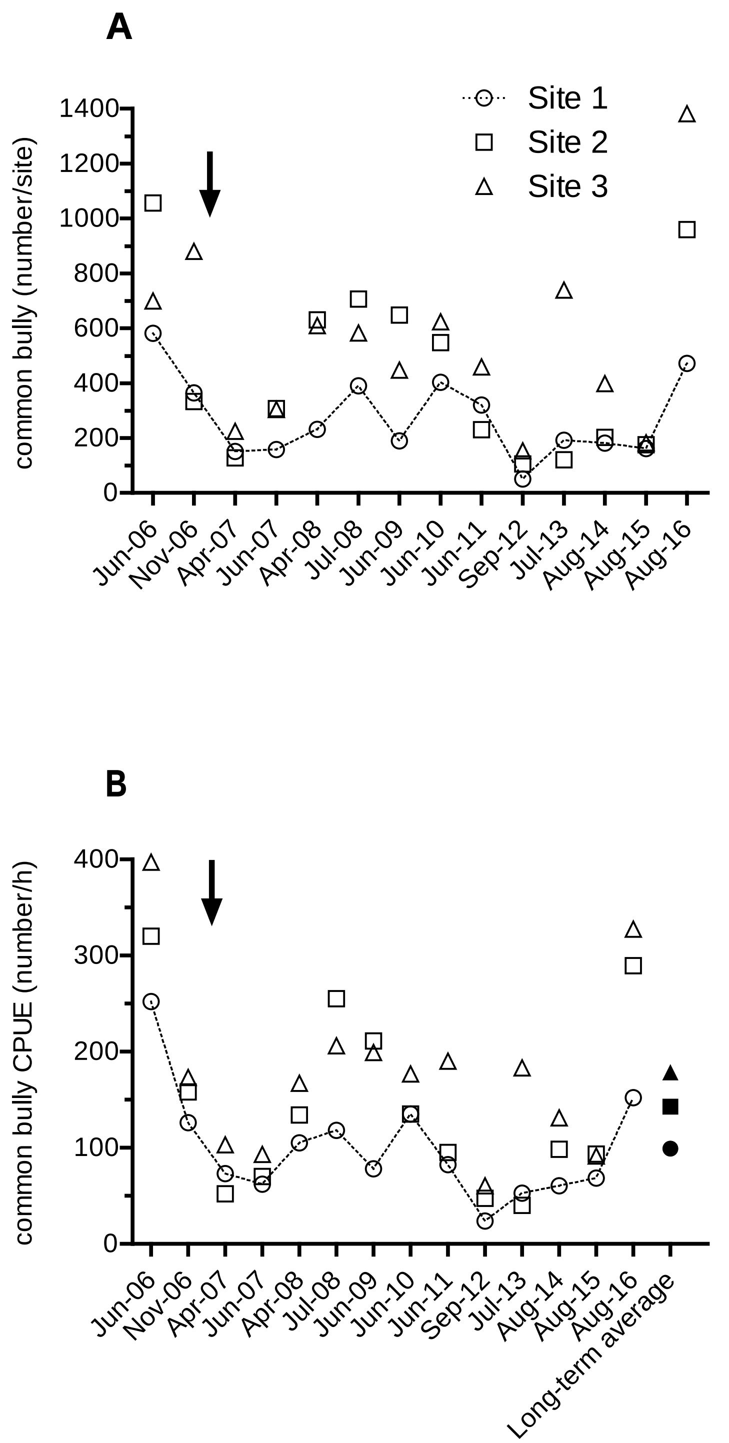
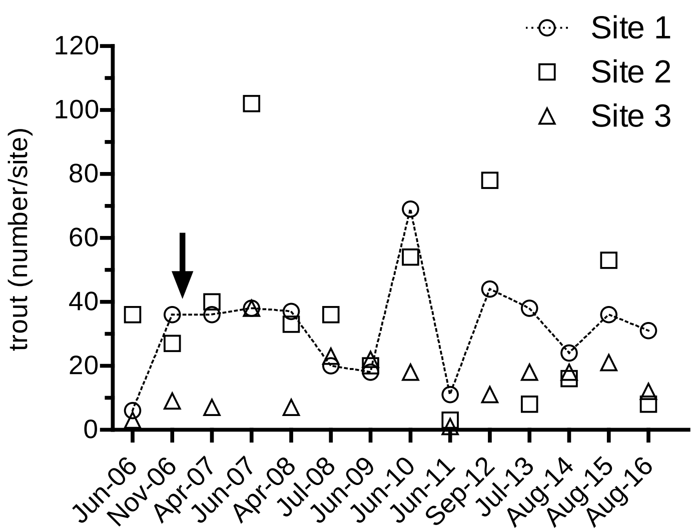


Figure 5. Relative density (A) and CPUE (B) of common bully in the Utuhina Stream since June 2006. Arrows indicate the commencement of alum dosing in the stream.

A



B

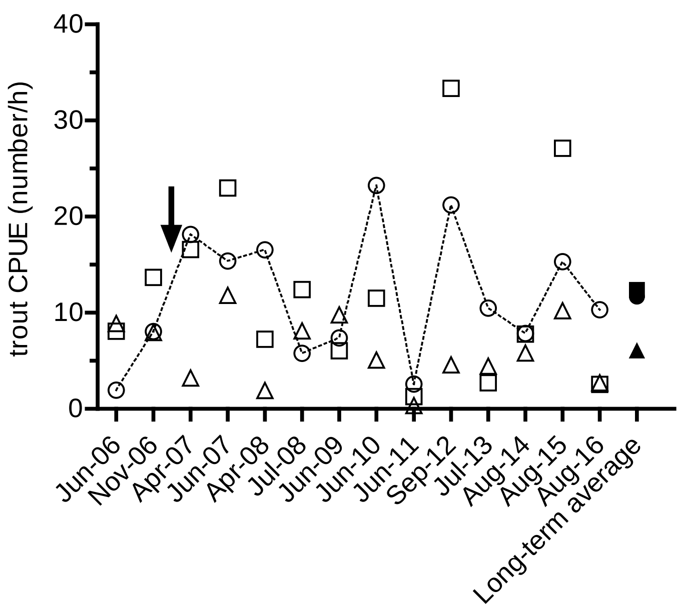


Figure 6. Relative density (A) and CPUE (B) of juvenile trout in the Utuhina Stream. Arrows indicate the commencement of alum dosing in the stream.

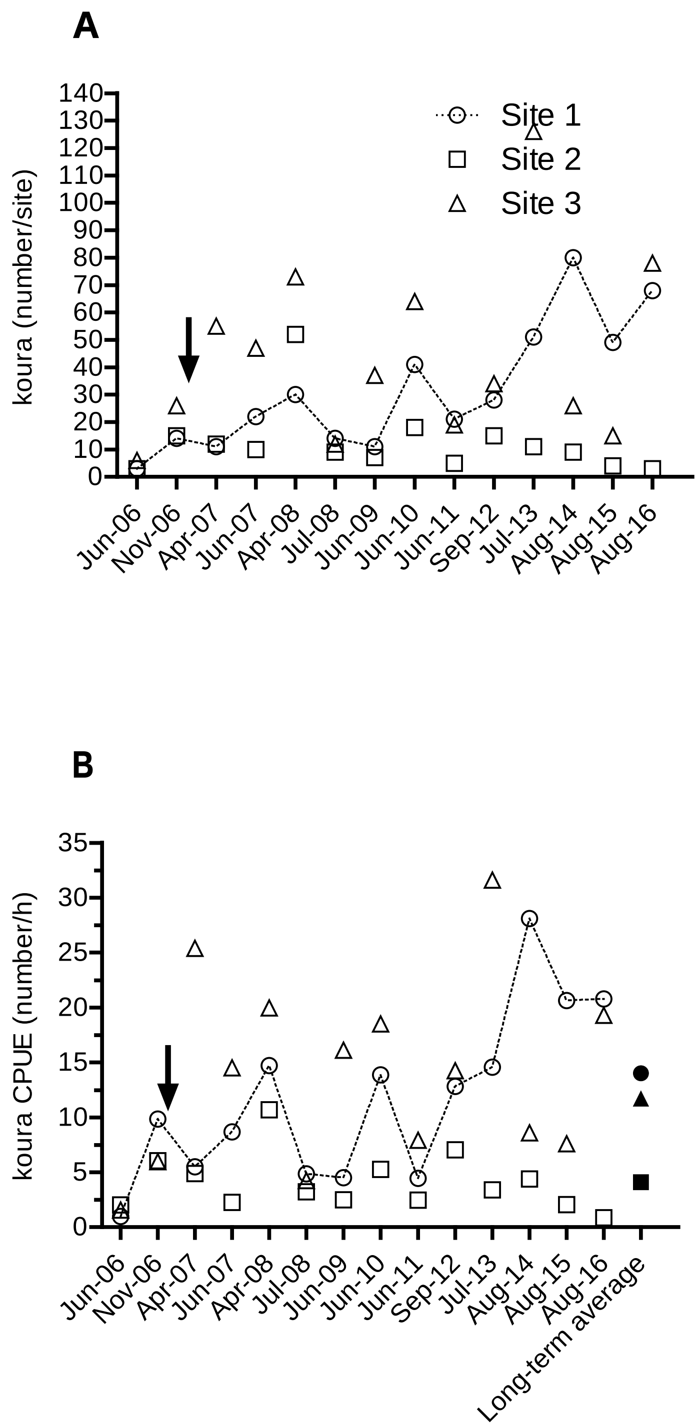


Figure 7. Relative density (A) and CPUE (B) of koura in the Utuhina Stream. Arrows indicate the commencement of alum dosing in the stream.

Figure 8. A large longfin eel (approximately1.3 m total length) captured 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 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 due to water depth >1.3 m. Accumulation of a large bank of fine muddy sediment immediately downstream of the fallen tree had caused significant changes in stream habitat for fish, however the abundance of all species seems unaffected. Subsequent removal of this willow on the true left bank has restored the original character of the stream at this site and a very large longfin eel was captured here in 2016 (Figure 8). Two longfin eels were also captured at this site in 2015 and it is possible that these fish are attracted to this site by the relatively abundance of koura as food (Jellyman 1989) or overhanging and shading bankside vegetation (Glova et al. 1998).

AQUATIC MACROINVERTEBRATES

Semi-quantitative macroinvertebrate community analysis (for soft-bottomed streams; MCI-sb) showed no difference between sites 1 and 2 with values close to the long-term average for years 2009-2016, however the value for site 3 was lower than previously observed (Figure 9). Values for the MCI-sb index fell within the "fair to good" quality classes (Table 1) of Stark & Maxted (2007) for all three sites, with the lowest value recorded from the downstream reach. 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 sites 1 and 2, 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). Although Clarke recorded a decline in MCI scores following commencement of alum dosing in 2006, this decline occurred at all sites including the upstream control site so was unlikely to be related to effects of alum. Clarke's calculation of MCI scores was based on the existing stony-bottom stream protocols prior to development of the soft-bottomed method (Stark & Maxted 2007) and the values given in Figure 9 for June 2006 are estimated from the respective stony-bottom MCI values given by Clarke.

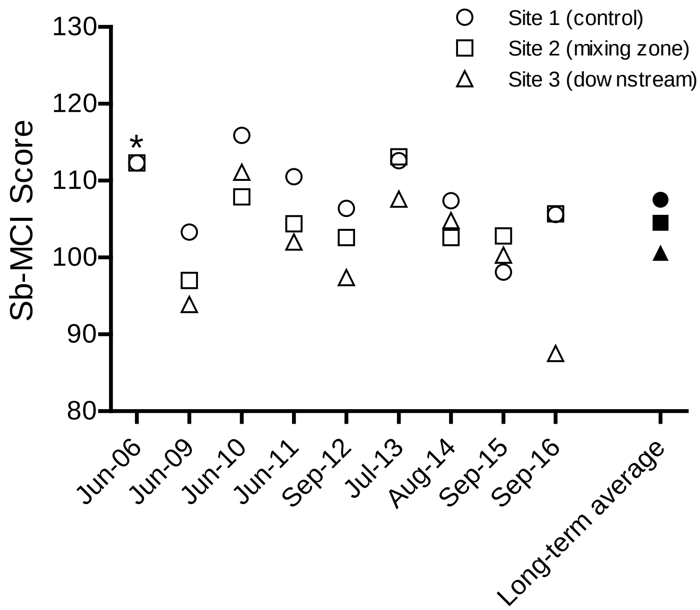


Figure 9. Soft-bottom stream semi-quantitative macroinvertebrate community assessment (Sb-MCI) for the Utuhina Stream since June 2006. * – values for sites 1 & 2 approximated from data in Clarke 2006.

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 two koura large enough for tissue analysis were captured at site 2 (alum mixing zone) but a sufficient number of large koura were obtained at the other sites and adequate numbers of common bully were obtained from all three sites.

In some of the previous years there was some evidence of aluminium bioaccumulation downstream of the Utuhina Stream alum diffuser, but total aluminium concentrations were generally low in tissues from both species (Ling 2015). Concentrations of aluminium in the tissues of koura (Figure 10) and common bully (Figure 11) are generally highly consistent across years with highest concentrations occurring in the gill tissue followed by the hepatopancreas (HP) and liver of koura and common bully. All animals appeared healthy and unaffected by these relatively low tissue aluminium levels.

Aluminium bioaccumulation primarily affects the gills of fish (Sparling & Lowe 1996) and crayfish (Alexopoulos et al. 2003) with little bioaccumulation occurring in internal organs. Toxicity is associated with disruption of gill osmoregulatory and respiratory functions. Alexopoulos et al. (2003) observed significant accumulation of aluminium on the gills of freshwater crayfish and significant changes in behavior at concentrations similar to those used to dose the Utuhina Stream although these were only apparent in the absence of any material (snail mucus in their study) that could act as a sink for removing aqueous aluminium. Production of alum floc and sorption to other materials, e.g., sediment and macrophytes, in the stream are likely to reduce aluminium bioavailability, and measured concentrations in the gills of Utuhina Stream koura were significantly lower than those recorded by Alexopoulos et al. which exceeded 1000 mg/kg dry weight.

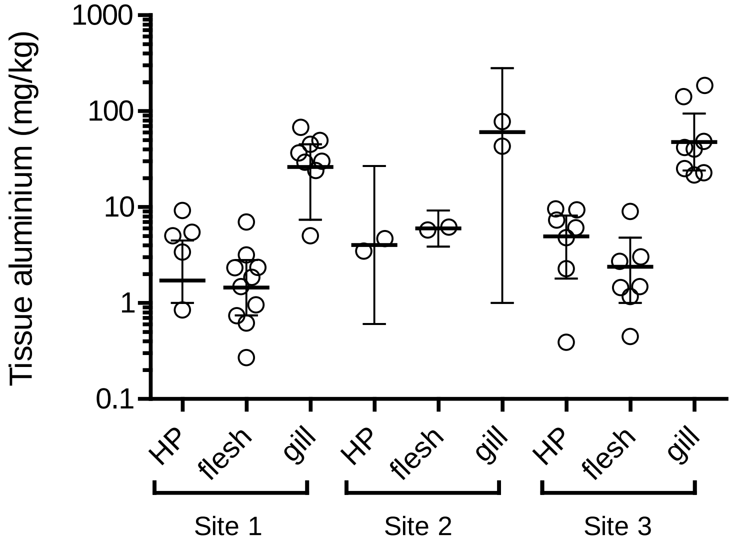


Figure 10. Koura tissue (hepatopancreas, flesh and gill) aluminium concentrations (mg/kg) - geometric mean with lower and upper 95% confidence intervals (CI). Site 1 = upstream control reach, Site 2 = alum mixing zone, Site 3 = downstream reach.

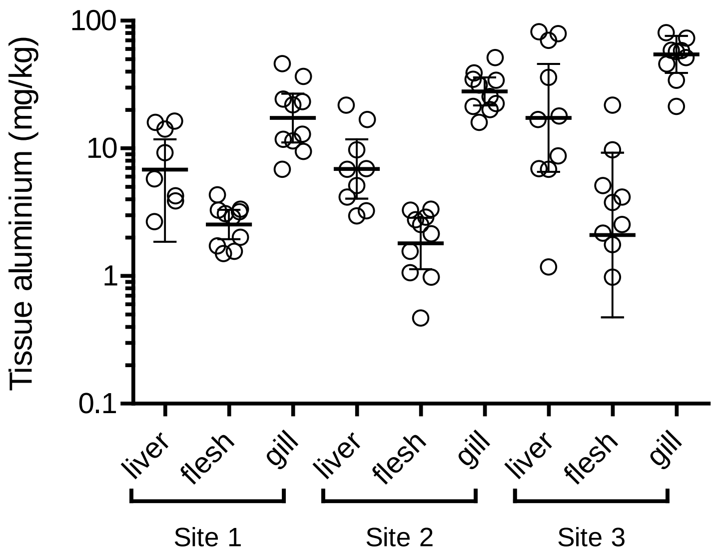


Figure 11. Common bully tissue (liver, flesh and gill) aluminium concentrations (mg/kg) - geometric mean with lower and upper 95% confidence intervals (CI). Site 1 = upstream control reach, Site 2 = alum mixing zone, Site 3 = downstream reach.

REFERENCES

Alexopoulos, E., McCrohan, C.R., Powell, J.J., Jugdaohsingh, R., White, K.N. (2003) Bioavailability and toxicity of freshly neutralized aluminium to the freshwater crayfish *Pacifastacus leniusculus*. Archives of Environmental Contamination and Toxicology 45, 509–514.

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.

Burns, N.M., Rutherford, J.C., Clayton, J.S. (1999) A monitoring and classification system for New Zealand lakes and reservoirs. *Lake and Reservoir Management* 15: 255-271.

Clarke, H. (2006) The effects of alum on the macroinvertebrate community index (MCI) in the Utuhina Stream. Unpublished project report. Auckland University of Technology. 35pp.

Glova, G.J., Jellyman, D.J., Bonnett, M.L. (1998) Factors associated with the distribution and habitat of eels (Anguilla spp.) in three New Zealand lowland streams, New Zealand Journal of Marine and Freshwater Research 32: 255-269, DOI:10.1080/00288330.1998.9516824

Jellyman, D.J. (1989) Diet of two species of freshwater eel (Anguilla spp.) in Lake Pounui, New Zealand. New Zealand Journal of Marine and Freshwater Research 23: 1-10.

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) 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.

Ling, N. (2015) Utuhina Stream monitoring 2014: effects of continuous alum dosing on fish and aquatic invertebrates. Client Report prepared for Environment Bay of Plenty. University of Waikato, Hamilton. 16 pp.

Sparling, D.W, Lowe, T.P. (1996) Environmental hazards of aluminium to plants, invertebrates, fish, and wildlife. Reviews of Environmental Contamination and Toxicology 145: 1-127.

Stark, J.D., Maxted, J.R. (2007) A biotic index for New Zealand's soft-bottomed streams. *New Zealand Journal of Marine and Freshwater Research* 41:1, 43-61.

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.