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4 April 2014

MEMORANDUM

TO Belinda Whyte | Christchurch City Council
FROM Alex James | EOS Ecology

Aquatic Ecology Monitoring of Styx Mill Conservation Reserve
EOS Job No: CHR01-13096

Dear Belinda,

Please find the results and interpretation of macroinvertebrate, habitat, macrophytes, and periphyton monitoring undertaken from one site within Styx Mill Conservation Reserve. This monitoring was a requirement of the newly granted Styx River SMP (CRC131249) thus this is the first time it has been undertaken. However, this site has been surveyed in the past as part of the CCC's long-term monitoring program. The aim of this memo is to:

» Compare the results with previous monitoring undertaken at the same site and discussion of any observed trends;
» Make a comparison of results to the surface water quality objectives of the consent (CRC131249) and other relevant guidelines (e.g., proposed Canterbury Land & Water Regional Plan);
» Provide an assessment of whether the stormwater discharges are having an effect on the receiving environment and recommendations to mitigate any negative effects of the discharges where relevant;
» And make recommendations on how to identify the reasons for not meeting any of the above objectives and guidelines where relevant, and recommendations to address these issues.

1 SITE LOCATION & METHODOLOGY

The sampling site was located in the Styx Mill Conservation Reserve (E2478252 N5749370). This site was previously sampled on 13 March 2008 and 27 February 2013 as part of the CCC's long-term monitoring of aquatic invertebrates and fish where it was designated as "Site 14". The results of those surveys are detailed in McMurtrie & Greenwood (2008) and James (2013) however, relevant data from those surveys are provided for comparison with the 2014 data in this memo.

The site was sampled on 21 February 2014 when the river was at base flow. At each site, three equally-spaced transects were placed across the stream at 10 m intervals (i.e. at 0, 10, and 20 m) and aspects of the instream habitat and aquatic invertebrate community quantified along them.

Instream habitat variables were quantified at 12 equidistant points across each of the three transects, with the first and last measurements across each transect at the water's edge. Habitat variables measured at each of these 12 points on each of the three transects (i.e. 36 points per site) included substrate composition (mud/silt/clay: <0.06 mm; sand: 0.06–2 mm; gravel: 2–16 mm; pebble: 16–64 mm; small cobble: 64–128 mm; large cobble: 128–256 mm), presence and type of organic material (i.e., submerged and emergent macrophytes, filamentous algae, algal mats, moss/liverworts, fine/coarse detritus, and terrestrial vegetation), depths (water, macrophyte and fine sediment). Water velocity was measured (using a Sontek ADV meter) at 10 of the 12 points across each of the three transects (points 1 and 12 along each transect were excluded as these points were at the water's edge). As per standard convention, velocity was measured at 0.4 $\times$ the water depth, and was measured at each sampling point over a 30 second interval. General bank attributes, including lower and upper bank height and angles, lower bank undercut, and lower bank vegetative overhang were measured for each bank at each transect. Bank material composition and stability were also recorded.

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A visual qualitative assessment of macrophyte cover was also assessed across each of the three transects. This involved qualitatively assessing macrophyte cover within a 1-m band along each of the three transects with the following variables recorded: visual estimation of streambed cover (%), identification of the dominant species present, and identification of the type present (emergent or submerged). Because macrophyte cover is often patchy at the site scale looking at only three transects does not necessarily give a good estimate of cover or composition. Therefore a visual qualitative assessment of macrophyte cover was also undertaken over the entire site (see below).

A visual qualitative assessment of a number of habitat parameters was also carried out over the entire site (i.e. site-wide assessments). The parameters measured at the site-scale included the following:

» Habitat type (% riffle/run/pool, and maximum pool depth).
» Visible sky was assessed as one of five percent cover categories (<5%, 5-25%, 25-50%, 50-75%, >75%), as per the Christchurch River Environment Assessment Survey (CREAS) criteria (McMurtrie & Suren, 2008). Visible sky is a measure of how much sky is visible from the centre of the stream, and so takes into account steep banks, buildings and other objects that may be situated back from the channel.
» Canopy tree cover was assessed as one of five percent cover categories (<5%, 5-25%, 25-50%, 50-75%, >75%), as per the CREAS criteria. This is also a measure of channel shading as it is an estimate of how much of the channel is shaded by tree cover within the site.
» Substrate embeddedness (the percentage of fine sediment surrounding large particles within the streambed) was assessed as one of five percent cover categories (<5%, 5-25%, 25-50%, 50-75%, >75%), as per the CREAS criteria.
» Bank attributes (bank erosion and bank vegetation cover), were assessed as one of five percent cover categories (<5%, 5-25%, 25-50%, 50-75%, >75%), as per the CREAS criteria.
» Lower bank material was categorised into one of seven categories: earth (includes soil, sand, and gravel), wood, brick, rock, concrete, iron, and tyres.
» Substrate composition. The percentage cover of the following particle size categories: mud/silt/clay: <0.06 mm; sand: 0.06–2 mm; gravel: 2–16 mm; pebble: 16–64 mm; small cobble: 64–128 mm; large cobble: 128–256 mm; boulder: > 256mm; bedrock/manmade concrete, as per the CREAS criteria. Percentage fine sediment cover was calculated as the combined coverage of mud/silt/clay and sand particle size categories.
» Bryophyte (moss, liverworts) coverage.
» Macrophyte coverage and composition. Macrophytes were identified to the lowest practicable level (either to genus or species), including whether it was a submerged or emergent growth form.
» Periphyton (including algae) coverage and composition. The periphyton types recorded were classified using the groups outlined in Biggs & Kilroy (2000): thin mat/film (<0.5 mm thick); medium mat (0.5–3 mm thick); thick mat (<3 mm thick); filaments, short (<2 cm long); and filaments, long (>2 cm long).

The riparian zone condition was assessed within a 5-m band along the 20-m site on either side of the bank. The cover of 15 different vegetation types was estimated on a ranking scale of present (<10%), common (10–50%), and abundant (>50%). The vegetation was assessed three dimensionally so included ground, shrub, and canopy cover levels. The vegetation categories were taken from the CREAS criteria (McMurtrie & Suren, 2008).

Aquatic benthic invertebrates were collected at each transect by disturbing the substrate across an approximate 1.5 m width and within a 0.3 m band immediately upstream of a conventional kicknet (500 µm mesh size). The full range of habitat types were surveyed across each transect, including mid-channel and margin areas, inorganic substrate (e.g. the streambed), and macrophytes (aquatic plants). Each invertebrate sample was kept in a separate container, preserved in 70% isopropyl alcohol, and taken to the laboratory for identification. The contents of each sample were passed through a series of nested sieves (2 mm, 1 mm, and 500 µm) and placed in a Bogorov sorting tray. All invertebrates were counted and identified to the lowest practical level using a binocular microscope and several identification keys (Winterbourn, 1973; Winterbourn *et al*., 2006; Chapman *et al*., 2011). Sub-sampling was utilised for particularly large samples and the unsorted fraction scanned for taxa not already identified. The lowest sub-sampling level used for any particular size fraction of a sample collected was 50%.

The methodology described above was the same as that used for the 2008 and 2013 surveys. The only methodological differences were:

- » The macrophyte cover assessment was altered in 2013 and 2014 compared to 2008. In 2008 macrophytes were assessed over the whole site while in 2013 and 2014 they were assessed over the entire site as well as across each transect. We have chosen to present the site wide percentage cover assessment as this allows comparison with the 2008 data. Additionally, site wide percentage cover provides a better indication of macrophyte cover than only looking at three transects as macrophytes often have a patchy distribution at the site scale.
- » The algal cover assessment (both site-wide and across each transect) was altered in 2013 and 2014 compared to 2008. In 2008 only the "algal mats" and "filamentous algae" categories were used while in 2013 and 2014 the categories of Biggs & Kilroy (2000) where recorded (thin mat/film (<0.5 mm thick); medium mat (0.5–3 mm thick); thick mat (<3 mm thick); filaments, short (<2 cm long); and filaments, long (>2 cm long)). Filamentous algae have not been recorded at this site over the three surveys so this change of is no consequence for its comparison. A direct comparison of algal mat cover should not be made between 2008 and the later surveys, although it is more than likely there has been no change in the thickness of the algal mats at the site over time.

2 DATA ANALYSIS

The data describing the substrate composition collected across each transect was simplified by creating a substrate index, such that:

Substrate index = [(0.7 x % boulders) + (0.6 x % large cobbles) + (0.5 x % small cobbles) + (0.4 x % pebbles) + (0.3 x % gravels) + (0.2 x % sand) + (0.1 x % silt) + (0.1 x % concrete/bedrock)] / 10

Where derived values for the substrate index range from 1 (i.e., a substrate of 100% silt) to 7 (i.e., a substrate of 100% boulder); the larger the index, the coarser the overall substrate. In general, coarser substrate (up to cobbles) represents better instream habitat than finer substrate. The same low coefficients for silt and concrete/bedrock reflect their uniform nature and lack of spatial heterogeneity, and in the case of silt, instability during high flow.

Invertebrate data were summarised by taxa richness, total abundance, and abundance of the five most common taxa. Biotic indices calculated were the number of Ephemeroptera-Plecoptera-Trichoptera taxa (EPT taxa richness), % EPT abundance, the Macroinvertebrate Community Index (MCI), Urban Community Index (UCI), and their quantitative equivalents (QMCI and QUCI, respectively). The paragraphs below provide brief clarification of these metrics.

Taxa richness is the number of different taxa identified in each sample. Taxa is generally a term for taxonomic groups, and in this case refers to the lowest level of classification that was obtained during the study. Taxa richness can be used as an indication of stream health or habitat type, where sites with greater taxa richness are usually healthier and/or have a more diverse habitat.

EPT refers to three Orders of invertebrates that are generally regarded as 'cleanwater' taxa. These Orders are Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies); forming the acronym EPT. These taxa are relatively intolerant of organic enrichment or other pollutants and habitat degradation. The exception to this are the hydroptilid caddisflies (e.g. Trichoptera: Hydroptilidae: *Oxyethira, Paroxyethira*), which are algal piercers and often found in high numbers in nutrient enriched waters and degraded with high algal content. For this reason, EPT metrics are presented without these taxa. EPT taxa richness and % EPT abundance can provide a good indication as to the health of a particular site. The disappearance and reappearance of EPT taxa also provides evidence of whether a site is impacted or recovering from a disturbance. EPT taxa are generally diverse in non-impacted, non-urbanised stream systems, although there is a small set of EPT taxa that are also found in urbanised waterways.

In the mid-1980s the MCI was developed as an index of community integrity for use in stony riffles in New Zealand streams and rivers, and can be used to determine the level of organic enrichment for these types of streams (Stark, 1985). Although developed to assess nutrient enrichment, the MCI will respond to any disturbance that alters macroinvertebrate community composition (Boothroyd & Stark, 2000), and as such is used widely to evaluate the general health of waterways in New Zealand. Recently a variant for use in streams with a streambed of sand/silt/mud (i.e. soft-bottomed) was developed by Stark & Maxted (2007) and is referred to as the MCI-sb. Both the hard-bottomed (MCI-hb) and soft-bottomed (MCI-sb) versions calculate an overall score for each sample, which is based on pollution-tolerance values for each invertebrate taxon that range from 1 (very pollution tolerant) to 10 (pollution-sensitive). MCI-hb and MCI-sb are calculated using presence/absence data and a quantitative version has been developed that incorporates abundance data and so gives a more accurate result by differentiating rare taxa from abundant taxa (QMCI-hb, QMCI-sb). MCI (QMCI) scores of ≥120 (≥6.00) are interpreted as 'excellent', 100–119 (5.00–5.99) as 'good', 80–99 (4.00–4.99) as 'fair', and <80 (<4.00) as 'poor' (Stark & Maxted, 2007). The sampling site was dominated by pebble-sized substrate (16–64 mm) therefore MCI-hb and QMCI-hb are the appropriate indices to use.

The UCI/QUCI score can be used to determine the health of urban and peri-urban streams by combining tolerance values for invertebrates with presence/absence or abundance invertebrate data (Suren *et al*., 1998). This biotic index is indicative of habitat relationships, and to some degree incorporates urban impacts. Negative scores are indicative of invertebrate communities tolerant of slow-flowing water conditions associated with soft-bottomed streams (and often with a high biomass of macrophytes), whereas positive scores are indicative of communities present in fast-flowing streams with coarse substrates (Suren *et al*., 1998).

One-way analysis of variance (ANOVA) was used to compare habitat parameters and macroinvertebrate community metrics between years to indicate if any overall changes at the survey site over the three surveys were evident. Where the assumptions of parametric ANOVA (i.e., equal variance and normality) could not be met even after data transformation, the non-parametric Kruskal-Wallis procedure was used. The level of significance was set at 5%. The Tukey multiple comparison procedure was used to indicate significant differences among means.

With respect to figures, the mean and standard error (SE) values presented on the graphs for water depth, fine sediment depth, and macrophyte depth are calculated from 36 points and water velocity from 30 points on the three transects. For channel width, substrate index, and all the macroinvertebrate metrics, there is a single value for each transect, thus means and SE are calculated from the three transect values.

3 RESULTS

3.1 PHYSICAL HABITAT

As it is located in a conservation reserve, the site has a riparian zone that is protected from development and has hence not changed much over the three survey dates (Figure 1). The substrate is dominated by pebble-sized substrate (16–64 mm), water velocities are moderate, and the site is entirely run habitat (Table 1). There were no significant differences in substrate index, water velocity, or wetted width over the three surveys (Figure 2 and Table 2). It is notable that mean water depth and fine sediment depth were significantly greater in February 2014 compared to the March 2008 survey (Figure 2 and Table 2). This may be related to the higher abundance of macrophytes at this time (see Section 3.2) influencing the water level and trapping fine sediment.

Figure 1 Photos of the Styx Mill Conservation Reserve site looking downstream from upstream boundary of the survey site on 13 March 2008 (top), 27 February 2013 (middle), and 21 February 2014 (bottom).

Table 1 Habitat attributes from the Styx Mill Conservation Reserve site from surveys undertaken in March 2008, February 2013, and February 2014.

Sampling Date	13 March 2008	27 February 2013	21 February 2014
Substrate composition (dominant substrate is in bold)	Large cobble: 2%	Large cobble: none	Large cobble: 1%
	Small cobble: 5%	Small cobble: none	Small cobble: 5%
	Pebbles: none	**Pebbles: 40%**	**Pebbles: 70%**
	Gravel: 60%	Gravel: 15%	Gravel: 5%
	Sand: 10%	Sand: 15%	Sand: 1%
	Mud/silt/clay: 23%	Mud/silt/clay: 30%	Mud/silt/clay: 20%
Surrounding land use	100% park/reserve	100% park/reserve	100% park/reserve
Habitat type (% riffle:run:pool)	0:0:100	0:0:100	0:0:100
Bank material composition	Earth (minor wood)	Earth	Earth
Riparian vegetation	Grass/herb mix, some low ground cover, some exotic deciduous trees.	Grass/herb mix, some low ground cover, native shrubs, and exotic deciduous trees.	Grass/herb mix, some native shrubs and trees, and exotic deciduous trees.
Canopy cover (% Stream shade)	5–25%	<5%	5–25%
Substrate embeddedness	50–75%	25–50%	25–50%

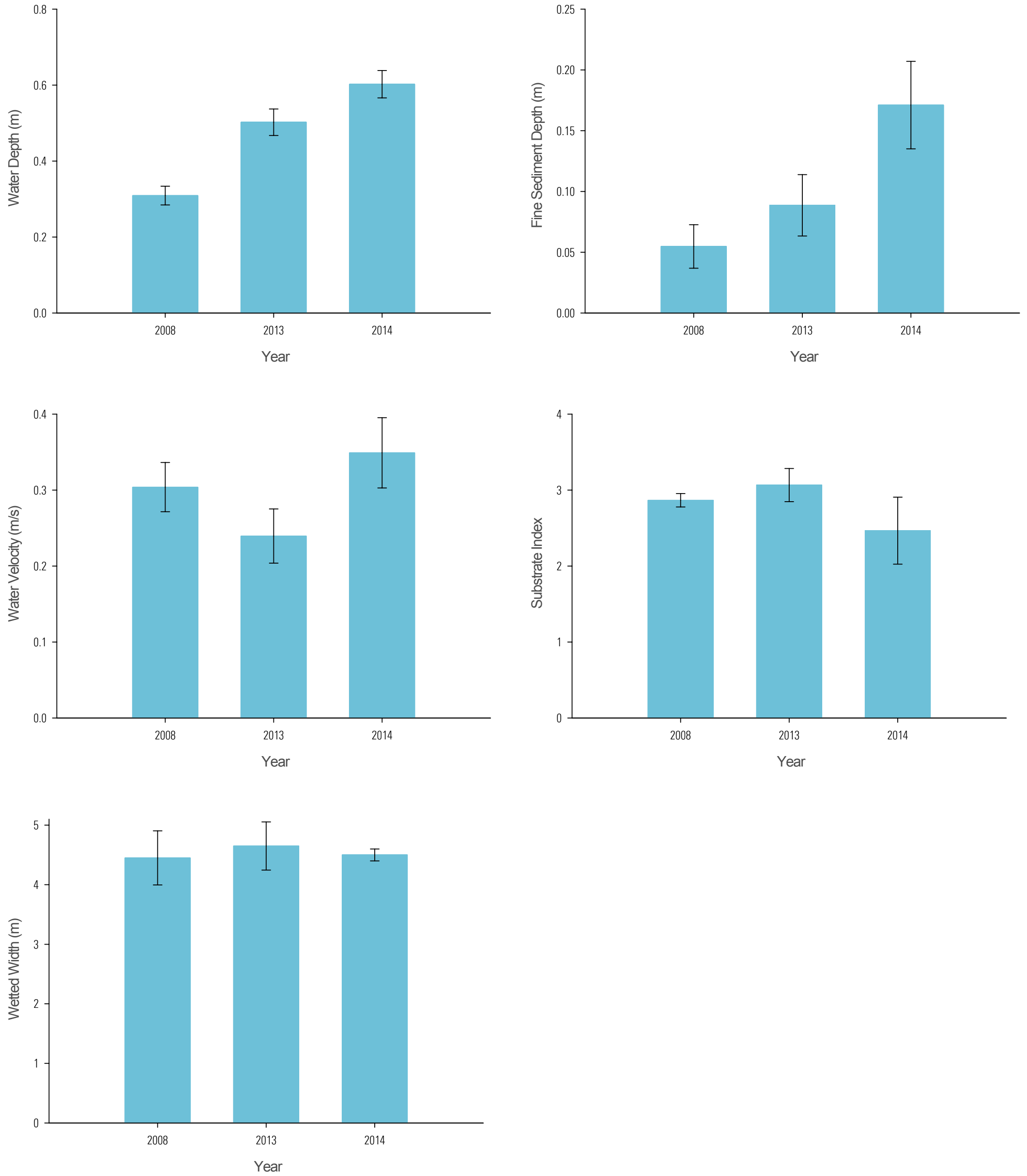

Figure 2 Mean (+/- 1 SE) aquatic habitat attributes of the survey site on 13 March 2008, 27 February 2013, and 21 February 2014. N=36 for water depth, fine sediment depth, and substrate index; N=30 for water velocity; and N=3 for wetted width.

Table 2 Results of one-way analysis of variance (ANOVA) on aquatic habitat attributes from the survey site on 13 March 2008, 27 February 2013, and 21 February 2014. The non-parametric Kruskal-Wallis test was used where the assumptions of ANOVA could not be met even after data transformation. The Tukey multiple comparison procedure was used to indicate significant differences among means.

Parameter	Statistic	N	H or F value	*p*	Significant Difference?	Multiple Comparison
Water depth	Kruskal-Wallis	36	H=36.71	<0.001	Yes	2008<2013=2014
Fine sediment depth	Kruskal-Wallis	36	H=8.31	0.016	Yes	2008=2013; 2013=2014; 2008<2014
Water velocity	Kruskal-Wallis	30	H=2.51	0.29	No	2008=2013=2014
Substrate Index	ANOVA	3	$F_{2,8}$=1.12	0.39	No	2008=2013=2014
Wetted width	ANOVA	3	$F_{2,8}$=0.09	0.92	No	2008=2013=2014

3.2 MACROPHYTES & PERIPHYTON

The immediate riverbank tended to be mostly long grass in 2008 while *Mimulus guttatus* (monkey musk) and *Rorippa* (watercress) were more prominent in this zone in 2013 and 2014 (Figure 1). These plants while rooted in the margins of the wetted channel, had most of their foliage outside the wetted channel thus only account for a small percentage cover in Table 3. Total macrophyte cover was at its highest in February 2014 and macrophyte depth was significantly greater in 2014 compared to 2008 (Figure 3 and Table 4). The only native macrophytes encountered at the site, *Myriophyllum triphyllum* dominated in 2014 followed by *Elodea canadensis*. It is interesting to note that a year previously, *M. triphyllum* was not even recorded (Table 3). This would indicate a dynamic macrophyte assemblage the composition of which can change relatively quickly. The Styx River undergoes regular channel maintenance (including removal of macrophytes from within the channel), which through the Styx Mill Conservation Reserve involves hand raking macrophyte removal. This likely has a major impact on macrophyte cover and composition. It was attempted to get information from Kevin Spaull (Citycare – Supervisor Waterways) regarding the timing of macrophyte clearance activity through the site, however none was forthcoming within the timeframe (e.g., prior to the due date for this memo). Emergent macrophyte cover remained low and did not vary much over the three survey dates, while filamentous algae have never been recorded (Table 3).

Table 3 Macrophyte and periphyton attributes from the Styx Mill Conservation Reserve site from surveys undertaken in March 2008 (McMurtrie & Greenwood, 2008), February 2013 (James, 2013), and February 2014. Only those aquatic vegetation and organic material cover categories that were present are shown. Note that algal categories in 2008 were recorded as only algal mats and filamentous algae, while in 2013 and 2014 the categories of Biggs & Kilroy were used.

Sampling Date	13 March 2008*	27 February 2013**	21 February 2014
Aquatic vegetation and organic material cover (dominant macrophyte taxon is in bold)	Terrestrial roots/vegetation: 10%	Algal mats (thin): 40%	***Myriophyllum triphyllum* (water milfoil): 70%**
	Algal mats: 5%	***Ranunculus trichophyllus* (water buttercup): 15%**	*E. canadensis* (Canadian pondweed): 15%
	***Elodea canadensis* (Canadian pondweed): 5%**	*P. crispus* (curly pondweed): 10%	*R. guttatus* (watercress): 5%
	***Potamogeton crispus* (curly pondweed): 5%**	*E. canadensis* (Canadian pondweed): 5%	*Glyceria* (sweetgrass): 1%
	Fine detritus (leaf litter): 5%	*Rorippa guttatus* (watercress): 5%	*M. guttatus* (monkey musk): 1%
	Glyceria (sweetgrass): 3%	Terrestrial roots/vegetation: 5%	Terrestrial roots/vegetation: 1%
	Rorippa (watercress): 1%	*Azolla*: 1%	
		Woody debris: 1%	
		Lemna minor (duckweed): 1%	
		Mimulus guttatus (monkey musk): 1%	
		Moss/liverworts: 1%	
Emergent macrophyte cover	4%	8%	6%
Total macrophyte cover (includes submerged and emergent macrophytes)	14%	38%	92%
Filamentous algal cover	0%	0%	0%

*From McMurtrie & Greenwood (2008) **From James (2013)

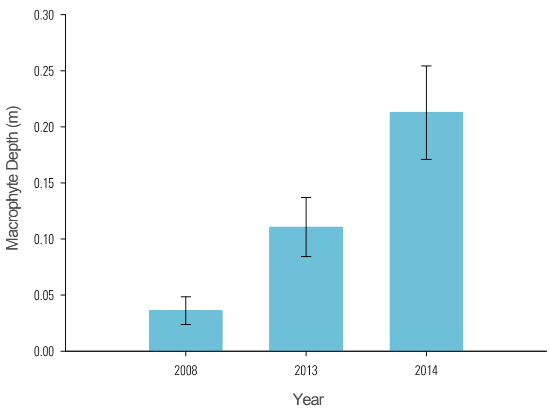

Figure 3 Mean (+/- 1 SE) macrophyte depth of the survey site on 13 March 2008, 27 February 2013, and 21 February 2014. N=36.

Table 4 Results of one-way analysis of variance (ANOVA) on macrophyte depth from the survey site on 13 March 2008, 27 February 2013, and 21 February 2014. The non-parametric Kruskal-Wallis test was used where the assumptions of ANOVA could not be met even after data transformation. The Tukey multiple comparison procedure was used to indicate significant differences among means.

Parameter	Statistic	N	H value	*p*	Significant Difference?	Multiple comparison
Macrophyte depth	Kruskal-Wallis	36	H=9.85	0.007	Yes	2008=2013; 2013=2014; 2008<2014

3.3 AQUATIC MACROINVERTEBRATES

There was little variability in the macroinvertebrate community over the three survey dates (Table 5, Figure 4, and Table 6). The three most abundant taxa were in the same order of relative abundance for each of the three surveys and were all non-insect taxa that are generally tolerant of degraded conditions or habitats with abundant macrophytes (Table 5). There were no significant differences in any of the metrics over the three surveys (Figure 4 and Table 6). The EPT taxa (Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)), which are considered to be particularly pollution-sensitive groups of aquatic insects had good diversity for a peri-urban waterway (site means in the 8 to 10 taxa range) and accounted for an average of around 15% of all invertebrates captured on 21 February 2014 (Figure 4). In February 2014 a total of 11 EPT taxa were captured overall, comprising of 10 caddisfly taxa and one mayfly, *Deleatidium* - a taxon that is now extinct in the more urbanised Heathcote and Avon River catchments. No stoneflies were found. Macroinvertebrate community index (MCI-hb) and its quantitative variant (QMCI-hb) were indicative of "fair" water and/or habitat quality (Figure 4).

Table 5 Percentage abundance of the five most abundant aquatic macroinvertebrate taxa from the survey site in March 2008, February 2013, and February 2014. EPT taxa are highlighted in bold.

Sampling Date	**13 March 2008**	**27 February 2013**	**21 February 2014**
Five most abundant taxa (% relative abundance)	*Paracalliope fluviatilis* (amphipod crustacean - 37%)	*Paracalliope fluviatilis* (amphipod crustacean - 33%)	*Paracalliope fluviatilis* (amphipod crustacean - 63%)
	Potamopyrgus antipodarum (snail - 27%)	*Potamopyrgus antipodarum* (snail - 15%)	*Potamopyrgus antipodarum* (snail - 13%)
	Ostracoda (seed shrimp crustacean - 12%)	Ostracoda (seed shrimp crustacean - 12%)	Ostracoda (seed shrimp crustacean - 10%)
	Orthocladiinae (midge larvae - 7%)	***Pycnocentria*** **(cased caddisfly - 9%)**	***Deleatidium*** **(mayfly - 2%)**
	Pycnocentrodes **(cased caddisfly - 4%)**	***Deleatidium*** **(mayfly - 6%)**	***Hudsonema amabile*** **(cased caddisfly - 2%)**

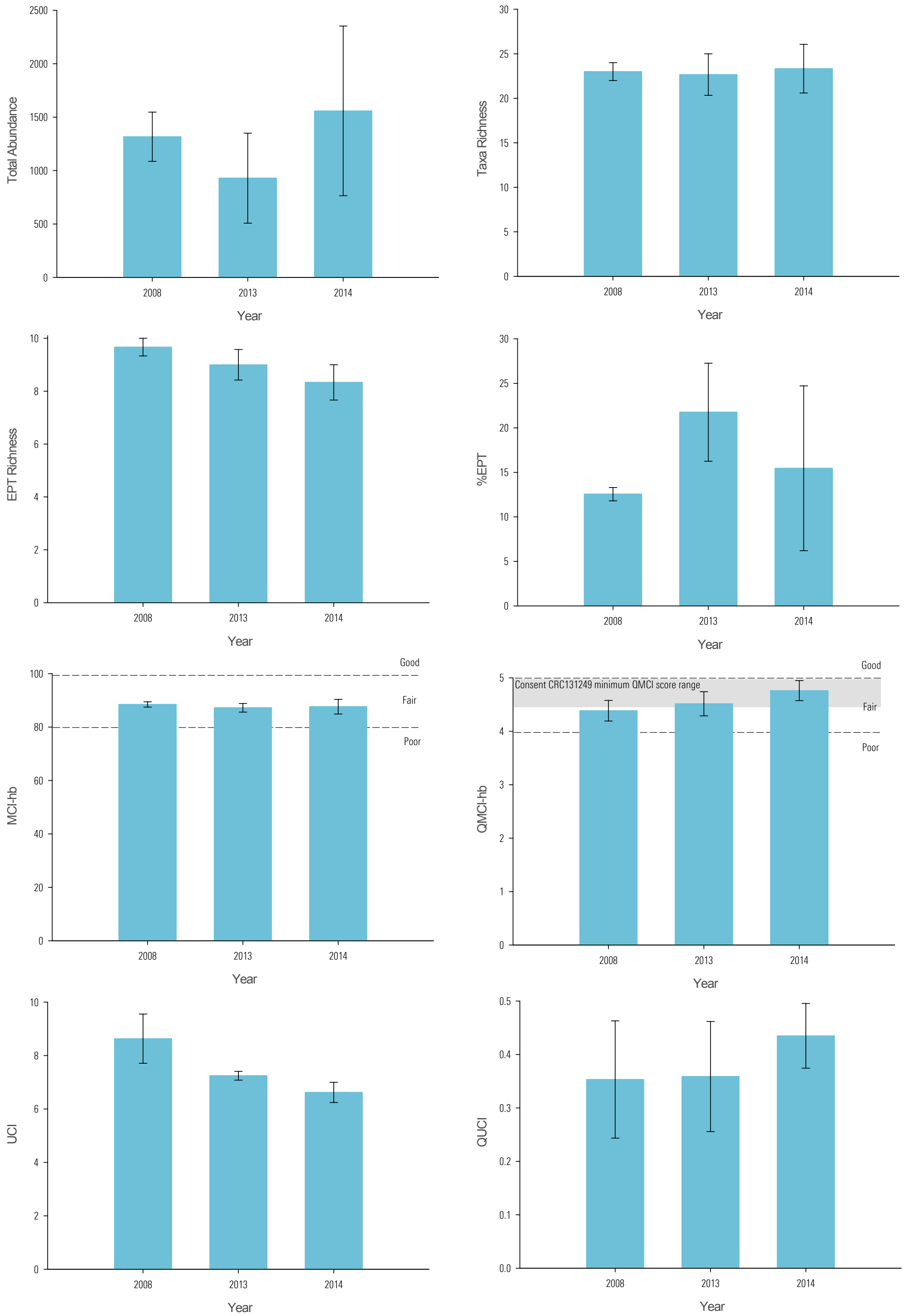

Figure 4 Mean (+/- 1 SE) macroinvertebrate community metrics of the survey site on 13 March 2008, 27 February 2013, and 21 February 2014. N=3. Note that hydroptilid caddisflies were excluded from the EPT metrics, as they are often abundant in degraded waterways with abundant algal growth. The dashed lines on the MCI-hb and QMCI-hb graphs show the "quality class" interpretation categories of Stark & Maxted (2007). The shaded box on the QMCI-hb graph shows the minimum QMCI score range requirement of Consent CRC131249.

Table 6 Results of one-way analysis of variance (ANOVA) on macroinvertebrate community metrics from the survey site on 13 March 2008, 27 February 2013, and 21 February 2014. The Tukey multiple comparison procedure was used to indicate significant differences among means.

Parameter	Statistic	N	F value	*p*	Significant Difference?	Multiple Comparison
Total abundance	ANOVA	3	$F_{2,8}$=0.35	0.72	No	2008=2013=2014
Taxa richness	ANOVA	3	$F_{2,8}$=0.02	0.98	No	2008=2013=2014
EPT richness	ANOVA	3	$F_{2,8}$=1.50	0.30	No	2008=2013=2014
% EPT	ANOVA	3	$F_{2,8}$=0.57	0.60	No	2008=2013=2014
MCI-hb	ANOVA	3	$F_{2,8}$=0.11	0.90	No	2008=2013=2014
QMCI-hb	ANOVA	3	$F_{2,8}$=0.90	0.46	No	2008=2013=2014
UCI	ANOVA	3	$F_{2,8}$=3.12	0.12	No	2008=2013=2014
QUCI	ANOVA	3	$F_{2,8}$=0.24	0.80	No	2008=2013=2014

4 COMPARSIONS WITH STYX RIVER SMP SURFACE WATER QUALITY OBJECTIVES AND OTHER GUIDELINES

Of the surface quality objectives from Consent CRC131249 only "macrophyte cover" was breached on 21 February 2014 with macrophytes covering some 92% of the riverbed (Table 7). If the QMCI score, fine sediment cover, macrophyte cover, and filamentous algae cover as measured on 21 February 2014 are compared against the latest version of the proposed Canterbury Land and Water Regional Plan (pLWRP) (Environment Canterbury, 2014) then QMCI, fine sediment cover, and total macrophyte cover are breached (Table 8).

Table 7 Comparison of the surface water quality objectives from Consent CRC131249 with measurements taken during the most recent survey at the Styx Mill Conservation Reserve site (21 February 2014). Parameters that breach the objectives are shaded.

Parameter	Surface water quality objectives from Consent CRC131249	Results from 21 February 2014 survey
Quantitative macroinvertebrate community index (QMCI)	Minimum score of 4.5–5	4.76
Fine sediment cover	Maximum of 40%	21%
Total macrophyte cover	Maximum of 50%	92%
Filamentous algae cover (>20 mm long)	Maximum of 30%	0%

Table 8 Comparison of selected "Freshwater outcomes for Canterbury Rivers" from the proposed Canterbury Land and Water Regional Plan – Decisions version (18 January 2014) (Environment Canterbury, 2014) with measurements taken during the most recent survey at the Styx Mill Conservation Reserve site (21 February 2014). Parameters that would breach the proposed limits are shaded.

Parameter	Proposed Canterbury Land & Water Regional Plan – Decisions Version (18 January 2014)	Results from 21 February 2014 survey
Quantitative macroinvertebrate community index (QMCI)	Minimum score of 5	4.76
Fine sediment (<2 mm diameter) cover	Maximum cover of 20%	21%
Emergent macrophyte cover	Maximum cover of 30%	6%
Total macrophyte cover	Maximum cover of 50%	92%
Filamentous algae cover (>20 mm long)	Maximum cover of 30%	0%

5 ASSESSMENT OF STORMWATER EFFECTS

- It is impossible to determine if stormwater discharges are having any impact on the receiving environment based on a single sampling site.
- All that can be said is between March 2008 and February 2014 the macroinvertebrate community has been relatively stable and dominated by non-insect taxa considered tolerant of degraded waterways and commonly found throughout Christchurch's urban waterways. Of note, is the presence of the mayfly *Deleatidium,* a taxon that is now extinct from the more urbanised Heathcote and Avon River catchments.
- While macrophyte cover was substantially greater than the consent objective, this has nothing to do with stormwater discharge and is most likely influenced by when the site underwent stream maintenance incorporating the removal of macrophytes. High macrophyte cover in a heavily maintained waterway like the Styx River is more likely a function of the time elapsed since the last macrophyte removal by CCC contractors than any other variable. It is notable that the native *Myriophyllum triphyllum* was the dominant macrophyte species in February 2014.

6 RECOMMENDATIONS

- More monitoring sites along the Styx River are required if yearly monitoring is ever to be effective at determining if stormwater discharges are having an impact on the receiving environment. These would need to be selected dependent on the major points of stormwater discharge, and would need to include a control site upstream that receives minimal urban stormwater. As aquatic biota also respond to physical habitat changes, water quality monitoring (dry and rain events) would also be required to determine whether there has been any degradation in water quality that could be linked back to a stormwater discharge. Information on macrophyte maintenance practices as each site would also be required to ensure that disturbance from macrophyte clearance is accounted for.
- The macroinvertebrate community is already dominated by taxa that are relatively insensitive to the impacts of stormwater discharges, therefore it will be difficult to detect stormwater impacts by relying on simple metrics like the QMCI. To truly determine if stormwater is having an impact then I would suggest more targeted monitoring such as:
    - Monitoring of heavy metal concentrations (e.g., zinc, lead, copper) in algal, macrophyte, and macroinvertebrate herbivore (e.g., *Deleatidium, Potamopyrgus*) tissue.
    - Quantitative sampling (i.e., Surber sampling) to determine any trends in the densities of the more sensitive taxa present (e.g., *Deleatidium*).
    - Water quality sampling during rain events to determine the levels of contaminants (e.g., heavy metals, total suspended sediment, and hydrocarbons) entering the Styx River when it is actually raining rather than continually collecting only dry weather samples.
    - A suitable number of sites so as to differentiate sites affected and unaffected by stormwater discharges (as discussed in the previous bullet).

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- » Macrophyte cover has little to do with stormwater discharges. In managed systems like the Styx River where the channel is regularly cleared of macrophytes then any percentage cover objectives become meaningless, as sampling within the weeks following macrophyte removal would ensure meeting the macrophyte objective, although there are flow-on issues regarding the subsequent decline in the invertebrate taxa as a result of the disturbance. Ultimately more information is needed about the short and long-term impacts of macrophyte removal on aquatic invertebrate communities, and the recovery time for communities in order to establish the optimal sampling time for a recovered invertebrate community vs. less macrophyte growth. In the meantime, canopy shading would help to reduce macrophyte growth in the long-term, with flow-on benefits of then needing less channel maintenance.
- » To reduce natural temporal variation as much as possible, it is recommended that future sampling be carried out at the same time of year (late February), however this is complicated by regular channel maintenance activities that remove macrophytes. Not withstanding the wider goals of channel maintenance, to minimise the 'noise' caused by yearly differences in the timing of invertebrate sampling relative to the completion of macrophyte removal, it is recommended that macrophyte removal be completed by a set date every year, if possible. This will help reduce macrophyte removal-mediated temporal 'noise' between years over the course of the monitoring. Otherwise, comparisons between years are meaningless if communities are potentially at a different stage of recovery at the time of sampling each year. Additionally, such channel maintenance activities likely have a major impact on the macrophyte cover metrics, which are conditions of Consent CRC131249. We recommend CCC contacts Kevin Spaull (Citycare – Supervisor Waterways – 0274370336 or kevin.spaull@citycare.co.nz) regarding the timing of channel maintenance. Monitoring in subsequent years should avoid sampling in the weeks following channel maintenance when macrophyte cover might be artificially low and the macroinvertebrate community in a state of recovery.
- » Management objectives regarding macrophytes and the relevance of setting macrophyte cover limits in policy may benefit from a system-by-system approach (e.g., some systems are naturally more likely to have macrophytes) and on a basis of exotic versus native species rather than total coverage per se. For example the dominance of native macrophytes species at a site (such as the 70% cover of *M. triphyllum* at the site in question in 2014) should be celebrated rather than being considered a negative factor.

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