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3 March 2013

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Summary

Continuous alum dosing of the Utuhina Stream, Rotorua, has been underway since mid-2006 in order to remove dissolved reactive phosphorus by fine particulate flocculation. Although regular monitoring of fish and macroinvertebrate communities of the stream have failed to detect any significant adverse effects of alum dosing, the possibility exists that benthic macroinvertebrates of Lake Rotorua could be negatively impacted within the area of the depositional fan of material discharged by the Utuhina Stream.

Benthic macroinvertebrates were sampled at sites in the littoral margin of Lake Rotorua within the presumed depositional zone for alum floc discharged by the Utuhina Stream taking into account the presence of a known current flow within this portion of the lake. Invertebrates were sampled at 3 shallow (1 m) and 3 deeper (4 m) sites that represented more or less likely areas for accumulation or impact of alum floc.

Macroinvertebrate abundance, taxa richness, and community composition (assessed using the soft-bottomed macroinvertebrate community index) all differed between shallow and deeper sites as expected based on influences of physical (sediment size and hydraulic energy) and biological (macrophyte abundance) factors.

No clear association between variations in macroinvertebrate community composition could be ascribed to the possible deposition of alum floc and the observed variability is assumed to depend upon other influences. Although alum dosing is only one of several potentially impacting influences on Utuhina Stream water quality, including Rotorua City stormwater and geothermal discharges, the results of this study suggest that there is no obvious negative influence of the Utuhina Stream inflow on benthic macroinvertebrates in the adjacent littoral zones of Lake Rotorua.

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 (nitrogen and phosphorus). Catchment reduction targets of 250 tonnes of nitrogen and 10 tonnes of phosphorus have been established. The Utuhina Stream carries an estimated 3 tonnes of phosphorus into Lake Rotorua each year, of which approximately 2 tonnes is in the form of dissolved reactive phosphorus (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 annually) 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.

Alum dosing of the Utuhina Stream has continued more or less continuously since mid-2006 and the possible impacts on stream fish and macroinvertebrate communities conducted annually have failed to detect any significant adverse effects (Ling 2012).

Alum treatment of natural waters serves to flocculate fine particulate material by neutralizing surface charges and allowing particles to bind together. Flocculation in the presence of phosphate ions causes adsorption of phosphate to the floc (Boisvert et al. 1997) thereby reducing levels of instream DRP. Although alum floc density depends greatly on the relative concentrations of aluminium ions and suspended particulate matter, floc density is sufficiently low that almost all of the Utuhina Stream material will be transported by the hydraulic energy of the stream into Lake Rotorua. Clearwater et al. (unpublished data) conducted a series of toxicity evaluations of the phosphorus inactivation agents Aqual-P (modified zeolite) and alum, and observed effects of alum at the highest tested dose (220 g m^{-2}) on survival and reburial of the fingernail clam (Sphaeridae). This species could therefore represent a relatively sensitive sentinel species for possible impacts of alum floc deposition on the benthic macroinvertebrate fauna in the littoral sediments of Lake Rotorua. Alum dosing of the Utuhina is regulated based on stream discharge and aims to maintain a dose rate of 1 g m^{-3} (1ppm) alum. While this is significantly lower than the dose affecting sphaerids in the study of Clearwater et al., continual discharge of alum floc to the littoral zone of Lake Rotorua could concentrate alum floc within depositional zones and potentially negatively affect benthic macroinvertebrate fauna.

This report presents the results of an assessment of the benthic macroinvertebrate fauna from shallow (1 m) and deeper sites (4 m) within the depositional zone of the Utuhina Stream in Lake Rotorua.

Site Description and Methods

The Utuhina Stream drains a catchment of approximately 59.6 km^2 to the southwest of Lake Rotorua (Hoare 1980). The upper catchment is predominantly pastoral agriculture with the lower catchment wholly urban. The uban area accounts for approximately 25% of the total catchment area and the stream receives stormwater from approximately 35% of Rotorua City (Macaskill et al. 2003). The Utuhina also receives significant geothermal infows within the lower urban catchment before it discharges into Lake Roturua adjacent to the geothermally active area at Ohinemutu. Average stream discharge is 1965 L s^{-1} but the catchment confers little retention of storm flows and the hydrograph responds rapidly to rainfall events with mean annual maximum flows exceeding 19000 L s^{-1} (Bay of Plenty Regional Council 2007). The stream bed of the lower Utuhina is a mobile bed of fine pumice and course sand.

The presence of an anticlockwise gyre in western Lake Rotorua, evident from the long-shore eastward drift of the colloidal sulphur plume from Sulphur Bay and analyses of surface current flows around Ngongataha (Jonathan Abell, unpublished data), suggests that deposition of alum floc from the Utuhina Stream outlet should principally affect the lake bed to the south-east of the stream outlet. Sediment grain sorting by wave action will tend to move fine flocculent material into deeper water rather than depositing it in the shallows close to shore. Utuhina flood flows will also deposit any aluminium floc further offshore into deeper water.

Benthic macroinvertebrates were sampled on 20th November 2012 from 6 sites on the 1 m and 4 m depth contours upstream, offshore and downstream of the Utuhina Stream outlet (Table 1, Figure 1) with respect to the direction of lake current. The upstream sites should therefore be considered as control sites relative to those immediately offshore and downstream. Upstream and downstream 1 m and 4 m sample sites were approximately 250 m and 500 m, respectively, from the stream mouth. Nine sediment samples were taken from each of the 6 sites using a Ponar grab (0.023 m^2 sample area) and individually processed for macroinvertebrates. Sediment was wet-seived (500 µm mesh) and enumerated for all macroinvertebrates present. Macroinvertebrates were enumerated as for the soft-bottomed stream macroinvertebrate community index.

Table 1: Site localities and water depths

	Longitude	Latitude	Depth
Site 1	176 14.765 E	38 7.417 S	0.9 m
Site 2	176 14.884 E	38 7.470 S	0.85 m
Site 3	176 14.944 E	38 7.552 S	0.78 m
Site 4	176 14.899 E	38 7.285 S	3.7 m
Site 5	176 15.039 E	38 7.366 S	3.6 m
Site 6	176 15.179 E	38 7.448 S	3.8 m

Sites 1, 2 and 3 (nominally ~1 m depth) are “upstream”, “stream mouth” and “downstream” of the Uthina Stream outlet, respectively. Sites 4, 5 and 6 (nominally ~4 m depth) are also respectively upstream, stream mouth and downstream.

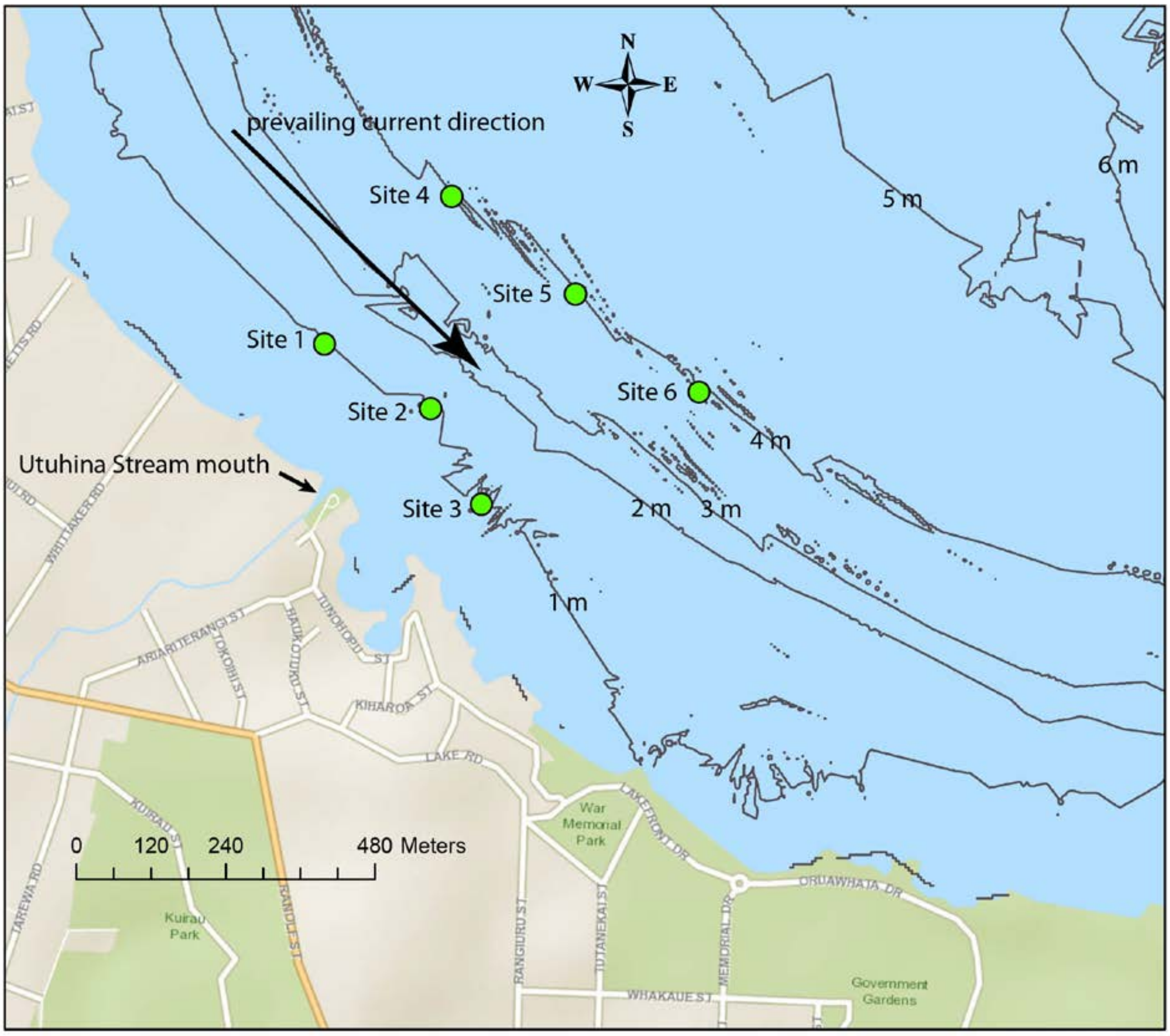

Figure 1: Site locations sampled for benthic macroinvertebrates in Lake Rotorua offshore from the Utuhina Stream mouth. A prevailing south-easterly, wind-generated current operates in this area of the lake. Bathymetry in metres.

Results

Sediments at sites 1, 2 and 3 from 1 m depth were characterised by fine and coarse sand and contained far fewer macroinvertebrates (Figure 2) than samples from 4 m depth at sites 4, 5 and 6. By far the majority of individuals at the deeper sites were chironomid larvae and oligochaete worms, comprising 80% and 10%, respectively of all individuals, as well as far greater numbers of orthoclad larvae than shallow sites. Macroinvertebrate abundance was significantly lower at site 2 immediately offshore of the stream mouth, however, site 3 samples had the most abundant macro-invertebrate fauna of all sites from 1 m depth so these changes in abundance are unlikely to be due to impacts of alum discharge from the stream.

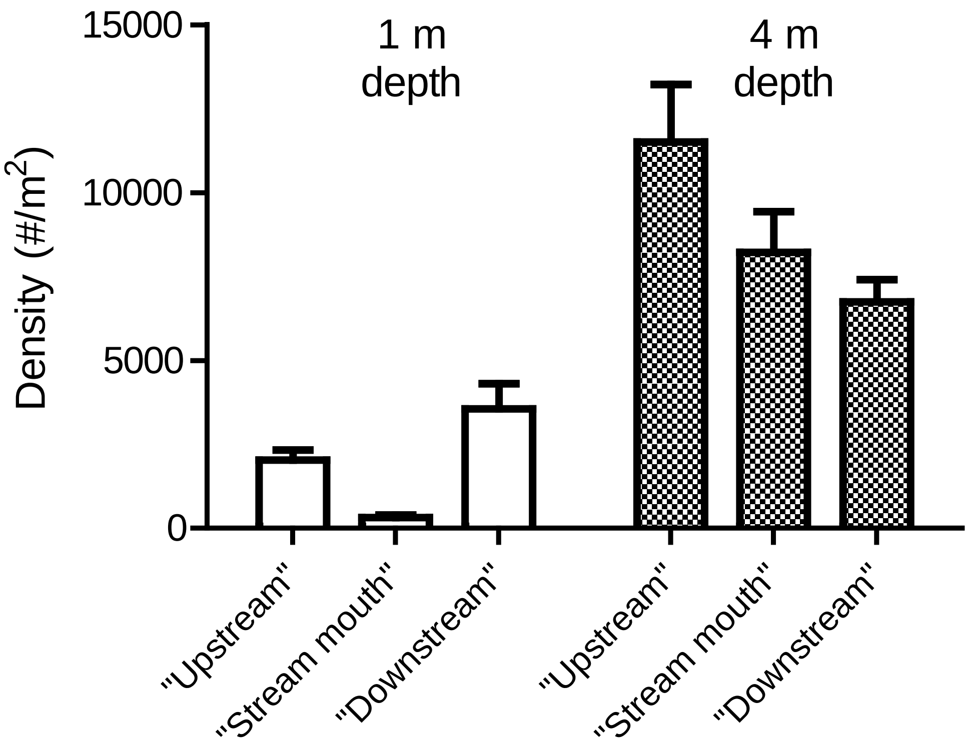

Figure 2: Density (individuals m^2) of benthic macroinvertebrates in Lake Rotorua sediments adjacent to the Utuhina Stream mouth at depths of 1m and 4 m. Values are means of 9 samples per site ± S.E.M.

Macroinvertebrate diversity was similar across all sites (Figure 3) with no clear trend that could be ascribed to proximity to the Utuhina Stream mouth or lake current flow, although diversity was significantly lower at site 2 and significantly higher at site 3. Species composition differed between shallow and deep sites, with *Paracalliope* amphipods only found at the shallow sites whereas Limnaea and Physa snails and leeches were only found in samples from 4 m depth. Potomopyrgus snails were much more abundant at shallow versus deeper water sites (369 ± 93 vs 14 ± 7 per m^2, respectively). Sphaerid clams were only found at site 3 and comprised 3.2% of all individuals (121 ± 41 per m^2).

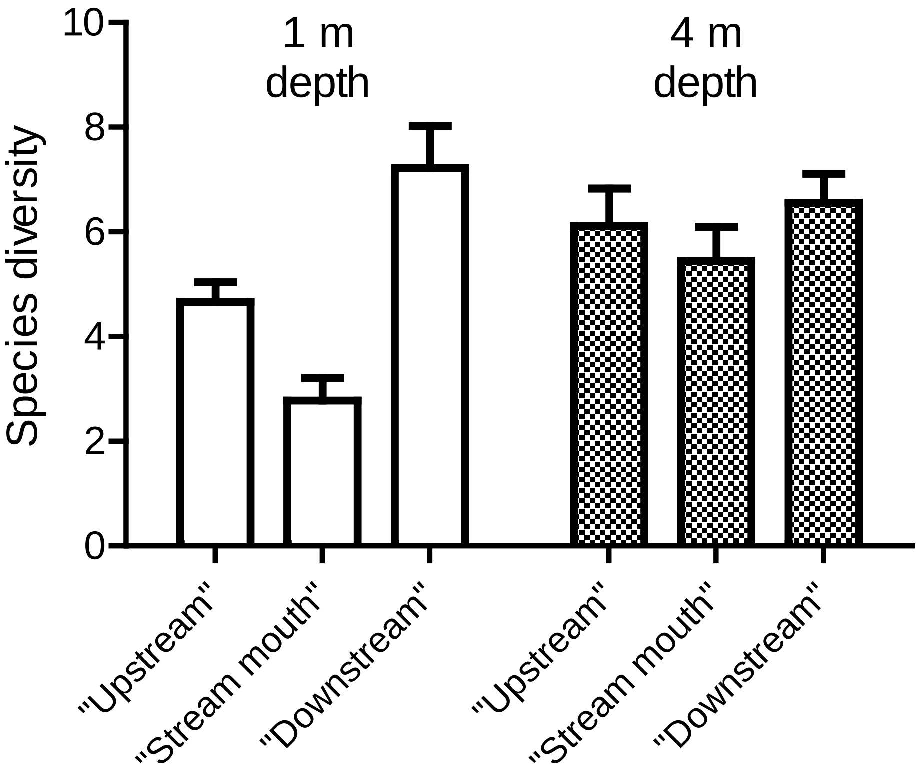

Figure 3: Benthic macroinvertebrate diversity in Lake Rotorua sediments adjacent to the Utuhina Stream mouth at 1 m and 4 m depths. Values are means of 9 samples per site ± S.E.M.

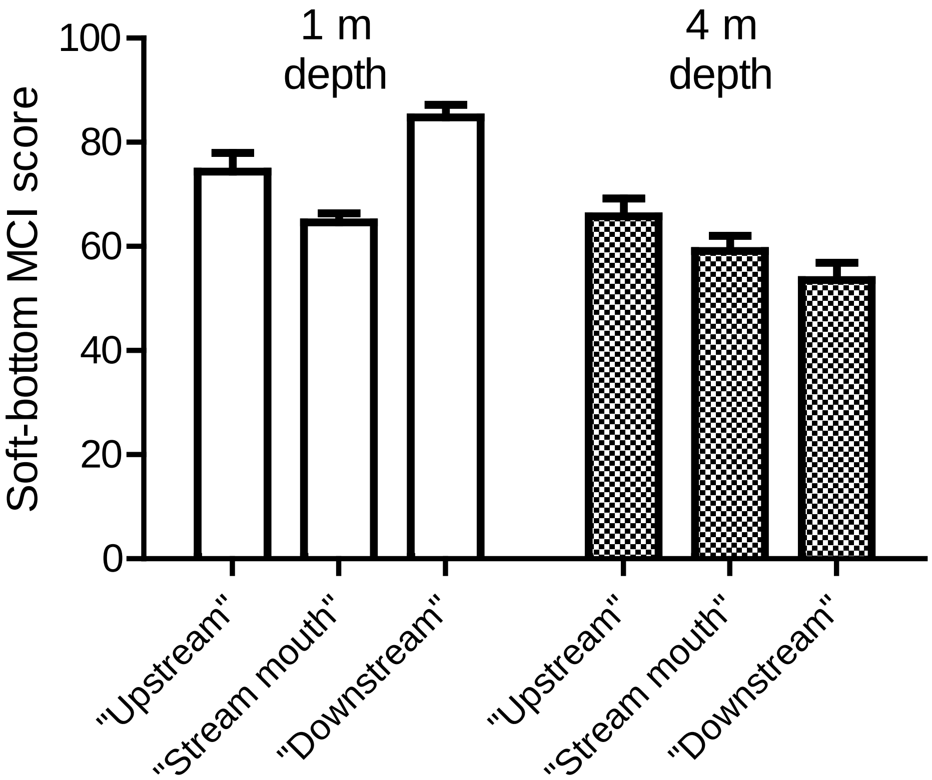

Figure 4: Benthic macroinvertebrate community index for soft-bottomed streams (Sb-MCI) in Lake Rotorua sediments adjacent to the Utuhina Stream mouth at 1 m and 4 m depths. Values are means of 9 samples per site ± S.E.M.

The macroinvertebrate community index for soft-bottomed streams showed clear differences between shallow and deeper sites with scores for the latter being generally lower. No clear differences between sites could be found that could be ascribed to an effect of alum floc deposition and the differences observed are more likely associated with highly localised differences in macrophyte abundance or substrate type.

Discussion

Weatherhead and James (2001) assessed the distribution of macroinvertebrates of the littoral zone of nine oligotrophic New Zealand lakes and observed that key abiotic (primarily sediment size) and biotic (primarily macrophyte abundance) factors exerted strong influence on the species composition and abundance of the macroinvertebrate community. Although Lake Rotorua is classed as eutrophic and therefore not directly comparable to the observations of Weatherhead and James, similar relationships between macroinvertebrate abundance and diversity were observed in this study. Sediment particle size and the presence of macrophytes were strongly associated with the macroinvertebrate fauna. Both these factors are influenced by water depth. Wave turbulence(hydraulic energy) drives particle size distribution, with coarser sediments present at shallower depths and fine matter in deeper water. Hydraulic energy associated with river flow also affects particle size of sediments close to the Utuhina Stream mouth. The Utuhina Stream bed is characteristically relatively coarse mobile sand and harbours few macroinvertebrates (pers. obs.). Discharge of this coarse sand material into the lake at the stream mouth and the greater hydraulic energy associated with the river's flow, especially during flood flows, account for the observed relatively larger particle size of sediment at site 2 compared with sites 1 and 3. Site 3 sediment contained an apparently greater proportion of finer material and organic matter deposited from the stream inflow and transported by the long-shore current, and these sediment characteristics likely accounted for the greater average abundance, diversity and Sb-MCI value at this site. This site is most likely to be influenced by alum discharge from the Utuhina Stream under normal flows and the presence of the sphaerid clam at this site alone, albeit at low densities, is evidence that this species may have quite specific habitat requirements but that the possible deposition of alum floc in this area poses little risk to benthic macroinvertebrates. This species was identified as potentially sensitive to alum floc deposition in a study of dose dependent toxic effects of alum by Clearwater et al.(unpublished data), although effects (increased mortality and reduced reburial) were only observed at the highest dose tested (220 g m^{-2}).

Schallenberg et al. (2011) observed that no MCI-type indices have yet been evaluated or published for lake sediments in New Zealand because considerable spatial heterogeneity exists within lakes due to factors such as depth, sediment size and organic content, and the presence or absence of macrophytes. The closest index is that could potentially be applied to littoral lake sites is that calculated for soft-bottomed streams (Sb-MCI) and which has been applied in this context in this study. However, it must be stated that no definitive assumptions may be made about habitat quality in lake sediments from the Sb-MCI score although the metric still serves as a useful index to compare macroinvertebrate composition across related sites with similar abiotic (sediment, depth, wave exposure) and biotic (macrophyte species and abundance) characteristics.

Although there were statistically significant changes in benthic macroinvertebrate fauna with increasing depth and with proximity to the Utuhina Stream mouth, it is not possible to ascribe any of these differences to possible deposition of alum floc, and the observed variability in macroinvertebrate fauna is more likely to result from localised variation in substrate size and chemistry, macrophyte abundance and patchiness, and major topographic features such as adjacent rocky reefs.

Of some concern with respect to this study is the observation that while sampling was taking place for benthic macroinvertebrates on 20th November 2012, a boat was operating within the designated sampling zone spraying what was apparently diquat for the control of macrophytes (Joseph Butterworth pers. com.). Since there had been no notification that this spraying was to take place, had sampling for this study been delayed by a week then it is highly likely that all macroinvertebrate communities in the vicinity would have been severely impacted. Diquat is toxic to many freshwater macroinvertebrates. Chemical macrophyte removal is likely to have greater immediate impacts on benthic macroinvertebrates than alum floc deposition due to the direct toxicity of diquat and also the significant habitat modification associated with macrophyte removal.

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