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Alum Dosing Effects on Fish and Aquatic Invertebrates: Utuhina Stream 2025

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Cover image: Downstream view of Utuhina Stream at Site 2 below the alum dosing point.

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Executive Summary

The Bay of Plenty Regional Council holds resource consent to alum (aluminium sulphate) dose the Utuhina Stream, an inflow to Lake Rotorua. Under circumneutral pH (pH 6–8) aluminium binds dissolved phosphate, reducing availability for phytoplankton and thereby inhibiting formation of algal blooms. Monitoring surveys for potential impacts on the fish and macroinvertebrate communities due to alum dosing on the Utuhina Stream are conducted annually. This report presents the results from the 2025 survey.

Macroinvertebrates, fish and kōura (freshwater crayfish; *Paranephrops planifrons*) were sampled from one control (Site 1) and two treatment (Sites 2 and 3) reaches of the Utuhina Stream using sweep nets for macroinvertebrates and bank mounted electrofishing for kōura and fish. Common bully (*Gobiomorphus cotidianus*) were the numerically dominant fish species, constituting 97% of individuals caught, with juvenile trout and eels (*Anguilla* sp.) also captured. Kōura were present at all sites, but in low abundance compared to common bully. There was an improvement in the semi-quantitative macroinvertebrate community (soft-bottomed streams; MCI-sb) score at Sites 1 and 3 in 2025 compared to the previous years, with Site 1 and Site 3 returning to the good (MCI-sb >100) category. However, the MCI-sb score for the Site 2 reach declined in characterisation from good in 2024 to fair (MCI-sb 80–100) in 2025. Large interannual variation in MCI-sb scores is typical for these reaches of the Utuhina Stream, which have been attributed to flood-related disturbances of the stream bank morphology and in-stream vegetative cover (Ling 2021).

Subsamples of up to 10 common bully and kōura from each site were frozen for later analysis of tissue aluminium concentrations. Common bully (flesh, gill, liver) and kōura (flesh, gill, hepatopancreas) tissue samples were triple digested using tetramethylammonium hydroxide, cold hydrogen peroxide and nitric acid. The samples were then diluted and aluminium concentrations determined by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Common bully sample numbers were limited at Site 3 due to small body sizes preventing extraction of tissues with sufficient mass for analysis, this prevented statistical comparison between upstream (Site 1) and downstream (Sites 2 and 3) of the alum dosing point. However, common bully tissue concentrations were generally equivalent to long-term mean values. Low sample size was also a factor limiting analysis of kōura at Site 1 due to the small number of individuals captured and small body size. Overall, there was little difference in tissue aluminium concentrations between upstream and downstream reaches of the alum dosing point. A notable difference was observed at Site 3 where 2025 kōura flesh concentrations (geometric mean 20.4 mg Al kg^{-1} wet weight) were significantly higher (ANOVA, $P < 0.05$) than the long-term mean concentrations (geometric mean 3.2 Al kg^{-1} wet weight). However, both long-term and 2025 kōura flesh concentrations were well below levels likely to result in toxicological impacts or present a risk to human health via consumption.

The findings of the current report support previous conclusions that alum dosing of the Utuhina Stream does not have a notable effect on macroinvertebrate and fish communities. While there are occasional interannual and site differences, these can be primarily attributed to hydrological and habitat variability.

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Introduction

The water quality of Lake Rotorua has undergone significant eutrophication since the 1960s, with prevalent algal blooms driven by land use change, farm intensification and discharge of treated wastewater from Rotorua City (Donald et al. 2019). The Lakes Rotorua and Rotoiti Action Plan (Bay of Plenty Regional Council 2009) sought to lower the trophic level index (TLI) of Lake Rotorua from 4.9 to 4.2 by reducing loading of nitrogen and phosphorus to the lake. It has been estimated that to achieve a TLI target of 4.2, a total phosphorus load of 33.7 – 38.7 tonnes per year would be required, along with a target of 435 tonnes nitrogen per year (Tempero et al. 2015; McBride 2022). Currently, this requires an annual reduction in the external phosphorus load to the lake of 10–15 tonnes per year or 43–64% of the current anthropogenic phosphorus load (Tempero et al. 2015).

The Lakes Rotorua and Rotoiti Action Plan proposed alum treatments be applied in up to three streams (Utuhina, Puarenga and one other) to reduce dissolved reactive phosphorus (DRP) entering Lake Rotorua by 6 tonnes per year (Bay of Plenty Regional Council 2009). The Utuhina Stream carries an estimated 4.0 tonnes of total phosphorus to Lake Rotorua each year, of which 1.6 tonnes is in the form of DRP (Hamill 2022). Based on a 1:1 molar binding ratio for aluminium and phosphorus, it was estimated that an alum dosing rate of 1 ppm (1 g m^{-3}) would remove the majority of DRP in the Utuhina Stream, with some excess phosphorus binding capacity remaining once the alum floc reached Lake Rotorua (Sanila 2026). Compared to lake bulk dosing rates which can exceed 50 mg Al L^{-1} (Brattebo et al. 2017; Hobbs and Roseweed 2025), the maximum dose rate applied to the Utuhina Stream was assessed as suitably conservative and unlikely to result in toxicological impacts within the circum-neutral pH range, although the effects of long-term exposure has not been widely investigated (Tempero 2015). Alum dosing of the Utuhina Stream began on a trial basis in mid-2006, with the Bay of Plenty Regional Council's current resource consent renewed in March 2018 and set to expire in July 2031. Alum dosing of the stream is varied according to stream flow but may not exceed a monthly average of 1 mg Al L^{-1} over background total aluminium levels (Resource Consent RM18-0213-AP). Total application of alum to the Utuhina Stream over the treatment period from July 2006 to 1 January 2026 was 11,713 tonnes, at a mean dose rate of 25 tonnes of aluminium per year (Figure 1).

Alum dosing is widely used for wastewater treatment and restoration of freshwater ecosystems through the removal of DRP, but it is not without risk (Cooke et al. 2005). At circumneutral pH (6–8), common to most surface waters, alum forms aluminium hydroxide ($Al(OH)_3$), a non-toxic white insoluble precipitate which adsorbs dissolved phosphorus, reducing its availability for phytoplankton growth. However, at high (>8.5) or low (<5.5) pH, dissolved monomeric (Al^{3+}) and hydroxy aluminium species occur in varying proportions with respect to acidic (i.e., Al^{3+}, $AlOH^{2+}$, $Al(OH)_2^{+}$) and alkaline (i.e., $Al(OH)_4^{-}$) conditions, with increasing toxicity to aquatic organisms. Aluminium toxicity primarily occurs through disruption of osmoregulation and respiration process at the gills (Alexopoulos et al. 2003;

Gensemer et al. 2018), which are the primary site of gas exchange, ion transport, and waste excretion in fish and crustaceans (Playle and Wood 1989).

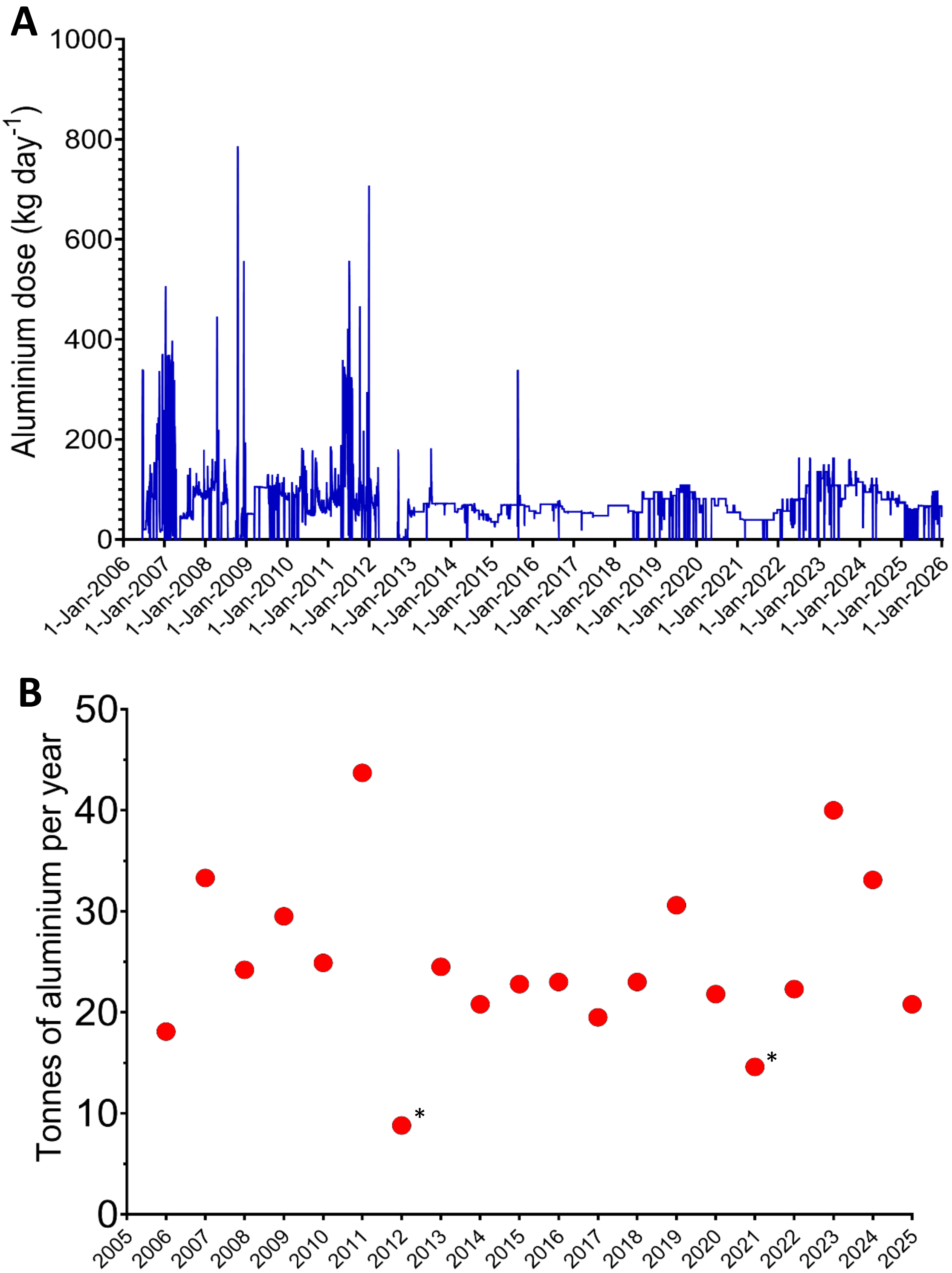

Figure 1. Quantity of aluminium discharged daily (A) and annually (B) to the Utuhina Stream since the commencement of dosing in June 2006. * alum dosing was mostly shut down from 1 July 2012 to 10 December 2012 for system maintenance and reduced in 2021 due to covid restrictions.

The University of Waikato has been contracted to undertake annual assessments of potential ecological impacts on the fish and macroinvertebrate communities from alum dosing of the Utuhina Stream. Determination of the bioavailability of aluminium in common bully (*Gobiomorphus cotidianus*) and kōura (freshwater crayfish; *Paranephrops planifrons*) has also been undertaken annually since 2009. Recent surveys of stream macroinvertebrates have shown no consistent differences between the upstream control site and the sites downstream of the alum dosing (Tempero and Ling 2025). There was some evidence of aluminium bioaccumulation in the gill and liver tissues of common bully in some years, but there has been no evidence of aluminium bioaccumulation in the tissues of kōura (Tempero and Ling 2025).

Methods

Study site

Lake Rotorua is the largest of 12 lakes jointly managed under the Rotorua Te Arawa Lakes Programme. It has a surface area of 80.6 km^2 and a mean depth of 10.8 m (maximum depth 45 m) (Burger et al. 2011). Lake Rotorua is currently classified as eutrophic, but water quality has significantly improved since the mid-2000s, with the TLI currently fluctuating around the target of 4.2 (Bay of Plenty Regional Council monitoring data). The Utuhina Stream is one of nine major inflows to Lake Rotorua. It drains a catchment of around 60 km^2, with land-use divided approximately evenly between urban, dry stock, bush and scrub, and forestry (Tempero et al. 2015). The Utuhina Stream arises west of Lake Rotorua and flows through residential and industrial areas within Rotorua City where it receives geothermal and stormwater inflows before discharging into the lake at Te Ruapeka Bay. The stream becomes highly channelised as it passes through the city; with a mean discharge of 1.81 $m^3\ s^{-1}$ to Lake Rotorua (Hammil 2018).

Fish community survey

Fish community abundance and density were determined for three 50-m reaches of the Utuhina Stream in December 2025 (Figure 2). Site 1 (control) was located 50 to 100 m upstream of the alum discharge in-stream diffuser, Site 2 was 50 to 100 m downstream of the alum diffuser, and Site 3 was 400 m further downstream of Site 2 in the vicinity of Lake Road. Relative fish abundance (total numbers captured) and CPUE (fish captured per hour) were estimated using a two-pass electrofishing procedure according to the method of Landman et al. (2008). A Ministry of Agriculture and Fisheries 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. Two teams of three people performed the fishing while one person remained on the bank for machine operation and safety. Estimates of absolute fish numbers in this stream could not be calculated from the two-pass removal method as catches are highly variable and occasionally greater fish numbers are captured in the second fishing passes. Common bully are the most abundant species in the Utuhina Stream and obtaining consecutive reductions in this species using multiple pass electrofishing is 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 kōura 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).

Aquatic macroinvertebrate community survey

Aquatic macroinvertebrate community analysis was undertaken separately to electrofishing but from the same three stream reaches examined for relative fish abundance. Invertebrates were sampled in October 2025, two months before electrofishing, to avoid effects of electrofishing disturbance. Sampling and analysis were 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 sorting and enumeration.

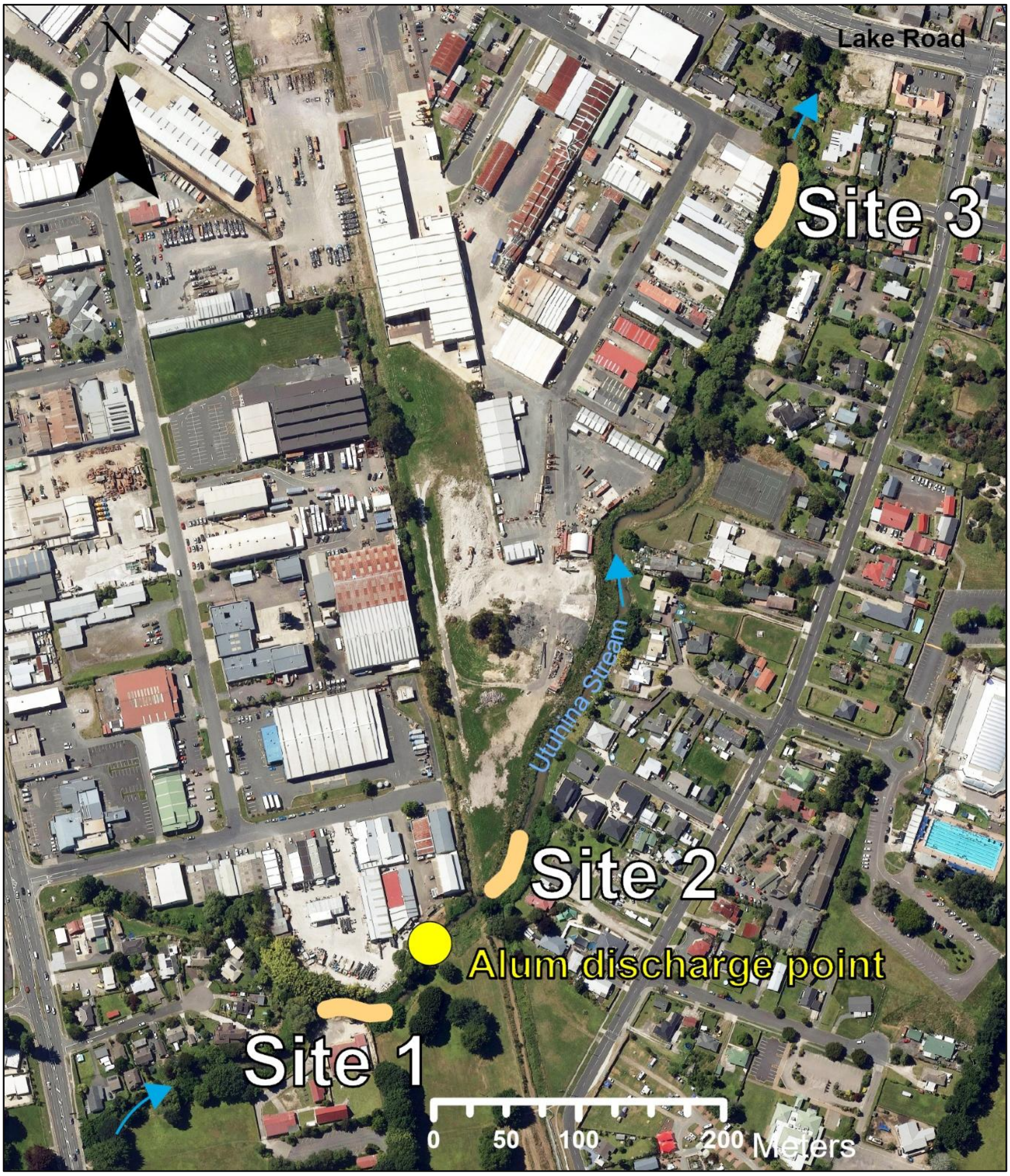

Figure 2. Macroinvertebrate and electrofishing sites on the Utuhina Stream including above the alum discharge (Site 1), in the alum mixing zone (Site 2) and upstream of Lake Rd (Site 3).

Tissue analysis

Samples of liver (common bully) or hepatopancreas (kōura), flesh and gills were carefully dissected using acid-washed instruments. Samples were weighed to the nearest 0.001 g and digested using tetramethylammonium hydroxide, heat (60°C) and mixing. The colloidal suspension was then cooled in ice and partially oxidized by the addition of cooled hydrogen peroxide, then allowed to oxidize overnight at 4°C. Metals were solubilized by acidification with nitric acid and heating (90°C for 2 hours). After cooling to room temperature, samples were diluted and filtered prior to analysis by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) by the University of Waikato Mass Spectrometry Facility. All tissue element concentrations were determined on a wet 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

Fish community

Four eels (*Anguilla* sp.; each >500 mm total length) were captured, one at Site 3 and three at Site 2. Common bully (*Gobiomorphus cotidianus*), juvenile trout (species undetermined), adult rainbow trout (*Oncorhynchus mykiss*) and kōura (*Paranephrops planifrons*) (Figure 3), were captured in the 2025 electrofishing survey. Common bully were the most numerically dominant fish species at each site, constituting 97% of individuals caught.

Figure 3. A kōura (*Paranephrops planifrons*) and common bullies (*Gobiomorphus cotidianus*) captured at Site 1 upstream of the alum dosing point December 2025.

Common bully relative density (fish per 50 m reach; Figure 4A) and CPUE (number hour^{-1}; Figure 4B) has varied substantially between years (2006–2025) and across sites, although numbers had increased in 2025 compared to 2024. Both measures indicate that common bully abundance was lower at the upstream control site (Site 1; long-term means: 256.5 fish site^{-1}, CPUE 101.6 fish hour^{-1}) compared to Site 2 (long-term means: 446.5 fish site^{-1}, CPUE 159.8 fish hour^{-1}) and Site 3 (long-term means: 595.5 fish site^{-1}, CPUE 184.2 fish hour^{-1}), which are downstream of the alum dosing point, although the magnitude of the difference is generally stable between years.

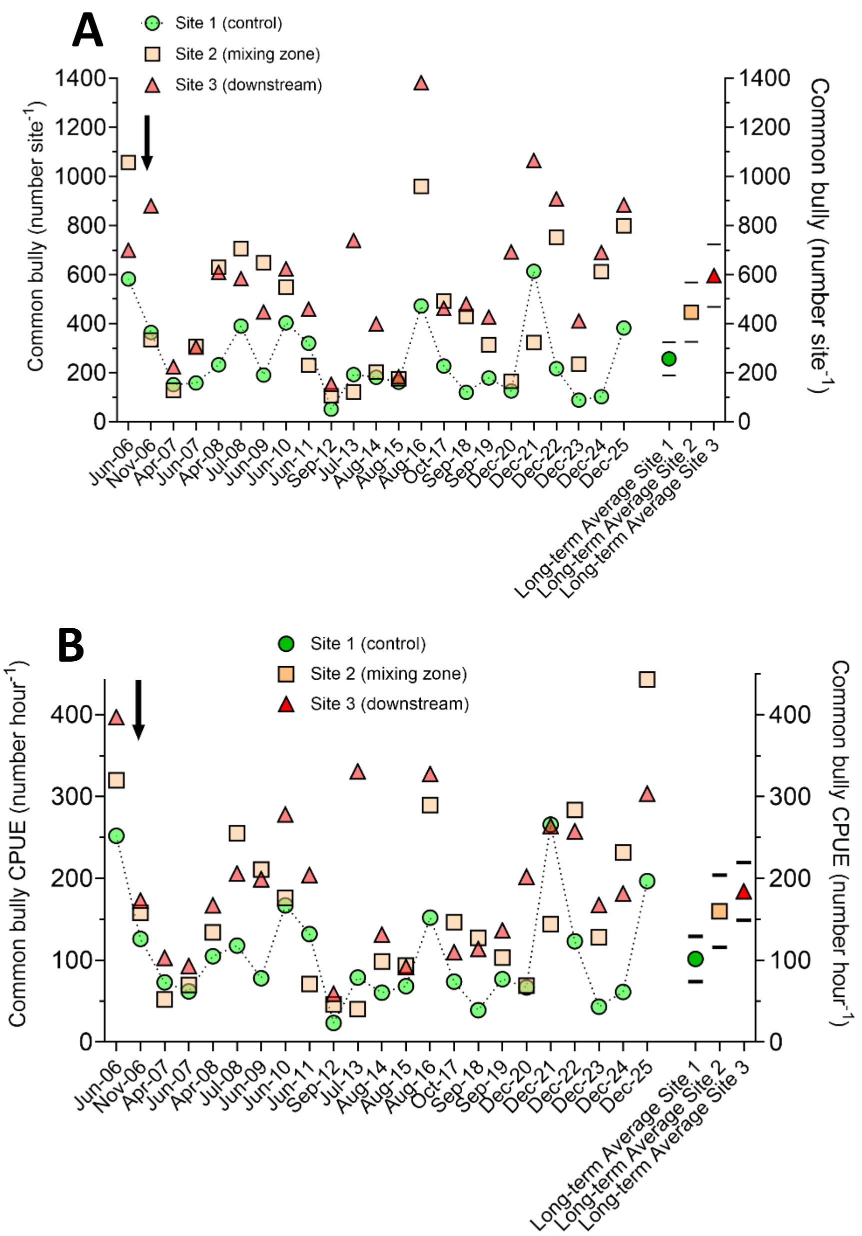

Figure 4. Common bully numbers captured per site (A) and catch per unit effort (CPUE; B) in the Utuhina Stream (June 2006 – December 2025). Arrow indicates the commencement of alum dosing in the stream. Values for long-term averages are means ± 1 standard deviation.

Juvenile trout (young of the year) were present at all sites, with density similar between the upstream control site (Site 1; long-term means: 26.7 fish site^{-1}, CPUE 10.4 fish hour^{-1}) and Site 2 (long-term means: 29.5 fish site^{-1}, CPUE 10.4 fish hour^{-1}), while fish density at Site 3 has been lower than the long-term mean for the past 4 years (long-term means: 16.0 fish site^{-1}, CPUE 5.6 fish hour^{-1}) (Figure 5). A single adult trout (fork length 475 mm) was captured at Site 3 and then returned to the stream.

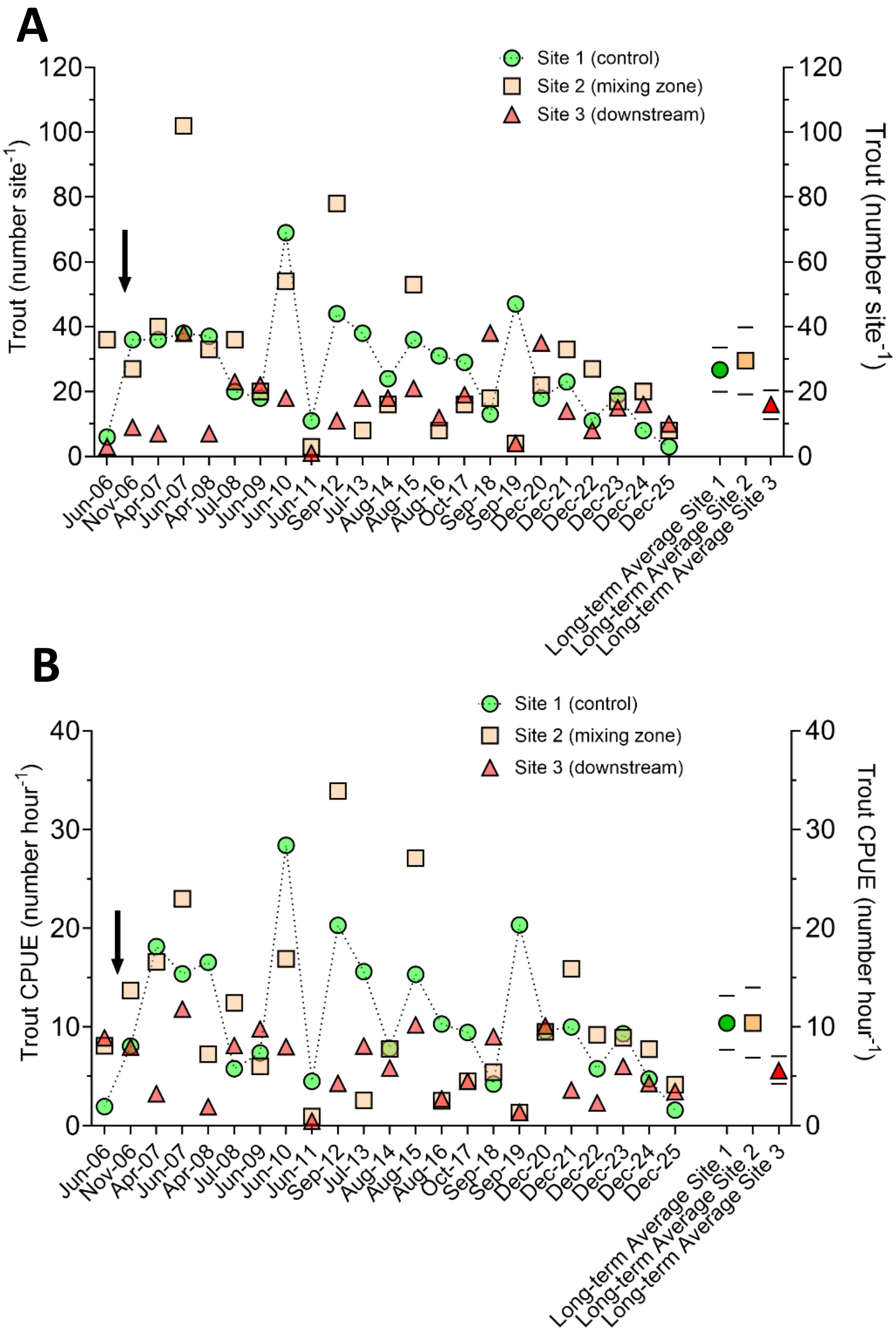

Figure 5. Total numbers of juvenile trout captured per site (A) and catch per unit effort (CPUE; B) in the Utuhina Stream since June 2006. Arrow indicates the commencement of alum dosing in the stream. Values for long-term averages are means ± 1 standard deviation.

Kōura relative abundance has fluctuated between years but were captured at all three sites in 2025. Numbers per site were similar to the long-term means at Site 2, which has generally been the site of least abundance (long-term means: 12.7 kōura site^{-1}, CPUE 4.6 kōura hour^{-1}). Site 3 abundance was notably lower in 2025 compared to the long-term mean, as this site generally has had the greatest abundance (long-term means: 40.0 kōura site^{-1}, CPUE 2.30 kōura hour^{-1}). Site 1 abundance was lower than the long-term mean for that site (long-term means: 24.4 kōura site^{-1}, CPUE 9.4 kōura hour^{-1}) (Figure 6).

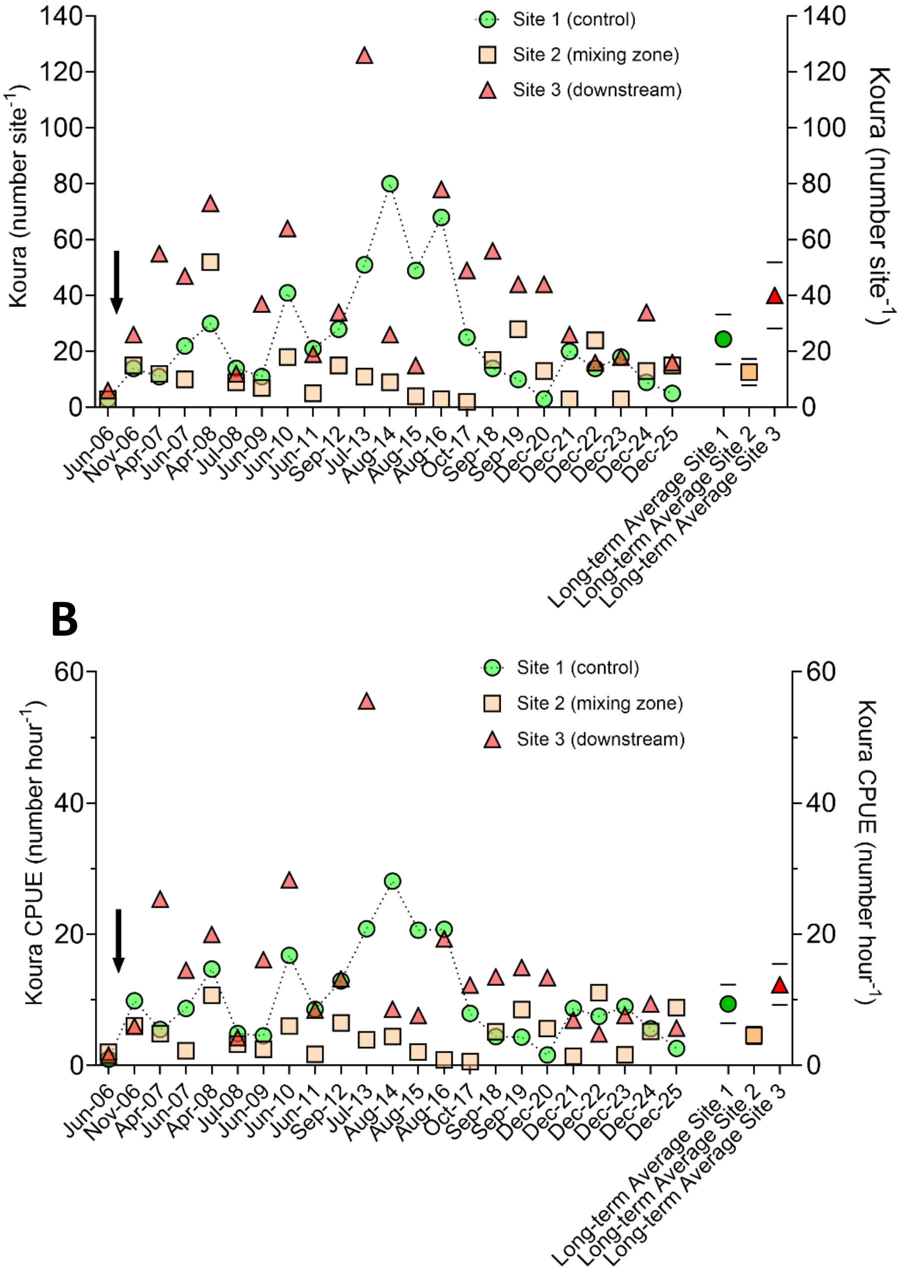

Figure 6. Kōura captured per site (A) and catch per unit effort (CPUE; B) in the Utuhina Stream since June 2006. Arrow indicates the commencement of alum dosing in the stream. Values for long-term averages are means ± standard deviation.

Macroinvertebrate community (MCI-sb)

The semi-quantitative macroinvertebrate community analysis for soft-bottomed streams; (MCI-sb) score had improved at Sites 1 and 3 in 2025 compared to 2024, returning to near the long-term mean. However, Site 2 scored <100 placing it in the fair-quality class for the 2025 survey (Figure 7).

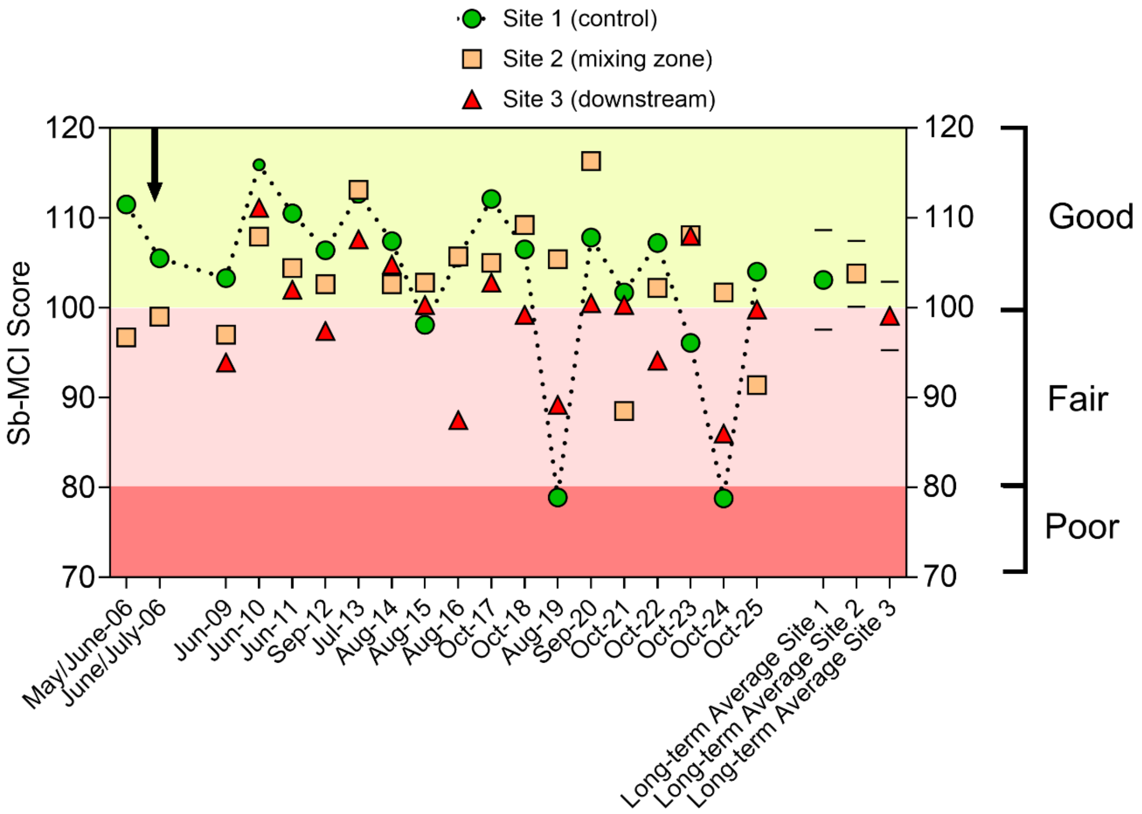

Figure 7. Soft-bottom stream macroinvertebrate community assessment (Sb-MCI) for the Utuhina Stream since June 2006. Values for long-term averages are means ± 95% confidence intervals. Note: values for sites 1 and 2 in 2006 are approximated from data in Clarke 2006.

Tissue aluminium concentrations

The small size of the common bully specimens (mean 60.6 mm total length) collected at Site 3 occasionally precluded extraction of sufficient tissue mass for analysis. As a result, sample numbers for gill and liver tissues at Site 3 were reduced (i.e., gill n = 4; liver n = 2), and no statistical comparisons were made with Site 3 liver tissue concentrations. Tissue concentrations were log transformed prior to statistical analysis to meet the assumption of normal distribution. There were no significant differences (ANOVA, P >0.05) in common bully geometric mean flesh aluminium concentrations between sites. There were also no significant differences (ANOVA, P >0.05) in geometric mean gill aluminium concentrations between Site 1 and Site 2; however, the Site 3 geometric mean gill concentration (1.94 mg Al kg^{-1} ww) was significantly lower (ANOVA, P =0.02) than the Site 2 mean gill concentration (11.3 mg Al kg^{-1}

ww) (Figure 8). Lognormal ANOVA tests with specified multiple comparisons between 2025 geometric mean tissue concentrations and long-term mean tissue aluminium concentrations for each site determined there were no significant differences (P >0.05) apart from gill tissue at Site 2. In this case, the 2025 geometric mean concentration (11.3 mg Al kg^{-1} ww) was significantly lower (P <0.001) lower than the long-term mean (34.8 mg Al kg^{-1} ww) (Figure 8). There appears to be a large difference between 2025 Site 3 flesh mean concentration and the long-term mean, however the difference was not significant (ANOVA, P = 0.053)

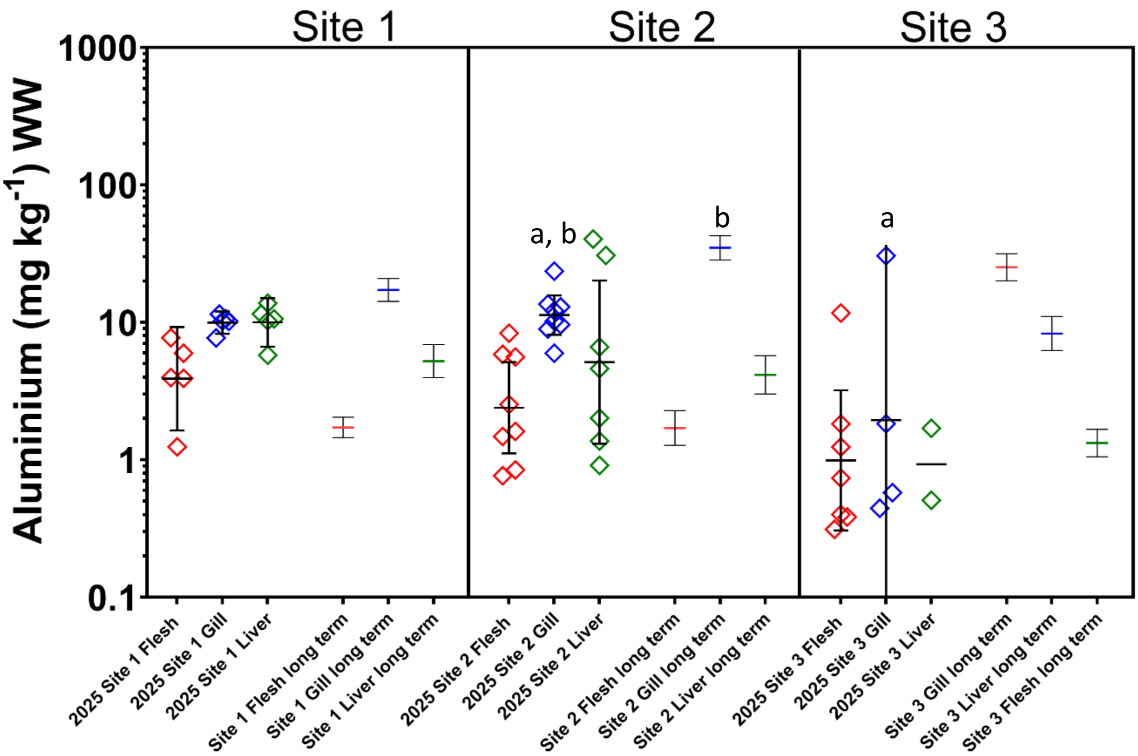

Figure 8. Common bully tissue (liver, flesh and gill) aluminium concentrations (mg kg^{-1} wet weight) for 2025 and mean tissue concentrations for monitoring years 2009–2024 - geometric mean with lower and upper 95% confidence intervals (CI). Matching letters indicate statistically significant differences between groups. Site 1 = upstream control reach, Site 2 = alum mixing zone, Site 3 = downstream reach.

Only two kōura were of sufficient size for analysis for tissue aluminium concentrations at Site 1 and sufficient flesh and hepatopancreas tissue for analysis could only be extracted from one of the specimens. Therefore, Site 1 was excluded from further statistical comparisons. There were no significant differences (ANOVA, P >0.05) in flesh, gill and hepatopancreas tissue geometric mean aluminium concentrations between sites 2 and 3 (Figure 9). Comparisons between 2025 geometric mean tissue concentrations and long-term mean tissue aluminium concentrations for each site were also conducted. At Site 2, there was a significant difference (ANOVA, P <0.05) in the geometric means of 2025 gill tissue (8.4 mg Al kg^{-1} ww) and the long-term mean (25.3 mg Al kg^{-1} ww). There was also a significant difference (ANOVA, P <0.01) in geometric mean flesh aluminium concentrations at Site 3, with 2025 mean concentration significantly greater (20.4 mg Al kg^{-1} ww) than the long-term geometric mean (3.2 mg Al kg^{-1} ww).

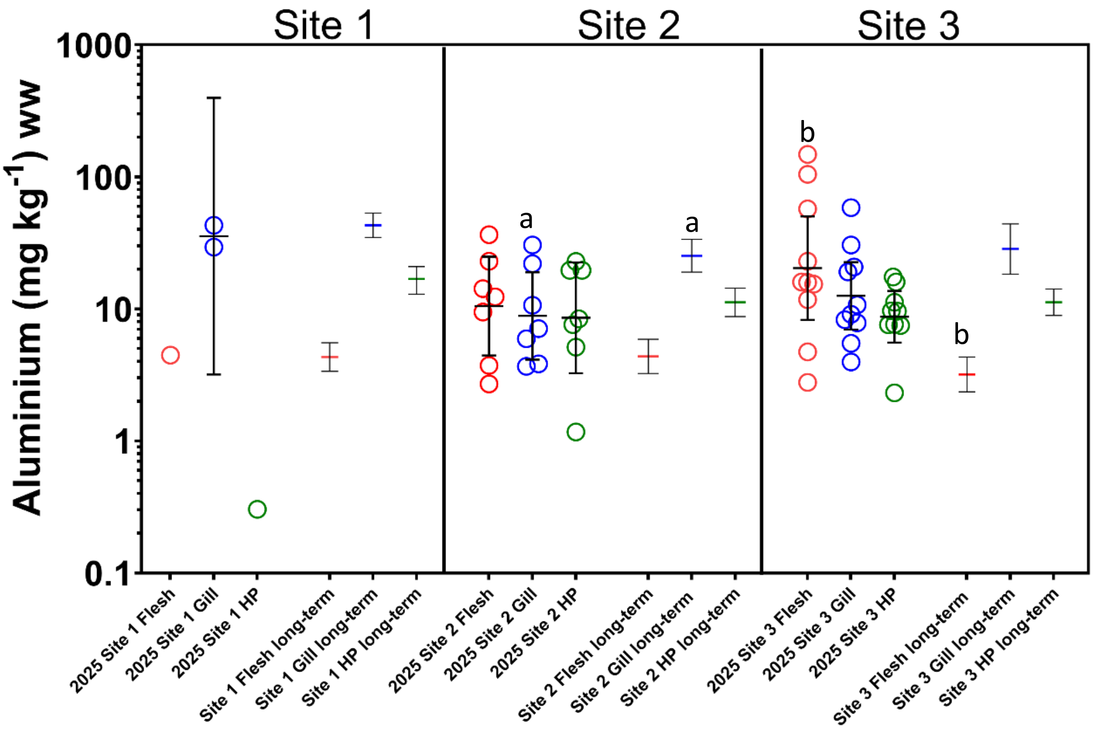

Figure 9. Kōura tissue (flesh, gill and hepatopancreas) aluminium concentrations (mg kg^{-1} wet weight) for 2025 and mean tissue concentrations for monitoring years 2009–2024 - geometric mean with lower and upper 95% confidence intervals (CI). Matching letters indicate statistically significant differences between groups. Site 1 = upstream control reach, Site 2 = alum mixing zone, Site 3 = downstream reach.

Discussion

Annual fish and macroinvertebrate surveys of the Utuhina Stream have been conducted since 2006 as a resource consent requirement for the Bay of Plenty Regional Council to alum dose for phosphorus control. The macroinvertebrate survey was conducted at three 50 m reaches in October 2025, one upstream and two downstream of the alum dosing point. An electrofishing survey of the same reaches was conducted in December 2025. Common bully liver, gill and muscle tissues, along with kōura gill, hepatopancreas and muscle tissues were analysed for aluminium content by ICP-MS.

Fish community

Although no kōaro were caught during the 2025 electrofishing survey, the capture of four eels was the first eel capture since 2022 and was the highest number captured in the 21 years this survey has been conducted. Eels are comparatively rare above the Kaituna falls and to avoid unnecessary stress from sedation were returned to the stream without measurement or species identification

There is typically large interannual variation in fish and kōura CPUE across all three surveyed reaches, much of which can be tentatively ascribed to modification of habitat as the stream is highly channelised as it passes through the city. During major flood events the stream bed becomes highly disturbed as the extent of instream and bankside vegetative cover is limited and significant erosion of the banks has been observed (Ling 2021). Common bully and kōura prefer relatively low flow velocities of around 0.4 $m^3 s^{-1}$ and stable substrate, while the Utuhina is primarily composed of mobile pumice sands and gravels at Sites 2 and 3 (Jowett and Richardson 1995; Collier and Smith 2003; Jowett et al. 2008) which are likely to be physically displaced by high velocities associated with major flood events. The data presented in this report further supports the conclusion by Tempero and Ling (2025) that alum dosing does not appear to have a notable effect on the fish and kōura community. Site and interannual variations can be primarily ascribed to hydrological conditions and habitat variability.

Macroinvertebrate community

The semi-quantitative macroinvertebrate community index for soft-bottomed streams (MCI-sb) score at Site 1 had improved from poor in 2024 to good (i.e., >100) after scoring poor in 2024. The MCI-sb at Site 2 declined in 2025 although remained in the fair category and both Sites 1 and 3 were similar to their long-term means (Figure 7).,. Overall, variation appears to be greatest at Sites 1 and 3, with Site 2 being more stable and interannual variation is likely due to natural factors such as stream velocity rather than alum dosing (Stark and Maxted 2007; Ling 2021).

Tissue aluminium concentrations

Kōura and common bully tissue aluminium concentrations were generally within the ranges observed in previous surveys. Common bully geometric mean flesh and gill tissue concentrations at Site 3 appeared to be lower than the long-term means for this site but were not significantly different. Significant differences were present between 2025 Site 2 gill concentrations and Site 3 long-term means and between Site 2 and Site 3 gill concentrations. However, there was large variation in observed gill tissue aluminium concentrations at Site 3, and when coupled with the low sample size these results should be interpreted with caution. In addition, the magnitude of the difference between the geometric means of 2025 Site2 gill tissues and the long-terms (i.e., a difference of 16.9 mg Al kg^{-1} ww) is inconsequential in terms of potential toxicological impact. Acute toxicological impacts from aluminium on freshwater fauna primarily occur through monomeric aluminium ions (Al^{3+}) disrupting osmoregulatory and respiratory processes at the gill surface and is mediated by environmental pH (Gensemer and Playle 1999). Aluminium concentrations and environmental pH within the Utuhina Stream fall within the safe range and acute effects are unlikely to occur in fish and macroinvertebrates. Further, chronic toxicity and accumulation from ingestion of aluminium is of minor concern as vertebrates and macroinvertebrate species such as freshwater crayfish have been found to effectively excrete aluminium with minimal uptake via ingestion (Tempero 2015). For example, tissue (gill, liver, muscle) aluminium concentrations from perch (*Perca fluviatilis*), pike (*Esox lucius*), roach (*Rutilus rutilus*) and bream (*Abramis brama*) sampled from two Irish lakes following bulk alum dosing (1 mg Al L^{-1}) were of a similar range to those observed for common bully in the Utuhina Stream (Bennett et al. 2026). Similarly, no differences were found between fish tissue concentrations pre- and post-alum dosing of the lakes (Bennett et al. 2026).

The 2025 kōura flesh aluminium concentrations at Site 3 were significantly higher (20.4 mg kg^{-1}) compared to the long-term mean (3.2 mg kg^{-1}). However, an exposure study of spiny-cheek freshwater crayfish (*Faxonius limosus*) to polyaluminium chloride reported that resulting flesh aluminium concentrations of 103 mg kg^{-1} did not appear to negatively impact animal health (Nędzarek and Czerniejewsk 2022). Further, tissue aluminium concentrations declined following exposure indicating depuration from tissues. The low number of samples from Site 1 (i.e., flesh n = 1; gill n = 2; hepatopancreas n = 1) were due low capture rate at this site, and the small body size of captured providing insufficient tissue for analysis. Kōura are a traditional mahinga kai species for Māori and excessive tissue aluminium levels would be of concern, as aluminium accumulation may affect bone mineralisation and formation in humans (Crisponi et al. 2013). However, the risk arising from aluminium consumption of kōura from the Utuhina Stream is negligible as 2025 mean flesh concentrations were approximately 20 mg kg^{-1}. The European Food Safety Agency established a maximum tolerable weekly aluminium intake of 1 mg per 1 kg of body weight (Bennett et al. 2026). Assuming other food sources were free of aluminium, this would require an 80 kg adult to eat >4 kg of kōura flesh per week to exceed the maximum tolerable intake rate, an ingestion rate that could not practicably be sustained by the stream environment.

Although intraspecific variability in the tissue concentrations of non-essential metals is recognised, it is poorly understood (Pan and Wang 2009). While differences might be expected due to obvious factors such as sex, size, age, diet and metabolic rate, individuals chosen for analysis in this study were selected to be the largest individuals captured on each occasion to reduce some of the influence of such effects. All animals appeared healthy and unaffected by the exposure to alum. Overall, there were no appreciable differences in tissue concentrations between the upstream control site and sites downstream of the alum discharge.

Conclusions

Exposure of macroinvertebrates, fish and kōura in the Utuhina Stream to low continuous alum dosing does not appear to result in changes in community abundance. While there was some departure from long-term mean aluminium concentrations in the gill tissue of common bully and flesh of kōura downstream of the dosing site, these should be considered negligible in terms of potential ecological impacts. In addition, differences in tissue aluminium concentrations does not appear to affect abundance at downstream sites compared to the control site or result in chronic toxicity.

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